



**TECHNISCHE FAKULTÄT DER  
CHRISTIAN-ALBRECHTS-UNIVERSITÄT  
ZU KIEL**



Christian-Albrechts-Universität zu Kiel

**almanach 13**

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## Preface

Dear Reader,

One of the most important activities at a university is the recruitment of (new) professors. In 2013, we managed to recruit five new professors, some will start in 2014 at our Faculty of Engineering:

- Prof. Dr.-Ing. Marco Liserre joint us in September 2013 (Power Electronics)
- Prof. Dr. Isabella Peters joint us in October 2013 (Web Science, joint professorship with the ZBW)
- Prof. Dr.-Ing. Michael Höft joint us in October 2013 (High Frequency Technology)
- Prof. Dr. Ansgar Scherp joins us in January 2014 (Knowledge Discovery, joint professorship with the ZBW)
- Prof. Dr. Mikhail Zheludkevich joins us in March 2014 (Electrochemistry, joint professorship with the HZG)

Prof. Dr. Christine Selhuber-Unkel was awarded an ERC Starting Grant of 1.5 Mio. EUR for five years and Prof. Dr.-Ing. Marco Liserre was awarded an ERC Consolidator Grant of 2 Mio. EUR for five years. With the ERC Grant awarded in 2012 to Prof. Dr. Martina Gerken, for which she received the Kiel Science Award 2013, we are now running three ERC Grants at our Faculty of Engineering. The extension proposal of SFB 855 "Magnetoelectric Composites - Future Biomagnetic Interfaces" has been positively evaluated by the DFG, but was finally not approved. It is planned to submit a follow-up proposal in 2015.

As in the previous years, the faculty was involved in various form of technology transfer. In June 2013, the fourth KoSSE-Tag took place. At this event, the competence cluster Software System Engineering KoSSE presents its technology transfer activities to the public. With, again, one hundred participants, this event has been established as a community meeting of the regional software industry. A new Competence Center "Nano Systems Technology" is funded from 2013 to 2015 via EFRE.

Student numbers again increased. We intend to introduce new international master programs. Plans for measures for energetic restoration and reconstruction of the buildings at the east campus have been continued, in close collaboration with university board and the government.



Prof. Dr. Wilhelm Hasselbring  
Dean of the Faculty of Engineering



# Department of Computer Science

## Results

For the Department of Computer Science the year 2013 was an exciting and successful one. Just as in previous years, the department gained recognition for its research both through individual research results and results of joint efforts. Good examples are several papers presented at top-ranking conferences: a paper on deployment and reconfiguration of software in the cloud, was co-authored by Professor Hasselbring, his PhD student Florian Fittkau, and his former PhD student Sören Frey, and presented at ICSE; a paper on automatic synthesis of node-link-diagrams, was co-authored by Professor von Hanxleden and his PhD students Christian Schneider und Miro Spönemann, and presented at VL/HCC; a paper on online packing, was co-authored by Professor Jansen and his PhD student Kim-Manuel Klein, and presented at ICALP; a paper on two-dimensional bin packing, was co-authored by Professor Jansen and his PhD student Lars Prädél, and presented at SODA; a paper on combinatorics on words, was co-authored by Professor Nowotka, his post-doc Florin Manea, his PhD student Robert Mercaş, Cătălin Tiseanu, and Paweł Gawrychowski, and presented at STACS; and a paper by Christian Giessen on evolutionary algorithms, was presented at GECCO.

Over the past years, the department has been reporting ever growing numbers of degrees awarded. The year 2013 was, in fact, another record-breaking year. For the first time, there were more than 100 graduates: to be precise, 110 received a degree from our department in the academic year 2012/2013. This gives us reassurance about the quality management initiative in teaching that we started early in the millenium.



Fig. 1: Graduation ceremony for the academic year 2012/2013. Foto/Copyright: Fabian Frühling/CAU

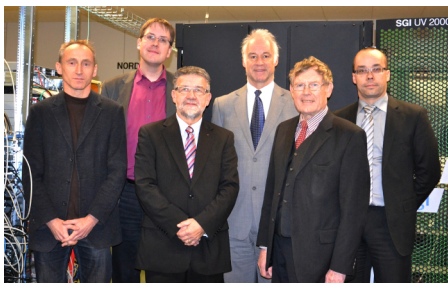


Fig. 2: From left to right: Prof. Thomas Slawig and Prof. Steffen Börm (Department of Computer Science), Dr. h.c. Klaus-Jürgen Wichmann, Prof. Manfred Schimmmler, Dr. Christian Zöllner (Petersen-Stiftung) and Prof. Dirk Nowotka (Department of Computer Science) in front of the new UV 2000 shared memory computer, and the computer itself. Foto/Copyright: Sebastian Maas/CAU

The year 2013 once more showed that the computer science department is well-connected internationally. For instance, in 2012 Professor Anand Srivastav held a Max-Planck Visiting Professorship at the Indo-German Max Planck Centre for Computer Science, and stayed in Bombay and New Delhi for a longer period, after he had successfully established a research network between German and Indian universities in the field of algorithm engineering. We hope that this connection to India will expand over the coming years. Ulf Rüegg, winner of the 2013 Award for Best Master's Degree Student, received a DAAD doctoral scholarship for a research visit to two Australian universities.

In 2013, the ties between the Department of Computer Science and the Leibniz Information Centre for Economics (ZBW) were deepened via joint appointments. Isabella Peters, an information scientist, started as a professor of web science in October 2013. Ansgar Scherp, a computer scientist, was jointly appointed by the ZBW and the CAU as a professor of

knowledge discovery and recently took up her post. Klaus Tochtermann, director of the ZBW and professor for new media in our department, was appointed member of the Committee on Scientific Library Services and Information Systems of the DFG which, in particular, is concerned with information infrastructure for research.

For the software and systems engineering initiative of the department, the year 2013 was again an excellent one. Our ties with the regional industry were further deepened. The KoSSE-Tag, the community meeting for software developers from the regional industry and researchers in software engineering, was once again a great success.

With regard to *real computing*, the Prof. Dr. Werner Petersen Foundation and the State of Schleswig-Holstein gave our department an SGI UV 2000 computer system, which is based on a distributed shared memory (DSM) architecture and has about 2.25 TByte of random access memory. We are expecting interesting numerical climate simulation and analyses of security-critical software to be carried out on it.

## Personnel

Head of the group: Prof. Dr. T. Wilke;

Staff:

A. Bock	01.01.-31.12.2013	(50%)	CAU
Computer Science and Business Information Technology Examination Office			
W. Burmeister	01.01.-31.12.2013		CAU
Computer and IT support team			
C. Dort	01.01.-31.12.2013		CAU
Computer and IT support team			
T. Grebien	22.07.-31.12.2013	(50%)	CAU
Computer and IT support team			
PD Dr. F. Huch	01.01.-31.12.2013		CAU, 65 percent
Computer Science and Business Information Technology Examination Office			
Dr. I. Pfannschmidt	01.01.-31.12.2013		CAU
Computer Science Department's Office			
P. Pichol	01.01.-31.12.2013		CAU
Computer and IT support team			
B. Scheidemann	01.01.-31.12.2013	(50%)	CAU
Computer Science and Business Information Technology Examination Office			
M. Sotiriadis-Gräßler	01.01.-31.12.2013	(50%)	CAU
Computer Science and Business Information Technology Examination Office			
R. Staecker	01.01.-31.12.2013	(50%)	CAU
Computer Science Department's Office			
K. Wandt	01.11.-31.12.2013	(50%)	CAU
Computer Science Department's Office			

Scientific Staff:

Prof. Dr. F. Foders	01.10.-31.12.2013
Information Systems	
H. Krasemann	01.04.-30.09.2013
Privacy Protection	
Dr. H. Lindhorst	01.04.-30.09.2013
IT Law	
Dr. A. Salski	01.01.-31.12.2013
KI	

Lecturer

Lecturer

Lecturer

Lecturer

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

Inf-Fuzzy: Fuzzy-Methoden, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Salski (+ A. Salski)

### *Summer 2013*

Inf-InfRecht: Informatikrecht, 2 hrs Lecture/Week,  
H. Lindhorst

Inf-DatSchutz: Datenschutz, 2 hrs Lecture/Week,  
H. Krasemann

Inf-KI: Künstliche Intelligenz, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Salski (+ A. Salski)

### *Winter 2013/2014*

Inf-Fuzzy: Fuzzy-Methoden, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Salski (+ A. Salski)

WInf-MSc-Sem1: Interdisziplinäres Seminar (Informationssysteme), 2 hrs Seminar/Week,  
F. Foders

tf  
informatics

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# Algorithmic Optimal Control - CO<sub>2</sub> Uptake of the Ocean

## What is Algorithmic Optimal Control?

In many scientific and technological applications, optimization problems for differential equations occur. Such tasks are called problems of optimal control. These problems are very complex in the field of mathematical analysis, numerical transformation, and algorithmic realization. They are a main topic of our research group. Important research areas are:

1. mathematical analysis and development of algorithms for optimal control problems,
2. nonlinear optimization methods,
3. analysis and numerical mathematics of nonlinear partial differential equations (transport equations, equations of fluid mechanics),
4. algorithmic sensitivity and gradient calculations (automatic differentiation).

## What is oceanic CO<sub>2</sub> uptake?

Oceans are able to store large amounts of carbon dioxide (CO<sub>2</sub>) by its fixation from the atmosphere. The oceans act as an enormous carbon sink, and have taken up about a third of the CO<sub>2</sub> emitted by human activity. This fact is quite important for climate discussion where the central topic concerns CO<sub>2</sub> as a greenhouse gas and its effects on global climate changes. The change of oceanic uptake of CO<sub>2</sub> caused by climate changes (e. g. increasing temperatures) is able to generate feedback effects. As the uptake of CO<sub>2</sub> is mainly driven by geobiochemical mechanisms, the aims of the project A3 are sensitivity analysis and data assimilation (i.e. adaptation of model parameters to measured results) in geobiochemical models coupled with ocean circulation models. These aims are implemented by using applied mathematics and computer science.

## Results

### 3-D Parameter Identification in Marine Ecosystems with Surrogate-based Optimization

We have applied the Surrogate-based Optimization (SBO) method on a parameter identification problem for a 3-D biogeochemical model. SBO is a method for acceleration of optimization processes when the underlying model itself is of very high computational complexity. In these cases, pure simulation runs already require a huge amount of computer time, whereas optimization runs may become unfeasible even with high-performance hardware. As a consequence, the key idea of SBO is to replace the original, and computationally expensive, (high-fidelity) model by a so-called surrogate, which is created from a less accurate but computationally cheaper (low-fidelity) model with a suitable correction approach to increase its accuracy. To date, the SBO approach has been widely and successfully used in engineering applications and also for parameter identification in a 1-D marine ecosystem model of NPZD type. In this paper, we apply the approach to a two-component biogeochemical model. The model is spun-up into a steady seasonal cycle via the Transport Matrix Approach. The low-fidelity model we use consists of a reduced number of spin-up iterations (several decades instead of the millennia used for the original model). A multiplicative correction operator is further exploited to extrapolate the rather inaccurate low-fidelity model onto the original one. This corrected model builds our surrogate. We validate this SBO method by twin-experiments that use synthetic observations generated by the original model. The proposed SBO technique is shown to yield a solution close to the target with a significant gain of computational efficiency. Without further regularization techniques, the method is able to identify most model parameters. The method is simple to implement and presents a promising and pragmatic tool to calibrate biogeochemical models in a global three-dimensional setting.

### GPU hardware accelerates Ecosystem Simulations

We have ported an implementation of the spin-up for marine ecosystem models based on transport matrices to graphics processing units (GPUs). The original implementation was designed for distributed-memory architectures and uses the

Portable, Extensible Toolkit for Scientific Computation (PETSc) library that is based on the Message Passing Interface (MPI) standard. The spin-up computes a steady seasonal cycle of ecosystem tracers with climatological ocean circulation data as forcing. Since the transport is linear with respect to the tracers, the resulting operator is represented by matrices. Each iteration of the spin-up involves two matrix-vector multiplications and the evaluation of the biogeochemical model used. The original code was written in C and Fortran. On the GPU, we use the Compute Unified Device Architecture (CUDA) standard, a customized version of PETSc, and a commercial CUDA Fortran compiler. We describe the extensions to PETSc and the modifications of the original C and Fortran codes that had to be done. Here we make use of freely available libraries for the GPU. We analyze the computational effort of the main parts of the spin-up for two exemplar ecosystem models and compare the overall computational time to those necessary on different CPUs. The results show that a consumer GPU can compete with a significant number of cluster CPUs without further code optimization.

### Linear Quadratic Optimal Control leads to an improved Ecosystem Model

We use an optimization method for enhancement of a climate model, namely a one dimensional non-linear marine ecosystem model of NPZD type. The original model contains temporally constant parameters that are subject to optimization in order to improve the fit of the model output to observational data. In several publications, this fit turned out to be rather poor. In this work, the method of Linear Quadratic Optimal Control (LQOC) is used to allow for temporally variant, but annually periodic parameters, in a linearized version of the original model. The periodicity of the parameters is assured by a special choice of the reference trajectory needed in the linearization process. The optimal periodic parameters obtained are used in the original non-linear model. In both validation and prediction experiments, they lead to a significant reduction of the model-data misfit, compared to results obtained with optimized constant parameters.

### Personnel

Head of the group: Prof. Dr. T. Slawig; Secretary: J. Eitzen (50%)

Scientific Staff:

Dipl.-Math. J. Gördes	15.11.-31.12.2013	(50%)	CAU
Dipl.-Math. A. Heinle	01.01.-31.03.2013	(50%)	CAU
Dipl.-Math. A. Heinle	01.06.-30.09.2013	(50%)	DFG
Cluster The Future Ocean			
Dipl.-Math. C. Kratzenstein	01.01.-30.09.2013		DFG
SPP 1253			
Dr. H. Mütze	01.01.-31.10.2013	(50%)	CAU
Dipl.-Math. J. Piwonski	01.01.-31.03.2013	(50%)	CAU
Dipl.-Math. J. Piwonski	01.04.-31.12.2013		CAU
Dipl.-Math. J. Reimer	01.01.-31.12.2013		DFG
Cluster The Future Ocean			
Dipl.-Math. C. Roschat	01.10.-31.12.2013	(50%)	DFG
Cluster The Future Ocean			

### Lectures, Seminars, and Laboratory Course Offers

Winter 2012/2013

Algorithmisches Differenzieren, 2 (+ 4) hrs Lecture (+ Exercises)/Week,



T. Slawig (+ J. Piwonski)

Algorithmische Aspekte numerischer Verfahren, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ J. Burmeister)

Informatik für Naturwissenschaftler, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ S. Esquivel)

Introduction to Matlab, 1 hrs Workshop/Week,  
T. Slawig

Matlab Advanced, 1 hrs Workshop/Week,  
T. Slawig

Masterprojekt - Algorithmische Optimale Steuerung / Klimasimulation, 4 hrs Exercise/Week,  
T. Slawig

Informatik für Nebenfächler, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ S. Esquivel)

Informatik für Nebenfächler (vertiefend), 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ S. Esquivel)

Oberseminar Algorithmische Optimale Steuerung - Informatik in der Meeresforschung, 2 hrs Seminar/Week,  
T. Slawig

### *Summer 2013*

Programmierpraktikum, 1 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ J. Piwonski, S. Schulmeister, I. Stucke)

Programmierpraktikum für Mathematiker, 1 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ J. Piwonski, S. Schulmeister, I. Stucke)

Klimamodelle und Klimasimulation, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ J. Burmeister)

MATLAB Intro ISOS Course, 2 hrs Seminar/Week,  
T. Slawig

Abschlussprojekt - Softwareentwicklung für mobile Geräte, 6 hrs Exercise/Week,  
T. Slawig

Masterprojekt - Softwareentwicklung für mobile Geräte, 4 hrs Exercise/Week,  
T. Slawig

Oberseminar Algorithmische Optimale Steuerung - Informatik in der Meeresforschung, 2 hrs Seminar/Week,  
T. Slawig

### *Winter 2013/2014*

Algorithmische Aspekte numerischer Verfahren, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ J. Burmeister)

Nichtlineare Optimierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ J. Piwonski, J. Reimer)

Nichtlineare Optimierung für Wirtschaftsinformatikstudierende, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Slawig (+ J. Piwonski, J. Reimer)

Masterprojekt - Algorithmische Optimale Steuerung / Klimasimulation, 4 hrs Exercise/Week,

T. Slawig

Oberseminar Algorithmische Optimale Steuerung - Informatik in der Meeresforschung, 2 hrs Seminar/Week,

T. Slawig

## Third-Party Funds

DFG Cluster The Future Ocean, *Personal*, 01.01.2012-31.12.2014 (132300 EUR)

DFG SPP 1253, *Personal/Sachmittel*, 01.01.2012-30.09.2013 (141500 EUR)

DFG Cluster The Future Ocean, *Personal/Sachmittel*, 01.05.-31.12.2013 (64500 EUR)

BMBF PerLe, *Personal*, 15.04.-30.11.2013 (4460 EUR)

## Further Cooperation, Consulting, and Technology Transfer

Prof. Dr. Andreas Oschlies **GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel**, Kiel

Prof. Dr. Martin Wahl **GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel**, Kiel

Dr. Iris Kiest, **GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel**, Kiel

Prof. Dr. Andreas Griewank, **MATHEON and Humboldt-Universität zu Berlin**, Berlin

Prof. Dr. Nicolas Gauger, **RWTH Aachen Aachen**

Dr. Uwe Prüfert, **TU Bergakademie Freiberg**, Freiberg

Prof. Dr. Slawomir Koziel, **Reykjavik University Reykjavik (Iceland)**

Prof. Dr. Kai Graf, **FH Kiel**, Kiel

## Diploma, Bachelor's and Master's Theses

T. Wittkopf, *Summierte Rechteck- und Trapezregel zur stabilen Lösung von gestörten Volterra-Integralgleichungen der ersten Art mit schwach singulären Kernen*, 10.01.2013

M. Henningsen, *Steuerungsproblem in Bezug auf eine Fischpopulation und die Optimierung der Entnahme von Fisch*, 07.02.2013

C. Irrgang, *Die Transportmatrixmethode bei marinen Ökosystemen*, 06.05.2013

M. Adolf, *Schritte zur Portierung der globalen Ozeansimulation METOS3D auf zwei GPUs*, 26.09.2013

B. Peiler, *Schritte zur Portierung des globalen Klimamodells NEMO auf GPUs*, 26.09.2013

S. Büsing, *Entwicklung einer iOS-Lernapp mit Schwerpunkt auf zufälliger Spielfeldgenerierung und didaktisch adaptiver Fragensauswahl*, 27.09.2013

B. Rohde, *Entwicklung einer Android-Lernapp mit Schwerpunkt auf den Export von Auswertungsstatistiken*, 27.09.2013

D. Jähde, *Entwicklung einer Android-Lernapp und eines Programms zur Generierung zugehöriger Fragenkataloge*, 27.09.2013

D. Goermann, *Entwicklung einer Android-Applikation mit MVC-Struktur zur Studienadministration mit einer serverseitigen Datenbankschnittstelle*, 30.09.2013

T. Coen, *Development of an Android Application for Marine Research with a large pre-existing Database following the MVC Pattern*, 30.09.2013

L. Gahlke, *Development of a Navigation-based Core Data iOS-Application in Objective C: A Tool for quick Identification of Fishes*, 30.09.2013

## Dissertations / Postdoctoral Lecture Qualifications

A. Heinle, *Interne Dynamik mariner Ökosystemmodelle*, 22.05.2013

## Publications

Published in 2013

- E. Siewertsen, J. Piwonski, T. Slawig, *Porting marine ecosystem model spin-up using transport matrices to GPUs*, Geophysical Model Development, **6**, 17 - 28 (2013)
- J. Rückelt, G. Bärwolff, T. Slawig, *The one-shot method for a pressure correction Navier-Stokes solver: An example where optimization can be faster than simulation*, International Journal of Mathematical Modelling and Numerical Optimisation, **4**, (2013)
- M. El Jarbi, J. Rückelt, T. Slawig, A. Oschlies, *Reducing the Model-Data Misfit in a Marine Ecosystem Model Using Periodic Parameters and Linear Quadratic Optimal Control*, Biogeosciences, **10**, 1169 - 1182 (2013)
- M. Prieß, S. Koziel, T. Slawig, *Marine Ecosystem Model Calibration with Real Data Using Enhanced Surrogate-Based Optimization*, Journal of Computational Science, **4:5**, 423 - 437 (2013)
- A. Heinle, T. Slawig, *Internal dynamics of NPZD type ecosystem models*, Ecological Modelling, **254**, 33 - 42 (2013)
- T. Slawig, A. Heinle, *Theoretical analysis and optimization of nonlinear ODE systems for marine ecosystem models*, System Modelling and Optimization, 501 - 510 (2013)
- M. Prieß, J. Piwonski, S. Koziel, A. Oschlies, T. Slawig, *Accelerated Parameter Identification in a 3D Marine Biogeochemical Model Using Surrogate-Based Optimization*, Ocean Modelling, **68**, 22 - 36 (2013)
- C. Kratzenstein, T. Slawig, *Simultaneous Model Spin-up and Parameter Identification with the One-Shot Method in a Climate Model Example*, International Journal of Optimization and Control: Theory and Applications, **3:2**, (2013)
- A. Heinle, T. Slawig, *Impact of parameter choice on the dynamics of NPZD type ecosystem models*, Ecological Modelling, 93 - 101 (2013)

## Presentations

- E. Siewertsen, J. Piwonski, T. Slawig, *Porting Marine Ecosystem Model Spin-up Using Transport Matrices to GPUs*, GPU Technology Conference, San Jose, USA, 25.-27.03.2013
- J. Reimer, *Optimizing Parameters for a 3-Dimensional Biogeochemical Model*, Tagung des Clusters, Schleswig, 09.-10.09.2013
- J. Reimer, *Reducing uncertainties in earth system sciences by optimizing model parameters and measurements*, Interdisciplinary Conference of Young Earth System Scientists, Hamburg, 22.-25.09.2013
- J. Reimer, *Optimal Experimental Design in Marine Science - An Application Example*, The International Conference on Recent Advances in Experimental Design, Guangzhou, China, 12.-16.12.2013

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# Business Information Technology

This group focuses on the development and integration of business application systems. The key issues are improved development by capturing business requirements as a system's specification and the automated validation if the system's models or the real systems meet these requirements. Examples of such commercial system are ERP systems, e-commerce systems, or the combination of these two in realizing a web shop.

The working group provides lectures, seminars, and practical courses for business information system and computer science students as well as economic studies (bachelor's and master's).

## Results

The experimental automated validation system has been extended in order to support further model types. Furthermore the further validation mechanisms have been integrated to the validation system.

These system's extensions open new opportunities to apply the validation concept. Currently these new possibilities are being explored and verified. The goal is to gain new fields of application of the automated validation.

## Personnel

Head of the group: Prof. Andreas Speck; Secretary: Sylvia Lassen (50%)

Technical Staff: B.Sc. Timo Wilgen

Scientific Staff:

Dipl.-Inf. Harm Brandt	01.01.-31.10.2013	(50%)	EU
User Driven Innovation			
Dr. Ing. Sven Feja	01.01.-31.12.2013		CAU
Dipl. Ing. Aneta Lotycz	01.01.-31.03.2013		CAU
Dipl. Ing. Aneta Lotycz	01.04.-30.09.2013	(50%)	ZBW
M.Sc. Sven Niemand	01.04.-30.09.2013	(50%)	ZBW
Dipl. Ing. Sören Witt	01.01.-31.12.2013		HSP

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2012/2013*

WInf-WInf1:-Grundlagen Wirtschaftsinformatik I, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Speck (+ S. Witt)

WInf-WInf1-WW:-Grundlagen Wirtschaftsinformatik I für Wirtschaftswissenschaftler, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Speck (+ S. Witt)

WInf-BetrStan: Betriebliche Standardsoftware, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Speck (+ S. Feja, A. Lotycz, S. Witt)

WInf-GenProg: Generative Programmierung, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Speck (+ S. Feja)

WInf-Pro: Projektgruppe, 4 hrs Practical/Week,

A. Speck (+ S. Witt, S. Feja)

WInf-MSc-Sem2: Interdisziplinäres Seminar, 2 hrs Seminar/Week,

A. Speck (+ S. Witt, S. Feja)

### Summer 2013

WInf-WInf2: Wirtschaftsinformatik II, 2 (+ 2) hrs Lecture (+ Exercises)/Week,

A. Speck (+ A. Lotycz)

WInf-WInf2: Wirtschaftsinformatik II für Wirtschaftswissenschaftler, 2 (+ 2) hrs Lecture (+ Exercises)/Week,

A. Speck (+ A. Lotycz)

WInf-eC:E-Commerce, 3 (+ 1) hrs Lecture (+ Exercises)/Week,

A. Speck (+ S. Witt)

WInf-Sem1: Seminar Wirtschaftsinformatik, 2 hrs Seminar/Week,

A. Speck (+ S. Feja, S. Witt)

WInf-Proj-BA1: Abschlussprojekt Wirtschaftsinformatik- Betriebliche Anwendungssysteme, 4 hrs Practical/Week,

A. Speck (+ A. Lotycz, S. Witt)

WInf-MSc-Pro2: Projekt Wirtschaftsinformatik (betriebliche Anwendungssysteme), 5 hrs Practical/Week,

A. Speck (+ S. Feja, S. Witt)

### Third-Party Funds

EU Interreg 4A –User driven Innovation–, *Personal*, 01.01.-31.10.2013 (222460 EUR)

BMW EXIT-Programm Projekt runpat, *Personal*, 01.01.-31.10.2013 (91600 EUR)

### Diploma, Bachelor's and Master's Theses

B. Blömer, *Konzept eines Change Managements zur Einführung eines ERP-Systems im Umfeld eines deutschen Medizinfachhandelsunternehmens*, 30.09.2013

M. Braune, *Steuerung einer betrieblichen Anwendung mit einer Workflow-Engine*, 30.09.2013

O. Cordsen, *Entwurf und prototypische Implementierung eines SaaS-basierten Buchungssystems für Ortsbezogene Buchungsbetriebe*, 23.09.2013

J. Dittmer, *Konzept zur Definition komplexer Operatoren auf Basis grafischer Validierungsregeln*, 25.09.2013

S. Feja, *Grafische Modellierung statischer Anforderungen zur Validierung*, 28.03.2013

J.-M. Götsche, *Transformations- und Validierungsprozessorchstrierung für Prozessmodelle auf Basis von semantischen Services*, 28.03.2013

S. Götz, *Entwicklung einer Webapplikation zur Modellierung von grafischen Validierungsregeln*, 11.03.2013

S. Lemke, *Vergleichende Evaluation von Business Process Management-Umgebungen mit dem Fokus auf Modell-getriebene Prozessausführung am Beispiel von iBPM*, 30.09.2013

E. Lurz, *Vergleichende Evaluation von Business Process Management-Umgebungen mit dem Fokus auf Modell-getriebene Prozessausführung am Beispiel von Activiti*, 30.09.2013

S. Niemand, *Qualitätsmanagement am Beispiel des Business Application Modeler*, 08.04.2013

P. Schlüwe, *Change Management anhand eines Anwendungsfalles bei der ThyssenKrupp Marine Systems GmbH*, 29.10.2013

M. Schulte-Althoff, *Vergleichende Evaluation von Business Process Management-Umgebungen mit dem Fokus auf Modell-getriebene Prozessausführung am Beispiel von Bonita BPM*, 30.09.2013

## Publications

Published in 2013

- A. Speck, S. Feja, E. Pulvermüller, S. Witt, *Dependencies in business process rule hierarchies*, International Conference on Intelligent Software Methodologies, Tools and Techniques (SoMeT 2013) IEEE, **12**, 203 - 207 (2013)
- A. Speck, S. Feja, E. Pulvermüller, S. Witt, *Integrating Validation Techniques for Process-based Models*, Proceedings of the 8th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE 2013), **8**, 246 - 253 (2013)
- S. Niemand, S. Feja, S. Witt, A. Speck, *Vorgehensmodellentwurf für Forschungsprototypen*, Eckart Hanser, Martin Mikusz, Masud Fazal-Baqaie (Hrsg.): Vorgehensmodelle 2013 - Vorgehensmodelle - Anspruch und Wirklichkeit, 175 - 177 (2013)
- S. Feja, S. Witt, *Automatische Validierung von Prozessmodellen*, Kieler Prozessmanagementforum, (2013)

# almanach 13



# Communication Systems

The Research Group for Communication Systems (AG ComSys) was established in the Dept. of Computer Science of the CAU Kiel in Oct. 2000, and has been directed since by Prof. Dr.-Ing. Norbert Luttenberger. The AG ComSys performs research work in four different application-oriented areas. These areas will be introduced in the following.

## Results

### 1. Verification of Railway Infrastructures

In close co-operation with Funkwerk IT GmbH, an ontology-based verifier for railway infrastructures was designed and implemented. In 2013, the focus was on establishing a railML-based ontology for railway infrastructures and the formalization of railway infrastructure design rules in SWRL language (Semantic Web Rule Language). Additionally, a semantic debugging aid was designed and implemented that helps the railway engineer when planning a specific railway infrastructure.

### 2. OWL to UML Transformation on the Metamodel Level

Though nowadays the Web Ontology Language (OWL) is mostly considered as a language for knowledge representation, it can also be used as a language for conceptual modelling of complex information systems, i.e. as a language for representing the entities of a certain domain and for expressing the meaning of various, usually ambiguous, terms and to identify the relationships between these. In this respect, OWL can be seen as a direct „competitor“ to static Unified Modelling Language (UML) class diagrams, which are for example, often used for this purpose in the ISO 191xx series of standards -. Both languages have their benefits. UML's visual syntax is easy to understand and there is a variety of software tools to choose from. OWL is backed up by formal logic and logical conclusions can be drawn on models using reasoner software. In order to benefit from the advantages and software tools of both languages, a tool was designed and implemented that automatically transforms a model written in one language into a model in the other language. This tool is built upon a common third between UML and OWL, namely the Meta Object Facility (MOF).

## Personnel

Head of the group: Prof. Dr.-Ing. N. Luttenberger; Secretary: N. Mard-Azad (50%)

Technical Staff: BSc. M. Westphal (50%)

Scientific Staff:

MSc. M. Lodemann	01.01.-31.07.2013
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Dr.-Ing. J. Zedlitz	01.08.-31.12.2013
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## Lectures, Seminars, and Laboratory Course Offers

*Winter 2012/2013*

Betriebssysteme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
N. Luttenberger (+ C. Motika, C. D. Schulze)

XML in Communication Systems, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
N. Luttenberger (+ M. Lodemann)

*Summer 2013*

Academic Writing, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
N. Luttenberger (+ N. Luttenberger)

Kommunikationssysteme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
N. Luttenberger (+ M. Lodemann)

## Diploma, Bachelor's and Master's Theses

Alexander Prange, *Entwurf und Entwicklung einer Multicast-Komponente für die Webanwendung ScenePoint*,  
01.08.2013

Krischan Kähler, *Extraktion und Clustering von Textmerkmalen für Blogposts*, 26.09.2013

Lars Rohwedder, *Entwurf und Realisierung einer Webanwendung für 3D Präsentationen*, 15.02.2013

## Dissertations / Postdoctoral Lecture Qualifications

J. Zedlitz, *Konzeptuelle Modellierung mit UML und OWL - Untersuchung der Gemeinsamkeiten und Unterschiede mit Hilfe von Modelltransformationen*, 26.03.2013

## Publications

Published in 2013

J. Zedlitz, N. Luttenberger, *Data Types in UML and OWL-2*, SEMAPRO 2013, The Seventh International Conference on Advances in Semantic Processing, (2013)

N. Luttenberger, *Und was bedeutet das jetzt für mich? Über schema.org oder: Wie Semantik im Semantic Web gemacht wird*, IK - Praxis der Informationsverarbeitung und Kommunikation, (2013)

J. Zedlitz, N. Luttenberger, *Bewertung von OWL-2-basierten Ontologien mit Metriken*, PIK - Praxis der Informationsverarbeitung und Kommunikation, (2013)

M. Lodemann, N. Luttenberger, E. Schulz, *Semantic Computing for Railway Infrastructure Verification*, Eighth IEEE International Conference on Semantic Computing, (2013)

# Computer-Aided Program Development

As in past years, in 2013 the research group also mainly investigated the fundamentals of programming languages in combination with formal methods for problem specification and development, the use of relation-algebraic and relation-like methods in mathematics and computer science, the application of graphs as modelling tools and objects for formal development of declarative and relational algorithms, and computational problems from Social Choice Theory. Again this has been done with specific regard to tool support. Besides the Kiel RELVIEW system we mainly used the automated theorem prover Prover9 and the counterexample generator Mace4.

## Results

With regard to relational algorithms and Computational Social Choice Theory we have developed a simple computing technique for the choice problem if the given dominance relation is a tournament, that is, asymmetric and complete. The technique rests upon a relation-algebraic modelling of the objects in question and uses the Kiel RELVIEW system for the evaluation of the relation-algebraic expressions that specify the solutions, and for the visualization of the computed results. We have applied our approach to most of the well-known tournament solutions, including the Copeland set, Condorcet winners, the set of Condorcet non-losers, the Schwartz set, the top cycle, the uncovered set, the minimal covering set, the Banks set, and the tournament equilibrium set. Our technique proved to be very flexible and especially appropriate for prototyping and experimentation, and as such, very instructive for educational purposes.

We have also considered the case where the given dominance relation is still asymmetric, but not complete. For such so-called weak tournaments J. Duggan proposed three possibilities to modify the Banks set. With the same technique as described above we have been able to develop relation-algebraic specifications that compute Duggan's modifications of the Banks set and some further variants of them.

Besides the Banks set we also have investigated coverings in case of weak tournaments. Over the years in the literature on tournament solutions three different kinds of covering have been investigated, viz. upward covering, downward covering, and bidirectional covering. Meanwhile it has been shown that they yield the same results, but in the case of weak tournaments different coverings may lead to different uncovered sets and different minimal covering sets. For both solution concepts we have been able to generalize our solutions for tournaments to three solutions for weak tournaments.

Using relation algebra we have introduced the decomposition of an arbitrary relation into a sequential composition of three relations, viz. of a mapping with a partial order and then the transpose of a mapping. We have investigated the specific classes of junkfree, irreducible and minimal decompositions and have shown that for all relations (up to isomorphism) a unique minimal decomposition exists. Based on this result, we have studied decompositions with regard to Dedekind-MacNeille completions and concept lattices. In our setting the fundamental theorem of concept lattices states that concept lattices are minimal-complete decompositions and all such decompositions are isomorphic. We have been able to prove this fact relation-algebraically. As our main result we have proven that the Dedekind-MacNeille completion of the order that belongs to the minimal decomposition of a relation is isomorphic to the concept lattice of that relation. To be as general as possible we have worked within the general framework of allegories. This implies that the results can be applied to all models of these algebraic structures, including, for instance, lattice-valued fuzzy relations.

In the context of graph algorithms in Haskell we have continued the development of a framework for a declarative implementation. We have abstracted one scheme that occurs in many applications and that can be viewed as a multiplication of a matrix with a vector. This scheme allows a flexible parameterization over the container types that are involved, which allows simple complexity estimates. This scheme is also suited for repeated applications that occur naturally when searching for paths with special properties. The flexibility allows a canonic combination with the Depth-First-Search implementation of King and Launchbury that can be used for combined search strategies.

The abstraction mentioned above can solve matrix oriented problems too. We have used the very same library to implement

a naive manipulation strategy in the context of approval voting, which easily translates to a matrix calculation.

Additionally, we have studied a structure that occurs in many order definitions. We were able to express this structure using the well-known concept of monoid actions. We have shown that every preorder is generated by a monoid action and have characterized the antisymmetry in several ways. Using this connection we have investigated concepts from order theory in the context of action theory, e.g. linearity, majorants and monotonicity. The obtained abstraction allows a simple and concise implementation in the functional logic programming language Curry. We have used this implementation to study some classic examples of orders using a declarative approach.

We developed a purely relation-algebraic algorithm that computes maximum matchings in bipartite graphs. With the Kiel RELVIEW system we tested our implementation of the algorithm on random bipartite graphs. Particularly, we were interested in the verification of the algorithm. Therefore we used standard Hoare logic and proved correctness in a purely relation-algebraic context. Our other approach was the automated verification by using an automated theorem prover. We choose the First-order theorem prover Prover9 because of its very easy handling, and the software Mace4 which searches for counterexamples. With these tools we were able to show the correctness of the algorithm after determining the pre- and postconditions and the invariants.

In the context of automated theorem proving we studied the automated verification of relation-algebraic formulae. We showed that Prover9 can also be used to verify equivalences of the relation-algebraic expressions and the predicate formulae.

## Personnel

Head of the group: Prof. Dr. R. Berghammer; Secretary: Jane Eitzen (50%), Linda Haberland (50%)

Scientific Staff:

Dipl.-Math. Nikita Danilenko 01.01.-31.12.2013  
Functional algorithms for discrete problems

Dipl.-Math Insa Stucke 01.01.-31.12.2013  
Approximation algorithms for Social Choice problems

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2012/2013*

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,  
R. Berghammer (+ M. Hanus)

Inf-Sem-MathMed: Mathematische Methoden in der Informatik, 2 hrs Seminar/Week,  
R. Berghammer (+ Nikita Danilenko, Insa Stucke)

Inf-Sem-PS: Semantik von Programmiersprachen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. Berghammer (+ Nikita Danilenko)

MS0402: Ordnungen und Verbände, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. Berghammer (+ R. Berghammer, Insa Stucke)

Oberseminar - Rechnergestützte Programmentwicklung, 2 hrs Seminar/Week,  
R. Berghammer

*Summer 2013*

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,  
R. Berghammer (+ M. Hanus)

Inf-BDD: Binäre Entscheidungsdiagramme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. Berghammer

Inf-Sem-MathMed: Mathematische Methoden in der Informatik, 2 hrs Seminar/Week,  
R. Berghammer (+ Nikita Danilenko)

Oberseminar - Rechnergestützte Programmentwicklung, 2 hrs Seminar/Week,  
R. Berghammer

Winter 2013/2014

Inf-Math-A: Mathematik für Informatiker A - Grundlagen und Diskrete Strukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. Berghammer (+ Nikita Danilenko, Ch. Gießen, Insa Stucke)

Inf-Sem-MathMed: Mathematische Methoden in der Informatik, 2 hrs Seminar/Week,  
R. Berghammer (+ N. Danilenko, I. Stucke)

## Further Cooperation, Consulting, and Technology Transfer

Applications of relational methods in computer science: with B. Möller (Augsburg), G. Schmidt (München), R.A. Schmidt (Manchester, UK), G. Struth (Sheffield, UK) and M. Winter (St. Catharines, Canada).

Automated theorem proving: with P. Höfner (Sydney, Australia).

Social software for elections, aggregation of tenders and coalition formation: with A. Rusinowska and M. Grabisch (Paris, France) and H. de Swart (Tilburg, The Netherlands).

Evolutionary and approximation algorithms, binary decision diagrams: with F. Neumann (Adelaide, Australia).

Case studies of the semantics of allValues in Curry: with J. Christiansen and F. Reck (Kiel).

A non-existence result concerning a pre-order structure generated by get/put in the context of bidirectional transformations: with S. Fischer (Kiel).

## Publications

Published in 2013

R. Berghammer, *Ordnungen und Verbände: Grundlagen, Vorgehensweisen und Anwendungen*, Springer Vieweg Verlag, Wiesbaden, (2013)

R. Berghammer, A. Rusinowska, H. de Swart, *Computing tournament solutions using relation algebra and RELVIEW*, European Journal of Operational Research, **226**, 636 - 645 (2013)

R. Berghammer, *Computing and visualizing Banks sets of dominance relations using relation algebra and RELVIEW*, Journal on Logic and Algebraic Programming, **82**, 123 - 136 (2013)

R. Berghammer, M. Winter, *Decomposition of relations and concept lattices*, Fundamenta Informaticae, **126** (1), 37 - 82 (2013)

N. Danilenko, *And... Action! - Monoid Actions and (Pre)Orders*, Technical Report, Kiel University, **1306**, 48 - 62 (2013)

## Presentations

R. Berghammer, *Simple games and the use of BDDs for solving problems*, NICTA, Sydney, Australia, 01.03.2013

R. Berghammer, *Computing tournament solutions using relation algebra and RELVIEW*, NICTA, Sydney, Australia, 06.03.2013

R. Berghammer, *Deklarative Lösung schwerer Probleme mittels Relationenalgebra und RELVIEW*, 30. Workshop der GI-Fachgruppe Programmiersprachen und Rechnerkonzepte, Bad Honnef, 06.-08.05.2013

Nikita Danilenko, *Orders via functions and logic*, 30. Workshop der GI-Fachgruppe Programmiersprachen und Rechnerkonzepte, Bad Honnef, 06.-08.05.2013

N. Danilenko, *And... Action! - Monoid Acts and (Pre)Orders*, 22nd Workshop on Functional and (Constraint) Logic Programming, Kiel, 11.-13.09.2013

N. Danilenko, *Functional Kleene Closures*, 17. Kolloquium Programmiersprachen, Wittenberg, 30.09.-02.10.2013

R. Berghammer, A. Rusinowska, H. de Swart, *Spatial voting games, relation algebra and RELVIEW*, Conference on Mathematics of Electoral Systems, Budapest, Hungary, 11.10.-13.11.2013

A. Rusinowska, R. Berghammer, H. de Swart, *Computing tournament solutions using relation algebra and RELVIEW*, 26th EURO Conference on Operational Research, Rome, Italy, 01.-04.07.2013

Insa Stucke, *Automated Verification of a Relation-Algebraic Matching Program*, 17. Kolloquium Programmiersprachen, Wittenberg, 30.09.-02.10.2013

## Further Activities and Events

R. Berghammer visited the NICTA institute (Sydney, Australia) from February 24 to March 8, 2012.

R. Berghammer, N. Danilenko and I. Stucke worked as reviewers for scientific publications.

R. Berghammer is a member of the international working group "Relational Methods in Computer Science. He is the chair of the Steering Committee of the conference series "Relational and Algebraic Methods in Computer Science" (RAMiCS) and one of the editors of the electronic journal "Journal on Relational Methods in Computer Science". In 2013 he was a member of the programme committee of RAMiCS 14, that took place in April 2013 in Marienstatt. At present he is a member of the programme committees of IWSBP 11, that will take place in Freiberg from September 17-19, 2014, and of AISC 2014, that will take place in Seville, Spain, from December 11-13, 2014.

Guests in 2013: P. Höfner (NICTA, Sydney) from June 24 to 29, 2013.

## Computer Media

Prof. Dr. Klaus Tochtermann is Managing Director of the Leibniz Information Centre for Economics (ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften Leibniz-Informationszentrum Wirtschaft).

Further information about the Leibniz Information Centre for Economics is available on the web: <http://www.zbw.eu/>

Leibniz Information Centre for Economics

Managing Director Prof. Dr. Klaus Tochtermann

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# almanach 13



# Computer Science Education

The main event in 2013 was the organization of the 15. GI-Fachtagung Informatik und Schule (INFOS 2013), including the publication of conference proceedings and a volume on school practice. The group also helped to organize the first computer science teacher day in Schleswig-Holstein.

## Personnel

Head of the group: Prof. Dr. Thomas Wilke - in charge on behalf of the department;

Scientific Staff:

Dr. rer. nat. Detlef Köhler	01.01.-31.12.2013	CAU
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Dr. rer. nat. Lars Willert	01.01.-31.12.2013	CAU
----------------------------	-------------------	-----

## Lectures, Seminars, and Laboratory Course Offers

### Summer 2013

Inf-FD1: Grundlagen fachbezogenen Lehrens und Lernens im Fach Informatik, 2 hrs Lecture/Week,  
D. Köhler

Inf-FD4: Fachdidaktisches Urteilen und Forschen sowie Weiterentwicklung von Unterrichtspraxis, 2 (+2) hrs Lecture  
(+ Exercises)/Week,  
L. Willert (+ L. Willert)

### Winter 2013/2014

Inf-Fd2: Planung, Durchführung und Analyse von Unterricht im Fach Informatik, 2 hrs Lecture/Week,  
D. Köhler

Inf-FD3: Fachunterricht - Konzeption und Gestaltung im Fach Informatik, 2 (+2) hrs Lecture (+ Exercises)/Week,  
L. Willert

## Diploma, Bachelor's and Master's Theses

A. Gerken, *Eine Einführung in die Programmierung - mit Blender und für die Sekundarstufe I (Bachelorarbeit)*,  
15.05.2013

K. Karlsson, *Ein elektronisches Lehrbüchlein für das Rechnen nach Adam Ries (Bachelorarbeit)*, 15.05.2013

A. Haak, *lili: Eine Programmierungsumgebung (Bachelorarbeit)*, 08.11.2013

## Publications

Published in 2013

N. Breier, P. Stechert, Th. Wilke, *INFOS 2013*, LNI, **P-219**, 1 - 157 (2013)

N. Breier, P. Stechert, Th. Wilke, *INFOS 2013 Praxisband*, Kiel Computer Science Series, **2013/3 v1.0**, 1 - 221 (2013)

M. Cyruk, G. Große-Bölting, *lili - eine Programmierungsumgebung für den Schulunterricht als Webanwendung*, *INFOS 2013 Praxisband*, (2013)

S. Schulmeister, *Movingart - ein fächerübergreifendes KunstInformatikProjekt in der Sekundarstufe I*, *INFOS 2013*, 67 - 76 (2013)



# Dependable Systems

The Dependable Systems Group investigates mathematical methods for the discovery and prevention of errors in computer systems. Modern computer systems are too complex to guarantee a high level of safety (that is, correct functionality) by mere testing or code inspection. Our research helps to find rigorous proofs, or at least strong indications, that a system possesses a certain safety feature or, in the case it does not, to deliver a counter example. In particular, we work in the field of formal specification and verification, model-checking, and the satisfiability problem of certain logics. Another field of research of our group is the investigation of algorithmic and combinatorial problems of sequential structures. Sequences are the most basic, nontrivial structures. Research on finding ways to efficiently transform, search, compress, generate, and analyse sequences is fundamental with an extremely wide application area.

## Results

### Verification of Concurrent Systems

We consider the problem of software safety in the context of embedded multicore systems. Embedded systems are often used in safety critical applications, like airbag systems in cars, or aircraft controllers. There exists a variety of methods for preventing and detecting errors in embedded code. For singlecore systems such methods have worked reasonably well in practice, however, the introduction of multicore embedded systems changes the situation drastically since programs are executed in parallel on the same system now. The most prominent error class introduced with such parallelism is called race conditions. Race conditions occur when two or more processes compete for a resource in an unregulated, and hence, unpredictable fashion. Such errors are extremely hard to detect by testing or code inspection alone. Therefore we investigate formal methods to analyse concurrent systems so that race conditions are reliably detected. These analysis methods are aimed at and tailored for real-world industrial applications. The goal is to construct a method (and the appropriate tool support) that finds race conditions reliably and fully automatically. These two conditions are very strong and not met by any approach known to us.

Our first approach is the employment of interval constraint solving algorithms for code analysis. These algorithms have a very high (exponential) worst case complexity. Our goal is to push the borders of using such formal methods to such a degree that real-world industrial code can be verified with reasonable effort. There are several strategies that we employ and implement in our verification tool MEMICS. Firstly, we use preprocessing steps of low computational complexity in

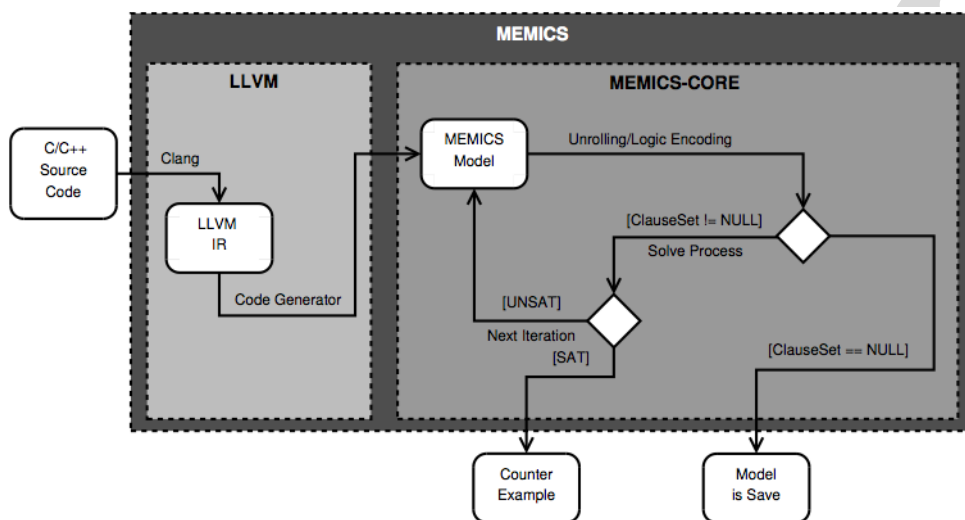


Fig. 2: An overview of the structure of MEMICS.

order to limit the problem size as much as possible to its core. Secondly, we optimise our solver to work best on constraints that are generated from actual software and not random. Constraints that model actual programs have a certain implicit structure that distinguishes them from other possible inputs. Our tool should work well on such special inputs instead of all possible inputs. Last but not least, we embedded the theory of memory arithmetics and access into the core of our solver in order to limit the size of the input model. Traditionally, the entire computational environment of a program is modelled in the logic of a constraint solver, which increases the model considerably. We try to circumvent that problem with our approach. The approach described is implemented in a tool called MEMICS, which is developed together with the Daimler AG within a larger BMBF research project called ARAMiS.

## High Performance Software Verification

The formal verification of software is a method for gaining more trust into safety critical systems that is rapidly growing in importance, as outlined in the previous paragraph. A precise analysis is only possible by applying formal methods. A core technique in that approach is constraint solving procedures. These (decision) procedures for certain suitable logics are powerful but also of high algorithmic complexity. In fact, their asymptotic worst case complexity is exponential in most cases. Therefore, there is no hope in applying this approach to all possible input instances. Yet, the advantages of the approach in terms of the precision of the analysis make it indispensable. On the positive side, not just the complexity of the analysed systems grows, but also computer performances.

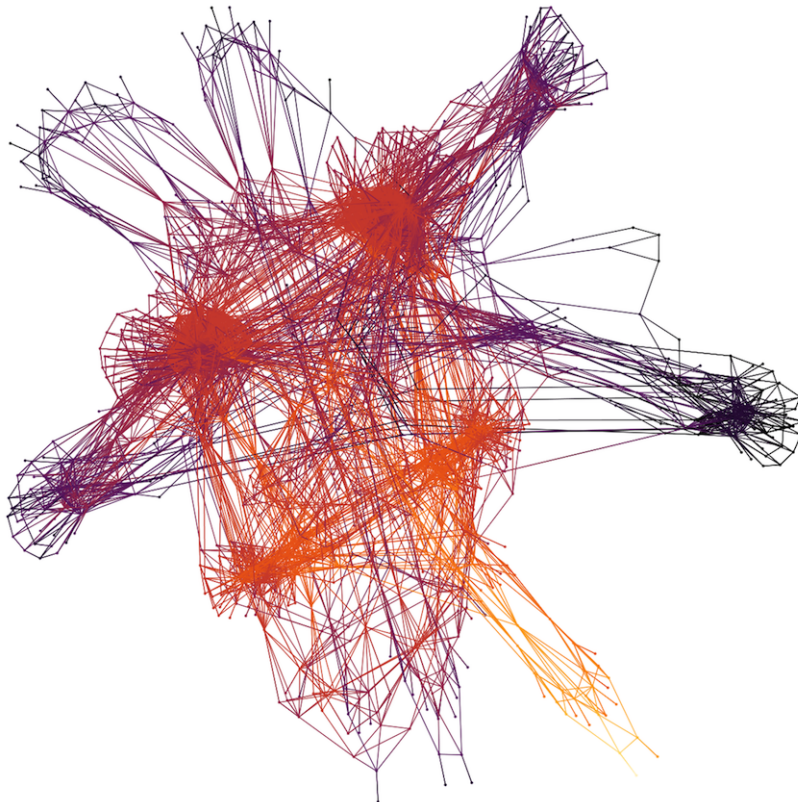


Fig. 1: The dependency graph of a verification problem.

In recent decades that speedup was mainly due to faster processing units and expanded memory. So, new hardware increased the speed of solvers basically without any modification of the implementation. However, that situation has changed drastically. Currently, a computational speedup is achieved by parallel hardware only. Ranging from desktop computers to simple smart phones, parallel processing units are employed. The number of cores of a processor has replaced

the clock speed as a measurement of performance. That means that tools that are to take advantage of faster computers need to employ algorithms that work in parallel. In the field of constraint solving, parallel approaches can be found only in a very mild form so far, e.g. solvers working on quad-core PCs. Scaling such programs up is a nontrivial task. In fact, new algorithms and approaches are needed. We investigate approaches for constraint solvers especially designed for massively parallel hardware. First investigations focus on large shared-memory computers, like a CRAY XMT, for two reasons. Firstly, the low data locality of constraint satisfaction problems indicate a shared memory for a first approach. Secondly, current developments suggest that future PCs will employ architectures using a shared memory, as seen in modern CPUs and coprocessors like the recent Intel Xeon Phi. Developing efficient verification tools on a CRAY supercomputer may therefore lead the way to efficient verification tools on future consumer hardware.

## Algorithms on Sequences

Sequences of symbols of a finite alphabet are the most fundamental nontrivial data structure. The examples range over bit streams in data communication, text, and speech processing, RNA sequences in molecular biology, and number theory questions in mathematics. Algorithmic questions on sequences arise therefore in many areas. Search, pattern matching, encodings, and sequence alignments are tasks that frequently occur and need to be computed efficiently. Naturally, algorithms on sequences have been investigated for a long time. However, many new questions emerge with new applications of data processing: for example the handling of large genomic data bases in microbiology, or fast online pattern matching for monitoring data streams.

One particular area of interest for us is the detection of repetitions in sequences modulo morphic or antimorphic permutations. A morphic permutation is the extension of a permutation on the alphabet to sequences over that alphabet. In other words, a morphic permutation is a function that takes a sequence and gives a sequence of the same length generated by permuting the letters (not the positions of letters!) of the input. In the antimorphic case, the same as in the morphic case happens but additionally the order of letters is reversed, like reading a word from right to left instead of the conventional left to right direction. A well-known instance of an antimorphic permutation (involution in fact) is the Watson-Crick complement of the DNA polymerase.

Matching patterns in a way parameterized by permutations, or more general morphisms and antimorphisms, is a largely unexplored field which we investigate. Repetitions modulo permutations occur in many manifestations ranging from genomic data to musical forms. In particular, the newly developing field of digital sciences, where more and more scientific progress is made by the computational analysis of huge amounts of experimental data, promises a wide area of applications of these new and more general matching algorithms. Considerable progress was made by our group in the investigation of algorithms on sequences in 2013, as documented by a number of publications.

## Combinatorics on Words

Combinatorics on words is the field of investigation of properties of sequences. The motivation for dealing with sequential structures has been indicated in the paragraph above by pointing out their ubiquity and the need to understand and process them. In fact, combinatorics on words provides the theoretical foundation for algorithms on sequences. Consequently, much of our work in 2013 has been focused on questions involving morphic and antimorphic permutations. In particular, avoidance questions were discussed, that is, questions on whether certain repetitions under permutations can be avoided in a sequence at all. Moreover, the inferences of different pseudo-periods (periods modulo morphisms and antimorphisms) were investigated.

When the application of processing of real world data from application areas like microbiology is considered, one often has to deal with imperfect data, that is, sequences that contain false or incomplete information due to sensoric or experimental conditions. The investigation of partial words, that is words that contain undefined positions, addresses this fact. Results on connecting the combinatorics on partial words with regular languages, that is sets of words that are recognised by finite automata, were published in 2013.

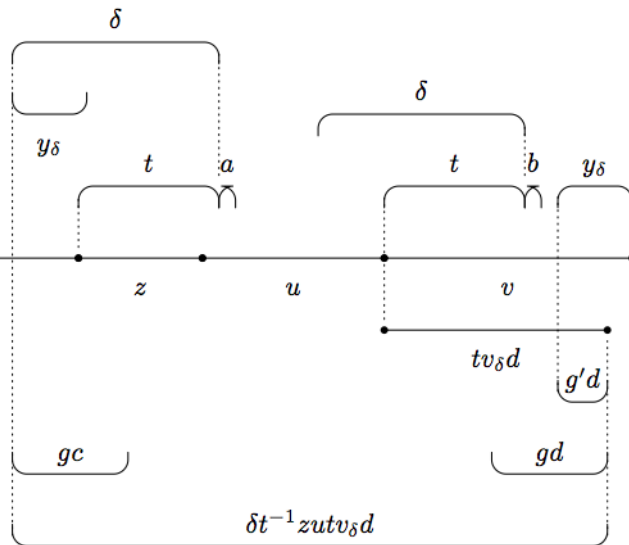


Fig. 3: Some word factorization.

Moreover, considerable progress on the characterization of the pseudo-periodic extension of the so called Lyndon-Schutzenberger equation was achieved.

## Personnel

Head of the group: Prof. Dr. D. Nowotka; Secretary: G. Walsdorf

Technical Staff: T. Grebien

Scientific Staff:

M. Sc. T. Ehlers ARAMiS	01.02.-31.12.2013	BMBF
Dr. F. Manea Algorithmische Kombinatorik auf Folgen	01.01.-31.12.2013	DFG
Dr. R. Mercas Kombinatorische Aspekte von Wörtern und deren Anwendungen	01.06.-31.12.2013	DFG
Dipl. Inf. M. Müller Kombinatorische Aspekte von Wörtern und deren Anwendungen	01.01.-31.12.2013	DFG
Dipl. Inf. P. Sieweck ARAMiS	01.01.-31.12.2013	BMBF

## Lectures, Seminars, and Laboratory Course Offers

Winter 2012/2013

Inf-SWT: Softwaretechnik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
D. Nowotka (+ J. Waller, S. Frey)

Übung zu: Hochleistungsrechnen, 2 hrs Exercise/Week,  
D. Nowotka

## Summer 2013

Inf-GSoZu: Grundlagen der Softwarezuverlässigkeit, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
D. Nowotka

Inf-MS-Sem-Sequenzen: Algorithmik und Kombinatorik von Sequenzen, 2 hrs Seminar/Week,  
D. Nowotka

Inf-Sem-HPC: Ausgewählte Themen des Hochleistungsrechnens, 2 hrs Seminar/Week,  
D. Nowotka

Inf-Sem-Sequenzen: Algorithmik und Kombinatorik von Sequenzen, 2 hrs Seminar/Week,  
D. Nowotka

NF-Inf-2: Systematisches Programmieren, 2 hrs Seminar/Week,  
D. Nowotka

## Winter 2013/2014

Inf-AlgSeq: Algorithms on Sequences, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Manea

Inf-EntVerf: Entscheidungsverfahren, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Nowotka

Inf-HPC: Hochleistungsrechnen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Nowotka (+ S. Christophersen)

Inf-MS-Sem-FSV: Formale Softwareverifikation, 2 hrs Seminar/Week,  
D. Nowotka

Inf-Sem-FSV: Formale Softwareverifikation, 2 hrs Seminar/Week,  
D. Nowotka



## Third-Party Funds

DFG, *Heisenbergprofessur*, 15.11.2011-14.11.2014 (324800)

DFG, *Kombinatorische Aspekte von Wörtern und deren Anwendungen*, 01.05.2011-31.10.2014 (365000)

DFG, *Algorithmische Kombinatorik auf Folgen*, 01.05.2013-30.04.2016 (192.900)

BMBF, *ARAMiS - Automotive, Railway and Avionics Multicore Systems*, 01.04.2012-30.11.2014 (327.030)



## Publications

Published in 2013

T. Catalin, P. Gawrychowski, F. Manea, R. Mercas, D. Nowotka, *Finding Pseudo-repetitions*, STACS, 257 - 268 (2013)

W. Hasselbring, D. Nowotka, M. Wasilewski, *Defining Requirements on Domain-Specific Languages in Model-Driven Software Engineering of Safety-Critical Systems*, Software Engineering (workshop), 467 - 482 (2013)

P. Gawrychowski, F. Manea, D. Nowotka, *Discovering Hidden Repetitions in Words*, CiE, 210 - 219 (2013)

R. Mercas, A. Saarela, *3-Abelian Cubes Are Avoidable on Binary Alphabets*, DLT, 374 - 383 (2013)

J. Dassow, F. Manea, R. Mercas, M. Müller, *Inner Palindromic Closure*, DLT, 155 - 166 (2013)

D. Nowotka, J. Traub, *Formal Verification of Concurrent Embedded Software*, IESS, 218 - 227 (2013)

Ch. Choffrut, R. Mercas, *The Lexicographic Cross-Section of the Plactic Monoid Is Regular*, WORDS, 83 - 94 (2013)

F. Manea, M. Müller, D. Nowotka, *On the Pseudoperiodic Extension of  $u^l = v^m w^n$* , FST&TCS, 475 - 486 (2013)

- S. Z. Fazekas, R. Mercas, *A Note on the Decidability of subword inequalities*, Int. J. Found. Comput. Sci., **24(4)**, 445 - 452 (2013)
- F. Manea, C. Tisceanu, *The hardness of counting full words compatible with partial words*, J. Comput. Syst. Sci., **79(1)**, 7 - 22 (2013)
- J. Dassow, F. Manea, B. Truthe, *Networks of evolutionary processors: the power of subregular filters*, Acta Inf., **50(1)**, 41 - 75 (2013)

## Presentations

- F. Manea, *Finding Pseudo-repetitions*, STACS, Kiel, 27.02.-02.03.2013
- M. Wasilewski, *Defining Requirements on Domain-Specific Languages in Model-Driven Software Engineering of Safety-Critical Systems*, ZeMoSS, Aachen, 27.02.-01.03.2013
- F. Manea, *Discovering Hidden Repetitions in Words*, CiE, Milano, Italy, 01.-05.07.2013
- R. Mercas, *3-Abelian Cubes Are Avoidable on Binary Alphabets*, DLT, Paris, France, 18.-21.06.2013
- M. Müller, *Inner Palindromic Closure*, DLT, Paris, France, 18.-21.06.2013
- J. Traub, *Formal Verification of Concurrent Embedded Software*, IESS, Paderborn, 17.-19.06.2013
- R. Mercas, *The Lexicographic Cross-Section of the Plactic Monoid Is Regular*, WORDS, Turku, Finland, 16.-20.09.2013
- M. Müller, *On the Pseudoperiodic Extension of  $u^l = v^m w^n$* , FST&TCS, Guwahati, India, 12.-14.12.2013

## Further Activities and Events

- All members of the group served as reviewers for several international conferences and journals.
- D. Nowotka served as a member of the programme committee of the WORDS 2013 conference.
- D. Nowotka co-organized the seminar „Challenges in Combinatorics on Words“ at the Fields institute in Toronto Canada from April 22-26.
- F. Manea was invited to serve on the steering committee of Computability in Europe (CiE).
- M. Müller spent a research visit at the University of Turku from July until December 2013.



# Discrete Optimization

Discrete or combinatorial optimization is a branch of mathematical optimization. It is concerned with solving discrete, finite optimization problems efficiently. "Algorithm Engineering" in discrete optimization is a key area of the discrete optimization group in Kiel.

Among international cooperations a special focus is on Indo-German projects in Algorithm Engineering (DFG priority program 1307).

The methods and results of modern discrete optimization touch many different areas of discrete mathematics and computer science, for example, combinatorics, graph theory, discrete probability theory, finite harmonic analysis, or the theory of complexity.

A central topic in discrete optimization is the design of efficient algorithms for NP-hard discrete optimization problems using sub-optimal paradigms such as randomization or approximation. Specific topics are: approximation algorithms, randomized and de-randomized algorithms, algorithms for multicast-networks, combinatorial and geometric discrepancy theory, combinatorial game theory, and discrete geometry.

## Results

A major focus of the group is on interdisciplinary research projects within the cluster of excellence "The Future Ocean", and further with economics, medicine, life sciences and industrial partners.

The group is part of several highly competitive research clusters. Among them are the DFG priority programme 1307 "Algorithm Engineering", the cluster of excellence "The Future Ocean" and the DFG-DST Indo-German network on "Algorithm Engineering".

In Kiel, the group is actively participating in the CAU research foci Kiel Marine Science (KMS) and Kiel Life Science (KLS).

Prof. Srivastav received the Indo-Max-Planck-Guest professorship Award for Computer Science at IIT Delhi, India, September 2013 and was elected for the Steering Committee of Kiel Marine Science, and for the executive board of the cluster of excellence "The Future Ocean", both for 2 years.

## Personnel

Head of the group: Prof. Dr. A. Srivastav; Secretary: A. Lochte-Holtgreven (50%)

Scientific Staff:

MA A. Afanasiewa	01.01.-31.12.2013	DFG (25%)
Cluster of Excellence 'The Future Ocean'		
Dipl. Inf. D. Ehlers	01.01.-30.09.2013 (50%)	DFG / CAU
Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen		
Dr. M. El Ouali	01.01.-30.09.2013 (50%)	DFG / CAU
Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen		
Dr. M. El Ouali	01.10.-31.12.2013 (50%)	DFG
Cluster of Excellence 'The Future Ocean', coordination Research Platform		
Dipl. Inf. Ch. Gießen	01.01.-31.12.2013 (50%)	DFG/CAU
Engineering von Matching u. Überdeckungsalgorithmen in großen Graphen und Hypergraphen		

Priv.-Doz. Dr. M. Gnewuch	01.01.-31.12.2013	Guest professor
Hochdimensionale numerische Integration		
Priv.-Doz. Dr. G. Jäger	01.01.-31.12.2013	Guest professor
Combinatorial Optimization (Umea University, Sweden)		
Dr. L. Kliemann	01.01.-31.12.2013	CAU
Algorithm Engineering in Discrete Optimization, Algorithmic Game Theory		
M.A. O. Kliemann	01.01.-31.05.2013	DFG (25%)
Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen		
MA O. Kliemann	21.10.-31.12.2013 (50%)	CAU
Dipl. Math. P. Munstermann	01.01.-31.12.2013 (50%)	DFG / CAU
Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen		
Dr. V. Sauerland	15.01.-14.07.2013 (50%)	DFG
Optimization in Marine Science, Cluster of Excellence 'The Future Ocean'		
Dr. V. Sauerland	15.07.-31.12.2013	DFG
Optimization in Marine Science, Cluster of Excellence 'The Future Ocean'		
MSc E. Shirazi	01.08.-31.12.2013	
doctoral candidate		
MSc Mayank Singhal	01.01.-31.05.2013 (50%)	DFG
Algorithm Engineering, Discrepancy Theory		
MSc Mayank Singhal	01.06.-31.12.2013	DAAD
Algorithm Engineering, Discrepancy Theory		
G. Wittig-Srivastav	01.01.-30.06.2013	CAU
Projektkoordination		

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Graphentheorie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Srivastav (+ L. Kliemann)

Mathematik für Informatiker A, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
A. Srivastav (+ L. Kliemann, M. El Ouali, C. Gießen)

Seminar Kombinatorik, 2 hrs Seminar/Week,  
A. Srivastav

Oberseminar Algorithmen, Kombinatorik und Komplexität, 2 hrs Seminar/Week,  
A. Srivastav

Seminar Diskrete Mathematik, 2 hrs Seminar/Week,  
A. Srivastav

### Summer 2013

Oberseminar Algorithmen, Kombinatorik und Komplexität, 2 hrs Seminar/Week,

A. Srivastav (+ K. Jansen)

Seminar - Diskrete Mathematik, 2 hrs Seminar/Week,

A. Srivastav (+ L. Kliemann)

Algorithmische Spieltheorie, 2 (+ 2) hrs Lecture (+ Exercises)/Week,

L. Kliemann

Kombinatorische Optimierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

A. Srivastav (+ M. El Ouali)

*Winter 2013/2014*

Graphentheorie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

A. Srivastav (+ M. El Ouali)

Seminar Kombinatorik, 2 hrs Seminar/Week,

A. Srivastav

Oberseminar Algorithmen, Kombinatorik und Komplexität, 2 hrs Seminar/Week,

A. Srivastav

Seminar Diskrete Mathematik, 2 hrs Seminar/Week,

A. Srivastav

Diskrete Probabilistische Methoden, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

A. Srivastav (+ V. Sauerland)

### **Third-Party Funds**

DFG SPP 1307 Phase 2, *Engineering randomisierter Algorithmen für Optimierungsprobleme in Hypergraphen*, 01.10.2009-31.03.2014 (136000 Euro)

DFG, *Exzellenzcluster The Future Ocean - Optimization in Marine Science*, 01.01.2012-31.12.2016 (61.600 Euro)

DFG, *The Future Ocean - Research Platform Coordination*, 01.04.2009-31.10.2016 (117000 Euro)

DFG SPP 1307 Phase 3, *Engineering von Matching- und Überdeckungsalgorithmen in großen Graphen und Hypergraphen*, 25.08.2011-24.08.2013 (177650 Euro)

DFG SPP 1401, *Indo-German Workshop on Engineering and Analysis of Evolutionary Algorithms (Indo-German Project)*, 01.01.2012-01.08.2013 (19916 Euro)

DFG SPP Phase 3 Teil 2, *Algorithm Engineering for Evolutionary Algorithms (Indo-German Project)*, 23.01.2012-23.01.2014 (19900 Euro)

DFG SPP KL2078/1, *Algorithm for Data Streaming Processing (Indo-German Project)*, 23.01.2012-23.08.2015 (12700 Euro)

### **Further Cooperation, Consulting, and Technology Transfer**

J. Dick (University of New South Wales, Sydney, Australia) Projects: fractional discrepancy, multivariate and infinite-dimensional integration.

B.Doerr, C. Doerr (formerly Winzen), M.Wahlstroem (Max-Planck-Institut für Informatik, Saarbrücken) Project: algorithms to calculate discrepancies and to construct small discrepancy samples.

M. Hefter, K. Ritter, Technische Universität Kaiserslautern, A. Hinrichs, Universität Rostock. Project: infinite-dimensional integration on Hilbert spaces.

DFG-DST project on "Algorithms for Data Stream Processing", Pls: Lasse Kliemann (CAU) and Sumit Ganguly (IIT Kanpur, India).

DFG-DST project on "Engineering of Evolutionary Algorithms", Pls: Anand Srivastav, C. Patvardhan (DEI Dayalbagh, India).

N. Garg, Indo-German-Max-Planck-Centre for Computer Science (IIT Delhi, India).

## Dissertations / Postdoctoral Lecture Qualifications

M. El Ouali, *Randomized Approximation for Matching and Vertex Cover Problems in Hypergraphs - Complexity and Algorithms*, 30.08.2013

## Publications

Published in 2013

- M. Gnewuch, S. Mayer, K. Ritter, *On weighted Hilbert spaces and integration of functions of infinitely many variables*, Journal of Complexity, **2013**, (2013)
- M. Gnewuch, *Lower error bounds for randomized multilevel and changing dimension algorithms*, J. Dick, F.Y. Kuo, G.W. Peters, I.H. Sloan (Eds.) Monte Carlo and Quasi-Monte Carlo Methods, **2012**, 399 - 415 (2013)
- L. Kliemann, *The Price of Anarchy in Bilateral Network Formation in an Adversary Model*, Proceedings of the 6th Intl. Symposium on Algorithmic Game Theory, Aachen, Germany, (2013)
- L. Kliemann, O. Kliemann, C. Patvardhan, V. Sauerland, A. Srivastav, *A new QEA Computing Near-Optimal Low-Discrepancy Colorings in the Hypergraph of Arithmetic Progressions*, Proceedings of the 12th Intl. Symposium on Experimental Algorithms, Rome, Italy, 67 - 78 (2013)
- L. Kliemann, *The Price of Anarchy in Nonatomic Consumption-relevance Congestion Games*, Networks, **vol.62**, 83 - 94 (2013)
- M. El Ouali, H. Fohlin, A. Srivastav, *A randomized approximation algorithm for the hitting set problem*, in: *Proc. of the 7th International Workshop on Algorithms and Computation, (WALCOM'13)*, IIT Kharagpur, India, Lecture Notes in Computer Science, **Vol. 7748**, 101 - 113 (2013)
- L. Kliemann, A. Srivastav, *Deutsch-Indische Kooperation im Algorithms Engineering*, Informatik Spektrum, **36 (2)**, 180 - 186 (2013)

## Presentations

- M. Gnewuch, *Optimal Randomized Algorithms for Integration on Function Spaces with Underlying ANOVA Decompositions*, Workshop on Uniform distribution and Quasi-Monte Carlo Methods, Hohann Radon Institut for Computational and Applied Mathematics (RCIAM), Linz, Austria, 16.-16.10.2013
- M. Gnewuch, *Optimal Randomized Algorithms for Integration on the Sequence Space*, )th IMACS Seminar on Monte Carlo Methods (MCM 2013), Annecy, France, 15.-15.07.2013
- M. Gnewuch, *New Results on Infinite-Dimensional Integration in the Deterministic and Randomized Setting*, 5th Workshop on High-Dimensional Approximation (HDA 2013), Canberra, Australia, 12.-12.02.2013
- L. Kliemann, *The Price of Anarchy in Bilateral Network Formation in an Adversary Model*, 6th Intl. Symposium on Algorithmic Game Theory, Aachen, Germany, 20.-24.10.2013
- L. Kliemann, *A new QEA Computing Near-Optimal Low-Discrepancy Colourings in the Hypergraph of Arithmetic Progressions*, Conference on Engineering and Analysis of Evolutionary Algorithms, Agra, India, 13.-20.01.2013
- L. Kliemann, *A new QEA Computing Near-Optimal Low-Discrepancy Colourings in the Hypergraphs of Arithmetic Progressions*, 12th Intl. Syposium on Experimental Algorithms, Rome, Italy, 04.-07.06.2013

- A. Srivastav, *An evolutionary algorithm for parameter optimization for marine CO2 productions*, DFG-Indo-German Workshop on, Agra, India, 18.-18.01.2013
- A. Srivastav, L. Kliemann, *Streaming Algorithms and Parallel Evolutionary Computation in Large Graphs and Hypergraphs*, DFG-Big Data Workshop, Uni Frankfurt, Frankfurt, Germany, 04.-04.03.2013
- A. Srivastav, *Randomized Approximation of b-Matching in Hypergraphs*, 16th International Conference on random Structures and Algorithms, Poznan, Poland, 07.-07.08.2013
- A. Srivastav, *Approximation of the b-Matching in Hypergraphs*, Indian Institute of Technology, Department of Computer Science, New Delhi, India, 17.-17.09.2013
- A. Srivastav, *The Set Covering Problem in Hypergraphs*, Indian Institute of Technology, Department of Computer Science, New Delhi, India, 24.-24.09.2013
- A. Srivastav, *Topics in Random Graph Theory, 6 lectures*, Indian Institute of Technology, New Delhi and Dayalbagh Educational Institute, New Delhi and Agra, India, 02.-25.09.2013

## Further Activities and Events

- M. Gnewuch: Research Fellow at the University of New South Wales, Sydney, Australia, from April 1, 2012 to March 31, 2013
- M. Gnewuch: Associated Editor of Journal of Complexity (published by Elsevier)
- M. Gnewuch: Organization of the Oberwolfach Workshop 1340 "Uniform Distribution Theory and Applications", Mathematisches Forschungsinstitut Oberwolfach, Germany, September 29 to October 5, 2013, (Joint with Frances Y. Kuo(UNSW Sydney), H. Niederreiter (RICAM Linz), H. Wozniakowski (Columbia University New York))
- A. Srivastav, C. Patvardhan: DFG-Indo-German Workshop on Engineering and Analysis of Evolutionary Algorithms (EAEA 2013), Dayalbagh Educational Institute, Deemed University, Agra, India, 16.01. - 18.01.2013

# almanach 13

# Information Systems Engineering

Research and teaching in the department of Information Systems Engineering concentrate on the following topics:

- integrated development of information systems based on co-design of structuring, functionality, distribution and interaction,
- theory of models, modelling and conceptual modelling,
- intelligent information systems and intelligent data exploration,
- theory of database systems, semantics of databases,
- analysis and prediction of crystal structures,
- theory and technology of content management systems,
- development, languages, methodologies, and programming of web information systems and the knowledge web,
- migration, evolution, performance assessment, forecasting, and tuning for large database applications.

## Results

### **BPMN (Business process modelling and notation)**

An abstract model for the dynamic semantics of the core process modelling concepts in the OMG standard for BPMN 2.0 has been created based on the development of a complete formalization of BPMN 1.0 and 1.1 that is the result of an international collaboration over the last few years. The UML class diagrams associated therein with each flow element are extended with a rigorous behaviour definition, which reflects the inheritance hierarchy structure by refinement steps. The correctness of the resulting precise algorithmic model for an execution semantics for BPMN can be checked by comparing the model directly with the verbal explanations in the BPMN standard. Thus, the model can be used to test reference implementations and to verify properties of interest for (classes of) BPMN diagrams. Based on the model a native BPMN 2.0 Process Engine and a BPMN debugger have been implemented.

### **Co-design of structuring, functionality, interaction and distribution of information systems**

Traditional software engineering and information systems engineering are structured, comprising requirements analysis and definition, systems design, systems implementation and testing, and systems operation and maintenance. For web information systems the traditional approach suffers from three obstacles: late integration of architectural decisions, neglect of user expectations, and late implementations.

The co-design approach integrates application domain description with development of presentation and information systems. At the same time the specification is executable due to our simulation system. The co-design methodology has been assessed by the SPICE committee and has been evaluated to be one of the first methodologies at maturity level 3. The methodology has been extended to web information systems. Coherence and co-existence of UML diagrams can be based on a global ASM-backed systems model. This model supports co-evolution and co-development of sets of UML diagrams.

Component systems are becoming the main approach for efficient and effective development of large systems. Based on the approaches to application modelling that have been developed in the department in the past, an approach to component-based information systems has been developed and tested in application projects. The theory of component systems has been extended by facilities for view exchange among components.

### **Data mining design**

Data mining algorithms aim to provide some means to expose the hidden information behind data. However, considering a particular problem statement raises the question as to which algorithm should be employed, and moreover, how and which processing steps should be nested to convey a target-aimed knowledge discovery process. Present approaches, such as the CRISP-DM, are mainly focused on the management or description of such processes but they do not really describe how such a discovery process should be designed. A novel framework has been developed that aims at the design of knowledge discovery processes where the prior knowledge of a user and his goals are central to the process design.

### **Moving object databases and analysis**

Current research in moving object databases focuses on data structures allowing the efficient storage and analysis of fine-grained data, i.e. trajectories are mostly indexed and analyzed by their spatial and/or temporal attributes, e.g. position and time. Analysis itself, however, often requires the association of such fine-grained data to more coarse-grained queries such as “return all trajectories where a turn has occurred and it is followed by a speed up”. To cover the resulting gap, the fundamentals of a framework for classification of moving objects based on their “behaviour” has been developed. In this case, classification is defined as the assignment of trajectory streams to predefined scenarios that represent interactions between arbitrary moving objects. To allow efficient association of trajectory data with coarse-grained scenario descriptions as above, a novel index structure for trajectories of moving objects has been proposed and implemented using techniques from the area of computational movement analysis. The proposed index has the advantage that it uses not only the spatiotemporal domain of trajectories but also their topologies. In that context, the notion of topology is provided as the relation between characteristic events during the life span of a moving object. Providing and using that kind of meta-information allows for the efficient computation of similarities between trajectories at a high level of abstraction.

### **Database technology**

Many modern applications are becoming performance critical. At the same time, the size of some databases has been increasing to levels that cannot be well supported by current technology. Performance engineering has been ruled in the past mainly by reactive techniques such as performance monitoring. A new active method for performance improvement has been developed. One of the potential methods for active performance improvement is performance forecasting based on assumptions of future operations and on extrapolations from the current situation.

Exceptions are considered to be unusual states that could be, but must not be, taken primarily into account. They form exclusions, represent cases to which a rule does not apply, and form specific states that are not going to be handled (at least by the current system) or might represent legal objections against the typical state. Information systems architectures can be made more flexible to cope with exceptions in a way that these systems are exception-aware, exception-reactive, and provide a management of exceptions in a coherent form.

Modernization of information systems is a fundamental but sometimes neglected aspect of conceptual modelling. The management of evolution, migration, and refinement and the ability for information systems to deal with modernization is an essential component in developing and maintaining truly useful systems that minimize service disruption and downtime, and maximize availability of data and applications. Migration and evolution are interwoven aspects. Migration strategies such as „big bang“, „chicken little“, and „butterfly“ can be based on systematic evolution steps. Evolution steps use the theory of model suites.

Classical software development methodologies take architectural issues as granted or pre-determined. Web information systems pay far more attention to user support and thus require sophisticated layout and playout systems. These systems go beyond what has been known for presentation systems. A framework has been developed that is based either on early architectural decisions, or on integration of new solutions into existing architectures. It allows co-evolution of architectures and software systems.

### **Database theory**

The theory of integrity constraints has led to a large body of knowledge and to many applications. Integrity constraints



are however often misunderstood, are given in the wrong database context or within the wrong database models, often combine a number of very different facets of semantics in databases, and are difficult to specify. A unifying approach to specification and treatment of integrity constraints has been developed.

NULL is a special marker used in SQL to indicate that a value for an attribute of an object does not exist in the database. The three-valued and many-valued logics developed in the past do not properly reflect the nature of this special marker. To support this we introduce a non-standard generalization of para-consistent logics. These logics reflect the nature of these markers. The solutions developed can be used without changing database technology.

Modelling with multi-level abstraction refers to representing objects at multiple levels of one or more abstraction hierarchies, mainly classification, aggregation, and generalization. Multiple representation, however, leads to accidental complexity, complicating modelling and extension. A theory of m-objects has been developed that offers powerful techniques for modular and redundancy-free models, for query flexibility, for heterogeneous level-hierarchies, and for multiple relationship-abstraction.

Local database normalization aims at the derivation of database structures that can easily be supported by the DBMS. Global normalization has not received appropriate attention in research despite the interest in its implementations. Our research on systematic treatment of this normalization resulted in new ER-based normalization techniques.

A general theory of database transformations defines the background for queries and updates, which are two fundamental types of computation in any database: the first provides the capability to retrieve data, and the second is used to maintain databases in the light of ever-changing application domains. In theoretical studies of database transformations, considerable effort has been directed towards exploiting the close ties between database queries and mathematical logics. It is widely acknowledged that a logic-based perspective for database queries can provide a yardstick for measuring the expressiveness and complexity of query languages.

Practical experience shows that the maintenance of very large database schemata causes severe problems and no systematic support is provided. Based on the analysis of a recent study, larger schemata may be built by composing smaller ones and frequently recurring meta-structures. Our approach leads to a category of schemata that is finitely complete and co-complete. We show that all constructors of the recently introduced schema algebra are well-defined in the sense that they give rise to schema morphism. The algebra is also complete in the sense that it captures all universal constructions in the category of schemata.

### **Graph-based analysis of inorganic crystal structures**

For a crystal-chemical approach to high-temperature superconductivity algorithms have been developed and implemented that allow the determination of so called Infinite Units of Strongly Overlapping Orbitals (IUSOOs). These units are assumed to be the conducting units in unconventional superconductors. Topological and geometric properties of IUSOOs have been identified for building a classification of inorganic compounds according to the assumptions of our approach.

A database has been set up and filled with information on IUSOOs taking all crystal structure data into account, which are provided by the ICSD, the world's largest database for inorganic crystal structures. Quality measures have been applied and modifications of structure data have been made in order to get a data collection suitable for a thorough analysis of local bond-valence distribution.

### **Information privacy**

Privacy is becoming a major issue of social, ethical and legal concern on the Internet. The development of information technology and the Internet have major implications for the privacy of individuals. A new conceptual model for databases that contain exclusively private information has been developed. The model utilizes the theory of infons to define "private infons", and develops taxonomy of these private infons based on the notions of proprietary and possession. The proposed model also specifies different privacy rules and principles, derives their enforcement, and develops and tests architecture for this type of database. The model allows several variants for privacy supporting systems. The concept of privacy wallets

has been implemented.

### **Knowledge bases and knowledge web**

The internet and web applications have changed business and human life. Nowadays almost everybody is used to obtaining data through the internet. Most applications are still Web 1.0 applications. Web 2.0 community collaboration and annotated data on the basis of Web 3.0 technologies support new businesses and applications. The quality dimension of the web is however one of the main challenges. Knowledge web information systems target high-quality data on safe grounds, with a good reference to established science and technology and with data adaptation to the user's needs and demands. They can be built based on existing and novel technologies.

The knowledge web approach has been applied to management of processes that allow flexible handling of catastrophes. Another application targets delivery of actionable information on demand in a way that users in juristical environments can easily assimilate to perform their tasks.

Our knowledge web approach is based on advanced content management and on the theory of media types. Content management is the process of handling information within an organization or community. We developed, applied, and implemented a novel data model for content, which treats semantic information not only as describing metadata but also incorporates on the same level the data itself, the intention behind it, its usage, and its origin.

### **Random databases**

We consider stochastic modelling for databases with uncertain data and for some basic database operations (e.g. join, selection) with exact and approximate matching. Approximate join is used for merging data or removing duplication in large databases. Distribution and mean of the join sizes are studied for random databases. A random database is treated as a table with independent random records with a common distribution (or a set of random tables). Our results can be used for integration of information from different databases, multiple join optimization, and various probabilistic algorithms for structured random data.

### **Quality management and assessment for information and software systems**

Software and information systems design and development coexist and co-evolve with quality provision, assessment and enforcement. However, most (including current) research provides only bread-and-butter lists of useful properties without giving a systematic structure for evaluating them. Software engineers have been putting forward numerous quantities of metrics for software products, processes and resources but a theoretical foundation is still missing. We developed and applied a framework for quality property specification, quality control, quality utilization, and quality establishment. Our framework has a theoretical basis that is adaptable to all stages of software development.

### **Theory of models and modelling**

Conceptual modelling is one of the central activities in Computer Science. A theory of conceptual models and a theory of modelling acts have been developed in our group. They are based on a general theory of modelling as an art, an apprenticeship, and a technology. Modelling is based on an explicit choice of languages, on application of restrictions, on negotiation, and on methodologies. Languages are defined through their syntactics, their semantics, and their pragmatics. Modelling is a process and is based on modelling acts. These modelling acts are governed by the purpose of modelling itself and of the model or models.

Conceptual modelling has changed over the years. Nowadays small scale conceptual modelling has become state-of-the-art for specialists and educated application engineers. Large scale conceptual modelling has been developed mainly within companies that handle large and complex applications. It covers a large variety of aspects such as models of structures, of business processes, of interaction among applications and with users, of components of systems and abstractions, or of derived models such as data warehouses and OLAP applications. We developed new architectural techniques for large scale conceptual modelling.

In software and information systems development different aspects and facets of the system being developed are usually analyzed and modelled independently from each other. A recurring challenge is the integration of the different partial models of the software system into one single consistent model. With the notion of model suites we introduce an approach which can be used to integrate heterogeneous models, to check consistency between those models, and to facilitate a consistent evolution of them. Model suites are based on explicit controllers for maintenance of coherence. They apply application schemata for their explicit maintenance and evolution, use tracers for establishment of their coherence, and thus support co-evolution of information system models. The use of model suites helps to minimize or completely avoid the risks, ambiguities, and contradictions that normally result from the parallel use of different modelling languages and modelling tools.

### Web information systems

We developed a general specification method for clouds. Technically, we understand a cloud as a federation of software services that are made available via the web and can be used by any application. A common understanding in the web services community is that a service is defined as a function or operation with the appropriate input/output specification. We take a general view regarding a service as a piece of software that not only provides functionality but also data. Services thus combine a hidden database layer with an operation-equipped view layer, and can be anything from a simple function to a fully-fledged web information system or a data warehouse.

Web information systems should also support speech dialogues. Their workflow and supporting infrastructure can be specified by storyboards. The integration of speech dialogues is however an unsolved issue due to the required flexibility, the wide variety of responses, and the expected nativeness. Speech dialogues must be very flexible in both recognition of questions and in generation of appropriate answers. We thus introduce a pattern-based approach to specification and utilization of speech dialogues. These patterns reflect the dialogue speech since answers and responses with a speech dialogue are instantiations or refinements of these patterns. It is possible to create patterns for common dialogue-forms. The results of this work show that only small adaptations regarding the storyboard concept are necessary and the extension of the presentation layer with a channel-dependent renderer is sufficient to be able to model natural language dialogues.

The design and reification of web information systems is a complex task, for which many integrated development methods have been proposed. While all these methods ultimately lead to the construction of web pages, very little attention is paid to the layout of these pages. Screenography developed in our group provides principles and rules for page layout that originate from knowledge of visual perception and communication and then investigates how layout can support the intentions associated with the WIS. This amounts to guidelines for partitioning pages and using layout objects, colour, light, and texture to obtain rhythm, contrast, and perspective as the carriers for web page comprehension. We use a pattern approach to systematic development of laying and playouting. These patterns can be combined to larger complex patterns. Therefore, an algebra for pattern construction will be developed.

On a high level of abstraction the storyboard of a web information system specifies who will be using the system, in what way, and for which goals. Storyboard pragmatics deals with the question as to what the storyboard means for its users. One part of pragmatics is concerned with usage analysis by means of life cases, user models, and contexts. We also addressed another part of pragmatics that complements usage analysis by WIS portfolios. These comprise two parts: the information portfolio, and the utilization portfolio. The former is concerned with information consumed and produced by the WIS users, which leads to content chunks. The latter captures functionality requirements, which depend on the specific category to which the WIS belongs.

### Personnel

Head of the group: Prof. Dr. B. Thalheim; Secretary: S. Jureit (50%)  
Technical Staff: Steffen Gaede

#### Scientific Staff:

Dipl.-Inf. K. Jannaschk	01.01.-06.10.2013	CAU
apl.-Prof. Dr. H.-J. Klein,	01.01.-31.12.2013	CAU
Dipl.-Inf. F. Kramer	01.04.-31.12.2013	CAU
Dipl.-Inf. T. Polomski	01.01.-31.12.2013	BMW
Projekt: Verbundprojekt: PITAS - Piraterie- und Terrorabwehr auf Seeschiffen		
Dipl.-Inf. O. Sörensen	01.01.-31.12.2013	CAU
Dipl.-Inf. M. Tropmann-Frick	01.01.-31.12.2013	AIF

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Data Mining, Data Application and Statistics (ISOS), 3 hrs Lecture/Week,  
B. Thalheim (+ K. Jannaschk)

MS0505: Datenbanktheorie, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
H.-J. Klein, (+ H.-J. Klein,)

MSP0501: Masterprojekt - Datenbankprogrammierung (Masterpraktikum DB), 4 hrs Exercise/Week,  
H.-J. Klein, (+ T. Polomski)

MSS0504: Oberseminar - Technologie der Informationssysteme, 2 hrs Seminar/Week,  
H.-J. Klein, B. Thalheim

WInf-InfMinKD: Information Mining and Knowledge Discovery, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
B. Thalheim (+ K. Jannaschk)

WInf-MSc-Pro1: Projekt - Wirtschaftsinformatik (Informationssysteme), 5 hrs Exercise/Week,  
H.-J. Klein, B. Thalheim

WInf-WebInfSys: Web Information Systems (WInf-WebInfSys), 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
B. Thalheim (+ K. Jannaschk, O. Sörensen)

WInf-WInf3: Wirtschaftsinformatik 3, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
B. Thalheim (+ O. Sörensen)

### Summer 2013

MSS0504: Oberseminar - Technologie der Informationssysteme, 2 hrs Seminar/Week,  
H.-J. Klein, B. Thalheim

WInf-DBProg: Datenbankprogrammierung, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
B. Thalheim (+ O. Sörensen)

WInf-ISIntMiEv: IS Integration, Migration and Evolution, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
B. Thalheim (+ F. Kramer)

WInf-ModIS: Modellierung von Informationssystemen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
B. Thalheim (+ O. Sörensen)

WInf-MSc-Sem1: Interdisziplinäres Seminar (Informationssysteme), 4 hrs Seminar/Week,  
B. Thalheim (+ W. Goerigk, F. Kramer)

WInf-Proj-BA2: Abschlussprojekt - Wirtschaftsinformatik (Informationssysteme), 4 hrs Exercise/Week,  
B. Thalheim

WInf-Proj-BA2: Abschlussprojekt - Wirtschaftsinformatik (Informationssysteme), 2 hrs Seminar/Week,  
B. Thalheim (+ K. Jannaschk)

*Winter 2013/2014*

MSS0504: Oberseminar - Technologie der Informationssysteme, 2 hrs Seminar/Week,  
H.-J. Klein, B. Thalheim

MS0506: Verteilte Informationssysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
H.-J. Klein,

WInf-ISADD: IS Analysis, Design and Development, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
B. Thalheim (+ O. Sörensen, F. Kramer)

WInf-MSc-Pro1: Projekt - Wirtschaftsinformatik, 5 hrs Exercise/Week,  
B. Thalheim (+ F. Kramer)

WInf-MSc-Sem1: Interdisziplinäres Seminar (Informationssysteme), 4 hrs Seminar/Week,  
B. Thalheim (+ F. Foders, F. Kramer)

WInf-WInf3: Wirtschaftsinformatik 3, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
B. Thalheim (+ F. Kramer)

Mathematik-Coaching Wirtschaftsinformatik, 4 hrs Exercise/Week,  
B. Thalheim

### **Third-Party Funds**

AIF, *ZIM - Zentrales Innovationsprogramm Mittelstand*, 01.10.-31.12.2013 (171.184,00 EUR)

BMWl, *A knowledge based system for detecting and classifying piracy attacks using scenario descriptions and sensor data (within project PITAS)*, 01.01.-31.12.2013 (160.740,00 EUR)

DAAD, *Projektbezogener Personenaustausch mit Finnland - PPP Finnland*, 01.01.-31.12.2013 (9.654,00 EUR)

### **Further Cooperation, Consulting, and Technology Transfer**

University of Antwerp (Jan Paredaens),

Humboldt University Berlin (Johann Christoph Freytag, Oliver Günther),

Alfred Renyi Institute Budapest (Gyula Katona, Dezső Miklós),

King Saud University Riyadh (Ajantha Dahanayake),

Keio University, Fujisawa, Japan (Yasushi Kiyoki),

MTA SZTAKI Budapest (Janos Demetrovics),

Cottbus University of Technology (Heinrich-Theodor Vierhaus),

University of Dortmund (Gabriele Kern-Isberner, Joachim Biskup),

Technical University Hamburg-Harburg (Joachim W. Schmidt),

Klagenfurt University (Heinrich Mayr),

Louisiana State University (Peter P. Chen),  
 Software Competence Centre Hagenberg (Klaus-Dieter Schewe, Bernhard Freudenthaler, Felix Kossak),  
 Lomonossov University Moscow (Elyar Gasonov, Valerij B. Kudrjavcev),  
 Charles University Prague (Jaroslav Pokorny),  
 Microsoft Research Redmond (Yuri Gurevich),  
 Fraunhofer-Institut IDMT Erfurt (Klaus-Peter Jantke),  
 Brigham Young University, Salt Lake City (David Embley),  
 Silicon Valley Lab IBM (Laura Haas, Holger Kache),  
 Tampere University of Technology (Hannu Jaakkola),  
 Tampere University (Hannu Kangassalo),  
 Umea University (Stephen Hegner, Oleg Seleznev),  
 Versailles University (Elisabeth Metais),  
 Portland State University (Lois Delcambre, David Maier),  
 Australian National University Qing Wang),  
 University of Vermont (X. Sean Wang),  
 Universita di Pisa (Egon Börger),  
 Auckland University, (Hui Ma, Sebastian Link),  
 KEIO University Tokyo (Yasushi Kiyoki),  
 NICT Institut Kyoto (Koji Zettsu).

## Diploma, Bachelor's and Master's Theses

J. Bogdahn, *Metadatenverwaltung für Benutzergemeinschaften.*, 31.08.2013  
 S. Brechler, *Migration und Weiterentwicklung von Informationssystemen - Migrationsstrategie und Datenbankdesign.*, 30.09.2013  
 C. Eggeling, *Datenqualität in Pharmakovigilanzdaten.*, 30.09.2013  
 E. Gasimov, *Anforderungsentwicklung und -ableitung für Web-Verwaltungssysteme.*, 31.08.2013  
 C. Horn, *Systematisierung von Workflows zur Ableitung der Generalizität.*, 30.09.2013  
 O. Jäger, *Privacy Wallet.*, 30.04.2013  
 L. Noelle, *Migration und Weiterentwicklung von Informationssystemen - Design einer dynamischen Benutzeroberfläche.*, 30.09.2013  
 T. Sochart, *Informationskomponenten für die Privatsphäre.*, 31.12.2013  
 M. Windrich, *Komposition von Ministories zu generischen Workflows.*, 30.09.2013  
 S. Zieger, *Statistische Methoden des Data Mining in der Pharmakovigilanz.*, 30.09.2013  
 C. Zirkelbach, *Entwicklung einer webbasierten Visualisierungsschnittstelle für eine wissenschaftliche Datenbank.*, 31.03.2013

Published in 2013

## Publications

- U. Bakhtina, D. Fleischer, K. Jannaschk, *Application of Systematic Data Mining for Prediction of Biological Quality Indices*, Database and Expert Systems Applications (DEXA), 2013 24th International Workshop on Biological Knowledge Discovery and Data Mining, 95 - 99 (2013)
- M. Berg, A. Düsterhöft, B. Thalheim, *Query and Answer Forms for Sophisticated Database Interfaces*, Information Modelling and Knowledge Bases XXIV, Frontiers in Artificial Intelligence and Applications, IOS Press, **251**, 161 - 180 (2013)
- A. Dahanayake, B. Thalheim, *The Conception of a Service Model*, Proc. ICNVICT 2013, IEEE, Amman, Jordan, 36 - 49 (2013)
- A. Dahanayake, B. Thalheim, *Continuous Database Engineering I*, Int. Journal Business Inf. Syst. (IJBIS), **11**, 26 - 58 (2013)
- A. Dahanayake, B. Thalheim, *Continuous Database Engineering II*, Int. Journal Business Inf. Syst. (IJBIS), **13**, 133 - 150 (2013)
- H. Jaakkola, B. Thalheim, *Exception-Aware (Information) Systems*, Information Modelling and Knowledge Bases XXIV, Frontiers in Artificial Intelligence and Applications, IOS Press, **251**, 300 - 313 (2013)
- H. Ma, R. Noack, K.-D. Schewe, B. Thalheim, Q. Wang, *Complete conceptual schema algebras*, Fundamenta Informaticae, **123**, 1 - 26 (2013)
- R. Noack, B. Thalheim, *Architecturing for Conceptual Modelling in the Large*, Proc. EJC 2013, 29 - 48 (2013)
- T. Polomski, H.-J. Klein, *TrIMPI: A Data Structure for Efficient Pattern Matching on Moving Objects*, 25th GI-Workshop on Grundlagen von Datenbanken 2013, 64 - 68 (2013)
- T. Polomski, H.-J. Klein, *How to Improve Maritime Situational Awareness using Piracy Attack Patterns*, 8th Future Security Research Conference Future Security 2013, 97 - 106 (2013)
- S. Sasaki, P. Vojtas, K. Jannaschk, B. Thalheim, H. Jaakkola, Y. Kiyoki, *Multimedia Information Systems for Social, Cross-Cultural and Environmental*, Information Modelling and Knowledge Bases XXIV, Frontiers in Artificial Intelligence and Applications, IOS Press, **251**, 344 - 365 (2013)
- O. Sörensen, B. Thalheim, *Semantics and Pragmatics of Integrity Constraints*, Semantics in Data and Knowledge Bases, Lecture Notes in Computer Science, Springer, **7693**, 1 - 17 (2013)
- S. Torge, W. Esswein, S. Lehmann, B. Thalheim, *A Meta Modelling Framework for the Description of Reference Models*, Proc. EJC 2013, 244 - 255 (2013)
- M. Tropmann-Frick, B. Thalheim, *Mini Story Composition for Generic Workflows in Support of Disaster Management*, DEXA 2013, IEEE Computer Society, 36 - 40 (2013)
- B. Thalheim, M. Tropmann-Frick, T. Ziebmayer, *Application of Generic Workflows for Disaster Management*, Proc. EJC 2013, 68 - 85 (2013)
- B. Thalheim, *The Definition of the (Conceptual) Model*, Proc. EJC 2013, 256 - 269 (2013)
- B. Thalheim, Y. Kiyoki, *Analysis-Driven Data Collection, Intergration and Preparation for Visualisation*, Information Modelling and Knowledge Bases XXIV, Frontiers in Artificial Intelligence and Applications, IOS Press, **251**, 142 - 160 (2013)
- B. Thalheim, *Open Problems of Information Systems Research and Technology*, Perspectives in Business Informatics Research, 12th International Conference, Lecture Notes in Business Information Processing, Springer, **158**, 10 - 18 (2013)
- B. Thalheim, *The Conception of the Model*, Business Information Systems - 16th International Conference, BIS 2013, Lecture Notes in Business Information Processing, Springer, **157**, 113 - 124 (2013)
- Q. Wang, B. Thalheim, *Data Migration: A Theoretical Perspective*, Data and Knowledge Engineering, **87**, 260 - 278 (2013)



## Presentations

- B. Thalheim, *Theoretische Grundlegung der Modellierung*, QFAM Modellierungsworkshop, Wildbad Kreuth, Germany, 07.03.2013
- B. Thalheim, *Visual reasoning with (functional) dependencies*, Automated Reasoning in Conceptual Schemas, Schloss Dagstuhl - Leibniz-Zentrum für Informatik, Wadern, Germany, 19.-24.05.2013
- B. Thalheim, *Visual SQL*, Datenbank-Datenbankstammtisch, Dresden, Germany, 24.05.2013
- T. Polowski, *TrIMPI: A Data Structure for Efficient Pattern Matching on Moving Objects*, 25th GI-Workshop on Grundlagen von Datenbanken, Ilmenau, Germany, 28.-31.05.2013
- B. Thalheim, *Modellierung als Programmierung der 5. Generation, Research Agenda for Conceptual Modelling*, QFAM Modellierungsworkshop, Frankfurt, Germany, 28.05.2013
- B. Thalheim, *Privatsphäre im Internet - Techniken und Möglichkeiten*, Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Lütjenburg, Germany, 30.05.2013
- B. Thalheim, *Conceptual Modelling in the Large*, EJC 2013, 23rd European Japanese Conference on Information Modelling and Knowledge Bases, Nara, Japan, 04.06.2013
- M. Tropmann-Frick, *Application of Generic Workflows for Disaster Management*, EJC 2013, 23rd European Japanese Conference on Information Modelling and Knowledge Bases, Nara, Japan, 03.-07.06.2013
- B. Thalheim, *Conceptual Modelling of Collaboration for Information Systems*, EJC 2013, 23rd European Japanese Conference on Information Modelling and Knowledge Bases, Nara, Japan, 05.06.2013
- B. Thalheim, *A Meta Modelling Framework for the Description of Reference Models*, EJC 2013, 23rd European Japanese Conference on Information Modelling and Knowledge Bases, Nara, Japan, 06.06.2013
- B. Thalheim, *The Definition of the (Conceptual) Model*, EJC 2013, 23rd European Japanese Conference on Information Modelling and Knowledge Bases, Nara, Japan, 06.06.2013
- B. Thalheim, *Visual SQL*, Keio University, SFC Campus, Fujisawa, Japan, 10.06.2013
- B. Thalheim, *The Conception of the Model*, BIS 2013, 16th International Conference on Business Information Systems, Poznan, Poland, 20.06.2013
- B. Thalheim, *The Conceptual Model = An Adequate and Professional Artifact Enhanced by Concepts*, Summer School - Graduate School Human Development in Landscapes, CAU Kiel, Schleswig, Germany, 03.08.2013
- B. Thalheim, *Higher Level Entity Relationship Modelling*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 19.08.2013
- B. Thalheim, *The Theory of Conceptual Models*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 19.08.2013
- B. Thalheim, *Co-Design of Structure, Functionality, Distribution, and Interaction*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 19.08.2013
- B. Thalheim, *Structuring of Databases*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 20.08.2013
- B. Thalheim, *Conceptual Modelling in the Large*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 20.08.2013
- B. Thalheim, *Functionality of Databases and Information Systems*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 21.08.2013
- B. Thalheim, *Database and Information Systems Querying*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 21.08.2013
- B. Thalheim, *Distribution Modelling for Information Systems*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 22.08.2013
- B. Thalheim, *Interactivity Design - Storyboarding*, 23rd Jyväskylä Summer School, Faculty of Mathematics and Science



- and the Faculty of Information Technology at the University of Jyväskylä, Jyväskylä, Finland, 22.08.2013
- K. Jannaschk, *Application of Systematic Data Mining for Prediction of Biological Quality Indices*, 24th International Workshop on Biological Knowledge Discovery and Data Mining, Prag, Czech Republik, 26.-29.08.2013
- T. Polomski, *How to Improve Maritime Situational Awareness using Piracy Attack Patterns*, 8th Future Security Research Conference Future Security, Berlin, Germany, 17.-19.09.2013
- B. Thalheim, *Open Problems for Information Systems Research and Technology (invited keynote)*, BIR 2013, Perspectives in Business Informatics Research, Warsaw, Poland, 23.-26.09.2013
- B. Thalheim, *Master Control Station and Observers for Visualisation*, EU-Projekt INDYCO, Konsortial-Meeting, Vienna, Germany, 02.10.2013
- B. Thalheim, *Privatsphäre oder Ego-Striptease im Internet*, Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Ahrensburg, Germany, 15.10.2013
- B. Thalheim, *The theory of models in sciences*, CAU Kiel, Sondersymposium, Kiel, Germany, 22.10.2013
- B. Thalheim, *The Conception of a Service Model*, ICNICT 2013, International Conference on New Visions for Information and Communication Technology, Amman, Jordan, 06.11.2013
- B. Thalheim, *Big Data - Big Problems*, Night of the Profs, Christian-Albrechts-Universität zu Kiel, Kiel, Germany, 15.11.2013
- B. Thalheim, *Privacy und Ego-Striptease im Internet: Technologie und ihre Folgen*, Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Husum, 19.11.2013
- B. Thalheim, *Query and Answer Forms for Sophisticated Database Querying*, DBDBD 2013, Dutch-Belgian Database Day, Invited Keynote, Rotterdam, The Netherlands, 29.11.2013
- O. Sörensen, *Zombie - Cookies - Case studies and mitigation*, ICITST 2013 : The 8th International Conference for Internet Technology and Secured Transactions, London, United Kingdom, 09.12.2013
- B. Thalheim, *Die Theorie und Praxis des konzeptuellen Modelles.*, RWTH Aachen, Kolloquium, Institut für Informatik, Aachen, Germany, 18.12.2013
- H.-J. Klein, *Abstraktion und Konsistenz bei der Integration von Daten aus heterogenen Quellen.*, 5. Computer Science and Transport Symposium, Kiel, Germany, 03.09.2013
- H.-J. Klein, *Wie kann man das Web zur Vermeidung von Piratenangriffen nutzen?*, Tag der Wirtschaftsinformatik, Kiel, Germany, 27.11.2013

## Further Activities and Events

### B. Thalheim

Kolmogorow-Professor, Lomonossow-University, Moscow, since 2005.

Best paper award, BIS 2013 (Wirtschaftsinformatik), International Conference on Business Information Systems.

Member of programme committee:

ABZ 2012, June 2012,  
 ADBIS 2013, September 2013, Genoa,  
 APCCM 2012, January, February 2012,  
 APWeb 2013, April 2013, Sydney,  
 BIS 2013, June 2013, Poznan,  
 BIR 2013, September 2013, Warsaw,  
 CAiSE 2013, June 2013, Valencia,  
 CEUP 2013, Oktober 2013, Lim,  
 ICAICTE 2013, September 2013, Hainan,  
 CMS 2013, September 2013, Prague,  
 CroWE 2012, July 2012,

CTS 2013, May 2013, San Diego,  
DEXA 2013, September 2013, Prague,  
EJC 2013, June 2013, Nara,  
ER 2013, November 2013, Hongkong  
IS 2012, September 2012,  
ISSASIM 2013, September 2013, Prag,  
NLDB 2013, June 2013, Montpellier,  
SOFSEM 2013, Januar 2013, Spindleruv Mlyn,  
UNISCON 2012, June 2012,  
WEBIST 2012, April 2012,  
WISM 2013, Oktober 2013, Hongkong,  
WWS 2013, June 2013, Erfurt.

Member of steering committees of international conferences:

ABZ, ADBIS, Baltic DB, EJC, ER, ISTA, NLDB, SDKB.

Editorial board membership:

Data and Knowledge Engineering (DKE),  
Journal of Intelligent Information Technologies,  
Journal of Web Engineering,  
Enterprise Modelling and Information Systems Architectures,  
Serdica Journal of Computing,  
Graduate School Human Development in Landscape,  
Foundation Board and Advisor of DAMA International.

Editor and Co-Chair of the Conference Proceedings:

Semantics in Data and Knowledge Bases, 5th International Workshop, SDKB 2011, LNCS 7693, Springer 2012.

Co-Chair:

- of the German group of DAMA International,
- of the Rotary-Club, Kiel-Düsternbrook,
- ombudsman of German Computer Science Society, Schleswig-Holstein.

Co-Chairman of workshops:

CMS 2013.

Member of the Scientific Advisory Board: with Dataport.

Member of board:

Graduate School Human Development in Landscapes.

PI (Primary Investigator):

- Cluster of Excellence Inflammation at Interfaces,
- Cluster of Excellence Future Ocean,
- Graduate School Human Development in Landscapes.

Reviewer of doctoral theses:

ETH Zurich, Switzerland,  
Lomonossow- University Moscow, Russia,  
Christian-Albrechts-University Kiel, Germany,  
University Delft, The Netherlands,  
University of Technology, Melbourne, Australia,  
Technion, Haifa, Israel.

Deputy:

for German Computer Science Society at Max-Planck Society.

Reviewer:

-for the German Research Foundation, DAAD, Australian Science Foundation, National Science Foundation (USA),  
-AQAS (accreditation agency),  
and a series of conferences and journals in Mathematics, Computer Science and Engineering.

# almanach 13

# Multimedia Information Processing

The Multimedia Information Processing group (MIP) is active in education, research and applications of 3D technology, computer vision, and computer graphics. The main focus of the group is on various aspects of 3D data processing from image and video data, and on sensor fusion with range and navigation data. In 2013, 11 researchers were involved in various research projects. Project funding was supplied by DFG, EU, Chinese Research Council, BMWi, Land Schleswig-Holstein, Innovationsstiftung S-H, Fraunhofer (ISIT, IPM) and Industry (WISKA, IBAK). The research results also found their way into teaching and student education. In total, 27 students on all levels of education (Bachelors, Masters, and Diplomas) as well as 3 doctoral PhD-students finished their thesis work in our group.

## Results

In 2013, the MIP group continued its active research in 3D technology and computer vision. Three main research topics dominated the research.

**Underwater imaging:** The close collaboration in the Excellence Cluster *Future Ocean* between GEOMAR and CAU on underwater imaging is actively pursued by MIP researchers. The PhD thesis of Anne Jordt on underwater vision is a good example of how theoretical insights into the imaging process can help to develop new practical camera models. Supported by DFG and the Future Ocean initiative, novel imaging techniques for underwater vision were developed, resulting in high-ranking publications in the top international computer vision conferences, and a Best Paper Award. In close collaboration with the archaeological diving team of the University, 3D models of historical underwater artifacts (ship wrecks, an ancient skull, etc.) were reconstructed from images.



Fig. 1: The partially submerged object shows the visual effects of underwater imaging which were modelled in the PhD thesis of Anne Jordt.

**Line-based 3D reconstruction:** Over the last years, systematic research on the exploitation of line structures helped to

develop new algorithms for 3D reconstruction of man-made structures that exploit the *Manhattan World assumption*. This assumption states that man-made objects like buildings and rooms are very often built with horizontal and vertical planes, forming right angles. Exploitation of these constraints, together with careful parameterization and optimization algorithms, have led to an exceptional PhD thesis by the CSC PhD student Lilian Zhang. The resulting algorithms are world-leading in efficiency and robustness, and a whole new class of 3D scene reconstruction algorithms could be developed.

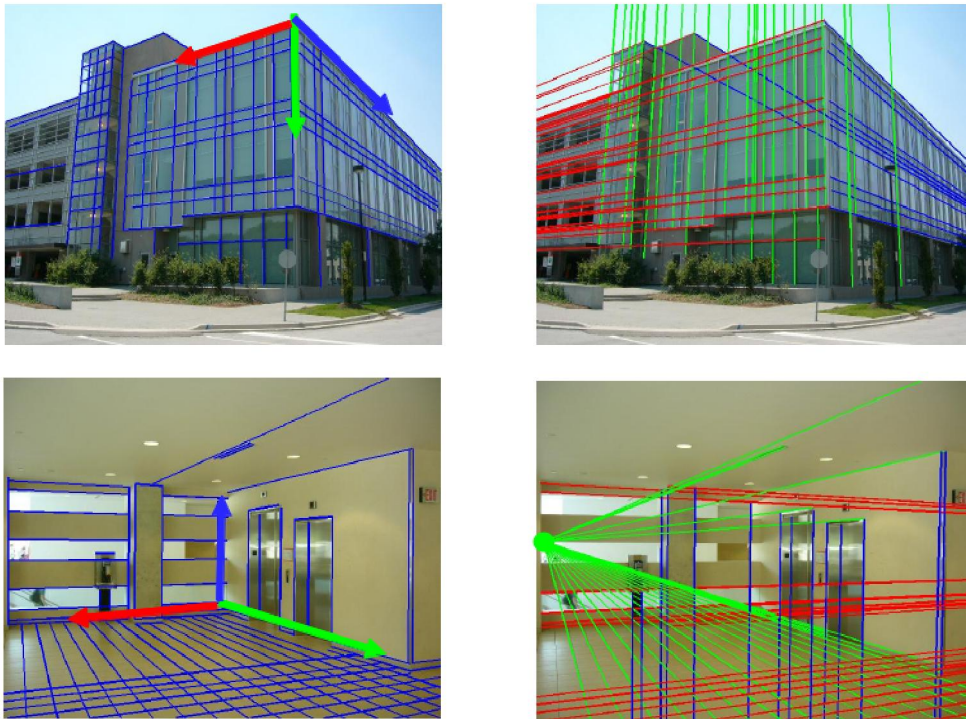


Fig. 2: Applications of line-based reconstruction algorithms are discussed in the PhD thesis of Lilian Zhang.

**Handling of deformable surfaces:** 3D scene capture of deforming objects pose a particular challenge in computer vision. Andreas Jordt has developed novel algorithms that can estimate surface deformations of flexible and deformable objects, like folding paper, cloth, or rubber sheets, from color and depth camera video in real-time. Depth cameras are novel sensing devices that allow to directly observe distance information, like with a laser scanner, for each image pixel of a video stream. From the depth and color video stream, the challenge is to determine global and local high-dimensional deformations of the surfaces in real-time with more than 20 frames per second of the image stream. This allows to design novel types of interactive user interfaces and interactive computer graphics applications. Figure 3 shows such deformations of a real sheet of paper, and the estimated deformations in a computer graphics visualisation.

## Personnel

Head of the group: Prof. Dr.-Ing. R. Koch; Secretary: R. Staecker (50%)

Technical Staff: T. Storm

Staff:

M. Kolasinski

DeCSMedia

01.01.-30.06.2013

EXIST

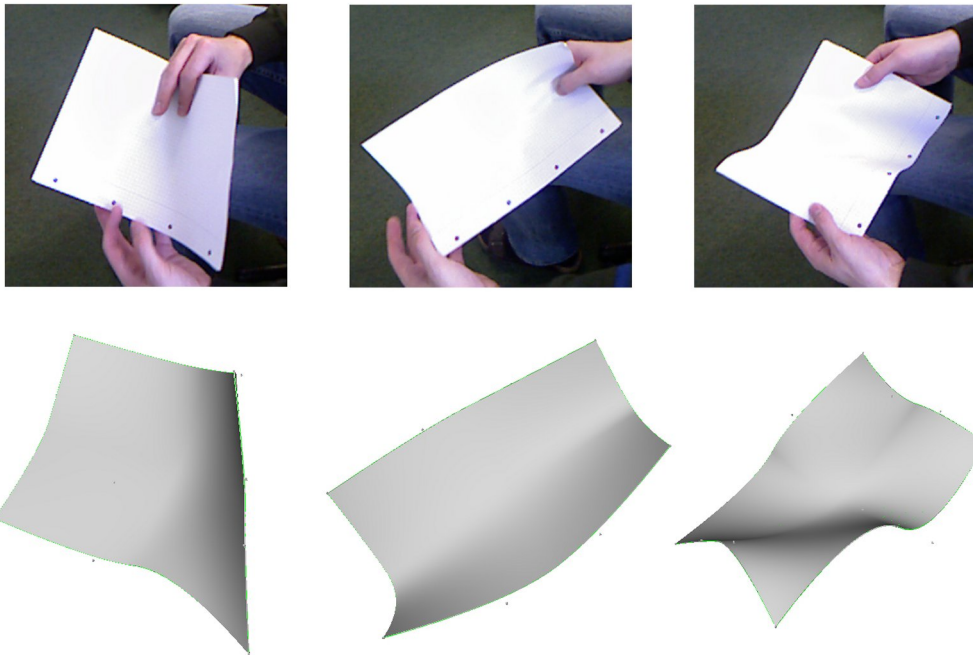


Fig. 3: Deforming the real sheet of paper (above) and its computer graphics representation (below).

#### Scientific Staff:

S. Esquivel	01.01.-31.12.2013	AIF
Intelligentes 3D Aufmaß		
Dr.-Ing. O. Fleischmann	01.11.-31.12.2013	CAU
Land		
M. Franke	01.01.-31.12.2013	ISH/Bund
MoDEST, PITAS		
A. Frick	01.01.-30.06.2013	EXIST
DeCSMedia		
A. Jordt	01.01.-31.12.2013	Industrie
Raytheon		
A. Jordt ( Sedlazeck)	01.01.-31.12.2013	Bund
Exzellenzcluster Future Ocean		
D. Jung	01.01.-31.12.2013	CAU
Land		
F. Kellner	01.01.-30.06.2013	EXIST
DeCSMedia		
Dr.-Ing. I. Schiller	01.01.-30.06.2013	EXIST
DeCSMedia		



D. Wolters

01.-31.12.2013

EKSH

Transferprämie

R. Wulff

01.05.-31.12.2013

DFG

Graduate School Human Landscapes, Third Party Funds

L. Zhang

01.01.2012-30.09.2013

Chinese Research Council

Stipend

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

MSP0601 Vertiefende Übung Visuelle Modellierung, 4 hrs Masterprojekt/Week,

R. Koch (+ D. Jung)

Informatik für Nebenfächler (vertiefend), 2 (+ 2) hrs Exercise (+ Exercises)/Week,

S. Esquivel (+ S. Esquivel)

080092 Inf-EinfBV: Einführung in die Bildverarbeitung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

R. Koch (+ D. Jung, O. Fleischmann)

### *Summer 2013*

Seminar Visuelle Modellierung, 2 hrs Seminar/Week,

R. Koch (+ S. Esquivel)

MS0602 Multimediale Signal- und Bildverarbeitung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

R. Koch (+ S. Esquivel)

BA6.7 Projektmodul, Bachelorarbeiten, 2 hrs Thesis seminar/Week,

R. Koch (+ S. Esquivel)

Informatik II für Ingenieurwissenschaften, 3 (+ 3) hrs Lecture (+ Exercises)/Week,

R. Koch (+ D. Jung, O. Fleischmann)

### *Winter 2013/2014*

MSP0601 Vertiefende Übung Visuelle Modellierung, 4 hrs Masterprojekt/Week,

R. Koch (+ D. Jung, O. Fleischmann, J. Brünge)

080092 Inf-EinfBV: Einführung in die Bildverarbeitung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

R. Koch (+ D. Jung, O. Fleischmann)

MS0601: Seminar - Visuelle Modellierung, 2 hrs Seminar/Week,

R. Koch (+ O. Fleischmann)

MS0603: 3D-Szenenrekonstruktion aus Bildfolgen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

R. Koch

Inf-AP-CG: Abschlussprojekt - Computer Graphic/Computer Vision, 6 hrs Bachelorarbeit/Week,

R. Koch (+ D. Jung, J. Brünge, O. Fleischmann)

## Third-Party Funds

ISH, Transferprämie, 01.04.2011-31.12.2013 (20.000,00 EUR)



WISKA/Verbundprojekt PITAS, *Software für visuelles Detektions- und Reaktionssystem, Bildanalyse und Kamerasteuerung*, 28.09.2010-30.06.2013 (41.000,00 EUR)  
 ISH, *MoDEST*, 01.05.2011-30.04.2013 (120.000,00)  
 FHG-ISIT, *Konzeptstudie für portables Spatial Augmented Reality System*, 01.10.2011-31.03.2014 (205.000,00)  
 FHG-IPM, *3D-Signage*, 01.10.2011-30.09.2013 (25.000,00)  
 DFG Graduate School, *1 Stipend*, 01.01.2010-30.04.2013 (42.800,00)  
 Chinese Research Council, *1 Stipend*, 01.09.2009-31.08.2013 (62.000,00)  
 BMWi, *EXIST*, 01.09.2011-28.02.2013 (466.532,00)  
 DFG, *Seafloor Modelling Folgeprojekt*, 01.09.2012-31.08.2014 (156.500,00)  
 EKSH/ISH, *Transferprämie*, 01.12.2012-31.12.2014 (5.000,00)  
 DFG, *Future Ocean CP 1340*, 16.06.-30.12.2013 (16.358,65)  
 DFG, *Future Ocean CP1331 Quabble*, 01.05.2013-30.04.2014 (63.000,00)  
 AIF/BMWi/ZIM, *3D Aufmaß*, 02.04.2013-31.03.2015 (150.388,00)

## Further Cooperation, Consulting, and Technology Transfer

Dr. Hunger, **Fa. IBAK**, Kiel  
 Prof. Dr.-Ing. Michael Felsberg, **Linköping University**, Linköping, Sweden  
 Fabian Doil, **VW**, Wolfsburg  
 Prof. Joachim Weickert, **Uni Saarland**, Saarbrücken  
 Yoav Schechner, **Israel Institute of Technology** Haifa, Israel  
 Soenke Ehlers, **Fa. WISKA** Kaltenkirchen  
 Prof. Bernhard Wagner, **Fraunhofer Institut, ISIT**, Itzehoe  
 Dr. Uwe Franke, **Daimler AG**, Sindelfingen  
 Dr. Jürgen Steimle, **Saarland University Cluster of Excellence Multimodal Computing and Interaction**  
 Prof. Dr. Reinhard Klette **CITR - The University of Auckland**, Auckland, New Zealand  
 Dr. Jan-Friso Evers-Senne **TESTO**, Leutkirch  
 Prof. Dr. Jens Greinert **IFM GEOMAR**  
 Dr. Peter Linke **IFM GEOMAR**

## Diploma, Bachelor's and Master's Theses

S. Borchert, *Diplomarbeit: Dense Stereo with Refractive Underwater Camera Model using Plane Sweep*, 19.02.2013  
 S. Spyropoulos, *Time consistent occlusion filling for novel view synthesis in videos through depth-based image inpainting*, 15.07.2013  
 L. Borchert, *Occlusion filling for novel view synthesis through depth-assisted inpainting*, 22.07.2013  
 H. Schade, *3D Reconstruction of Indoor Scenes with a Rotating Camera*, 16.05.2013  
 M. Manthey, *Bildstabilisierung mit OpenCL für die Schiffbasierte Videoüberwachung*, 02.08.2013  
 F. Holdt, *Calibration of Underwater Dome Port Cameras*, 29.05.2013  
 J. Bork, *Refractive Structure-from-Motion using an Angular Error Function*, 22.05.2013  
 N. Eschger, *Super-Resolution Interpolation von Videosequenzen*, 10.04.2013  
 D. Zens, *Effiziente Videokompression für Farb- und Thermalkameras*, 10.04.2013

- T. Börding, *Bildbasiertes Erzeugen neuer Ansichten einer Szene auf der Grafikkarte*, 05.02.2013
- D. Wolters, *Automatische Vermessung von Innenraum-Szenen auf Basis von Kinect Tiefendaten*, 05.11.2013
- Ch.-W. Reimer, *A GPU based multiview stereo plane-sweep method for dynamic camera arrays*, 20.12.2013
- J. Hoffmann, *Fusion von 3D-Punktdaten mit lokaler Oberflächenschätzung*, 05.02.2013
- O. Kwast, *Interaktive und positionsabhängige Bilderzeugung für ein stereoskopisches Anzeigesystem*, 27.09.2013
- T. Rossow, *Tiefen- und winkelabhängige Bilderzeugung auf der GPU für ein interaktives 3D-Visualisierungssystem*, 27.09.2013
- M. Waurisch, *Position-Verfolgung für interaktive 3D-Bilddarstellung*, 27.09.2013
- S. Clausen, *Nutzerverfolgung und Gestenerkennung zur interaktiven Bilderzeugung unter Verwendung einer Tiefenkamera*, 27.09.2013
- Ch. Born, *Interferenzreduktion und Datenfusion zwischen Microsoft Kinect Kameras*, 26.09.2013
- H. Müller, *Objektpositions- und Geschwindigkeitsschätzung aus Tiefendaten eines mobilen Roboters*, 25.09.2013
- D. Köster, *Echtzeit Objektlokalisation in Tiefenbildern*, 25.09.2013
- I. Pingel, *Farbbasierte Objekterkennung für einen mobilen Roboter*, 25.09.2013
- T. Horstmann, *Phong-Splat-Rendering und Streaming von Punktwolken: eine Browser-Basierte Javascript Implementierung*, 26.09.2013
- S. Vogt, *Implementierung und Vergleich von Cluster Algorithmen zur Ebenensegmentierung in Punktwolken*, 26.09.2013
- M. Reimers, *Analyse und Prädiktion von Objektpositionen zur Interaktion mit einem Roboter*, 25.09.2013
- J. Krone, *Navigation und Kollisionsvermeidung für einen mobilen Roboter*, 25.09.2013
- J. Kunst, *Kartografierung von Innenräumen aus Tiefendaten eines mobilen Roboters*, 25.09.2013
- F. Thum, *Objektverfolgung in Tiefen- und Farbbildern in Echtzeit*, 26.09.2013

## Dissertations / Postdoctoral Lecture Qualifications

- L. Zhang, *Line Primitives and their Applications in Geometric Computer Vision*, 08.08.2013
- A. Petersen, *A Specialized Kalman Filter Framework for IMU Aided Stereo SLAM*, 01.10.2013
- A. Jördt, *Underwater 3D Reconstruction Based on Physical Models for Refraction and Underwater Light Propagation*, 12.11.2013

## Publications

Published in 2013

- D. Jung, R. Koch, *Image Based Rendering from Perspective and Orthographic Images for Autostereoscopic Multi-View Displays*, Proceedings of the 18th International Workshop on Vision, Modelling and Visualization VMV, (2013)
- A. Jördt-Sedlazeck, R. Koch, *Refractive Structure from Motion for Underwater Images*, Proceedings of ICCV 2013, (2013)
- A. Jördt-Sedlazeck, D. Jung, R. Koch, *Refractive Plane Sweep for Underwater Images (Best Paper Award)*, Lecture Notes in Computer Science (Proceedings of GCPR 2013), **8142**, (2013)
- S. Esquivel, R. Koch, *Structure from Motion Using Rigidly Coupled Cameras without Overlapping Views*, Lecture Notes in Computer Science (Proceedings of GCPR 2013), **8142**, (2013)
- J. Steimle, A. Jördt, P. Maes, *Highly Flexible Bending Interactions for Projected Handheld Displays ACM International Conference on Human Factors in Computing (Best Paper Honorable Mention)*, CHI 2013 Proceedings ACM International Conference on Human Factors in Computing, (2013)
- A. Jördt, R. Koch, *Reconstruction of Deformation from Depth and Colour Video with Explicit Noise Models Time-of-Flight and Depth Imaging*, Sensors, Algorithms, and applications LNCS, **8200**, (2013)
- L. Zhang, R. Koch, *An efficient and robust line segment matching approach based on LBD descriptor and pairwise geometric consistency*, JVCI Journal of Visual Communication and Image Representation, **24 (7)**, 794 - 805 (2013)
- R. Wulff, A. Sedlazeck (Jördt), R. Koch, *3D Reconstruction of Archeological Trenches from Photographs*, Scientific

Computing and Cultural Heritage Contributions in Mathematical and Computational Sciences 3, Springer Heidelberg, 273 - 281 (2013)

- L. Zhang, *Line Primitives and their Applications in Geometric Computer Vision*, Kiel Computer Science Series Department of Computer Science, 2013. Dissertation, Faculty of Engineering, Kiel University., 2013/1, (2013)
- M. Grzegorzec, C. Theobalt, R. Koch, A. Kolb, *Time-of-Flight and Depth Imaging: Sensors, Algorithms, and Applications (Editors)*, Time-of-Flight and Depth Imaging: Sensors, Algorithms, and Applications, Lecture Notes in Computer Science ISBN 978-3-642-44963-5, **LNCS 8200**, (2013)
- D. Lefloch, R. Nair, F. Lenzen, H. Schäfer, L. Streeter, M. Cree, R. Koch, A. Kolb, *Technical Foundation and Calibration Methods for Time-of-Flight Cameras*, Time-of-Flight and Depth Imaging: Sensors, Algorithms, and Applications Springer Verlag, ISBN 978-3-642-44963-5, **LNCS 8200**, 3 - 24 (2013)
- R. Wulff, R. Koch, *Image-Based 3D Documentation of Archeological Trenches Considering Spatial, Temporal and Semantic Aspects*, Archaeology in the Digital Era, Papers from the 40th Annual Conference of Computer Applications and Quantitative Methods in Archaeology (CAA) ISBN: 978 90 8964 663 7. 2013, (2013)

## Presentations

- A. Jordt-Sedlazeck, D. Jung, R. Koch, *Refractive Plane Sweep for Underwater Images*, GCPR (DAGM) 2013 September 3rd - 6th, Saarbrücken, Germany, 05.09.2013
- S. Esquivel, R. Koch, *Structure from Motion Using Rigidly Coupled Cameras without Overlapping Views*, GCPR (DAGM) 2013 September 3rd - 6th, Saarbrücken, Germany, 04.09.2013
- A. Jordt-Sedlazeck, R. Koch, *Refractive Structure from Motion for Underwater Images*, ICCV International Conference on Computer Vision 2013, Sydney, Australia, 03.12.2013
- D. Jung, R. Koch, *Image Based Rendering from Perspective and Orthographic Images for Autostereoscopic Multi-View Displays*, Vision, Modelling and Visualization VMV 2013, Lugano, Switzerland, 13.09.2013

## Further Activities and Events

*Refractive Plane Sweep for Underwater Images*, by Anne Jordt-Sedlazeck, Daniel Jung and Reinhard Koch, won a **Best Paper Award** at the **GCPR 2013** in Saarbrücken September 3rd to 6th.

**Christoffer Menk** was awarded **500,00 Euro** for the **best dissertation** 2012, donated by the **Förderverein Technische Fakultät**. He was honoured by the **Chairperson Dr. Philipp Murmann**.

Experts from **Ophthalmic Clinic** and the **Multimedia Group** showed experiments and explained *3D Vision, 3D Cinema* on **Kiel Museums' Night**, August 30th also commemorating **125 Years of Ophthalmology in Kiel**.

**Andreas Jordt** together with **Jürgen Steimle** won a **Best Paper Honourable Mention Award** for *Highly Flexible Bending Interactions for Projected Handheld Displays* at the **ACM International Conference on Human Factors in Computing 2013**.

**Anne Jordt** was given the opportunity to present her work on **SAT 1** during the popular broadcast **Planetopia** in a documentary about **Underwater Archaeology** on August 5th.

**Daniel Jung** spoke on *Bilderzeugung für autostereoskopische Multi-View Displays* at the 38th meeting of the **Arbeitskreis Bildverarbeitung der Initiative Bildverarbeitung e.V.** in Itzehoe on December 12th 2013.

### Activities of Prof. Koch

- Vice-President of the German Association for Pattern Recognition (DAGM e.V.) since 2012.

Member of the programme committee of the following international conferences and workshops:

- 3DV 2013,

- CVMR 2013,
- GCPR 2013,
- ICCV 2013,
- VMV 2013.

- Reviewer for the DFG

**Member of the editorial board for the following journals:**

- Journal of Realtime Image Processing (JRTIP), Springer, since 2007,
- Journal of Visual Communications and Image Representation (JVCI) Elsevier, since 2008.

**Reviewer for the following journals:**

- IEEE-IE Transactions IE, Special Issue on Optomechatronics,
- International Journal of Image and Graphics,
- IEEE T-PAMI Transactions of Pattern Analysis and Machine Intelligence,
- Journal on CVIU Computer Vision and Image Understanding,
- International Journal on Computer Vision

# Programming Languages and Compiler Construction

The research group “Programming Languages and Compiler Construction” is interested in the design, implementation and application of programming languages intended to support the reliable implementation of complex systems. The research ranges from object-oriented design methods and the analysis of concurrent and distributed systems, to the implementation and application of declarative programming languages, in particular, in the area of web-based systems.

During the period reported below, the research group worked on a new advanced implementation of the multi-paradigm language Curry and achieved new research results related to the design, semantics, implementation, and analysis of declarative programming methods. Furthermore, the research group organized the international conference event “Kiel Declarative Programming Days 2013” which unified the 20th International Conference on Applications of Declarative Programming and Knowledge Management (INAP 2013), the 22th International Workshop on Functional and (Constraint) Logic Programming (WFLP 2013), and the 27th Workshop on (Constraint) Logic Programming (WLP 2013) in Kiel.

## Results

The scientific work of the research group involved all areas related to declarative programming languages, e.g. design, semantics, implementation, development tools, and application of such languages. Declarative programming languages are based on clear mathematical foundations. They abstract from the underlying computer architecture and thus provide a higher programming level leading to more reliable systems. In particular, much of the research is focused towards the integration of the most important declarative programming paradigms: functional and logic programming. Due to our long-standing interest in this research area, we wrote a comprehensive survey on functional logic programming which was published during the reported period. This survey might be used as a standard reference in this area in future research and teaching activities.

In order to evaluate the concepts of declarative programming in practice, we worked on the *application and implementation* of the functional logic programming language Curry. In particular, we continued the development of our recent implementation of Curry, called KiCS2, which is based on compiling Curry programs into purely functional Haskell programs. The advantage of this implementation is the good performance of purely functional computations and the explicit representation of non-deterministic computed results in a single data structure. Due to the compilation into a purely functional target language, the implementation of typical logic programming features, like logic variables and constraints, is not immediately clear and thus, challenging. We developed a new implementation of these features and published the quite positive results.

A good implementation of high-level programming languages, like Curry, requires advanced *program analysis* techniques. For instance, the KiCS2 compiler analyzes dynamic program properties, like potential non-deterministic computations, to produce efficient target code. However, building program analyzers for realistic applications is not an easy task. In order to support developers of language tools (e.g. compiler, editor, documentation generator) in this respect, we developed a new framework and implementation for the generic and modular analysis of declarative programs. This tool, called CASS (Curry Analysis Server System), is based on a plug-in architecture to accommodate various program analyzers. Moreover, CASS provides various usage interfaces so that it can be used by various tools, such as compilers, and documentation generators as well as Eclipse plug-ins for Curry. Finally, CASS itself is implemented as a master/worker architecture in order to exploit parallel or distributed hardware environments.

During the reported period, we also worked in the area of the *design and semantics* of declarative languages. In a previous collaboration with the Portland State University (Oregon, USA), we developed a new technique to encapsulate non-deterministic computations in functional logic programs. It is based on associating to each function a set-valued function encapsulating the non-determinism caused by the function’s execution. It is the first referentially transparent approach to encapsulate non-deterministic computations and thus solves a long-standing problem in this area. Due to the

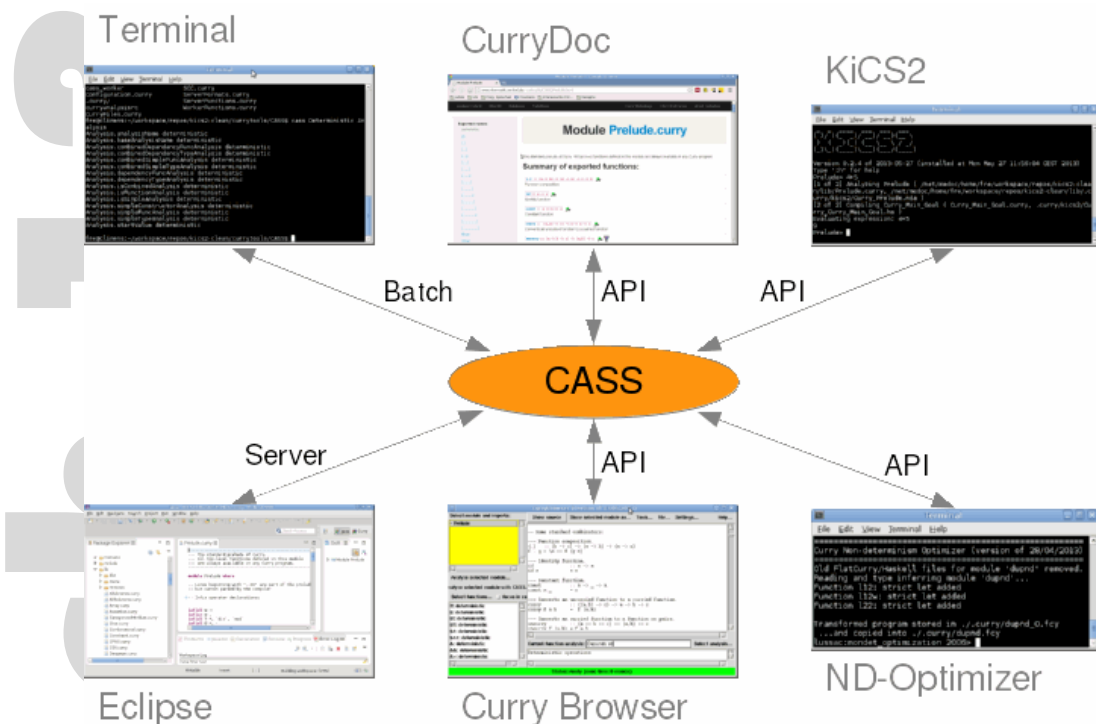


Fig. 1: The application structure of CASS

advanced implementation techniques used in KiCS2, we were also able to implement set functions in this system. During these implementation efforts, it turned out that the original proposal for set functions is underspecified so that various semantic options (empty result sets, nested set functions) are unclear. Therefore, we developed a new formal description of all these details and obtained the first denotational description of set functions. This description is not only of theoretical interest, but the basis of our new implementation of set functions. In particular, we adapted our initial implementation according to the new theoretical insights. Now, KiCS2 is the first implementation with a full support for set functions that is based on a solid theoretical foundation.

Due to the orthogonal combination of functional programming features, like lazy evaluation, and logic programming features, like non-deterministic computations, in Curry, there are different semantic options for their integration. Most researchers prefer the so-called “call-time choice” semantics since it provides an execution-independent understanding together with an efficient implementation. Recently, other researchers advocated a so-called “plural” semantics which supports, in particular cases, a more natural view on non-deterministic operations. However, the implementation of both semantic options is quite different so that it would be a huge effort to implement both in a single system. To overcome this drawback, we developed a new technique to compile the plural semantics into the call-time choice semantics. The practical implementation showed that this indirect approach is also more efficient than other approaches to implement the plural semantics in a direct manner.

Our research group also organized an international conference event, called “Kiel Declarative Programming Days 2013” (KDPD 2013). This event unified the 20th International Conference on Applications of Declarative Programming and Knowledge Management (INAP 2013), the 22th International Workshop on Functional and (Constraint) Logic Programming (WFLP 2013), and the 27th Workshop on (Constraint) Logic Programming (WLP 2013) in Kiel. This was the first time that these three events were jointly organized. It attracted researchers from many countries in Europe as well as Japan, USA, Canada, and Mexico. They presented their newest research result in the area of modern programming languages and declarative knowledge management. The post-proceedings of KDPD 2013 will appear in the Springer Lecture Notes in



Fig. 2: Participants of the Kiel Declarative Programming Days 2013

Computer Science series.

Finally, we developed a web-based distributed information system to support the master's students to plan their course of studies. It should help the students to organize their curricula as well as the faculty staff to plan their resources. This study planner is maintained by our group and currently used by our institute.

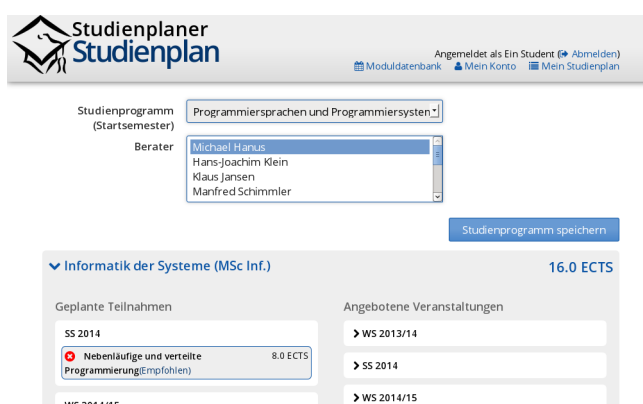


Fig. 3: The study planner developed and maintained in our group

## Personnel

Head of the group: Prof. Dr. Michael Hanus; Secretary: Jane-Maria Eitzen (50%), Linda Haberland (50%)  
Technical Staff: Mike Gabriel (50%)

Scientific Staff:

Dr. Sebastian Fischer	01.01.-31.12.2013	Guest
PD. Dr. Frank Huch	01.01.-31.12.2013	CAU (35%)
M. SC. Björn Peemöller	01.01.-31.12.2013	CAU
Dr. Friedemann Simon	01.01.-31.12.2013	Guest
Dipl.-Inf. Fabian Skrlac	01.01.-31.12.2013	CAU
Dipl.-Inf. Jan Rasmus Tikovsky	01.04.-31.12.2013	CAU





## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,  
M. Hanus (+ R. Berghammer)

MSS0303: Masterabschlusseminar - Programmiersprachen, 2 hrs Seminar/Week,  
M. Hanus

Inf-MS-Sem-PS: Programmiersprachen und Programmiersysteme, 2 hrs Seminar/Week,  
M. Hanus (+ F. Huch)

Inf-Prog: Programmierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Hanus (+ F. Reck, B. Peemöller, L. Prädél, N. Danilenko, D. Ehlers, P. Munstermann)

MS0303: Deklarative Programmiersprachen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Hanus (+ B. Peemöller)

MS0306: Nebenläufige und verteilte Programmierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
F. Huch (+ F. Reck)

Inf-Sem-PS: Programmierung und Programmiersprachen, 2 hrs Seminar/Week,  
M. Hanus

### Summer 2013

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,  
M. Hanus (+ R. Berghammer)

MSS0303: Masterabschlusseminar - Programmiersprachen, 2 hrs Seminar/Week,  
M. Hanus

Inf-FortProg: Fortgeschrittene Programmierung, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Hanus (+ B. Peemöller, Jan Rasmus Tikovsky, Nikita Danilenko)

Inf-MP-PS: Masterprojekt - Programmiersprachen und Programmiersysteme, 6 hrs Practical/Week,  
M. Hanus (+ F. Reck, Jan Rasmus Tikovsky)

MS0302: Übersetzerbau, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
Michael Hanus (+ Björn Peemöller)

### Winter 2013/2014

Arbeitsgemeinschaft Informatik, Logik und Mathematik, 2 hrs Seminar/Week,  
M. Hanus (+ R. Berghammer)

MSS0303: Masterabschlusseminar - Programmiersprachen, 2 hrs Seminar/Week,  
M. Hanus

Inf-MS-Sem-PS: Programmiersprachen und Programmiersysteme, 2 hrs Seminar/Week,  
M. Hanus (+ F. Huch)

Inf-Prog: Programmierung, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Hanus (+ Jan Rasmus Tikovsky, B. Peemöller, P. Munstermann)



MS0301: Prinzipien von Programmiersprachen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Hanus (+ Björn Peemöller)

Inf-MP-PS: Masterprojekt - Programmiersprachen und Programmiersysteme, 6 hrs Practical/Week,  
Michael Hanus

NF-Inf-1: Informatik für Nebenfächler, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
Frank Huch (+ Fabian Skrlac, J. Piwonski)

NF-Inf-1: Informatik für Nebenfächler (vertiefend), 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
Frank Huch (+ Fabian Skrlac, J. Piwonski)

## Further Cooperation, Consulting, and Technology Transfer

During the reported period, the research group collaborated with

Sergio Antoy (Portland State University, USA)

Jan Christiansen

Sebastian Fischer

Daniel Seidel (Universität Bonn)

## Diploma, Bachelor's and Master's Theses

Torge Petersen, *Social Tagging und Folksonomies - ein Ansatz zur kollaborativen Indexierung*, 24.03.2013

Malte Hecht, *Erstellen einer Abstimmungssoftware für Vorlesungen*, 11.04.2013

Jan-Patric Baye, *Design and Implementation of Remote Function Invocation with Template Haskell*, 27.09.2013

Finn Teegen, *Implementation of a library for declarative, resolution-independent 2D graphics in Haskell*, 30.09.2013

Jan C. Gehrke, *Vergleich von Ansätzen zur Parallelisierung in Haskell*, 30.09.2013

Matthias Böhm, *Erweiterung von Curry um Typklassen*, 01.11.2013

Lukasz Rybinski, *Verteiltes Software-Transactional-Memory in Scala*, 02.09.2013

Niclas Flieger, *Uniwahlen - online*, 20.09.2013

Robert Zahnnow, *Uniwahlen - online*, 20.09.2013

## Publications

Published in 2013

Bernd Braßel, Michael Hanus, Björn Peemöller, Fabian Reck, *Implementing Equational Constraints in a Functional Language*, Proc. of the 15th International Symposium on Practical Aspects of Declarative Languages, PADL 2013, **Springer LNCS 7752**, 125 - 140 (2013)

Michael Hanus, *Functional Logic Programming: From Theory to Curry*, Programming Logics - Essays in Memory of Harald Ganzinger, **Springer LNCS 7797**, 123 - 168 (2013)

Michael Hanus, *Adding Plural Arguments to Curry Programs*, Theory and Practice of Logic Programming, **13 (4-5)**, (2013)

Jan Christiansen, Michael Hanus, Fabian Reck, Daniel Seidel, *A Semantics for Weakly Encapsulated Search in Functional Logic Programs*, Proc. of the 15th International Symposium on Principles and Practice of Declarative Programming, PPDP 2013, **ACM Press**, 49 - 60 (2013)

Michael Hanus, Fabian Reck, *A Generic Analysis Server System for Functional Logic Programs*, Proceedings of the 13th International Colloquium on Implementation of Constraint and Logic Programming Systems, CICLOPS 2013, (2013)

Michael Hanus, *Adding Plural Arguments to Curry Programs*, Ifl Research Report, **1304**, (2013)

Michael Hanus, Ricardo Rocha, *Kiel Declarative Programming Days 2013*, IfI Technical Report, **1306**, (2013)

## Presentations

Fabian Reck, *Implementing Equational Constraints in a Functional Language*, 15th International Symposium on Practical Aspects of Declarative Languages, PADL 2013, Rome, Italy, 21.01.2013

Michael Hanus, *Adding Plural Arguments to Curry Programs*, 30th GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 06.05.2013

Fabian Reck, *Übersetzen durch Pretty Printing*, 30th GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 06.05.2013

Sebastian Fischer, *“Putback” is the Essence of Bidirectional Programming*, 30th GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 08.05.2013

Björn Peemöller, *Implementing Residuation in KiCS2*, 30th GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 08.05.2013

Jan Rasmus Tikovsky, *Integration von FD-Constraints in KiCS2*, 30th GI-Workshop Programmiersprachen und Rechenkonzepte, Bad Honnef, Germany, 08.05.2013

Michael Hanus, *A Generic Analysis Server System for Functional Logic Programs*, 13th International Colloquium on Implementation of Constraint and Logic Programming Systems, Istanbul, Turkey, 25.08.2013

Michael Hanus, *Adding Plural Arguments to Curry Programs*, 29th International Conference on Logic Programming, Istanbul, Turkey, 27.08.2013

Fabian Reck, *A Semantics for Weakly Encapsulated Search in Functional Logic Programs*, 15th International Symposium on Principles and Practice of Declarative Programming (PPDP 2013), Madrid, Spain, 16.09.2013

## Further Activities and Events

M. Hanus: programme committee member of the Sixth Working Conference on Programming Languages (ATPS 2013), Aachen, February 2013 (part of the conference Software Engineering 2013)

M. Hanus: programme committee member of the 13th International Colloquium on Implementation of Constraint and Logic Programming Systems (CICLOPS 2013), Istanbul (Turkey), August 2013

M. Hanus: programme committee member of the 18th ACM SIGPLAN International Conference on Functional Programming (ICFP 2013), Boston (Massachusetts), September 2013

M. Hanus: programme committee chair of the 22th International Workshop on Functional and (Constraint) Logic Programming (WFLP 2013) and 27th Workshop on (Constraint) Logic Programming (WLP 2013), Kiel, September 2013

M. Hanus: organization of the Kiel Declarative Programming Days 2013, unifying the 20th International Conference on Applications of Declarative Programming and Knowledge Management (INAP 2013), the 22th International Workshop on Functional and (Constraint) Logic Programming (WFLP 2013), and the 27th Workshop on (Constraint) Logic Programming (WLP 2013), Kiel, September 2013

M. Hanus: programme committee member of the Seventh Working Conference on Programming Languages (ATPS 2014), Aachen, February 2014 (part of the conference Software Engineering 2014)

M. Hanus: member of the steering committee of the Symposia on Logic-based Program Synthesis and Transformation

M. Hanus: chair of the steering committee of the ACM SIGPLAN Symposia on Principles and Practice of Declarative Programming

M. Hanus: member of the executive committee and vice-chair of the GLP (Gesellschaft für Logische Programmierung), German-speaking branch of the Association for Logic Programming (ALP)

M. Hanus: member of the advisory board of the GLP (Gesellschaft für Logische Programmierung), German-speaking branch of the Association for Logic Programming (ALP)

M. Hanus: member of the selection committee of the DAAD (German Academic Exchange Service) for the project-related support to scientific cooperation with Spain and Portugal

M. Hanus: member of the advisory board of the „Berufsakademie an der Wirtschaftsakademie Schleswig-Holstein“

M. Hanus: member of the executive board of the „Fakultätentag Informatik der Bundesrepublik Deutschland“

M. Hanus: chair of the selection committee of the award for the best diploma or master thesis in computer science in Germany 2013

M. Hanus: member of the selection committee of the b + m-Preis Software- und Systems-Engineering 2013

M. Hanus: chair of the examinations board of computer science studies, University of Kiel

M. Hanus: member of the Senate Curriculum Committee, University of Kiel

M. Hanus: vice-member of the Senate Equal Opportunities Committee, University of Kiel

F. Huch: organization of the 30th Workshop of the GI-Fachgruppe Programmiersprachen und Rechenkonzepte, Bad Honnef (Germany), May 2013

F. Huch: member of the Steering Committee of Symposia on Implementation and Application of Functional Languages (IFL)

F. Huch: chair of the executive committee of the Fachgruppe „Programmiersprachen und Rechenkonzepte“ of the Gesellschaft für Informatik e.V.

# almanach 13

# Real Time Systems / Embedded Systems

The research interest of the RTSYS group is the systematic design and analysis of “computers that are not perceived as such,” which is one definition of *embedded systems*. These systems appear in all contexts of daily life: miniaturized hearing aids, x-ray scanners, mobile phones, airbag controllers, anti-lock brakes, fly-by-wire aircraft. Such systems not only have to provide the correct outputs to the environment, they also have to provide the outputs promptly. In other words, these are *real-time systems*. Of particular interest for us are *reactive systems*, which continuously react to (mainly discrete) input events of the environment with corresponding output events.

## Results

Current research activities concentrate on the development of reactive embedded real-time systems. Key areas are:

- Pragmatics-aware model-based design of complex reactive systems,
- Automatic layout of graphical models, and
- Deterministic concurrency and synchronous languages.

The **pragmatics-aware model-based design** concentrates on the practical aspects of creating, maintaining, and visualizing graphical system models, with the goal of enhanced designer effectiveness and productivity. The Kiel Integrated Environment for Layout Eclipse Rich Client (KIELER) is a prototypical modelling environment that serves as a test bed to explore and validate novel modelling approaches. A key enabler is the ability to automatically compute the layout of graphical models. This frees the user from the tedious task of manually drawing diagrams, and allows novel techniques such as customized views during simulation. 2013 saw major enhancements in the automatic generation of light-weight, transient views of model components, the development of technologies for web-based diagram synthesis and layout, as well as the integration of SC Charts modelling and simulation. In 2010 KIELER’s layout capabilities were integrated into UC Berkeley’s Ptolemy system and have since been used by a whole range of other projects. A user survey conducted in 2013 showed a high degree of satisfaction.

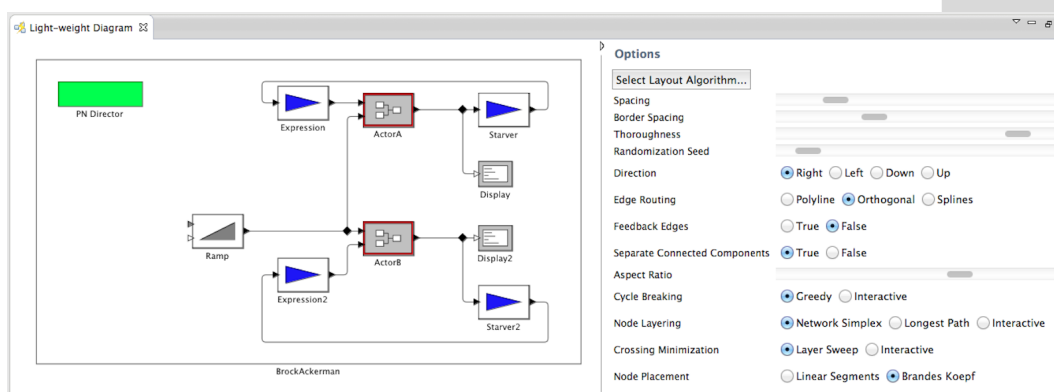
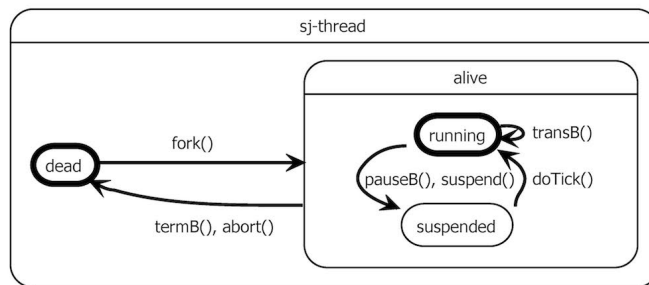


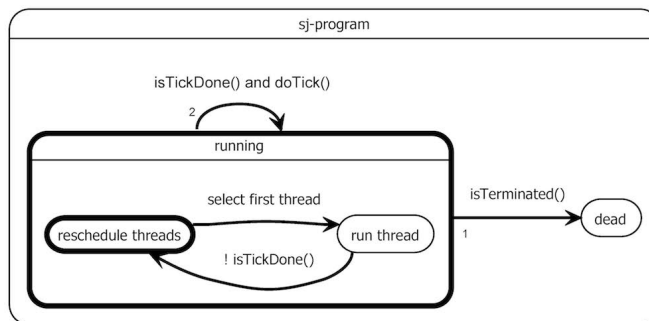
Fig. 1: A process network diagram imported from the Ptolemy project (UC Berkeley) rendered in KIELER/CLighD, with sliders and buttons for direct manipulation of layout options (adapted from [Spönemann et al. 2013])

In the area of **deterministic concurrency and synchronous languages** we have concentrated on *Sequential Constructiveness* (SC). This model of computation (MoC) combines deterministic, synchronous concurrency with sequential scheduling information inherent in traditional programming languages such as C or Java. This builds on a large body of

theoretical work that has emerged from the synchronous programming community since the 1980s, but is also of practical interest for designing safety-critical systems. It has emerged from a collaboration with colleagues working in theoretical computer science, notably Prof. Michael Mendler (U Bamberg), and with industrial users, notably National Instruments. Two languages that use the SC MoC are *Synchronous Java* and the graphical *SCCharts* language, a dialect of statecharts.



(a) Life cycle of an individual SJ thread



(b) Life cycle of a complete SJ program

Fig. 2: State diagrams for the reactive life cycle of a Synchronous Java (SJ) program and its individual threads [Motika et al. 2013].

## Personnel

Head of the group: Prof. Dr. R. von Hanxleden; Secretary: G. Walsdorf (50%)

Technical Staff: Dipl.-Inf. T. Grebien (50%)

Scientific Staff:

Dipl.-Inf. Insa Fuhrmann PRETSY	01.01.-31.12.2013	DFG
Dipl.-Inf. C. Motika	01.01.-31.12.2013	Land
Dipl.-Inf. C. D. Schulze	01.01.-31.12.2013	Land
Dipl.-Inf. M. Spönnemann	01.01.-31.12.2013	Land

## Lectures, Seminars, and Laboratory Course Offers

Winter 2012/2013

Inf-AP-ES: Abschlussprojekt - Echtzeitsysteme/Eingebettete Systeme (Eclipse Modeling), 6 hrs Practical/Week,  
W. Hasselbring (+ M. Spönnemann, C. D. Schulze)



Fig. 3: "Mindstorms Contest" in the class Embedded System Design (26.06.2013).

MSP1101: Masterprojekt - Echtzeitsysteme/Eingebettete Systeme (Eclipse Modeling), 4 hrs Practical/Week,  
W. Hasselbring (+ M. Spönemann, C. D. Schulze)

### *Summer 2013*

Inf-EmSysDes: Embedded System Design, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. von Hanxleden (+ C. Motika)

Inf-EntEinSys: Entwurf eingebetteter Echtzeitsysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. von Hanxleden (+ C. Motika)

Inf-OAR: Organisation und Architektur von Rechnern, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. von Hanxleden (+ M. Spönemann, C. D. Schulze)

BA6.1: Projektmodul - Echtzeitsysteme/Eingebettete Systeme (Layout), 6 hrs Practical/Week,  
R. von Hanxleden (+ M. Spönemann, C. D. Schulze)

MSP1101: Masterprojekt - Echtzeitsysteme/Eingebettete Systeme (Layout), 4 hrs Practical/Week,  
R. von Hanxleden (+ M. Spönemann, C. D. Schulze)

Inf-Sem-Echtz: Bachelorseminar Echtzeitsysteme/Eingebettete Systeme (Layout), 2 hrs Seminar/Week,  
R. von Hanxleden (+ M. Spönemann, C. D. Schulze)

MSS1101: Seminar - Echtzeitsysteme / Eingebettete Systeme (Layout), 2 hrs Seminar/Week,  
R. von Hanxleden (+ M. Spönemann, C. D. Schulze)

MSS1102: Masterabschlusssseminar - Echtzeitsysteme / Eingebettete Systeme, 2 hrs Seminar/Week,  
R. von Hanxleden

### *Winter 2013/2014*

MSS1102: Synchrone Sprachen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. von Hanxleden (+ C. Motika)

Inf-Sem-Echtz: Bachelorseminar Echtzeitsysteme / Eingebettete Systeme, 2 hrs Seminar/Week,  
R. von Hanxleden (+ I. Fuhrmann)

MSS1101: Seminar - Echtzeitsysteme / Eingebettete Systeme, 2 hrs Seminar/Week,  
R. von Hanxleden (+ I. Fuhrmann)

MSS1102: Masterabschlusssseminar - Echtzeitsysteme / Eingebettete Systeme, 2 hrs Seminar/Week,  
R. von Hanxleden

## Third-Party Funds

DFG Sachbeihilfe, *Precision-Timed Synchronous Reactive Processing (PRETSY)*, 01.11.2011-30.10.2014 (251925)

## Further Cooperation, Consulting, and Technology Transfer

Cooperation with Edward A. Lee, University of California, Berkeley, on the automatic layout of Ptolemy II diagrams and simulation of SyncCharts.

Cooperation with Kim Marriott, Monash University, Melbourne, Australia, on automated graph drawing.

Cooperation with John Grundy, Swinburne University of Technology, Melbourne, Australia, on modelling pragmatics.

Cooperation with ETAS/Bosch, on visual model exploration.

Cooperation with National Instruments, on Statecharts modelling and hardware synthesis.

Cooperation with Michael Mendler, Bamberg University, on sequential constructiveness.

Cooperation with Petra Mutzel, University of Dortmund, on layout algorithms with port constraints.

Cooperation with Partha Roop and Zoran Salcic, University of Auckland, New Zealand, on reactive processors and timing analysis.

Cooperation with Irkutsk State University, on model-based design and reactive processors (funded by DAAD, Ostpartnerschaften-Programm)

## Diploma, Bachelor's and Master's Theses

W. Haribi, *A SyncChart-Editor based on Yakindu*, 14.03.2013

H. Wißmann, *Graphische Visualisierung von Java-Variablen zur Laufzeit*, 28.03.2013

S. Nasin, *Graphische Zuordnung von Elementen einer Modelltransformation*, 28.03.2013

H. Müller, *Designing Applications with the e4 Application Model*, 28.03.2013

S. Smyth, *Code Generation for Sequential Constructiveness*, 24.07.2013

G. Hoops, *Automatic Layout of UML Sequence Diagrams*, 19.04.2013

## Publications

Published in 2013

S. Andalam, P. Roop, A. Girault, C. Traulsen, *A Predictable Framework for Safety-Critical Embedded Systems*, IEEE Transactions on Computers, (PrePrint), (2013)



- R. von Hanxleden, Michael Mendler, J. Aguado, B. Duderstadt, I. Fuhrmann, C. Motika, S. Mercer, O. O'Brien, *Sequentially Constructive Concurrency-A Conservative Extension of the Synchronous Model of Computation*, In Proceedings of the Design, Automation and Test in Europe Conference (DATE'13), Grenoble, France, IEEE, 581 - 586 (2013)
- C. Motika, R. von Hanxleden, M. Heinold, *Programming Deterministic Reactive Systems with Synchronous Java (Invited Paper)*, In Proceedings of the 9th Workshop on Software Technologies for Future Embedded and Ubiquitous Systems (SEUS), IEEE Proceedings, Paderborn, Germany, (2013)
- R. von Hanxleden, M. Mendler, J. Aguado, B. Duderstadt, I. Fuhrmann, C. Motika, S. Mercer, O. O'Brien, *Sequentially Constructive Concurrency-A Conservative Extension of the Synchronous Model of Computation*, Technical Report 1308, Christian-Albrechts-Universität zu Kiel, Department of Computer Science, ISSN 2192-6247, (2013)
- M. Spönemann, C. D. Schulze, C. Motika, C. Schneider, R. von Hanxleden, *KIELER: Building on Automatic Layout for Pragmatics-Aware Modelling (Showpiece)*, In Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'13), San Jose, CA, USA, (2013)
- C. Schneider, M. Spönemann, R. von Hanxleden, *Just Model! - Putting Automatic Synthesis of Node-Link-Diagrams into Practice*, In Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'13), San Jose, CA, USA, (2013)
- C. Motika, S. Smyth, R. von Hanxleden, M. Mendler, *Sequentially Constructive Charts (SCCharts)*, Poster presented at 10th Biennial Ptolemy Miniconference (PTCONF'13), Berkeley, CA, USA, (2013)
- R. von Hanxleden, B. Duderstadt, C. Motika, S. Smyth, M. Mendler, J. Aguado, S. Mercer, O. O'Brien, *SCCharts: Sequentially Constructive Statecharts for Safety-Critical Applications*, Technical Report 1311, Christian-Albrechts-Universität zu Kiel, Department of Computer Science, ISSN 2192-6247, (2013)
- P. Axer, R. Ernst, H. Falk, A. Girault, D. Grund, N. Guan, B. Jonsson, P. Marwedel, J. Reineke, C. Rochange, M. Sebastian, R. von Hanxleden, R. Wilhelm, W. Yi, *Building Timing Predictable Embedded Systems*, ACM Transactions on Embedded Computing Systems, (2013)

## Presentations

- R. von Hanxleden, *On the Pragmatics of Model-Based Design*, Seminar at Swinburne University of Technology, Melbourne, Australia, 05.02.2013
- R. von Hanxleden, *Taming Graphical Modelling*, Seminar at Monash University, Melbourne, Australia, 06.02.2013
- C. Motika, R. von Hanxleden, M. Heinold, *Programming Deterministic Reactive Systems with Synchronous Java*, 9th Workshop on Software Technologies for Future Embedded and Ubiquitous Systems (SEUS), Paderborn, Germany, 17.06.2013
- M. Spönemann, C. D. Schulze, C. Motika, C. Schneider, *KIELER: Building on Automatic Layout for Pragmatics-Aware Modelling*, IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'13), San Jose, CA, USA, 15.-19.09.2013
- C. Schneider, M. Spönemann, R. von Hanxleden, *Just Model! - Putting Automatic Synthesis of Node-Link-Diagrams into Practice*, IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'13), San Jose, CA, USA, 15.-19.09.2013
- U. Rüegg, C. Schneider, C. D. Schulze, M. Spönemann, C. Motika, R. von Hanxleden, *Light-Weight Synthesis of Ptolemy Diagrams with KIELER*, Tenth Biennial Ptolemy Miniconference, Berkeley, CA, USA, 07.11.2013
- R. von Hanxleden, B. Duderstadt, C. Motika, S. Smyth, M. Mendler, J. Aguado, S. Mercer, O. O'Brien, *SCCharts: Sequentially Constructive Statecharts*, Synchronous Programming (SYNCHRON'13), Schloss Dagstuhl, Germany, 19.11.2013
- R. von Hanxleden, B. Duderstadt, C. Motika, S. Smyth, M. Mendler, J. Aguado, S. Mercer, O. O'Brien, *Compiling SCCharts to Hardware and Software*, Synchronous Programming (SYNCHRON'13), Schloss Dagstuhl, Germany, 19.11.2013

## Further Activities and Events

### R. von Hanxleden:

Member of the *ArtistDesign European Network of Excellence on Embedded System Design*. Reviewer for the *ACM Transactions on Embedded Computing Systems (ACM TECS)*, *IEEE Computer*, *Science of Computer Programming*, *IEEE Transactions on Embedded Computing Systems*, *Transactions on Computers*, and the *Workshop on Methodical Development of Modelling Tools (MeDMoT2013)*. Reviewer of the EU-FP7 Project DESTECS (*Design Support and Tooling for Embedded Control Software*). Research visit to the University of Auckland, to NICTA, Sydney, and to Swinburne and Monash Universities, Melbourne (10.2012-03.2013).

### U. Rüegg:

DAAD doctoral scholarship (FITweltweit) for a research stay at Swinburne and Monash Universities, Melbourne (11.2013-05.2014)

### C. Motika, C. Schneider:

Demonstration of the Model-Railway, Girls' Day 2012 (25.04.2013) and the *Schnupperstudium* (15./16.10.2013)

### B. Duderstadt:

Reviewer for *Transactions on Computers*.

### I. Fuhrmann:

Reviewer for *Science of Computer Programming*.

### C. Motika:

Reviewer for *IEEE Computer*.

### C.-D. Schulze:

Reviewer for *Workshop Methodical Development of Modelling Tools (MeDMoT2013)*.

### Further Activities

Visit from Alexei Zhukov, Irkutsk State University (04.-29.11.2013) (funded by DAAD, Ostpartnerschaften-Programm)

## Scientific Computing

The Scientific Computing group focuses on the development of fast solvers for partial differential equations and integral equations arising in scientific applications. Since these equations usually cannot be solved analytically, they have to be approximated by a discretization scheme, and the accuracy of these schemes typically depends crucially on the number of variables. Therefore we are faced with the task of solving very large systems of equations.

For partial differential equations, we can approach this challenge by using a *preconditioner*, i.e. an approximation of the solution operator that can be evaluated efficiently. The preconditioner leads to an iteration scheme that computes a sequence of better and better approximations of the solution. For simple partial differential equations with smooth coefficients, multigrid methods provide good preconditioners that lead to rapid convergence.

We are interested in developing preconditioners that can also handle non-smooth coefficients arising, for example, in geophysical or medical simulations where different materials with different material parameters appear in the computational domain. As with multigrid methods, we rely on a hierarchical approach: the domain is split into subdomains, and each subdomain is equipped with a local basis that can be used to approximate its interaction with other domains. The resulting  $\mathcal{H}^2$ -matrix representation can be constructed by a recursive algorithm, and it is possible to prove that it leads to preconditioners able to handle even discontinuous coefficients.

For integral equations, on the other hand, even representing the system of equations poses a challenge, since each variable depends on all other variables. Again  $\mathcal{H}^2$ -matrix methods can be used: we split the computational domain into a hierarchy of subdomains and construct bases for these subdomains by interpolation, quadrature or cross approximation. Taking advantage of connections between different levels of the hierarchy allows us to construct algorithms of linear or nearly linear complexity that can handle very large matrices efficiently.

In order to take advantage of modern computing hardware, it is not enough to develop fast algorithms, it is also very important to consider the efficient implementation of these algorithms. Today's supercomputers typically rely on parallelization to reach their high performance, splitting a large computational task into sub-tasks that can be assigned to different computing units.

We are interested in several kinds of parallelization: *distributed computing* involves multiple computers that are connected by a network. Algorithms have to manage communication between the computers explicitly, giving the programmer a significant degree of control, but also demanding a careful analysis of communication patterns in order to avoid unnecessary waiting and deadlocks. Most of today's supercomputers are constructed based on the principle of distributed computing, since it leads to very cost-effective and flexible systems.

*Shared-memory computing* is based on multiple processors or processor cores sharing the same memory. In this model, the programmer does not have to worry about communication between the computers, only about the proper synchronization of the different steps in a larger computation. Most of today's personal computers and workstations are shared-memory machines involving one or several processors with multiple processor cores, making this approach very attractive for medium-sized applications.

*Vectorization* and *SIMT computing* uses processors equipped with multiple arithmetic/logic units that carry out the same task simultaneously. Vectorization can increase the execution speed of an algorithm significantly, if the algorithm can be organized in a way that requires the *same* operation to be performed uniformly on large arrays of data. Vector units are present in most of today's processors, for example, for handling video or audio signals, and more prominently in graphics processors that can contain several thousand arithmetic/logic units able to work in parallel, leading to a dramatically increased performance for certain applications.

## Results

Research activities in 2013 focused on three main projects: a new method for approximating integral operators appearing in the context of the boundary element method, the development of new algorithms for constructing robust preconditioners for integral equations and elliptic partial differential equations, and a new approach for treating matrix equations and certain higher-dimensional differential equations arising, for example, in the context of uncertainty quantification.

**Quadrature approximation.** The first project uses Green's representation formula to obtain the equation

$$g(x, y) = \int_{\partial\omega} g(x, z) \frac{\partial g}{\partial n(z)}(z, y) dz - \int_{\partial\omega} \frac{\partial g}{\partial n(z)}(x, z) g(z, y) dz$$

for the kernel function  $g$ . Choosing the domain  $\omega$  sufficiently far from  $x$  and  $y$  allows us to approximate the integral by a quadrature rule, yielding

$$g(x, y) \approx \sum_{\nu=1}^k w_{\nu} g(x, z_{\nu}) \frac{\partial g}{\partial n(z_{\nu})}(z_{\nu}, y) - \sum_{\nu=1}^k w_{\nu} \frac{\partial g}{\partial n(z_{\nu})}(x, z_{\nu}) g(z_{\nu}, y).$$

Since the variables  $x$  and  $y$  are separated on the right-hand side, this approximation can be used to construct efficient approximation schemes for the corresponding integral operator.

We have been able to prove that the approximation converges exponentially, and we have developed an implementation that demonstrates that the method works as expected for a number of model problems. A closer look at the numerical experiments indicated that it is possible to reduce the storage requirements by taking advantage of the special structure of the matrices appearing in the algorithm. Combining the method with an adaptive cross approximation scheme led to a significant improvement and also allowed us to construct approximations in the  $\mathcal{H}^2$ -matrix representation that reduces both the time and storage requirements.

The new algorithm is superior to most competing techniques, and we are now working on improving our implementation and performing large-scale experiments to demonstrate its advantages.

**$\mathcal{H}^2$ -matrix preconditioners.** The second project's goal is the development of efficient preconditioners for integral and partial differential equations. Good preconditioners are based on approximations of the inverse of the underlying operator. Since this inverse is typically a non-local operator, we have to use a representation that can handle non-local interactions.

We have chosen an approach based on the  $\mathcal{H}^2$ -matrix representation that combines a hierarchical decomposition of the matrix into submatrices with a multi-level basis that is used to express these submatrices. A new algorithm allows us to perform low-rank updates to a matrix in this representation efficiently, and these low-rank updates can in turn be used to develop higher-level algorithms that approximate products, inverses, and factorizations of  $\mathcal{H}^2$ -matrices.

The resulting algorithm involves multiple recursive procedures that have to interact in a carefully chosen pattern in order to obtain the required order of complexity and accuracy. We were able to implement a prototype, allowing us to verify that the new approach exhibits the hoped-for properties: the algorithm works equally well for integral equations and elliptic partial differential equations, it requires  $O(n \log n)$  operations to approximate the Cholesky decomposition of an  $n \times n$  matrix, and requires  $O(n)$  units of storage. Combining the resulting preconditioner in a conjugate gradient method leads to a very fast solver.

**Matrix Galerkin.** The third project focuses on matrix equations, e.g. on the Lyapunov equation

$$AX + XA^T = B.$$

Even an optimal-order solver requires at least  $O(n^2)$  operations to compute the  $n \times n$  matrix  $X$ . In many applications, the matrix  $X$  inherits certain properties from  $A$  that allow us to approximate it by an  $\mathcal{H}^2$ -matrix. If we can find this

matrix, the storage requirements would be reduced to  $O(nk)$  with a parameter  $k$  controlling the accuracy, and we could hope to be able to construct the approximation more efficiently.

The matrix Galerkin method is based on the fact that  $\mathcal{H}^2$ -matrices can be written in the form

$$\tilde{X} = \sum_{b=(t,s) \in P} V_t S_b W_s^T,$$

where  $(V_t)_t$  and  $(W_s)_s$  correspond to multi-level bases and the coupling matrices  $S_b$  contain the coefficients of matrix blocks  $\tilde{X}|_{t \times s}$  corresponding to these bases. As with any Galerkin method, we multiply the matrix equation with test matrices  $V_p S_{p,q} W_q^T$  using the Frobenius inner product and obtain a linear system of equations for the coupling matrices  $S_b$ .

We have developed efficient algorithms for constructing the linear system. Since the system contains connections of matrix blocks on different levels of the underlying hierarchy, carefully designed recursive procedures have to be used. Our prototype is able to set up the linear system in linear complexity and to solve it by iterative methods. The most sophisticated solver implemented so far is a conjugate gradient method using a multigrid preconditioner. Our experiments suggest that this solver requires only a constant number of steps to find a sufficiently accurate approximate solution.

In order to be able to apply standard finite element and multigrid theory to extend the method, we have started to implement a modified version of the algorithm that no longer relies on matrices, but constructs a subspace of the tensor space  $H^1(\Omega) \otimes H^1(\Omega)$  that is the continuous-level counterpart of a  $\mathcal{H}^2$ -matrix. We hope that this generalized method will allow us to prove convergence and to construct efficient solvers for partial differential equations arising in the context of uncertainty quantification.

**Teaching.** Each of the terms in 2013 involved writing a script for a new series of lectures: in the winter term 2012/13, a new module “Hochleistungsrechnen” (High-Performance Computing) was introduced, in the summer term 2013 the Scientific Computing group was responsible for the module “Algorithmen und Datenstrukturen” (Algorithms and Data Structures), and in the winter term 2013/14, a new module “Wissenschaftliches Rechnen” (Scientific Computing) was added to the collection of courses.

“Hochleistungsrechnen” was developed in cooperation with the group “Zuverlässige Systeme” and gives an overview of programming techniques required to take advantage of modern computing hardware. The lecture covers vectorization, shared-memory parallelization, distributed and GPGPU computing. Since most current PCs and notebooks are equipped with SIMD extensions, multi-core processors and graphics card supporting CUDA or OpenCL, we can offer the students a chance to experience the advantages and disadvantages of the different programming models first-hand.

“Wissenschaftliches Rechnen” gives an overview of different applications of numerical methods in Science and Engineering, covering simple methods for ordinary differential equations, finite difference discretization schemes for mechanical and electromagnetic waves and conservation equations, finite element methods for electrostatic potentials, linear elasticity and groundwater flow, and efficient solution techniques for the corresponding systems of linear equations. This series of lectures is aimed not only at students of mathematics, but also at students of computer science, physics and engineering.

## Personnel

Head of the group: Prof. Dr. S. Börm; Secretary: A. Bock

Scientific Staff:

Dipl.-Math. N. Albrecht	01.01.-31.12.2013	(50%)	CAU
Dipl.-Math. D. Boysen	01.01.-31.12.2013	(50%)	CAU
Dipl.-Math. J. Burmeister	01.01.-31.12.2013		CAU

Dipl.-Inf. S. Christophersen	15.03.-31.12.2013	(50%)	CAU
Dipl.-Math. J. Gördes	01.01.-31.03.2013		DFG, 75 percent
Separation der Fundamentallösungen elliptischer Differentialgleichungen mit Hilfe von Quadraturverfahren			
Dipl.-Math. J. Gördes	01.04.-30.09.2013	(50%)	CAU
Dipl.-Math. K. Reimer	01.01.-31.12.2013		DFG, 75 percent
$\mathcal{H}^2$ -Matrix-Vorkonditionierer für Integral- und elliptische partielle Differentialgleichungen			

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Einführung in die numerische Mathematik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
S. Börm (+ J. Burmeister, N. Albrecht, D. Boysen)

Iterative Verfahren für große Gleichungssysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
S. Börm (+ K. Reimer)

Hochleistungsrechnen, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
S. Börm (+ D. Nowotka)

Elementare numerische Methoden und ihre Implementierung 1, 1 (+ 1) hrs Practical (+ Exercises)/Week,  
S. Börm (+ J. Burmeister)

### Summer 2013

Algorithmen und Datenstrukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
S. Börm (+ S. Christophersen, J. Gördes)

Numerische Mathematik für Ingenieure, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
S. Börm (+ N. Albrecht)

Numerische Mathematik, 2 hrs Seminar/Week,  
S. Börm (with M. Braack)

Numerik von Eigenwertproblemen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
S. Börm (+ J. Burmeister)

Elementare numerische Methoden und ihre Implementierung 2, 1 (+ 1) hrs Practical (+ Exercises)/Week,  
S. Börm (+ J. Burmeister)

### Winter 2013/2014

Einführung in die numerische Mathematik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
S. Börm (+ J. Burmeister, N. Albrecht)

Elementare numerische Methoden und ihre Implementierung 1, 1 (+ 1) hrs Practical (+ Exercises)/Week,  
S. Börm (+ J. Burmeister)

Wissenschaftliches Rechnen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
S. Börm (+ D. Boysen)

Algorithmische Aspekte numerischer Verfahren, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
J. Burmeister (+ J. Burmeister)

## Third-Party Funds

Deutsche Forschungsgesellschaft,  $\mathcal{H}^2$ -Matrix-Vorkonditionierer für Integral- und elliptische partielle Differentialgleichungen, 01.01.2013-31.12.2014 (115.000 EUR)

## Diploma, Bachelor's and Master's Theses

S. Christophersen, *Schnelle Berechnung von Randintegraloperatoren auf der Grafikkarte*, 12.02.2013  
 J. Magenheimer,  *$\mathcal{H}^2$ -Matrixapproximation von vollbesetzten Matrizen durch Hierarchische Kompression*, 15.05.2013  
 J. Schikowski, *Realisierung eines Mehrgitterverfahrens in OpenCL*, 25.09.2013  
 M. Franck, *Zweistufige multiplikative überlappende Gebietszerlegungsverfahren*, 26.07.2013  
 S.-M. Schröder, *Implementierung einer strukturellen Simulation*, 30.09.2013

## Dissertations / Postdoctoral Lecture Qualifications

J. Gördes, *Effiziente Approximation von Integraloperatoren mit Hilfe der Green'schen Darstellungsformel*, 13.12.2013

## Publications

Published in 2013

S. Börm, J. Gördes, *Low-rank approximation of integral operators by using the Green formula and quadrature*, Numerical Algorithms, **64**, 567 - 592 (2013)  
 D. Boysen, S. Börm, *A Galerkin approach for solving matrix equations with hierarchical matrices*, PAMM, **13**, 405 - 406 (2013)

## Presentations

S. Börm, K. Reimer, *Efficient local low-rank updates for  $\mathcal{H}^2$ -matrices*, INS Bonn, Bonn, 15.11.2013  
 S. Börm, D. Boysen, *Hierarchical tensor approximation*, International Symposium on Numerics and Scientific Computing, Bruchsal, 24.10.2013  
 S. Börm, *Introduction to hierarchical matrices*, Workshop Hierarchical methods in linear algebra, Maison de la Simulation, Gif-sur-Yvette, France, 03.10.2013  
 S. Christophersen, *Galerkin-BEM on the GPU*, Workshop BEM + +, University College, London, United Kingdom, 19.09.2013  
 S. Börm,  *$\mathcal{H}^2$ -matrices for boundary element applications*, Workshop BEM + +, University College, London, United Kingdom, 19.09.2013  
 S. Börm, K. Reimer, *Efficient local low-rank updates for  $\mathcal{H}^2$ -matrices*, GAMM Workshop Applied and Numerical Linear Algebra, Wuppertal, 10.09.2013  
 S. Börm, S. Christophersen, J. Gördes, *Fast evaluation of boundary element matrices by quadrature techniques*, ENUMATH 2013, EPF, Lausanne, Switzerland, 26.08.2013  
 S. Börm, D. Boysen, *Hierarchical Tensor Approximation*, Oberseminar, Aachen, 18.07.2013  
 D. Boysen, S. Börm, *A Galerkin Approach for Solving Matrix Equations with Hierarchical Matrices*, GAMM Annual Meeting, Novi Sad, Serbia, 19.03.2013

## Further Activities and Events

Prof. Dr. Börm was presented with the "Best Prof Award" by the student representatives of mathematics and computer science.

Prof. Dr. Börm was one of the organizers of the winter school „Hierarchical matrices“ held at the Max Planck Institute for Mathematics in the Sciences at Leipzig.

Prof. Dr. Börm taught a course on „Hierarchical matrices“ at the Maison de la Simulation, CEA Saclay.



# Software Engineering

Research of the Software Engineering Group focuses on Software Engineering for parallel and distributed systems. Traditionally, software engineering addresses the process of constructing and evolving software systems. The operation of systems that are expected continuously to provide services with required quality properties is another great challenge. One goal of the Software Engineering Group is to investigate innovative techniques and methods for engineering, evolving, and operating continuously running software systems.

Of particular interest are our **KoSSE** network with colleagues of the Computer Science Institutes in Kiel and Lübeck (<https://www.kosse-sh.de>), and the KoSSE office that we are establishing together with the Cluster Management DiWiSH (<http://www.diwish.de/>).

We contribute to several **research data management** activities, for instance in the Excellence Cluster Future Ocean and the project PubFlow on publication workflows for research data.

## Results

### Kieker

In addition to studying the construction and evolution of software services, the software engineering discipline needs to address the operation of continuously running software services. Needed for robust operation are means for effective monitoring of software runtime behaviour. In contrast to profiling for development activities, monitoring of operational services should only impose a small performance overhead. Furthermore, instrumentation should be non-intrusive to the business logic, as far as possible.

The Kieker framework supports monitoring of software runtime behaviour, e.g. performance or (distributed) trace data. The flexible architecture allows the replacement or addition of framework components, including monitoring probes, analysis components, and record types shared by logging and analysis. Kieker creates Sequence Diagrams, Dynamic Call Trees, Markov chains, and Component Dependency Graphs from monitoring data. As a non-intrusive instrumentation technique, Kieker currently employs, but is not restricted to, aspect-oriented programming.

Extensive lab studies quantified the low overhead caused by the framework components. Qualitative evaluations provided by industrial case studies demonstrate the practicality of the approach.

Kieker is available as open-source software. For more information on Kieker, refer to <http://www.kieker-monitoring.net>

Kieker is a recommended tool of the SPEC Research Group: <http://research.spec.org/projects/tools.html>

### ExplorViz

In ExplorViz, Kieker is extended for live trace visualization for system and program comprehension in large software landscapes.

ExplorViz is available as open-source software. For more information on ExplorViz, refer to <http://www.explorviz.net/>

### PubFlow

The goal of PubFlow is to investigate workflow support for research data publication and build a software prototype to assist researchers in their daily work with research data. PubFlow is not about long-term preservation, but is about the workflows from institutional archives towards publication of research and archival data in world data centres. The goal of the project is to create a workflow environment for the work with research data, based on established business workflow systems, to increase the degree of automation in the publication process. The assumption is that the quality of the published data will increase if the data is enriched with automatically collected provenance data.

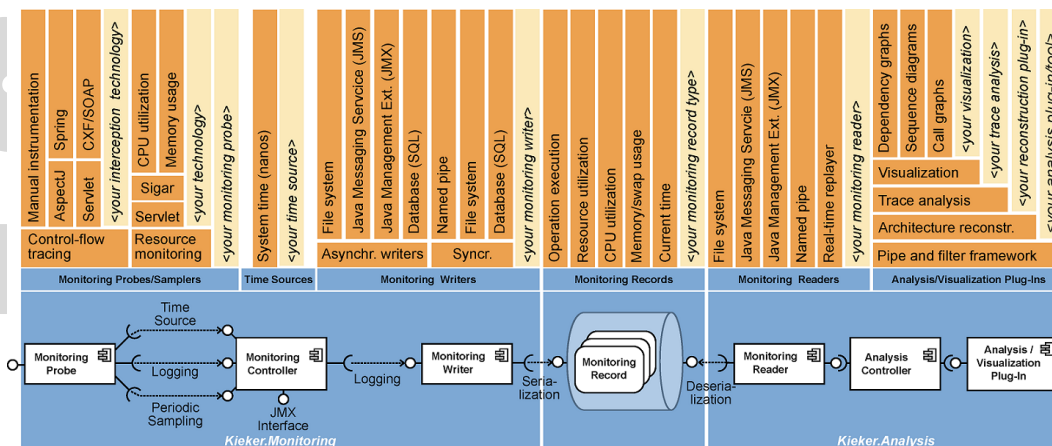


Fig. 1: Kieker Architecture and Reusable Components

To meet the requirements that scientific workflows pose on the business workflow systems that are employed in PubFlow, a software environment will be developed in which the business workflow engine is embedded. This software environment provides tools for the automatic collection of provenance information as well as enhanced business workflow monitoring features and interfaces for the interaction with the users and the data archives. The software architecture is a service-oriented architecture, such that individual software components can be exchanged independently. In PubFlow, Kieker is extended for workflow monitoring.

To facilitate the work with scientific workflows, the PubFlow system will provide various abstraction mechanisms. Scientists and data managers will be able to define their workflows in a BPMN 2.0 compliant, customized, domain-specific workflow language, which then will be translated to BPEL for execution. During their daily work, scientists interact through a simple, easy to use task-management interface with the PubFlow system. There should be no need for them to deal with complex workflows.

In the first phase of the project the ideas and tools created will be tested in the field of Marine Sciences. The PubFlow project started in August 2011 and will last until July 2014.

For more information on PubFlow, refer to <http://www.pubflow.uni-kiel.de/>

## iObserve

The increased adoption of service-oriented technologies and cloud computing creates new challenges for the adaptation and evolution of long-living software systems. Software services and cloud platforms are owned and maintained by independent parties. Software engineers and system operators of long-living software systems only have limited visibility and control over those third-party elements. Traditional monitoring provides software engineers and system operators with execution observation data which are used as a basis to detect anomalies. If the services and the cloud platform are not owned and controlled by the engineers of the software systems, monitoring the execution of the software system is not straightforward.

The aim of the iObserve project is to develop and validate advanced techniques which empower the system engineers to observe and detect anomalies of the execution of software systems they do not fully own and control. It will extend and integrate previous work on adaptive monitoring, online testing, and benchmarking and will use models@runtime as a means to adjust the observation and anomaly detection techniques during system operation. To demonstrate the feasibility and potential benefits gained, and for providing feedback to guide the research, the results will be continuously evaluated using an established research benchmark (CoCoME) as well as an industry-driven open-source application (Eclipse Skalli) that runs on a cloud platform.

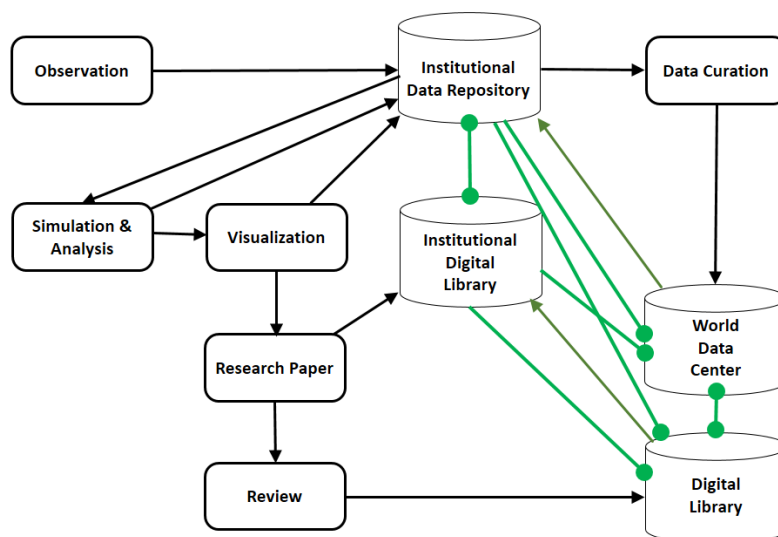


Fig. 2: Data and paper flows in PubFlow

The iObserve project started in November 2012 and will last until October 2015.

For more information on iObserve, refer to <http://www.dfg-spp1593.de/index.php?id=44>

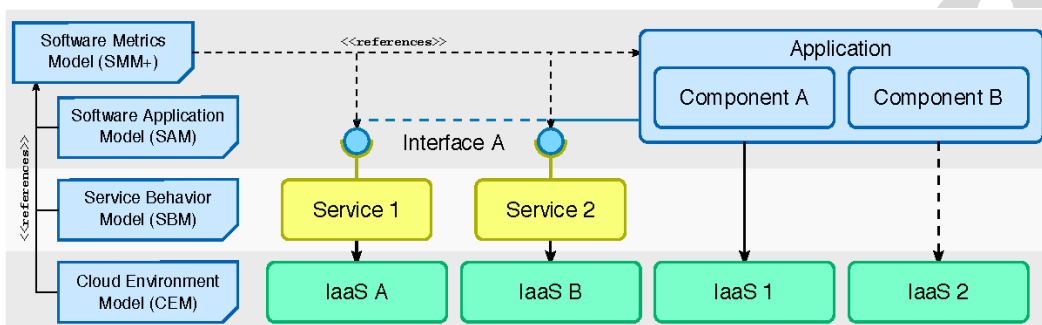


Fig. 3: Integrated Observation and Modelling Techniques to Support Adaptation and Evolution of Software Systems in iObserve

## ESN Software Lab

ESN Software Lab is a collaborative project between ESN EnergieSystemeNord GmbH and the software engineering group to advance technology transfer in software engineering. In the first phase, we are inventing a new product line architecture for web-based software cockpits. The ESN Software Lab started in November 2012.

## Personnel

Head of the group: Prof. Dr. W. Hasselbring; Secretary: C. Krüger (50%)  
Technical Staff: B.Sc. A. Plumhoff, B.Sc. M. Westphal (50%)

Staff:

Prof. Dr. W.-P. de Roever

01.01.-31.12.2013

retired

#### Scientific Staff:

Dipl. Inf. P. Brauer PubFlow, Kieker	01.01.-31.12.2013	DFG
M.Sc. N. Ehmke Kieker	15.11.-31.12.2013	CAU
M.Sc. F. Fittkau ESN Software Lab, Kieker, ExplorViz	01.01.-31.12.2013	CAU, ESN
M.Sc. S. Frey CloudMIG, Kieker	01.01.-31.08.2013	CAU
A. Johanson HOSST	01.01.-31.12.2013	GEOMAR
Dipl. Inf. R. Jung Kieker, iObserve	01.01.-31.12.2013	DFG
Dipl.-Inform. A. van Hoorn Kieker	01.01.-01.12.2013	Universität Stuttgart
Dipl. Inf. J. Waller Kieker	01.01.-31.12.2013	CAU
M.Sc. C. Wulf ESN Software Lab, Kieker	01.01.-31.12.2013	CAU, ESN

### Lectures, Seminars, and Laboratory Course Offers

#### Winter 2012/2013

Softwarearchitektur, 2 (+ 1) hrs Seminar (+ Exercises)/Week,  
W. Hasselbring (+ S. Frey)

Softwareprojekt, 3 hrs Exercise/Week,  
W. Hasselbring (+ C. Wulf, F. Fittkau)

Softwaretechnik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
D. Nowotka (+ S. Frey, J. Waller)

Masterseminar - Software Performance Engineering, 2 hrs Seminar/Week,  
W. Hasselbring (+ J. Waller, F. Fittkau, C. Wulf)

Abschlussprojekt - Software Engineering, 6 hrs Exercise/Week,  
W. Hasselbring (+ S. Frey, J. Waller)

#### Summer 2013

Abschlussprojekt - Software Engineering, 6 hrs Exercise/Week,  
W. Hasselbring (+ J. Waller, F. Fittkau, C. Wulf)

Softwareprojekt, 3 (+ 1) hrs Exercise (+ Exercises)/Week,  
W. Hasselbring (+ C. Wulf)

Software Engineering für parallele und verteilte Systeme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

W. Hasselbring (+ S. Frey, C. Wulf)

Masterprojekt - Software Engineering für parallele und verteilte Systeme, 4 hrs Exercise/Week,  
W. Hasselbring (+ F. Fittkau, C. Wulf, J. Waller)

*Winter 2013/2014*

Abschlussprojekt - Software Engineering, 6 hrs Exercise/Week,  
W. Hasselbring (+ F. Fittkau, J. Waller, C. Wulf)

Softwarearchitektur, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
W. Hasselbring

Softwareprojekt, 3 (+ 1) hrs Exercise (+ Exercises)/Week,  
W. Hasselbring (+ N. Ehmke, F. Fittkau)

Softwaretechnik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
D. Nowotka (+ N. Ehmke, J. Waller)

Masterprojekt - Software Engineering für parallele und verteilte Systeme, 4 hrs Exercise/Week,  
W. Hasselbring (+ F. Fittkau, J. Waller, C. Wulf)

Masterseminar - Software Performance Engineering, 2 hrs Seminar/Week,  
W. Hasselbring (+ N. Ehmke, F. Fittkau, C. Wulf, J. Waller)

### **Third-Party Funds**

DFG, *iObserve: Integrated Observation and Modelling Techniques to Support Adaptation an Evolution of Software Systems*, 01.11.2012-31.10.2015 (247.683 EUR)

DFG, *PubFlow: Publikationsprozesse für Forschungsdaten: Von der Erhebung und Verarbeitung zur Archivierung und Publikation*, 01.08.2011-31.07.2014 (218.500 EUR)

ISH, *Transferprämie 2011*, 01.06.2011-31.05.2013 (10.000 EUR)

ISH, *Transferprämie 2012*, 01.11.2012-31.12.2013 (10.000 EUR)

ESN, *ESN Software Lab*, 16.11.2012-15.11.2014 (85.650 EUR)

Helmholtz Association, *Helmholtz Research School Ocean System Science and Technology (HOSST)*,  
01.11.2012-31.10.2015 (Ph.D. Scholarship)

### **Further Cooperation, Consulting, and Technology Transfer**

In the excellence cluster Future Ocean, we cooperate with the Kiel Data Management Team at GEOMAR.

In HOSST (Helmholtz Research School Ocean System Science and Technology), we cooperate with GEOMAR.

In Kieker, we cooperate with several industrial partners such as b + m Informatik AG, Airbus, and XING AG as well as with researchers from other universities, such as Karlsruhe Institute of Technology (KIT) and the University of Stuttgart.

In KoSSE (Kompetenzverbund in Software Systems Engineering, <http://www.kosse-sh.de/>), we cooperate with several groups of the computer science departments of Kiel and Lübeck, with the Cluster Management DiWiSH, and with several regional companies.

In PubFlow, we cooperate with GEOMAR (their Library and Data and Computing Centre), ZBW (Leibniz-Informationszentrum Wirtschaft), as well as the Library and Computing Centre of the CAU, and the excellence cluster Future Ocean.

In iObserve, we cooperate with the Karlsruhe Institute of Technology (KIT) and the University of Duisburg-Essen.

In ESN Software Lab, we cooperate with ESN EnergieSystemeNord GmbH.



Published in 2013

- S. Becker, W. Hasselbring, A. van Hoorn, R. Reussner, *Proceedings of the Symposium on Software Performance: Joint Kieker/Palladio Days 2013*, CEUR Workshop Proceedings, **1083**, (2013)
- P. Brauer, W. Hasselbring, *PubFlow: provenance-aware workflows for research data publication*, 5th USENIX Workshop on the Theory and Practice of Provenance (TaPP '13), April 2-3, 2013, Lombard, USA, (2013)
- P. Brauer, W. Hasselbring, *PubFlow: a scientific data publication framework for marine science*, IMDIS 2013 International Conference on Marine Data and Information Systems, 23.-25.09.2013, Lucca, Italy, (2013)
- N. Ehmke, J. Waller, W. Hasselbring, *A Concurrent and Distributed Analysis Framework for Kieker*, Symposium on Software Performance: Joint Kieker/Palladio Days 2013 (KPDAYS 2013), November 27-29, 2013, Karlsruhe, Germany, (2013)
- F. Fittkau, J. Waller, C. Wulf, W. Hasselbring, *Live Trace Visualization for Comprehending Large Software Landscapes: The ExplorViz Approach*, 1st IEEE International Working Conference on Software Visualization (VISOFT 2013), September 27-28, 2013, Eindhoven, The Netherlands, (2013)
- F. Fittkau, J. Waller, P. Brauer, W. Hasselbring, *Scalable and Live Trace Processing with Kieker Utilizing Cloud Computing*, Symposium on Software Performance: Joint Kieker/Palladio Days 2013 (KPDAYS 2013), November 27-29, 2013, Karlsruhe, Germany, (2013)
- F. Fittkau, *Live Trace Visualization for System and Program Comprehension in Large Software Landscapes Technical Reports by Department of Computer Science, TR-1310*, Department of Computer Science, Kiel University, Germany, (2013)
- S. Frey, F. Fittkau, W. Hasselbring, *Search-Based Genetic Optimization for Deployment and Reconfiguration of Software in the Cloud*, 35th International Conference on Software Engineering (ICSE 2013), 18.-26. May 2013, San Francisco, CA, USA, (2013)
- J. Waller, *Benchmarking the Performance of Application Monitoring Systems Technical Reports by Department of Computer Science, TR-1312.*, Department of Computer Science, Kiel University, Germany., (2013)
- J. Waller, W. Hasselbring, *A Benchmark Engineering Methodology to Measure the Overhead of Application-Level Monitoring*, Symposium on Software Performance: Joint Kieker/Palladio Days 2013 (KPDAYS 2013), November 27-29, 2013, Karlsruhe, Germany., (2013)
- J. Waller, C. Wulf, F. Fittkau, P. Döhring, W. Hasselbring, *SynchroVis: 3D Visualization of Monitoring Traces in the City Metaphor for Analyzing Concurrency*, 1st IEEE International Working Conference on Software Visualization (VISOFT 2013), September 27-28, 2013, Eindhoven, The Netherlands, (2013)
- A. van Hoorn, S. Frey, W. Goerigk, W. Hasselbring, H. Knoche, H. Köster, H. Krause, M. Porembski, T. Stahl, M. Steinkamp, N. Wittmüss, *DynaMod: Dynamische Analyse für modellgetriebene Software-Modernisierung Technische Berichte des Instituts für Informatik, TR-1305*, Department of Computer Science, Kiel University, Kiel, Germany, (2013)
- R. Jung, R. Heinrich, E. Schmieders, *Model-driven Instrumentation with Kieker and Palladio to forecast Dynamic Applications*, Symposium on Software Performance: Joint Kieker/Palladio Days 2013, **1083**, 99 - 108 (2013)
- W. Hasselbring, R. Heinrich, R. Jung, A. Metzger, K. Pohl, R. Reussner, E. Schmieders, *iObserve: Integrated Observation and Modelling Techniques to Support Adaptation and Evolution of Software Systems*, Technical Report, 1309, Kiel, Germany., **1309**, (2013)
- N. Ehmke, *Everything in Sight: Kieker's WebGUI in Action*, Symposium on Software Performance — Joint Kieker/Palladio Days 2013 (KPDAYS 2013), November 27-29, 2013, Karlsruhe, Germany, (2013)
- R. Jung, C. Schneider, W. Hasselbring, *Type Systems for Domain-specific Languages*, ATPS 2013, 26.2.2013, Aachen., (2013)

- P. Brauer, *Workflowautomatisierung in PubFlow*, PubFlow Workshop 2013, Bremen, Germany, 18.04.2013
- P. Brauer, *PubFlow: a scientific data publication framework for marine science*, PubMan Days, München, Germany, 23.10.2013
- P. Brauer, *Workflowautomatisierung in PubFlow*, 2nd ZBW International PhD Summer School, Skopje, Macedonia, 31.05.2013
- P. Brauer, *PubFlow: a scientific data publication framework for marine science*, IMDIS 2013 International Conference on Marine Data and Information Systems, Lucca, Italy, 23.-25.09.2013
- P. Brauer, *Capturing Provenance Information in Scientific Workflow Environments*, SWIB13, Hamburg, Germany, 25.11.2013
- F. Fittkau, C. Wulf, *Grails - Schnelle, robuste und plugin-basierte Webentwicklung mit Groovy*, KoSSE-Workshops Web-Applikationen, Lübeck, Germany, 29.01.2013
- F. Fittkau, *SynchroVis: 3D Visualization of Monitoring Traces in the City Metaphor for Analyzing Concurrency [Talk]*, 1st IEEE International Working Conference on Software Visualization (VISSOFT 2013), Eindhoven, The Netherlands, 27.09.2013
- F. Fittkau, *Live Trace Visualization for Comprehending Large Software Landscapes: The ExplorViz Approach [Talk]*, 1st IEEE International Working Conference on Software Visualization (VISSOFT 2013), Eindhoven, The Netherlands, 28.09.2013
- F. Fittkau, *Scalable and Live Trace Processing with Kieker Utilizing Cloud Computing [Talk]*, Symposium on Software Performance: Joint Kieker/Palladio Days 2013 (KPDAYS 2013), Karlsruhe, Germany, 28.11.2013
- S. Frey, W. Hasselbring, *Search-Based Genetic Optimization for Deployment and Reconfiguration of Software in the Cloud*, 35th International Conference on Software Engineering (ICSE 2013), San Francisco, CA, USA, 18.-26.05.2013
- W. Hasselbring, R. Jung, *Application Performance Monitoring with Kieker: Failure detection, capacity management, reverse engineering and more*, SPP Design for Future, 1 Mar 2013, Aachen, Germany, 01.03.2014
- W. Hasselbring, *Rules of Good Scientific Practice: How can Software Systems and Services Contribute?*, Helmholtz Research School Ocean System Science and Technology (HOSST), Kiel, Germany, 23.01.2013
- W. Hasselbring, *Software und Enterprise Architekturen*, Barmeria CampusLab Ringvorlesung, Essen, Germany, 27.02.2013
- W. Hasselbring, *Modellbasiertes Performance-Testen modernisierter Software*, KoSSE-Tag, Lübeck, Germany, 05.06.2013
- W. Hasselbring, *Bewährte Muster zur Migration von Informationssystemen*, Softwareforen Leipzig, User Group Softwarearchitektur, Leipzig, Germany, 11.06.2013
- W. Hasselbring, *Workflow-basierte Verarbeitung und Archivierung von Ozeanbeobachtungsdaten*, Kieler Marktplatz Ozeanbeobachtung, Kiel, Germany, 18.06.2013
- W. Hasselbring, *Rules of Good Scientific Practice: How can Software Systems and Services Contribute?*, Graduiertenzentrum, Kiel, Germany, 28.08.2013
- W. Hasselbring, *iObserve: Integrated Observation and Modelling Techniques to Support Adaptation and Evolution of Software Systems*, 3rd Workshop of the DFG Priority Programme 1593, München, Germany, 10.10.2013
- W. Hasselbring, *Rules of Good Scientific Practice: How can Software Systems and Services Contribute?*, Integrated School of Ocean Sciences, Kiel, Germany, 03.12.2013
- R. Jung, *Model-driven Instrumentation with Kieker and Palladio to forecast Dynamic Applications*, Symposium on Software Performance: Joint Kieker/Palladio Days 2013, Germany, 01.01.2013
- R. Jung, *Type Systems for Domain-specific Languages*, ATPS 2013, Aachen, Germany, 26.02.2013
- A. van Hoorn, *Kieker 101*, Joint Kieker/Palladio Days (KPDAYS 2013), Karlsruhe, Germany, 27.11.2013
- J. Waller, *Wie funktioniert Facebook?*, Girls' Day, Kiel, Germany, 25.04.2013
- J. Waller, *Kieker: A Framework for Application Performance Monitoring and Dynamic Software Analysis*, Guest Lecture

SEPVS, Kiel, Germany, 22.05.2013

J. Waller, *A Benchmark Engineering Methodology to Measure the Overhead of Application-Level Monitoring [Talk]*,  
Symposium on Software Performance: Joint Kieker/Palladio Days 2013 (KPDAYS 2013), Karlsruhe, Germany,  
27.-29.09.2013

J. Waller, N. Ehmke, *Kieker: A Framework for Application Performance Monitoring and Dynamic Software Analysis*,  
Guest Lecture SWT, Kiel, Germany, 11.11.2013

J. Waller, *Adaptive Monitoring with Kieker*, Guest Lecture SA, Kiel, Germany, 22.10.2013

## Further Activities and Events

### P. Brauer:

- Reviewer for the following conference:
  - PESOS 2013:** 5th International Workshop on Principles of Engineering Service-Oriented Systems
- Organization of:
  - PubFlow Workshop 2013, Haus der Wissenschaft, Bremen

### S. Frey:

- Member of the programme committee of the following conferences:
  - CLOUD COMPUTING 2013:** 4th International Conference on Cloud Computing, GRIDs, and Virtualization
  - PESOS 2013:** 5th International Workshop on Principles of Engineering Service-Oriented Systems
- Reviewer for the following journals:
  - IEEE Internet Computing
  - International Journal on Advances in Intelligent Systems

### W. Hasselbring:

- Dean of the Faculty of Engineering
- Member of the Excellence Cluster Future Ocean (Principal Investigator for the second Phase)
- Member of the Excellence Cluster Inflammation at Interfaces
- Member of the Computational Sciences Centre at CAU
- Chairman of the Kiel KoSSE Projects
- Chairman of the Board of GI-Fachgruppe Softwaretechnik
- Board of GI-Fachgruppe Software-Architektur
- Reviewer for the following funding agencies:
  - BMBF: Bundesministerium für Bildung und Forschung



- DFG: Deutsche Forschungsgemeinschaft
- FWF: Fonds zur Förderung der wissenschaftlichen Forschung, Österreich
- GIF: German Israeli Foundation for Scientific Research and Development

- Editorial Board of the following journals:

- Advances in Software Engineering
- Enterprise Modelling and Information Systems Architectures - An International Journal
- International Journal of Software Architecture
- International Review on Modelling and Simulations
- Softwaretechnik-Trends

- Reviewer for the following journals and publishers:

- Computer Science — Research and Development
- Computer Standards & Interfaces
- Concurrency and Computation: Practice and Experience
- IEEE Transactions on Software Engineering
- IEEE Transactions on Cloud Computing

- Member of the programme committee for various conferences and workshops such as

**TEAR 2013:** 8th Workshop on Trends in Enterprise Architecture Research

**SE 2013:** GI-Fachtagung Software Engineering

**NFPinDSML 2012** Fourth International Workshop on Non-functional System Properties in Domain Specific Modelling Languages

**ICPE 2013:** International Conference on Performance Engineering

**ICSE 2013:** International Conference on Software Engineering

**CSMR 2013:** 17th European Conference on Software Maintenance and Reengineering

**BCSE 2013:** Workshop Business Clouds Software Engineering

**SESoS 2013:** International Workshop on Software Engineering for Systems-of-Systems

**DFF 2013:** 5. Workshop Design for Future

**PESOS 2013:** 5th International Workshop on Principles of Engineering Service-Oriented Systems

**SERENE 2013:** 5th International Workshop on Software Engineering for Resilient Systems

**ECSA 2013:** 7th European Conference on Software Architecture

**CBI 2013:** 15th IEEE Conference on Business Informatics

**DIS 2013:** Workshop Datenmanagement und Interoperabilität im Gesundheitswesen

**MBSOPTI 2013:** 8th Workshop on Model Based Software, Data, Process and Tool Integration

**OTC 2013:** HPI Workshop Operating the Cloud

**CSMR 2014:** 18th European Conference on Software Maintenance and Reengineering

**SE 2014:** Software Engineering 2014

**ICPE 2014:** 5th ACM/SPEC International Conference on Performance Engineering

**CSE 2014:** International Workshop on Continuous Software Engineering

**MAT2014:** Workshop Modellierung in der Automatisierungstechnik

**ECSA2014:** 8th European Conference on Software Architecture

**DFF 2014:** Workshop Design for Future

**MMSM2014:** Workshops Modellbasierte und modellgetriebene Softwaremodernisierung

**PESOS 2014:** 6th International Workshop on Principles of Engineering Service-Oriented and Cloud Systems

**WETICE 2014:** IEEE 23rd International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises

**CBI 2014:** 16th IEEE Conference on Business Informatics

**TEAR 2014:** 9th Trends in Enterprise Architecture Research Workshop

- Organization of
  - KoSSE-Tag 2013
  - Software Engineering 2014

**A. van Hoorn:**

- Reviewer for the following journal:
  - Journal of Software Engineering Research and Development
- Organization of
  - Symposium on Software Performance: Joint Kieker/Palladio Days 2013, Karlsruhe, Germany, November 27-29, 2013
- Publicity Chair of
  - SPEC Research Group

**R. Jung:**

- Reviewer for the following conference:
  - KPDAYS 2013:** Joint Kieker/Palladio Days 2013

**J. Waller:**

- Reviewer for the following journal:
  - Journal of Systems and Software
- Reviewer for the following conferences:
  - ICPE 2013:** 4th ACM/SPEC International Conference on Performance Engineering
  - ICPE 2014:** 5th ACM/SPEC International Conference on Performance Engineering
  - KPDAYS 2013:** Joint Kieker/Palladio Days 2013

# Technical Computer Science

The research group "Technical Computer Science" works in the area of the physical design of computer systems and their applications in different fields. The main focus is on massively parallel systems, particularly systems that can speed up computer intensive operations by the use of special purpose hardware architectures. The activities during 2013 can be subsumed under three headings: first, the on-going development of new massively parallel architectures, second, the development and implementation of new parallel algorithms for specific computationally demanding problems in bioinformatics, and third, the deployment of massively parallel algorithms for economic optimisation problems.

## Results

### RIVYERA

Many problems in scientific computing and cryptanalysis are currently intractable due to the limitations of standard PC architectures or clusters of them. Solutions for that lack of performance are problem specific architectures such as supercomputers, grid computing, or even application specific circuits (ASICs). Lately, a new architectural approach has proven its benefits: the field programmable gate arrays. These reconfigurable silicon devices combine the flexibility of general-purpose circuits, like CPUs in computers, with the speed-up of ASICs.

The Technical Computer Science research group utilizes these reconfigurable devices in a massively parallel architecture called RIVYERA. The RIVYERA architecture has been designed and developed in a HWT2-project funded by the ISH (Innovation Society Schleswig-Holstein) significantly driven by the company SciEngines GmbH, a startup from our research group. During 2009 to 2012 this design was implemented in several stages. It uses new versions of the Xilinx-Spartan series: the Spartan3-5000. In 2011 a prototype of the new machine with Spartan6 chips had been developed. It has been in operation since July 2012. This machine is the basis of the research of 2013:

### Massively Parallel Implementation of Algorithms in Bioinformatics

Current research in the area of bioinformatics is focussed on two externally funded projects. Firstly, in collaboration with the ICMB, the challenge is to massively parallelize the process of SNP imputation on the FPGA-based hardware architecture RIVYERA S6-LX150, containing 128 Xilinx Spartan6-LX150 FPGAs.

SNP imputation is used by biologists to determine the two haplotype vectors of an individual from its genotype information on a set of SNP positions. The imputation is based on Hidden Markov Models (HMMs) and the Viterbi algorithm. It becomes computationally very intensive due to a runtime and memory complexity proportional to the number of sites (SNPs), number of references, number of states per site, and the number of iterations. A normal run takes from several hours up to a whole day on a workstation cluster for a standard dataset. Our realization of the imputation is currently in the conceptual phase. It is based on the recently published method SHAPEIT2 (Delaneau et al., 2013).

Secondly, we started an AiF project (ZIM-KOOP) in cooperation with SciEngines GmbH and Johannes Gutenberg University Mainz to combine the advances of FPGAs with the advances of GPU technology with a focus on particular areas of algorithms in bioinformatics including SNP-SNP interactions in Genome-Wide Association Studies (GWAS) and Short-Read-Alignment (SRA). Current research considers the creation of contingency tables, as they are used in many GWAS algorithms on FPGAs of Xilinx' Kintex7 series, while the calculation of a statistical test value is relinquished to the GPU. As a proof-of-concept we implemented the tool iLOCi (Piriyapongsa et al., 2012) on the existing hardware platform RIVYERA S6-LX150. We gained a speedup of more than a factor of 285 (4m vs. 19h) against two quad-core CPUs. The results are to be published in 2014.

### Massively Parallel Portfolio Optimization

RIVYERA has turned out to be very suitable for optimization problems in the area of financial mathematics (portfolio optimization, strategy analysis). In 2013 we developed a number of parallel financial mathematics algorithms for the

architecture. These algorithms have been implemented in VHDL. The results achieved are impressive in terms of runtime and energy efficiency. It is planned to launch a start-up company to exploit the results of the research in this area.

## Personnel

Head of the group: Prof. Dr. M. Schimmler; Secretary: B. Scheidemann (50%)

Technical Staff: Dipl.-Ing. G. Diesner

Staff:

Ines Pohlmann	01.01.-15.09.2013	CAU
Scientific Staff:		
M. Sc. A. Abbas	01.01.-31.12.2013	
M. Sc. S. Koschnicke	01.01.-31.12.2013	CAU
M. Sc. Jan Kässens	15.03.-31.12.2013	Exzellenzcluster/ZIM
M. Sc. F. Schatz	01.01.-31.12.2013	Getdigital
Dr.-Ing. Ch. Starke	01.01.-31.12.2013	CAU
Dipl.-Inf. L. Wienbrandt	01.01.-31.12.2013	BLZ/Exzellenzcluster

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Digitale Systeme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Schimmler (+ S. Koschnicke, M. Schimmler, C.M.Y. Yeo)

Digital Systems, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Schimmler (+ M. Schimmler, C.M.Y. Yeo)

Hardwarepraktikum, 4 hrs Practical/Week,  
M. Schimmler (+ S. Koschnicke)

Algorithmenentwurf für massiv parallele Hardware, 4 hrs Practical/Week,  
M. Schimmler (+ S. Koschnicke)

Algorithmen der Bioinformatik, 2 hrs Seminar/Week,  
M. Schimmler (+ L. Wienbrandt, C.M.Y. Yeo)

### Summer 2013

Hardwarepraktikum, 4 hrs Practical/Week,  
M. Schimmler (+ S. Koschnicke)

Rechnergestützter Entwurf digitaler Systeme, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Schimmler (+ M. Schimmler, J. Ch. Kässens)

Implementierung massiv paralleler Systeme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Schimmler (+ M. Schimmler, S. Koschnicke, L. Wienbrandt)

Masterprojekt - Algorithmenentwurf für massiv parallele Hardware, 4 hrs Practical/Week,  
M. Schimmler (+ S. Koschnicke)

Algorithmen der Bioinformatik, 2 hrs Seminar/Week,  
M. Schimmler (+ L. Wienbrandt)

*Winter 2013/2014*

Digitale Systeme, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Schimmler (+ S. Koschnicke, M. Schimmler, Ch. Starke, J. Brünger)

Digital Systems, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Schimmler (+ M. Schimmler)

Hardwarepraktikum, 4 hrs Practical/Week,  
M. Schimmler (+ S. Koschnicke, J. Brünger)

Algorithmenentwurf für massiv parallele Hardware, 4 hrs Practical/Week,  
M. Schimmler (+ S. Koschnicke)

Algorithmen der Bioinformatik, 2 hrs Seminar/Week,  
M. Schimmler (+ L. Wienbrandt)

### **Third-Party Funds**

Ministerium für Wissenschaft, Wirtschaft und Verkehr, *BLK-Modellversuch*, 01.08.2012-31.12.2013 (60.000,00)

Dr. Werner Petersen-Stiftung, *Software-Challenge*, 28.05.2013 (30.000,00)

dataport AöR, *Software-Challenge*, 29.01.2013 (3.600,00)

ESN Nord GmbH, *Software-Challenge*, 26.07.2013 (7.000,00)

fls GmbH, *Software-Challenge*, 02.09.2013 (3.600,00)

PPI AG, *Software-Challenge*, 15.11.2013 (1.800,00)

WTSH GmbH, *Software-Challenge*, 18.10.2013 (2.155,97)

Exzellenzcluster, *Inflammation at Interfaces*, 01.02.-31.12.2013 (54.200,00)

AiF-Projekt GmbH, *FuE-Kooperationsprojekt Rechnerarchitektur für Bioinformatik*, 01.03.-31.12.2013 (32.426)

### **Further Cooperation, Consulting, and Technology Transfer**

Research cooperation with SciEngines GmbH and Johannes Gutenberg-Universität Mainz Project: hybrid-parallel algorithms for short-read alignment of NGS data and hybrid-parallel algorithms for genome-wide association studies.

Project cooperation with Institute of Clinical Molecular, Comprehensive Centre for Inflammation Medicine and Muthesius Academy of Fine Arts Design Project: a power-saving benchtop machine for ultra-fast genetic data analysis and interpretation in the Inflammation Clinic

### **Diploma, Bachelor's and Master's Theses**

Sven Hüser, *Detektion von Gen-Gen-Interaktionen in genomweiten Fall-Kontroll-Studien mit Hilfe von FPGAs*, 30.09.2013

Nabil Imran, *Mining digitaler Währungen mit Hilfe von RIVYERA*, 30.09.2013

Vasco Grossmann, *FPGA-basierte technische Finanzmarktanalyse zur Optimierung eines Wertpapierportfolios*, 24.01.2013

U. Rüegg, *Parallelized FPGA-based Graph Creation for De Novo Genome Assembly*, 19.03.2013

### **Publications**

Published in 2013

- L. Wienbrandt, *Bioinformatics Applications on the FPGA-based High-Performance Computer RIVYERA*, High Performance Computing Using PFAs edited by Wim Vanderbauwhede, Khaled Benkrid, Springer 2013, ISBN 978-1-4614-1790-3, (2013)
- T. Güneysu, T. Kasper, M. Novotný, Ch. Paar, L. Wienbrandt, R. Zimmermann, *High-Performance Cryptanalysis on RIVYERA and COPACOBANA Computing Systems*, High Performance Computing Using PFAs edited by Wim Vanderbauwhede, Khaled Benkrid, Springer 2013, ISBN 978-1-4614-1790-3, (2013)
- S. Koschnicke, V. Grossmann, Ch. Starke, M. Schimmler, *Quality and Consistency Assurance of Quote Data for Algorithmic Trading Strategies*, to appear in 2014 IEEE Conference on Computational Intelligence for Financial Engineering & Economics (CIFEr) - Proceedings, (2014)

## Presentations

- F. Schatz, *Hochperformantes hashbasiertes Short-Read-Alignment*, Studierendentagung zu Life Sciences, Kiel, 05.12.2013
- S. Koschnicke, V. Grossmann, Ch. Starke, M. Schimmler, *submitted paper: Quality and Consistency Assurance of Quote Data for Algorithmic Trading Strategies; appear in 2014, IEEE Computational Intelligence for Financial Engineering and Economics 2014, London, United Kingdom, 27.-28.03.2014*

## Further Activities and Events

The group Technical Computer Science together with the CEO of the company SciEngines GmbH, Gerd Pfeiffer, received the „Umweltpreis der Stadtwerke Kiel 2013“ for the development of several massively parallel computer architectures with extremely low energy consumption. The award was presented in the Town Hall of Kiel at a celebration on the 17th of December 2013.

# Theoretical Computer Science

The year 2013 was an atypical year for the theory group of the department in that considerable effort was put into organizing two conferences: the 30th Symposium on Theoretical Aspects of Computer Science (STACS 2013), one of the two most prestigious European conferences on theoretical computer science, and the "15. GI-Fachtagung Informatik und Schule (INFOS 2013)".

## Results

*Theory of Automata on Infinite Words* Over recent years, the theory group has continuously advanced the theory of automata on infinite words, in particular, it has invented several crucial automata-theoretic constructions. The key finding in 2013 was a structural explanation for constructions from previous years. It is hoped that this can serve as a basis for improved constructions.

*Game Theory and Security* Many security properties of cryptographic protocols have game-theoretic components, which is why it would be desirable to be able to check them automatically. In 2013 the group achieved seminal results in this direction. Furthermore, in cooperation with researchers from the University of Luxembourg, the group studied cryptographic protocols with respect to rational strategies. A major finding was that the security definitions commonly used do not cover strategic aspects sufficiently.

*Epistemic Security Properties* The group studied a new kind of attack on e-commerce protocols, where an adversary exploits the fact that he or she has control over user data and violates anonymity requirements. For a large class of protocols, an exact characterization of the cases in which such an attack is possible was obtained.

*Computational Social Choice* The result of an election can be tampered with by the organizers in different ways, for example, by adding or removing voters or candidates. For the specific problem *constructive control by adding candidates*, the group achieved a dichotomy result for so-called scoring rules. More precisely, for each (polynomial-time uniform) scoring rule, the stated problem is either in polynomial time or NP-complete. In addition, a complete list of the polynomial-time solvable cases was compiled. For the dual problem, *constructive control by deleting voters*, and the voting system *Uncovered Alternatives*, an NP-completeness result was shown and a relational approach was developed.

## Personnel

Head of the group: Prof. Dr. Th. Wilke; Secretary: K. Flöth (50%)

Technical Staff: Dipl.-Ing. H. Schmidt (50%)

Scientific Staff:

Dipl.-Math. S. Eggert	01.01.-31.12.2013		CAU
Dipl.-Inf. Björn Kinscher	01.08.-31.12.2013	(50%)	CAU
Dipl.-Math. S. Preugschat	01.01.-03.05.2013	(50%)	CAU
Dipl.-Math. S. Preugschat	04.05.-31.12.2013		DFG
Dr. H. Schnoor	01.01.-31.12.2013		CAU
StR S. Schulmeister	01.01.-31.07.2013	(50%)	CAU
Dipl.-Inf. Oliver Woizekowski	01.07.-31.12.2013	(50%)	CAU

Summer 2013

Inf-LogInf: Logik in der Informatik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
Th. Wilke (+ Th. Wilke, R. Berghammer)

Abschlussarbeiten AG Wilke, 2 hrs Lecture/Week,  
Th. Wilke (+ S. Eggert, H. Schnoor)

Inf-IS: Informationssysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
H. Schnoor (+ S. Eggert, C. Starke, D. Ehlers, P. Munstermann)

Inf-SecCom: Secure Communication, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Th. Wilke (+ Th. Wilke)

Winter 2013/2014

Abschlussarbeiten AG Wilke, 2 hrs Lecture/Week,  
Th. Wilke (+ S. Eggert, H. Schnoor)

Inf-AP-EdSoft: Bildungssoftware, 6 hrs Lecture/Week,  
Th. Wilke

Inf-EinfPP: Einführendes Programmierpraktikum, 3 hrs Exercise/Week,  
H. Schnoor

Inf-MP-ITSec: Masterprojekt Kryptographie und IT-Sicherheit, 4 hrs Exercise/Week,  
Th. Wilke

Inf-MS-Sem-Theorie: Masterseminar Theoretische Informatik, 2 hrs Lecture/Week,  
Th. Wilke (+ S. Eggert)

Inf-ITSec4: IT-Sicherheit (4), 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Th. Wilke (+ B. Kinscher, O. Woizekowski)

MS0102: Automaten, Logiken, Spiele, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
Th. Wilke (+ Th. Wilke)

Third-Party Funds

DFG, STACS 2013, 27.02.-02.03.2013 (4.125,48 EUR)

DFG, *Eindeutige endliche Automaten auf unendlichen Wörtern*, 04.05.2013-03.05.2016 (220.230,00 EUR)

DiWiSH, *Schnupperstudium Informatik*, 14.-18.10.2013 (1.500,00 EUR)

European Cooperation in Science and Technology, *Complexity of Copeland Manipulation*, 29.10.-14.11.2013 (1.550,00 EUR)

Further Cooperation, Consulting, and Technology Transfer

The group works with others in Trier (Prof. Ralf Küsters), Hannover (Prof. Heribert Vollmer), Rochester (Prof. Edith Hemaspaandra, Prof. Lane Hemaspaandra), Marseille (Prof. Nadia Creignou), Luxembourg (Wojciech Jamroga, PhD), Krakow (Prof. Piotr Faliszewski), Jerusalem (Prof. Orna Kupferman), Houston (Prof. Moshe Y. Vardi), San Antonio (Seth Fogarty, PhD), and Sydney (Prof. Ron van der Meyden), as well as with the group „Rechnergestützte Programmierung“ here in Kiel (Prof. Rudolf Berghammer).



## Diploma, Bachelor's and Master's Theses

- C. Lu, *Design and implementation of a generic attack detection and response mechanism for a centralized V2X credential management system (Masterarbeit)*, 21.02.2013
- D. Brunsch, *Funktionale Abhängigkeiten aus logischer Sicht (Bachelorarbeit)*, 05.03.2013
- M. Cyruk, *Blockly für den Schulunterricht (Bachelorarbeit)*, 05.03.2013
- G. Große-Bölting, *Blockly für den Schulunterricht (Bachelorarbeit)*, 05.03.2013
- P. Hein, *Charakterisierung eines Fragments der temporalen Logik durch eindeutige Automaten (Bachelorarbeit)*, 05.03.2013
- B. Kinscher, *Ein sicherer mehrbenutzerfähiger Netzwerkspeicher: Entwurf und Implementierung (Diplomarbeit)*, 08.11.2013

## Publications

Published in 2013

- N. Breier, P. Stechert, Th. Wilke, *INFOS 2013*, LNI, **P-219**, 1 - 157 (2013)
- N. Breier, P. Stechert, Th. Wilke, *INFOS 2013 Praxisband*, Kiel Computer Science Series, **2013/3 v1.0**, 1 - 221 (2013)
- R. Berghammer, H. Schnoor, *Relation-algebraic and Tool-supported Control of Condorcet Voting*, CoRR, **1304.7244**, 1 - 16 (2013)
- S. Eggert, R. van der Meyden, H. Schnoor, Th. Wilke, *Complexity and Unwinding for Intransitive Noninterference*, CoRR, **1308.1204**, 1 - 51 (2013)
- S. Eggert, H. Schnoor, Th. Wilke, *Noninterference with Local Policies*, MFCS, **2013**, 337 - 348 (2013)
- S. Fogarty, M. Y. Vardi, Th. Wilke, *Unifying Büchi Complement Construction Constructions*, Logical Methods in Computer Science, **9(1)**, 1 - 26 (2013)
- S. Fogarty, M. Y. Vardi, Th. Wilke, *Profile Trees for Büchi Word Automata, with Application to Determinization*, Gandalf, **2013**, 107 - 121 (2013)
- W. Jamroga, M. Melissen, H. Schnoor, *Defendable Security in Interaction Protocols*, PRIMA, **2013**, 132 - 148 (2013)
- N. Portier, Th. Wilke, *Proceedings of STACS 2013*, LIPIcs, **20**, 1 - 647 (2013)
- S. Preugschat, Th. Wilke, *Effective Characterizations of Simple Fragments of Temporal Logic Using Carton-Michel Automata*, Logical Methods in Computer Science, **9(2)**, 1 - 22 (2013)
- H. Schnoor, *Quantified Epistemic and Probabilistic ATL*, ICAART, **2013**, 14 - 23 (2013)
- H. Schnoor, O. Woizekowski, *Active Linkability Attacks*, CoRR, **1311.7236**, 1 - 20 (2013)
- S. Schulmeister, *Movingart - ein fächerübergreifendes KunstInformatikProjekt in der Sekundarstufe I*, INFOS 2013, 67 - 76 (2013)

## Presentations

- H. Schnoor, *Quantified Epistemic and Probabilistic ATL*, ICAART 2013, Barcelona, Spain, 15.-18.02.2013
- S. Eggert, H. Schnoor, Th. Wilke, *Noninterference with Local Policies*, MFCS 2013, Klosterneuburg, Austria, 26.-30.08.2013
- Wojciech Jamroga, Matthijs Melissen, H. Schnoor, *Defendable Security in Interaction Protocols*, PRIMA 2013, Dunedin, New Zealand, 01.-06.12.2013
- Seth Fogarty, Orna Kupferman, Moshe Y. Vardi, Thomas Wilke, *Profile Trees for Büchi Word Automata, with Application to Determinization*, Gandalf 2013, Borca di Cadore, Italy, 29.-31.08.2013

## Further Activities and Events

Th. Wilke was elected *Sprecher des Fachbereichs Grundlagen der Gesellschaft für Informatik e.V.*

Th. Wilke was elected member of the Council of the European Association for Theoretical Computer Science.

Th. Wilke was co-chair of the programme committee of STACS 2013.

Th. Wilke was member of the programme committee of INFOS 2013.

The group organized one week of Schnupperstudium Informatik, jointly with the business office of the department and Priv.-Doz. Dr. Frank Huch.

The group organized a computer animation contest for schools in Schleswig-Holstein.

# Theory of Parallelism

Our group performs research in the field of optimization problems. On the one hand, we are interested in efficient approximation algorithms, and on the other, in algorithm engineering in order to use these algorithms for practical applications. The group's main areas of interest include: approximate solvers for linear programs (that generate provably good solutions quickly as opposed to solving instances to optimality in excessive time), approximation schemes (that permit a controllable trade-off between efficiency and accuracy), parameterized complexity (where the aim is to obtain better running times for instances with a special structure), scheduling problems (that include problems in industrial production planning), geometrically constrained packing problems (which feature several optimization aspects and models, for instance, the packaging of goods in containers or the loading of trucks with resources), network flow problems (that model the transportation of physical commodities as well as data), and finally, timetabling problems (which are fundamental in staff scheduling in administrative systems, educational systems and medical care).

In 2013 Professor Jansen organized the *39th International Workshop on Graph-Theoretic Concepts in Computer Science* (WG2013) together with Andreas Brandstädt (Rostock University) and Rüdiger Reischuk (University of Lübeck).

## Personnel

Head of the group: Prof. Dr. K. Jansen; Secretary: U. Iaquinto (50%)

Technical Staff: P. Karimi Massouleh (50%)

Scientific Staff:

M. Kaluza	01.10.-31.12.2013	(50%)	DFG	Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese
K.-M. Klein	01.01.-30.09.2013		CAU	
K.-M. Klein	01.10.-30.11.2013	(50%)	DFG	Programmpauschale
K.-M. Klein	01.10.-31.12.2013	(50%)	CAU	
S. Kraft	01.01.-30.09.2013		DFG	Entwicklung von effizienten polynomiellen Approximationsschemata für Scheduling- und verwandte Optimierungsprobleme
S. Kraft	01.10.-30.11.2013	(50%)	DFG	Programmpauschale
S. Kraft	01.10.-31.12.2013	(50%)	CAU	
Felix Land	01.01.-31.12.2013		DFG	Approximative Algorithmen für zwei- und dreidimensionale Packungsprobleme und verwandte Schedulingprobleme
Kati Land	01.02.-31.12.2013		DFG	Entwicklung von Approximationsalgorithmen für Scheduling auf heterogenen Maschinen
M. Maack	01.10.-31.12.2013	(50%)	CAU	Hochschulpakt 20/20
M. Maack	01.10.-31.12.2013	(50%)	DFG	Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese

L. Prädel  
Programmpauschale

L. Prädel  
Programmpauschale

01.04.-31.05.2013 (50%) DFG

01.06.-30.09.2013 DFG

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Vorlesung - Theoretische Grundlagen der Informatik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
K. Jansen (+ K.-M. Klein)

Seminar - Algorithmen und Komplexität, 2 hrs Seminar/Week,  
K. Jansen (+ F. Land, K. Land)

Seminar - Theoretische Informatik, 2 hrs Seminar/Week,  
K. Jansen (+ F. Land, K. Land)

Fortgeschrittenenseminar - Algorithmen, Kombinatorik und Komplexität, 2 hrs Seminar/Week,  
K. Jansen (+ A. Srivastav)

Masterprojekt - Effiziente Algorithmen, 4 hrs Practical/Week,  
K. Jansen (+ K.-M. Klein, S. Kraft)

### Winter 2013/2014

Vorlesung - Theoretische Grundlagen der Informatik, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
K. Jansen (+ K.-M. Klein)

Algorithmen für praktische Optimierungsprobleme, 2 (+ 4) hrs Lecture (+ Exercises)/Week,  
K. Jansen (+ S. Kraft)

Projekt Wirtschaftsinformatik (Operations Research), 5 hrs Exercise/Week,  
K. Jansen (+ M. Maack, S. Kraft)

Seminar - Algorithmen und Komplexität, 2 hrs Seminar/Week,  
K. Jansen (+ F. Land, K. Land)

Seminar - Theoretische Informatik (Aktuelle Forschungsfragen der theoretischen Informatik), 2 hrs Seminar/Week,  
K. Jansen (+ F. Land, K. Land)

Masterprojekt - Effiziente Algorithmen, 4 hrs Practical/Week,  
K. Jansen (+ S. Kraft, K.-M. Klein)

## Third-Party Funds

DFG-Projekt, Entwicklung und Analyse von approximativen Algorithmen für zwei- und dreidimensionale  
Packungsprobleme, *Personel, travel, and acquisition*, 01.10.2011-31.01.2014 (211.700 EUR)

DFG-Projekt, Entwicklung von effizienten polynominellen approximationsschemata für Scheduling- und verwandte  
Optimierungsprobleme, *Personel, travel, and acquisition*, 01.10.2010-30.09.2013 (205.200 EUR)

DFG-Projekt, Entwicklung von Approximationsalgorithmen für Scheduling auf heterogenen Maschinen, *Personel, travel, and acquisition*, 01.02.2012-31.01.2015 (228.100 EUR)

DFG-Projekt, Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponentialzeithypothese,  
*Personel, travel and acquisition*, 01.10.2013-30.09.2016 (222.510 EUR)

## Further Cooperation, Consulting, and Technology Transfer

Our group cooperates closely with that of Prof. Guochuan Zhang from the College of Computer Science of Zhejiang University, China, with Roberto Solis-Oba from the University of Western Ontario, Canada, as well as with Denis Trystram who is working at the LIG - Laboratoire d'Informatique de Grenoble, France, with whom we have an ERASMUS partnership. In addition we have established an active exchange with Janka Chlebikova who by an ERASMUS exchange of students, is working at the University of Portsmouth, United Kingdom.

Initiated by Professor Jansen, of the Department of Informatics of the University of Bergen, has visited our Department of Computer Science in November 2013 and as a result we are anticipating an ERASMUS partnership and a closer cooperation.

## Diploma, Bachelor's and Master's Theses

- K. Haase, *Strip-Packing mit konstanter Anzahl von Itemtypen*, *Diploma thesis*, 18.01.2013
- J. Bielke, *Algorithmen für das Dial-a-Ride Problem mit Transfers*, *Diploma thesis*, 11.09.2013
- S. Röpsdorf, *Efficient Optimization of School Timetables*, *Bachelor's thesis*, 20.09.2013
- K. Rahf, *Fairness in Round Robin Tests*, *Bachelor's thesis*, 30.09.2013
- C. C. Wiechmann, *Effiziente Lösungen für das Delay Management Problem*, *Bachelor's thesis*, 30.09.2013
- P. Lund, *Approximative Algorithmen für das Steinerbaumproblem*, *Bachelor thesis*, 30.09.2013
- T. Blume, *Scheduling on Identical Machines with a Bounded Number of Different Production Times*, *Bachelor's thesis*, 30.09.2013
- K. Prohn, *Approximative Algorithmen für Scheduling auf identischen Maschinen*, *Bachelor's thesis*, 30.09.2013

## Dissertations / Postdoctoral Lecture Qualifications

- L. Chen, *On Schemes of Scheduling Problems*, 15.07.2013

## Publications

Published in 2013

- R. Harren, K. Jansen, L. Prädel, U. Schwarz, R. van Stee, *Two for One: Tight approximation of 2D Bin Packing*, *International Journal of Foundations of Computer Science*, (2013)
- K. Jansen, S. Kratsch, D. Marx, I. Schlotter, *Bin packing with fixed number of bins revisited*, *Journal of Computer and System Sciences*, **79** (1), 39 - 49 (2013)
- K. Jansen, L. Prädel, *New approximability results for two-dimensional bin packing*, *SIAM-ACM Symposium on Discrete Algorithms*, (2013)
- K. Jansen, S. Kraft, *An improved knapsack solver for column generation*, *Computer Science Symposium in Russia (CSR 2013)*, Springer LNCS, **7913**, 12 - 23 (2013)
- K. Jansen, K.-M. Klein, *A robust AFPTAS for online bin packing with polynomial migration*, *40th International Colloquium on Automata, Languages and Programming (ICALP)*, Springer LNCS, **7965**, 589 - 600 (2013)
- K. Jansen, Felix Land, Kati Land, *Bounding the running time of algorithms for scheduling and packing problems*, *Workshop on Algorithms and Data Structures Symposium (WADS 2013)*, Springer LNCS, **8037**, 439 - 450 (2013)
- P.- F. Dutoit, K. Jansen, C. Robenek, D. Trystram, *A (2+epsilon) - approximation for scheduling parallel jobs in platforms*, *The International European Conference on Parallel and Distributed Computing (Euro-Par 2013)*, Springer LNCS, **8097**, 78 - 89 (2013)
- T. Ehlers, K. Jansen, *Online-scheduling on identical machines with bounded migration*, *15th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (SYNASC 2013)*, (2013)

- K. Jansen, L. Prädél, *New approximability results for two-dimensional bin packing*, SIAM-ACM Symposium on Discrete Algorithms (SODA 2013), New Orleans, USA, 06.-08.01.2013
- K. Jansen, L. Prädél, *New approximability results for two-dimensional bin packing*, 10th EURO special Interest Group on Cutting and Packing meeting (ESICUP), Lille, France, 24.-26.04.2013
- K. Jansen, *Efficient polynomial time approximation schemes (Invited Tutorial)*, 11th Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP 2013), Pont à Mousson, France, 23.-28.06.2013
- K. Jansen, S. Kraft, *An improved knapsack solver for column generation*, Computer Science Symposium in Russia (CSR 2013), Ekatarinburg, Russia, 25.-29.06.2013
- K. Jansen, Felix Land, Kati Land, *Bounding the running time of algorithms for scheduling and packing problems*, International Workshop on Approximation, Parameterized and EXact algorithms (APEX 2013), Riga, Latvia, 07.07.2013
- K. Jansen, K.-M. Klein, *A robust AFPTAS for online bin packing with polynomial migration*, 40th International Colloquium on Automata, Languages and Programming (ICALP), Riga, Latvia, 08.-12.07.2013
- K. Jansen, Felix Land, Kati Land, *Bounding the running time of algorithms for scheduling and packing problems*, Workshop on Algorithms and Data Structures Symposium (WADS 2013), London, ON, Canada, 12.08.2013-14.08.2014
- P.- F. Dutot, K. Jansen, C. Robenek, D. Trystram, *A (2+epsilon) - approximation for scheduling parallel jobs in platforms*, The International European Conference on Parallel and Distributed Computing (Euro-Par 2013), Aachen, Germany, 26.-30.08.2013
- T. Ehlers, K. Jansen, *Online-scheduling on identical machines with bounded migration*, 15th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (SYNASC 2013), Temeswar, Romania, 23.-26.09.2013

## Further Activities and Events

Prof. Jansen has been a member of the Steering Committee of the Special Interest Group on Algorithms of the Gesellschaft für Informatik (GI) since 2010.

Prof. Jansen was involved in the organization of the following conferences:

He was a workshop Chair at the *16th International Workshop on Approximation Algorithms for Combinatorial Optimization Problems*, and the *17th International Workshop on Randomization and Computation (APPROX-RANDOM 2013)* in Berkley, CA, USA and the *39th International Workshop on Graph-Theoretic Concepts in Computer Science (WG 2013)* in Lübeck, Germany. In addition Prof. Jansen was a steering committee member of the *12th International Symposium on Experimental Algorithms (SEA 2013)* in Rome, Italy.

Prof. Jansen was a programme committee member of the following conferences:

the *39th International Conference on Current Trends in Theory and Practice of Computer Science (SOFSEM 2013)* in Spindleruv Mlyn, Czechia,

the *19th Annual International Computing and Combinatorics Conference (COCOON 2013)* in Hangzhou, China,

the *International Workshop on Approximation, Parameterized and Exact algorithms (APEX 2013)* in Riga, Latvia,

the *13th International Symposium on Algorithms and Data Structures (WADS 2013)* in London, Ontario, Canada,

the *Workshop on Scheduling for Parallel Computing (SPC 2013)* in Warsaw, Poland,

the IEEE conference on *High Performance Computing (HiPC 2013)* in Bangalore, India.

# Institute of Electrical and Information Engineering

The Institute of Electrical and Information Engineering (ET&IT) of the Christian-Albrechts-Universität zu Kiel (CAU) is extensively integrated into cooperative and interdisciplinary research projects. Within the topic Information Engineering members of ET&IT closely cooperate with the Department of Computer Science. ET&IT also maintains a close research partnership with the Institute for Materials Science mainly in the research area "Nanosystems Engineering". In particular, several members of ET&IT are principal investigators in the Collaborative Research Centre SFB 855 Magneto-Electric Composites - Future Biomagnetic Interfaces, working together with materials scientists, physicists, and physicians. In addition, the Institute has been engaged in the Computational Sciences Centre of the CAU and in the regional research network CEwind - Centre of Competence in Wind Energy.

The Institute of ET&IT consists of 11 professorships including the external professorship held by Prof. Dr.-Ing. Wolfgang Benecke, who is also the Managing Director of the Institut für Siliziumtechnologie (ISIT) in Itzehoe. Two of these professorships were reassigned in 2013: in September 2013, Prof. Dr.-Ing. Marco Liserre took over the professorship "Power Electronics" as the successor of Prof. Dr.-Ing. Friedrich W. Fuchs who retired at the end March 2013. Half a year later, Prof. Dr.-Ing. Reinhard Knöchel retired as well and Prof. Dr.-Ing. Michael Höft became the new head of the microwave group at the beginning of October 2013.

Since October 2012, Prof. Dr.-Ing. Gerhard Schmidt has been the executive member of the Institute's board.

In June 2013, Prof. Dr. Martina Gerken received the "Kieler Wissenschaftspreis 2013" in recognition of her outstanding research in the field of nanotechnology.

The number of new students, who enrolled in the five academic courses offered by the Institute of ET&IT in 2013, stayed nearly the same as in the previous year. In the summer semester 2013, 30 freshmen enrolled in the master's programmes Electrical and Information Engineering and Electrical and Information Engineering and Business Management. For the winter semester 2013/2014 a total of 238 new students enrolled in the Institute's academic courses. In detail, 62 students started the bachelor's programme Electrical and Information Engineering and 131 enrolled in the bachelor's programme Electrical and Information Engineering and Business Management. In the corresponding master's programmes 32 students took up their studies, and 13 new students enrolled in the international 4-semester master's programme Digital Communications where all courses are offered in English.

In June 2013, Prof. Dr. Martina Gerken received the "Kieler Wissenschaftspreis 2013" in recognition of her outstanding research in the field of nanotechnology.

The number of new students, who enrolled in the five academic courses offered by the Institute of ET&IT in 2013, stayed nearly the same as in the previous year. In the summer semester 2013, 30 freshmen enrolled in the master's programmes Electrical and Information Engineering and Electrical and Information Engineering and Business Management. For the winter semester 2013/2014 a total of 238 new students enrolled in the Institute's academic courses. In detail, 62 students started the bachelor's programme Electrical and Information Engineering and 131 enrolled in the bachelor's programme Electrical and Information Engineering and Business Management. In the corresponding master's programmes 32 students took up their studies, and 13 new students enrolled in the international 4-semester master's programme Digital Communications where all courses are offered in English.





# Automatic Control

The research activities of the Chair of Automatic Control comprise mathematical modelling of dynamic systems, model-based control and observer design for nonlinear and distributed-parameter systems with applications in smart adaptive structures, cooperative multi-agent systems, chemical, biochemical and thermal processes as well as computational methods for control. Here, research has a strong focus on the development of analytic and semi-analytic methods and their numerical and experimental evaluation.

Teaching addresses control design for linear systems using frequency and state space techniques, nonlinear control systems taking into account differential geometric and Lyapunov-based approaches, optimization and optimal control, control of distributed-parameter systems, as well as model-based estimator and observer design. Basic and advanced student lab hours complete the curriculum.

## Results

### Distributed-Parameter Systems and Control Theory

Distributed-parameter systems are characterized by state variables depending on both time and space. Mathematical modelling hence yields a system description in terms of partial differential equations (PDEs). Well known examples include elastomechanic or thermomechanic structures in mechatronics or aeronautics, fixed-bed and tubular reactors in chemical and process engineering, reheating and cooling processes in steel manufacture and forming, heat exchangers, fluid flow and fluid-structure interactions, and collective dynamics of robots, crowds and flocks.

The research activities in particular address the development of systematic model-based analysis and design techniques for motion planning, feedback stabilization and observer design. Here, so-called late lumping approaches are considered that directly exploit the underlying mathematical PDE structure. For this, novel flatness-, backstepping- and passivity-based techniques are developed for linear and nonlinear distributed-parameter systems with single, and in particular higher-dimensional, spatial domains. In addition, it is shown that the combination of the determined approaches yields sophisticated tracking control concepts to realize prescribed spatial-temporal paths. Stability (exponential or asymptotic) of the feedback and tracking control schemes is analyzed using operator and semigroup theory.

In order to address the complexity arising in many applications, e.g. due to complex shaped geometries or the number of dependent state variables, semi-analytical design techniques are deduced by combining the developed analytical approaches with numerical discretization and approximation schemes such as finite difference, finite volume or finite element methods.

### Smart Material Structures

Smart material structures denote elastic carriers with embedded distributed actuators and sensors. These structures occur in a large variety of technical applications including vibration suppression, static or dynamic shape control, or fault detection. In addition, new application areas evolve such as adaptive optics in telescopes, adaptive wings or so-called smart skins, where transiently varying shapes are used for the modulation of optical wave fronts, the adaption of drag for specific flight conditions, or the improvement of aeroelastic characteristics. For this, piezoelectric elements typically serve as actuators by exploiting the indirect piezoelectric effect to convert electrical voltage into mechanical strain.

For the mathematical modelling of smart material structures the spatial extension of the structure and the distribution of actuators and sensors has to be considered and leads to a description in terms of partial differential equations (PDE). This PDE formulation can be exploited for motion planning, stabilization and observer design. For piezoactuated beam and plate structures systematic flatness-based motion planning techniques have been developed to realize the desired transient behaviour of an open-loop controller. Taking into account passivity-based feedback control within the so-called two-degrees-of-freedom (2DOF) control concept yields an asymptotically stable tracking error dynamics. Here, the research activities address non-collocated feedback control design, which results in a dynamic output feedback scheme involving a

distributed-parameter state observer. The asymptotic stability of the closed-loop control can be verified in a rather general setting by making use of operator and semigroup theory. State-of-the-art experimental benchmark examples confirm the high tracking accuracy of the proposed motion planning and 2DOF control concept. An example is provided in Fig. 1, illustrating a flexible beam structure with embedded piezoelectric macro-fibre composite (MFC) actuators.

Current research addresses interconnected structures of coupled elements, optimal actuator and sensor placement as well as applications in active flow control for maritime structures.

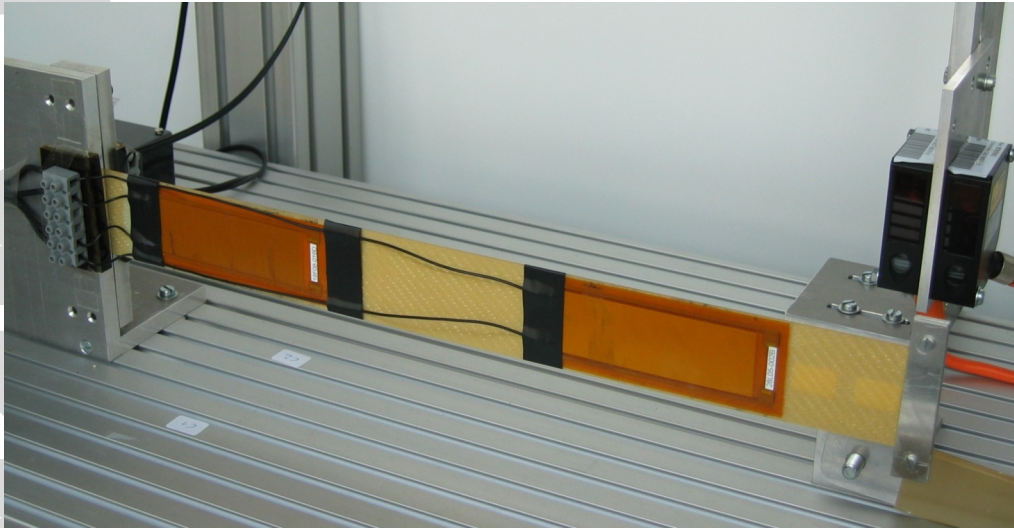


Fig. 1: Flexible beam structure with embedded piezoelectric macro-fibre composite (MFC) actuators.

### Multi-Agent Systems

In the past decades, extensive research has been conducted on the cooperative formation control of multi-agent systems with possible applications ranging from uncrewed aerial vehicles (UAVs) through transportation systems to micro-satellite clusters. Thus, different analysis and design approaches have emerged depending on the available communication topology and the considered multi-agent formation control task. Besides the discrete analysis of the interconnected individual agents, continuous models based on PDEs have been used to model, analyze and control many particle systems, traffic flow or large vehicular platoons.

The research activities of the Chair of Automatic Control focus on the application of PDE-based motion planning and feedback control strategies to achieve consensus, formation control and synchronization of multi-agent systems. For this, flatness-based techniques are considered and combined, e.g. with backstepping-based state feedback control and observer design for the tracking error dynamics. The transfer from the agent continuum to the discrete formulation is finally achieved by discretization which imposes the communication topology. Hence, rather generic analysis and design tools are developed that, in particular, are independent of the actual communication topology.

### Control in Biotechnology

Lactic acid bacteria are extensively used as starter cultures for the manufacture of several dairy products such as yoghurt or cheese. One of the most commercially important lactic acid bacteria in the dairy industry is the bacterium *Streptococcus thermophilus*. In the industrial production of *Streptococcus thermophilus* it is of major importance to determine exactly the time when the bacteria reach the maximum of their activity. This time marks the end of the fermentation process and where the downstream process of the bacterial culture is started. Hence, the harvesting time is a very important factor determining the quality of the starter culture and has to be detected during the ongoing fermentation as well as predicted at an early stage of the process in order to prepare the downstream process in time.

To detect the harvesting time for the starter culture a Kalman filtering technique was used. Since the optimal harvesting

time is assumed to be at the inflection point of base added to the medium in order to keep the pH constant, an extended Kalman filter has been designed to estimate the second derivative of the added base. The zero crossing of the estimate finally gives the time of the inflection point of the curve and thus the harvesting time for the starter culture. To predict the optimal harvesting time at an early stage of the process an adaptive model-based approach has been developed using a dynamic model of the batch fermentation process in combination with a static pH model serving as the measurement model. Using the appropriate starting conditions, the bacterial activity and thus the harvesting time for the starter culture can be predicted by simulating the dynamic process model.

The dynamic process model consists of a set of coupled ordinary differential equations, where the biomass, the concentration of the substrate lactose, and the concentration of the product lactate serve as state variables. The static pH model has been developed for a model-based calculation of the pH value applying the calculated lactate concentration resulting from the dynamic process model as input. Due to the sensitivity of the biotechnological process, the starting conditions of the fermentation process have to be adapted to the real process exploiting on-line measurements of the pH in the first stage of the fermentation process where the pH value decreases until a predefined set point is reached and the controller is adding base to the medium in order to keep the pH constant. Fitting the calculated pH curve to the on-line measurements by nonlinear regression the appropriate starting conditions in the actual fermentation process, i.e. the concentration of the bacteria at startup can be determined. The predicted harvesting time for the starter culture finally results from simulation of the adapted dynamic process model.

### **Control of thermal and fluid-dynamical systems**

Thermal and fluid-dynamical systems comprise a large class of challenging control problems. Examples include heat-up of metal slabs in reheating furnaces or the prevention of flow separation in aeroelastic structures. In this, the distributed-parameter nature of the system dynamics has to be taken into account explicitly for the control and observer design. Since typically complex geometries arise methods of approximation and model order reduction techniques have to be integrated for the explicit evaluation.

The research activities of this department address heat-up processes in smart forming tools, where heating cartridges are embedded into the tool to realize a desired temperature distribution in selected parts of it. For this, a flatness-based design technique has been developed that makes use of the spectral properties of the corresponding system operator. This enables the systematic design of an open-loop controller to achieve finite time transitions between stationary temperature profiles within the forming tool. Extensions to tracking control using the two-degrees-of-freedom control concept have been considered and analyzed. Besides the simulation results our research is marked by the experimental validation of the control concept.

Research in fluid-dynamical systems focuses on motion planning, i.e. the determination of an open-loop control to achieve a desired prescribed flow velocity profile. Based on the Stokes equations for this a flatness-based design technique has been developed that enables the control problem to be solved systematically. Simulation results confirm both the applicability and the control performance. An example is depicted in Fig. 2, where the evolution of the controlled velocity is shown for the transition from a zero profile to a desired steady state profile.

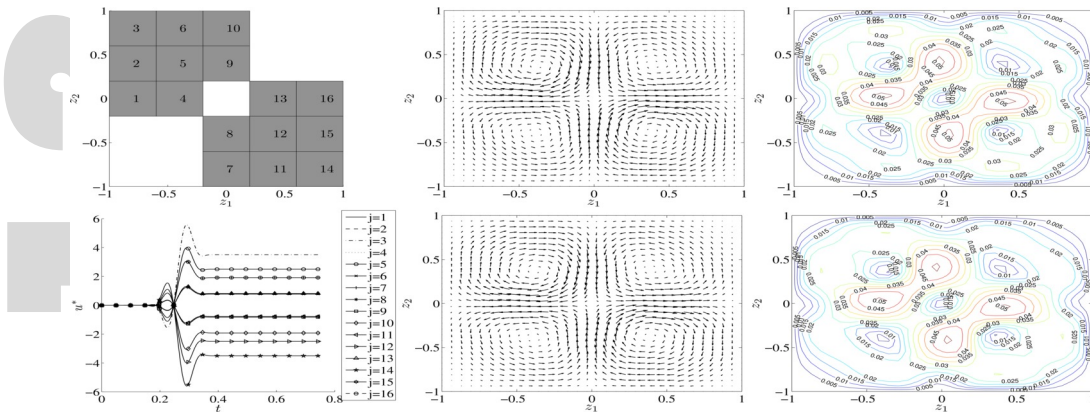


Fig. 2: Simulation results for flatness-based feedforward control: actuator location (top, left), feedforward controls (bottom, left), desired velocity field and velocity contour for flatness-based state parametrization (top, middle and right), and respective simulation result (bottom, middle and right).

## Personnel

Head of the group: Prof. Dr.-Ing. T. Meurer; Secretary: S. Marquardt-Hansen (50%)

Technical Staff: Dipl.-Ing (FH) B. Doneit, Dipl.-Ing (FH) M. Lieb (50%)

Scientific Staff:

Dipl.-Ing. A. Kater	15.03.-31.12.2013	CAU
Smart adaptive structures		
Dipl.-Ing. F. Koschmieder	01.01.-14.03.2013	CAU
Coriolis Mass Flow Measurement		
Dipl.-Wirtsch.-Ing. E. Peter	01.01.-31.12.2013	CAU
Process Control in the Dairy Industry		

## Lectures, Seminars, and Laboratory Course Offers

Winter 2012/2013

Regelungstechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,

T. Meurer (+ F. Koschmieder, E. Peter)

Summer 2013

Projekt Brain Controlled Robotics, 3 hrs Projekt/Week,

T. Meurer (+ A. Kater)

Bachelorpraktikum, 4 hrs Practical/Week,

T. Meurer (+ E. Peter, A. Kater)

Regelung nichtlinearer Systeme, 3 (+ 1) hrs Lecture (+ Exercises)/Week,

T. Meurer

Regelung verteilt parametrischer Systeme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

T. Meurer

Ausgewählte Kapitel der Regelungstechnik, 2 hrs Seminar/Week,  
T. Meurer (+ E. Peter, A. Kater)

Winter 2013/2014

Regelungstechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
T. Meurer (+ A. Kater, E. Peter)

Projekt Brain Controlled Robotics, 3 hrs Projekt/Week,  
T. Meurer (+ A. Kater)

Masterpraktikum Regelungstechnik, 4 hrs Practical/Week,  
T. Meurer (+ E. Peter, A. Kater)

Optimization and Optimal Control, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
T. Meurer (+ A. Kater)

Ausgewählte Kapitel der Regelungstechnik, 2 hrs Seminar/Week,  
T. Meurer (+ E. Peter, A. Kater)

## Diploma, Bachelor's and Master's Theses

- H. Reitz, *Measures for optimal sea motion adaption of a ship autopilot*, 04.06.2013  
H. Lammers, *Modelling of heating and cooling systems for batch-reactors*, 17.10.2013  
S. Heidkamp, *Intuitive control of cybernetics of a mobile manipulator using a data glove*, 31.10.2013  
G. Kenmoe, *Mathematical modelling of an electromagnetic trigger system using Matlab/Simulink*, 12.12.2013

## Publications

Published in 2013

- B. Schörkhuber, T. Meurer, A. Jüngel, *Flatness of semilinear parabolic PDEs - a generalized Cauchy-Kowalevski approach*, IEEE Transactions on Automatic Control, **58(9)**, 2277 - 2291 (2013)  
T. Meurer, *On the extended Luenberger observer for semilinear distributed-parameter systems*, IEEE Transactions on Automatic Control, **58(7)**, 1732 - 1743 (2013)  
J. Schröck, T. Meurer, A. Kugi, *Motion Planning for Piezo-Actuated Flexible Structures: Modelling, Design, and Experiment*, IEEE Transactions on Control Systems Technology, **21(3)**, 807 - 819 (2013)  
J. Schmidt, T. Meurer, *Semi-numerical trajectory planning for coupled systems of linear diffusion-convection-reaction equations*, 1st IFAC Workshop on Control of Systems Modelled by Partial Differential Equations (CPDE), Paris (F), 31 - 36 (2013)  
L. Jadachowski, T. Meurer, A. Kugi, *State Estimation for Parabolic PDEs with Reactive-Convective Non-Linearities*, European Control Conference (ECC), Zürich (CH), 1603 - 1608 (2013)  
T. Böhm, R. Struck, T. Meurer, M. Dagen, *Model-based temperature control of a deep drawing tool*, Conference of the Int. Deep-Drawing Research Group (IDDRG), Zürich (CH), 41 - 46 (2013)

## Presentations

- T. Meurer, *Motion planning and tracking control for PDE systems*, Lothar-Collatz-Kolloquium für Angewandte Mathematik, Universität, Hamburg, Germany, 11.-11.04.2013  
J. Schmidt, T. Meurer, *Semi-numerical trajectory planning for coupled systems of linear diffusion-convection-reaction equations*, 1st IFAC Workshop on Control of Systems Modelled by Partial Differential Equations (CPDE), Paris, France, 25.-27.09.2013

L. Jadachowski, T. Meurer, A. Kugi, *State Estimation for Parabolic PDEs with Reactive-Convective Non-Linearities*, European Control Conference (ECC), Zürich, Schweiz, 17.-19.07.2013

T. Böhm, R. Struck, T. Meurer, M. Dagen, *Model-based temperature control of a deep drawing tool*, Conference of the Int. Deep-Drawing Research Group (IDDRG), Zürich, Schweiz, 02.-06.06.2013

## Further Activities and Events

**Prof. Meurer** serves as Chair of the IFAC Technical Committee 2.6 Distributed Parameter Systems.

**Prof. Meurer** was International Programme Committee Chair of the 1st IFAC Workshop on Control of Systems Modelled by Partial Differential Equations (CPDE2013), Sep. 25-27, 2013, Paris.

**Prof. Meurer** serves as Associate Editor for the Conference Editorial Board of the IEEE Control Systems Society.

**Prof. Meurer** serves as Associate Editor for the IFAC Journal Control Engineering Practice.



# Communications

The research activities of this group are as follows: optical communications (measurement, prototyping, and simulation of high speed data communication systems, equalization of optical transmission channels, optical modulation formats, optical line coding, WDM networks), simulation and modelling of communication systems (development and application of modular simulation tool on system level), and synchronization in communication systems (clock and carrier synchronization, PLL-applications, deep space laser communication systems).

## Results

### First Field Trial of OFDMA-PON at Telekom T-Labs in Berlin

For the next generation optical access networks (NGOA), high data rates and flexible resource allocation will be the key requirements. To realize higher data rates, passive optical networks (PON) are a likely candidate to replace the currently installed copper based access networks. In the project ATOB, funded by the BMBF, orthogonal frequency-division multiple access (OFDMA) was investigated due to the flexible user allocation. After demonstrating the feasibility of the system in the optical laboratory at the University of Kiel, a field trial together with the Deutsche Telekom AG and the Technical University of Munich was conducted in Berlin, necessitating the relocation of a large amount of our lab equipment to Berlin. The field trial included 37.5 km of field deployed optical fibre going from Berlin-Schöneberg to Berlin-Wannsee.

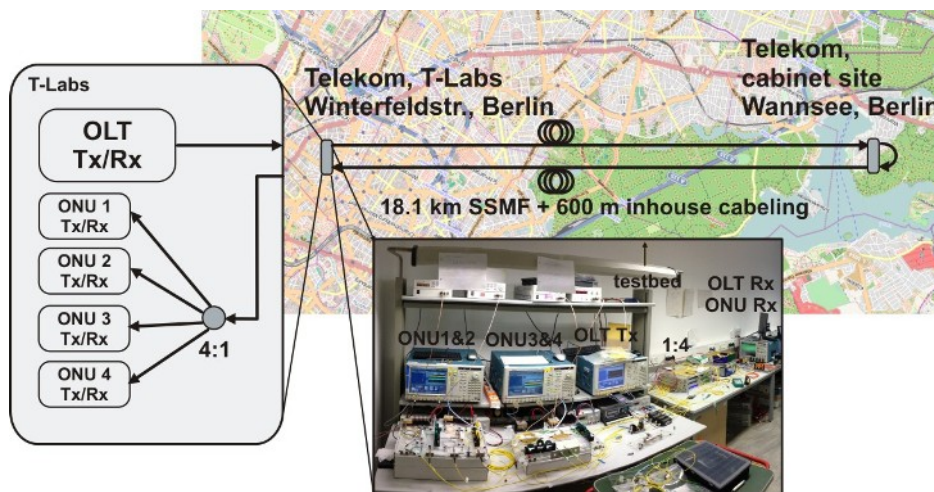


Fig. 1: Field Trial Setup in the ATOB Testbed in Berlin

In Berlin we were able to demonstrate a realistic OFDMA-PON in both upstream and downstream direction over a field deployed feeder fibre of 37.5 km and supporting 32 ONUs. A total net data rate of 20 Gbit/s and an aggregated net data rate of 6.5 Gbit/s was achieved in the downstream and upstream directions respectively. This is considered as the first field trial of an OFDMA-PON with a dynamic allocation of the subcarriers without frequency gap.

### Multidimensional Constellations

Bandwidth resources are running low in optical transport networks. Therefore, flexible bandwidth allocation according to availability and requirements, such as transmission reach, is becoming important and is considered as a key enabler for future transmission systems. Bandpass transmission systems like mobile or optical communications offer two degrees of freedom for signal transmission, namely the in-phase and the quadrature component that modulate the two orthogonal components of a carrier wave respectively. Two-dimensional modulation formats like quadrature amplitude modulation (QAM) appear as well-established technology to exploit these two degrees of freedom. Depending on the number  $n$  of bits

mapped to each symbol in the two-dimensional plane,  $M=2n$ -ary QAM formats (e.g. 4-QAM, 8-QAM, 16-QAM etc.) are available. Unfortunately, the performance penalty that occurs when the modulation order  $M$  is doubled is fairly high. As a consequence, the trade-off between spectral efficiency (quantified for example by  $n$ ) and system performance may be optimized only in a very rough way. If non-integer values for the number of bits per symbol would be allowed, a better basis for optimization would exist. Rational values for the number of bits per symbol are possible if a certain number of bits is mapped to a group of symbols. Consequently, the number of dimensions of such a group of symbols is larger than two. Fig. 2 (right) shows a group of symbols with three dimensions. Within each dimension, a real-valued four-level symbol may be transmitted resulting in  $4^3=64$  different groups of symbols. Mapping five bits to this space results in  $5/3=1.667$  bits per symbol. From this constellation, a six-dimensional 16-QAM constellation may be constructed that transmits  $10/3=3.333$  bits per complex symbol. This constellation has been shown to perform better than other approaches currently under investigation in the optical communications community. The results will be published in a journal paper in spring 2014.

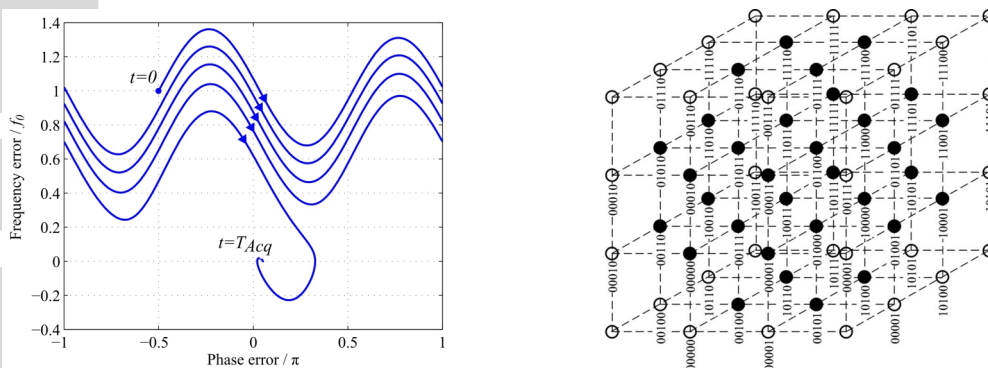


Fig. 2: The nonlinear characteristic of the OPLL (left); Three-dimensional 64-ary group of symbols (right)

## Optical phase-locked-loop

The Chair for Communication focuses on optical high speed data transmission, which is the basis of internet traffic systems. A main part of these complex transmission systems is the receiver, which should be robust against signal impairments. Furthermore it has to have a high signal sensitivity to detect very small signal levels, as is the case, for example, in optical satellite communication systems with transmission distances of several thousand kilometres. To meet the demand for high data rates, coherent detection systems are needed which allow full signal information recovery, i.e. phase and amplitude. However, the coherent receiver is much more complex than a simple photodiode in direct detection systems. Usually a complex synchronization scheme is required to extract the carrier phase and frequency information of the received signal; this scheme should allow signal tracking and acquisition adaptively. Typical concepts solving these problems are the phase-locked-loop (PLL) and the Costas loop; the latter is an extension of the PLL and in addition allows data demodulation. The optical implementation (OPLL) consists of a  $90^\circ$ -Hybrid, which is necessary to separate the in-phase and quadrature part of the incoming signal, a loop filter to influence the PLLs dynamic characteristic and a tuneable laser as local oscillator (LO). The Costas loop is a nonlinear control loop which produces an error signal, containing information about the phase and frequency difference between the received and the LO-signal. During acquisition these errors ideally become smaller: nonlinear because of the sinusoidal phase detector. The OPLLs typical nonlinear behaviour is shown in Fig. 2 (left). A frequency offset  $f_0$  and a phase error of  $\pi/2$  is initialized for  $t=0$ . After acquisition ( $t=T_{Acq}$ ) both errors are nearly equal to zero. The next step would be the data demodulation (e.g. BPSK), which can be obtained directly from the in-phase branch in the loop.

## Recirculating loop for optical long-haul experiments

Optical networks are for the most part built out of links whose maximum length may be a couple of hundreds of kilometres. However, there are certain scenarios where this length may extend to more than a thousand kilometres, i.e. submarine



optical fibre communications. When new technologies for these scenarios are studied, the experimental signals have to transmit over the same distance to get reasonable results. However, it is quite expensive to have several thousand kilometres of optical fibre and tens of optical amplifiers available for system testing. A solution is to use the available resources (ca. 365 km optical fibres and less than ten optical amplifiers) more efficiently. Therefore, a loop structure has been built to allow a signal to travel through the available optical path as many times as required according to the desired total length of the link. Such a loop is possible by means of switches that open and close at the right times to keep the signal circulating for the specified number of round trips. The loop consists of 4 fibre spans (3 X 88 km and one 100 km), 4 erbium-doped optical fibre amplifiers (EDFA), 2 band-pass filters, a polarization scrambler and a controlling board with optical switches. In practice, a short period of the optical signal from the transmitter (Tx) passes the first switch. Some portion reaches the receiver (Rx), while the rest enters the fibre loop. After a further short period the first switch blocks the signal from the Tx and the second switch allows the signal from the loop to recirculate. After each roundtrip some portion reaches the receiver. The longer the signal is circulating in the loop, the larger is the equivalent distance. By triggering the receiver at the right time, any desired transmission distance can be achieved. The polarization of the optical signal is changed randomly by the polarization scrambler every loop iteration to average potential polarization dependent effects of the relative short fibre path over the whole transmission. The overall system, including proper timing of the optical switches, output power of the EDFAs, parameters for the polarization scrambler and triggering of the receiver is meant to be controlled via MATLAB. Hence, functions and scripts have been programed to allow easy control over all electronic loop devices. Construction of the rack began in October 2013 and over the following 2 months, thanks to the workshop of the TF manufacturing components, all the units of the system were put into place. Currently, the control software is being developed in order to produce a functional and adequate control platform. For 2014, it is expected that the whole system and control platform will be operational and long-haul experiments can start.

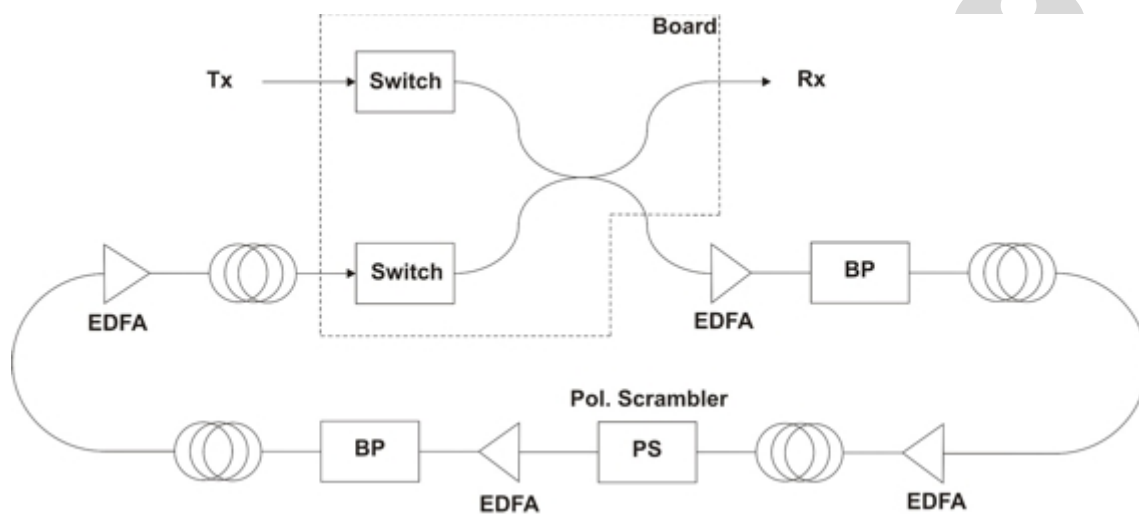


Fig. 3: Block diagram of the recirculating loop

## Personnel

Head of the group: Prof. Dr. Werner Rosenkranz; Secretary: Petra Usinger  
Technical Staff: Dipl.-Ing. (FH) Sandra Robien

Scientific Staff:

Dr.-Ing. Abdulmir Ali

01.01.-30.04.2013

CAU

Orthogonale Frequenzmultiplextechnik (OFDM)

Dipl.-Ing. Dennis Clausen	01.01.-31.12.2013	BMBF
SASER - Signalverarbeitung für sichere Übertragung		
Dr.-Ing. Jochen Leibrich	01.01.-31.12.2013	CAU
Modulationsformate und Simulationswerkzeuge		
M.Sc. Roi Rath	01.01.-31.12.2013	Industry/CAU
SASER - Signalverarbeitung für sichere Übertragung		
Dipl.-Ing. Christian Ruprecht	01.01.-31.12.2013	BMBF
OFDM-Konzepte für das optische Zugangsnetz		
M.Sc. Semjon Schaefer	01.01.-31.12.2013	BMBF
Optical Satellite Communications		
Dipl.-Ing. Johannes von Hoyningen-Huene	01.01.-31.12.2013	Industry
Optical Communication		

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

Nachrichtenübertragung II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
W. Rosenkranz (+ J. von Hoyningen-Huene)

High-speed Communication Networks, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
W. Rosenkranz (+ C. Ruprecht)

Numerische Simulation analoger und digitaler Nachrichtensysteme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
J. Leibrich (+ S. Schaefer)

Projekt, 3 hrs Projekt/Week,  
W. Rosenkranz und Mitarbeiter

Communications Lab, 4 hrs Lab/Week,  
W. Rosenkranz und Mitarbeiter

Seminar Nachrichtentechnik, 3 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Seminar über Bachelor- und Masterarbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informationstechnik, 2 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Digital Communications, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
W. Rosenkranz (+ A. Ali)

Advanced Topics Lab, 6 hrs Lab/Week,  
W. Rosenkranz und Mitarbeiter

### *Summer 2013*

Nachrichtenübertragung, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
W. Rosenkranz (+ J. von Hoyningen-Huene)

Optical Communications, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
W. Rosenkranz (+ J. Leibrich)

Projekt, 3 hrs Projekt/Week,  
W. Rosenkranz und Mitarbeiter

Bachelorpraktikum Nachrichten- und Informationstechnik, 4 hrs Lab/Week,  
W. Rosenkranz und Mitarbeiter

Seminar Nachrichtentechnik, 2 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Seminar über ausgewählte Kapitel der Nachrichtentechnik, 3 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Seminar über Studien- und Diplomarbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informationstechnik, 2 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

### *Winter 2013/2014*

Nachrichtenübertragung II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
W. Rosenkranz (+ J. von Hoyningen-Huene)

High-speed Communication Networks, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
W. Rosenkranz (+ C. Ruprecht)

Numerische Simulation analoger und digitaler Nachrichtensysteme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
J. Leibrich (+ S. Schaefer)

Projekt, 3 hrs Projekt/Week,  
W. Rosenkranz und Mitarbeiter

Communications Lab, 4 hrs Lab/Week,  
W. Rosenkranz und Mitarbeiter

Seminar Nachrichtentechnik, 3 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Seminar über Bachelor- und Masterarbeiten der Nachrichtentechnik, 2 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Anleitung zum wissenschaftlichen Arbeiten für Studierende der Elektrotechnik und Informationstechnik, 2 hrs Seminar/Week,  
W. Rosenkranz und Mitarbeiter

Digital Communications, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
W. Rosenkranz (+ R. Rath)

Advanced Topics Lab, 6 hrs Lab/Week,  
W. Rosenkranz und Mitarbeiter



### **Third-Party Funds**

BMBF, *OFDM-Konzepte für das optische Zugangsnetz*, 01.01.-31.12.2013 (72.200)

BMBF, *Signalverarbeitung für sichere Übertragung*, 01.01.-31.12.2013 (84.000)

Industry, -, 01.01.-31.12.2013 (92.200)



## Further Cooperation, Consulting, and Technology Transfer

The chair is member of the contact group which annually arranges the workshop **Optical Communications**:

- TU Munich (Prof. N. Hanik),
- "Research Centre COM", TU Copenhagen (Prof. P. Jeppesen),
- FhG Heinrich Hertz Institut, Berlin,
- Deutsche Telekom T-Systems, Berlin, Darmstadt.

## Diploma, Bachelor's and Master's Theses

- Zaid Hatem Dhannoon, *Investigation of Optical and Electrical Phase Conjugation for Joint Compensation of Fibre Impairments*, 31.01.2013
- Fahd Babelli, *Synchronization Schemes for Optical OFDMA Access Networks*, 15.02.2013
- Fabian Weißenborn, *Untersuchungen zur verzerrungsfreien PAPR-Reduktion für optische Übertragung mit OFDM*, 19.02.2013
- Guido Schroer, *Nichtlineare Entzerrung bei Störungen in der optischen nachrichtenübertragung mit direkt moduliertem Laser und Direktdetektion*, 15.04.2013
- Benjamin Marquardt, *Untersuchung LED-basierter optischer drahtloser OFDM-Übertragung*, 22.07.2013
- Sumit Kuma Jha, *Clustering Based Equalization for Compensation of Transmission Impairments in a Fibre-Optic System*, 17.12.2013

## Dissertations / Postdoctoral Lecture Qualifications

- Annika Dochhan, *Evaluierung und Optimierung ausgewählter Modulationsverfahren mit Direktempfang für optische Netze bis 100 Gb/s*, 14.06.2013

## Publications

Published in 2013

- J. Xu, J. von Hoyningen-Huene, C. Ruprecht, R. Rath, W. Rosenkranz, *Robust Transmission of 29-Gb/s OFDM Signal Over 1-km OM1 MMF Under Centre Launching*, *Photonics Technology Letters*, **Vol. 25, Issue 2**, 206 - 209 (2013)
- S. Adhikari, S. Jansen, M. Kuschnerov, O. Gaete, B. Inan, M. Bohn, W. Rosenkranz, *Analysis of Spectral Shaping on DFT-OFDM*, *Photonics Technology Letters, IEEE*, **Vol. 25, Issue 3**, 287 - 290 (2013)
- J. von Hoyningen-Huene, H. Griebner, M. Eiselt, W. Rosenkranz, *Experimental Demonstration of OFDMA-PON Uplink-Transmission with Four Individual ONUs*, *OFC, OTh3A.2*, (2013)
- J. Xu, C. Ruprecht, J. von Hoyningen-Huene, W. Rosenkranz, *Transmission of 25.5-Gb/s OFDM Signal over 200-m G62.5/125 MMF Using Mode Group Diversity Multiplexing*, *OFC, OTh4A.2*, (2013)
- J. von Hoyningen-Huene, W. Rosenkranz, *Passive Optical Networks based on OFDM: Perspectives and Experimental Verifications*, *ICTON, Tu.D3.4*, (2013)
- Y. Chen, C. Ruprecht, W. Rosenkranz, N. Hanik, *Fibre Nonlinearity Compensation for Dispersion Unmanaged PDM 8-QAM CO-OFDM using Expectation Maximization*, *OptoElectronics and Communications Conference (OECC/PS)*, **WR4-7**, (2013)
- J. von Hoyningen-Huene, H. Griebner, M. Eiselt, W. Rosenkranz, *Asynchronous Signal Reception in OFDMA-PON-Uplink*, *SPPCom, SPM4D.2*, (2013)

- J. von Hoyningen-Huene, R. Ryf, P. Winzer, *LCoS-based mode shaper for few-mode fibre*, Opt. Express, **21**, 18097 - 18110 (2013)
- R. Rath, W. Rosenkranz, *Tomlinson-Harashima Precoding for Fibre-Optic Communication Systems*, ECOC, **We.2.C.2**, (2013)
- C. Kottke, J. von Hoyningen-Huene, M. Eiselt, H. Griebel, J.P. Elbers, K. Habel, W. Rosenkranz, *Coherent SCM-WDM-PON System using OFDM or Single Carrier with SSB Modulation and Wavelength Reuse*, ECOC, (2013)
- C. Ruprecht, K. Habel, J. von Hoyningen-Huene, Y. Chen, N. Hanik, W. Rosenkranz, *Timing Advance Tracking for Coherent OFDMA-PON Upstream System*, ACP, **AF1G.4**, (2013)

## Presentations

- W. Rosenkranz, *New Challenges for Communications Engineers in Advanced Optical Networking*, International Conference on Systems, Communication, and Coding (SCC), München, Germany, 21.-24.01.2013
- S. Schaefer, J. von Hoyningen-Huene, W. Rosenkranz, *Experimentelle Untersuchung der OFDM-Übertragung mit direkt moduliertem Laser für das Zugangsnetz*, Workshop der ITG Fachgruppe 5.3.1, Optische Kommunikationssysteme - offline to realtime, Stuttgart, Germany, 14.-15.02.2013
- J. von Hoyningen-Huene, H. Griebel, M. Eiselt, W. Rosenkranz, *Experimental Demonstration of OFDMA-PON Uplink-Transmission with Four Individual ONUs*, OFC, Anaheim, CA, USA, 18.-21.03.2013
- J. Xu, C. Ruprecht, J. von Hoyningen-Huene, W. Rosenkranz, *Transmission of 25.5-Gb/s OFDM Signal over 200-m G62.5/125 MMF Using Mode Group Diversity Multiplexing*, OFC, Anaheim, CA, USA, 18.-21.03.2013
- R. Rath, C. Schmidt, W. Rosenkranz, *Is Tomlinson-Harashima Precoding Suitable for Fibre-Optic Communication Systems?*, 14. ITG Fachtagung Photonische Netze, Leipzig, Germany, 06.-07.05.2013
- A. Ali, J. Leibrich, W. Rosenkranz, *Carrier-Interferometry-OFDM for Nonlinear Tolerance Improvement in Optical Systems with Direct Detection*, 14. ITG Fachtagung Photonische Netze, Leipzig, Germany, 06.-07.05.2013
- J. von Hoyningen-Huene, W. Rosenkranz, *Passive Optical Networks based on OFDM: Perspectives and Experimental Verifications*, ICTON, Cartagena, Spain, 23.-27.06.2013
- Y. Chen, C. Ruprecht, W. Rosenkranz, N. Hanik, *Fibre Nonlinearity Compensation for Dispersion Unmanaged PDM 8-QAM Co-OFDM using Expectation Maximization*, OptoElectronics and Communications Conference (OECC/PS), Kyoto, Japan, 01.-04.07.2013
- J. v. Hoyningen-Huene, H. Griebel, M. Eiselt, W. Rosenkranz, *Asynchronous Signal Reception in OFDMA-PON-Uplink*, SPPCom, Rio Grande, Puerto Rico, 14.-17.07.2013
- R. Rath, W. Rosenkranz, *Tomlinson-Harashima Precoding for Fibre-Optic Communication Systems*, ECOC, London, United Kingdom, 22.-26.09.2013
- C. Kottke, J. von Hoyningen-Huene, M. Eiselt, H. Griebel, J.P. Elbers, K. Habel, W. Rosenkranz, *Coherent SCM-WDM-PON System using OFDM or Single Carrier with SSB Modulation and Wavelength Reuse*, ECOC, London, United Kingdom, 22.-26.09.2013
- C. Ruprecht, K. Habel, J. von Hoyningen-Huene, Y. Chen, N. Hanik, W. Rosenkranz, *Timing Advance Tracking for Coherent OFDMA-PON Upstream System*, ACP, Peking, China, 12.-15.11.2013

## Further Activities and Events

Mitgliedschaft von Prof. Rosenkranz in folgenden Gremien:

- \* Fachausschuss 5.1 der ITG im VDE: "Signal- und Systemtheorie"
- \* Fachausschuss 5.3 der ITG im VDE: "Optische Nachrichtentechnik"
- \* Fachgruppe 5.3.1 der ITG im VDE: "Simulation und Modellierung in der optischen Nachrichtentechnik"
- \* Normungsausschuss 412.2 "Komponenten für Kommunikationskabelanlagen" der DKE

Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE

Prof. Rosenkranz ist Mitglied im Programmkomitee folgender internationaler Konferenzen:

- \* *“ European Conference on Optical Communications (ECOC) ”*
- \* *“ IEEE International Conference on Transparent Optical Networks (ICTON) ”*
- \* *“ Asia Communications and Photonics Conference and Exhibition (ACP) ”*
- \* *“ International Conference on Computers, Communications and Power (ICCCP) ”*
- \* Chair of the Photonic Detection Technical Group of OSA (Optical Society of America) **Awards**

Das Drittmittelprojekt 100GET wurde von Eureka Celtic-Plus als “Candidate for the Innovation Award 2013” nominiert.

Prof. Rosenkranz was awarded “Fellow of the OSA” for sustained contributions to the field of optical communications for more than 20 years, most recently in equalization and compensation of impairments in fibre optic systems.

# Computational Electromagnetics

The activities in the Computational Electromagnetics Group include the analytical and numerical treatment of electromagnetic fields and corresponding applications towards the solution of relevant technical problems. Research in these areas focuses on the development of methods to analytically and numerically calculate electromagnetic fields (e.g. multipole analysis, finite-difference methods, finite-element methods, integral-equation methods). These methods are then applied to improve existing codes (such as Finite-Difference Time-Domain (FDTD) algorithms) and to investigate and solve problems in the area of Electromagnetic Compatibility (EMC), among others. Furthermore, the research comprises fundamental investigations regarding electromagnetic fields (e.g. uniqueness theory and its application to inverse problems, scattering by canonical objects). Finally, new multipole-based approaches are being investigated to solve biomagnetic problems with the aim to improve corresponding medical applications such as magnetoencephalography (MEG) and magnetocardiography (MCG). On the educational side the group offers courses in electromagnetic theory, computational electromagnetics, mathematical methods in field theory, electromagnetic compatibility, fields and waves in biological systems, and tomographic methods in medicine.

## Results

### a) Time-domain near-field to near-field transformation

Multipole analysis is a classical technique to analytically describe electromagnetic, acoustic, and elastic fields and waves using series expansions. It is an orthogonal decomposition of the field into the dipole, quadrupole, octopole, etc. fields with respect to a chosen origin. Historically, such methods have been successfully employed to solve several classical boundary value problems in the frequency domain. Applications of spherical-multipole analysis include the diffraction by a perfectly conducting or dielectric sphere (Mie solution) and diffraction by a perfectly conducting cone. The current project uses the extraordinary features of multipole analysis to evaluate and post-process near-fields obtained by numerical schemes. Within the FDTD-method, a near-field to near-field or a near-field to far-field transformation utilizes an equivalence principle: the sources of the field are replaced by electrical and magnetical dipoles suitably distributed on a surface completely enclosing all radiating sources. Conventionally, for each far-field point of interest a numerical integration over this whole surface used to be required. As has been shown for the frequency-domain and later for the time-domain, the new approach avoids that problem. In addition, the analytical multipole expansions of the near- and far-fields allow for a systematic post-processing as well as an enhancement of the numerically obtained results using the spatial frequency filter provided by this technique.

### b) Numerical and analytical examination of shielding and shielding effectiveness

Shielding is one of the most important steps to ensure the electromagnetic compatibility of devices and systems. Shape and position of the shielding structures depend on its desired mechanical features and on the frequency range of the anticipated disturbances. Quantitative measures of a shield's capability to reduce the influence of electric and magnetic disturbances at low frequencies are the electric and magnetic shielding effectiveness. However, these measures are not applicable for high frequency disturbances or pulsed (transient) disturbances. Consequently, this research project concentrates on the evaluation of definitions of the shielding effectiveness for these cases. We are particularly interested in the case when the source of interference is located in the near-field as compared to the case when it is in the far-field.

### c) Statistical EMC

Statistical EMC is an important part of statistical electromagnetics because many parameters in EMC (frequencies, amplitudes, waveforms, geometry) are known only by means of their statistical parameters. Such statistically varying parameters might be given in terms of the first few statistical moments of their distributions. The special direction of this research is the combination with a spherical-multipole expansion of the electromagnetic field where the spherical-multipole amplitudes are described through their statistical moments. This leads to a very compact and non-redundant description of

the field statistics applicable for instance, to investigate the statistical moments of the shielding effectiveness as a function of those of the geometrical parameters of the shielding structure. Particularly, the method is useful in the case of small variations in these parameters.

#### d) Complex rays and multipole analysis

Geometric optics is used to handle scattering of fields by electrically large objects, i.e. structures of dimensions much larger than the wavelength. At geometric singularities such as edges or tips, geometric optics fails and diffraction must be taken into account. This leads to diffraction coefficients which can be shown to dominate the field outside the directions of reflection. Usually, these diffraction coefficients are calculated from solutions for canonical structures. As an example the edge diffraction coefficient has been derived from the series expansion of the field diffracted by a wedge. The associated special case of a half-plane has been solved by Sommerfeld.

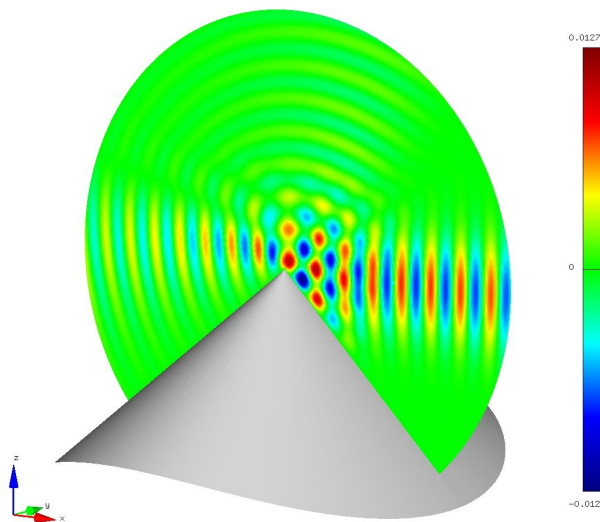


Fig. 1: Snapshot of the acoustic field for a complex-source beam impinging an acoustically soft semi-infinite circular cone.

In this DFG-sponsored research project we have determined diffraction coefficients for the elliptic cone. This structure is most interesting particularly because it includes a very general tip. Moreover, by appropriately choosing the ellipticity parameters the elliptic cone includes the circular cone as well as the plane angular sector and the corresponding tip geometries as special cases. The associated diffraction coefficients are obtained by a numerical evaluation of the corresponding spherical-multipole expansion in sphero-conal coordinates. The commonly observed convergence problems in case of plane-wave incidence are avoided by choosing a complex-source beam as the incident field. Possible applications include a more precise consideration of the fields scattered by aircraft and airport constructions to improve instrument landing systems.

#### e) Multipole-based reconstruction methods for the biomagnetic problem

The project is part of the Collaborative Research Centre (SFB) 855 on "Magnetoelectric Composites - Future Biomagnetic Interfaces" founded by the Deutsche Forschungsgemeinschaft (DFG). It focuses on new strategies for the measurement of biomagnetic fields (from the brain and heart) on optimized surfaces and new algorithms for the solution of the corresponding inverse problem.

#### f) Modelling and localization of cardiomagnetic sources

The project is part of the Collaborative Research Centre (SFB) 855 on "Magnetoelectric Composites - Future Biomagnetic



Interfaces" founded by the Deutsche Forschungsgemeinschaft (DFG). The goal of this project is to model physiological and pathological currents in the heart by means of a minimal number of unknowns.

## **Personnel**

Head of the group: Prof. Dr.-Ing. L. Klinkenbusch; Secretary: S. Thielbörger (50%)

Technical Staff: Dipl.-Ing. J. Buschmann (50%)

Scientific Staff:

Dipl.-Phys. H. Ahrens	01.01.-31.12.2013	DFG
SFB855 - D1: Multipole-based reconstruction schemes		
Dipl.-Phys. F. Argin	01.01.-31.12.2013	DFG
SFB855 - D1: Multipole-based reconstruction schemes		
M.Sc. H. Brüns	01.11.-31.12.2013	DFG
Scattering by semi-infinite structures		
Dipl.-Phys. K. Körber	01.01.-31.12.2013	CAU
Statistical EMC		

## **Lectures, Seminars, and Laboratory Course Offers**

*Winter 2012/2013*

Elektromagnetische Felder 2, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Klinkenbusch (+ K. Körber)

Numerische Feldberechnung, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Klinkenbusch (+ K. Körber)

Intensivübung Elektromagnetische Felder, 1 hrs Exercise/Week,  
L. Klinkenbusch (+ F. Argin, K. Körber, H. Ahrens)

Projekt, 3 hrs Lecture/Week,  
L. Klinkenbusch (+ K. Körber)

Tomographische Verfahren in der Medizin, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Klinkenbusch (+ F. Argin)

Seminar Medizintechnik, 2 hrs Seminar/Week,  
L. Klinkenbusch

Masterpraktikum Mikrowellentechnik und EMV, 4 hrs Practical/Week,  
L. Klinkenbusch (+ H. Brüns)

*Summer 2013*

Elektromagnetische Felder 1, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Klinkenbusch (+ H. Ahrens)

Elektromagnetische Verträglichkeit, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Klinkenbusch (+ H. Brüns)

Seminar Feldtheorie, 1 hrs Seminar/Week,  
L. Klinkenbusch



Mathematische Methoden in der Feldtheorie, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

L. Klinkenbusch (+ H. Brüns)

Projekt, 3 hrs Exercise/Week,

L. Klinkenbusch (+ K. Körber)

Felder und Wellen in biologischen Systemen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

L. Klinkenbusch (+ F. Argin)

*Winter 2013/2014*

Elektromagnetische Felder 2, 3 (+ 1) hrs Lecture (+ Exercises)/Week,

L. Klinkenbusch (+ K. Körber)

Numerische Feldberechnung, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

L. Klinkenbusch (+ H. Brüns)

Intensivübung Elektromagnetische Felder, 1 hrs Exercise/Week,

L. Klinkenbusch (+ F. Argin, K. Körber, H. Ahrens)

Projekt, 3 hrs Lecture/Week,

L. Klinkenbusch (+ K. Körber)

Tomographische Verfahren in der Medizin, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

L. Klinkenbusch (+ H. Ahrens)

## Third-Party Funds

DFG, *Semi-infinite Strukturen*, 01.01.-31.12.2013 (1/1 E13 + 1 WiMi + Sachmittel)

DFG, *SFB 855 TP D1*, 01.01.-31.12.2012 (2 E13 + Sachmittel)

## Further Cooperation, Consulting, and Technology Transfer

1. Prof. Dr. H. Chaloupka, Bergische Universität Wuppertal: Subject: multimode antennas.

2. Prof. Dr. R. Sikora, Westpomeranian University Szczecin (Poland): Subject: non-destruction evaluation & ERASMUS partnership.

3. Prof. Dr. E. Cardelli, University Perugia (Italy): Subject: ERASMUS partnership.

4. Prof. Dr. E. Heyman, Tel-Aviv University (Israel): Subject: complex-source beams and multipole expansions

5. Prof. L. Pichon, University Paris-Sud (XV), Paris (France): Subject: EMC of complex systems, ERASMUS partnership

6. Prof. G. Manara, University of Pisa (Italy): Subject: ray methods & ERASMUS partnership

7. Prof. Dr. K.-J. Langenberg, Kassel University: Subject: multipole expansions of elastic waves

## Diploma, Bachelor's and Master's Theses

Thomas Eichhorn, *Multipolbasierte Quellmodellierung einer simulierten Hirnaktivität anhand eines einfachen Kopfmodells*, 28.03.2013

Michael Grischian, *Vergleich zwischen direkt und induktiv eingekoppelten Strömen für medizinische Schrittmachersysteme*, 03.06.2013

Timo Patelczyk, *Analyse und Kompensation von Integrationseffekten in automotiven Antennensystemen*, 28.03.2013

Alwin Reinhardt, *Streuung eines beliebigen Complex-Source Beams am seminifiniten Kreiskegel*, 30.11.2013

Sergej Sudheimer, *Numerische Berechnung der Einflüsse von Störstellen in Kabelbäumen im Zeitschrittverfahren*, 23.07.2013

Larissa Welsch, *Theoretische Untersuchung verschiedener Spulen für die transkranielle Magnetstimulation (TMS)*, 30.04.2013

## Publications

Published in 2013

- M. Kijowski, L. Klinkenbusch, *Exact and Physical-Optics Analysis of the Electromagnetic Scattering by an Elliptic Cone*, COMPEL, **32**, 868 - 884 (2013)
- K. Körber, L. Klinkenbusch, *Statistical Multipole Expansion and its Application to an Arbitrary Shielding Geometry with Small Variations*, Proc. 2013 IEEE International Symposium on Electromagnetic Compatibility, 38 - 42 (2013)
- F. Argin, H. Ahrens, L. Klinkenbusch, *Design of an Optimized Biomagnetic Measurement Surface by a Spherical-Multipole Approach (invited)*, Proc. 2013 URSI International Symposium on Electromagnetic Theory, 362 - 364 (2013)
- L. Klinkenbusch, K.-J. Langenberg, *Spherical-Multipole Analysis of Elastodynamic Wave Fields (invited)*, Proc. 2013 International Conference on Electromagnetics in Advanced Application, 62 - 65 (2013)
- L. Klinkenbusch, *Time-Domain Spherical-Multipole Analysis of the Poynting Vector of Radiated Electromagnetic Fields (invited)*, Proc. 2013 European Microwave Conference (EuMC2013), 247 - 250 (2013)
- H. Brüns, L. Klinkenbusch, M. Katsav, E. Heyman, *Electromagnetic Complex-Source Beam Diffraction by the Tip of a Circular Cone (invited)*, Proc. 2013 International Conference on Electromagnetics in Advance Applications, 1083 - 1086 (2013)
- M. Katsav, E. Heyman, L. Klinkenbusch, *Complex-Source Beam Diffraction by a Wedge: Exact and Complex Rays Solutions (invited)*, Proc. 2013 International Symposium on Electromagnetic Theory, 915 - 918 (2013)
- H. Brüns, L. Klinkenbusch, *Electromagnetic Diffraction and Scattering of a Complex-Source Beam by a Semi-Infinite Circular Cone*, Advances in Radio Science, **11**, 31 - 36 (2013)
- H. Ahrens, F. Argin, L. Klinkenbusch, *Comparison of the Extended Kalman Filter and the Unscented Kalman Filter for Magnetocardiography Activation Time Imaging*, Advances in Radio Science, **11**, 341 - 346 (2013)

## Presentations

- K. Körber, L. Klinkenbusch, *Statistical Multipole Expansion and its Application to an Arbitrary Shielding Geometry with Small Variations*, 2013 IEEE Int. Symp. on Electromagnetic Compatibility, Denver, USA, 05.-09.08.2013
- F. Argin, H. Ahrens, L. Klinkenbusch, *Design of an Optimized Biomagnetic Measurement Surface by a Spherical-Multipole Approach (invited)*, 2013 URSI International Symposium on Electromagnetic Theory, Hiroshima, Japan, 20.-24.05.2013
- L. Klinkenbusch, K.-J. Langenberg, *Spherical-Multipole Analysis of Elastodynamic Wave Fields (invited)*, 2013 International Conference on Electromagnetics in Advanced Applications, Turin, Italy, 09.-13.09.2013
- L. Klinkenbusch, *Time-Domain Spherical-Multipole Analysis of the Poynting Vector of Radiated Electromagnetic Fields (invited)*, 2013 European Microwave Conference, Nuremberg, Germany, 06.-11.10.2013
- H. Brüns, L. Klinkenbusch, M. Katsav, E. Heyman, *Electromagnetic Complex-Source Beam Diffraction by the Tip of a Circular Cone (invited)*, 2013 International Conference on Electromagnetics in Advance Applications, Turin, Italy, 09.-13.09.2013
- M. Katsav, E. Heyman, L. Klinkenbusch, *Complex-Source Beam Diffraction by a Wedge: Exact and Complex Rays Solutions (invited)*, 2013 URSI International Symposium on Electromagnetic Theory, Hiroshima, Japan, 20.-24.05.2013
- H. Ahrens, L. Klinkenbusch, *Kalman Filter Based Solutions of a Nonlinear State- Space Model for Magnetocardiography Activation Time Imaging on a 3D Anisotropic Muscle Fibre Heart Model*, Kleinheubacher Tagung, Miltenberg, Germany, 23.-25.09.2013

H. Brüns, L. Klinkenbusch, *Acoustic Scattering of a Complex-Source Beam by the Corner of a Plane Angular Sector*, Kleinheubacher Tagung, Miltenberg, Germany, 23.-25.09.2013

L. Klinkenbusch, *Multipolentwicklungen und Complex-Source Beams*, URSI Kommission B Workshop, Poel, Germany, 20.-21.03.2013

## Further Activities and Events

Since 2009 Prof. Klinkenbusch has been a Committee member of the German Academic Exchange Service (Deutscher Akademischer Austauschdienst - DAAD) for the region Near-East/ North Africa. Since July 2012, he has been acting as Vice Dean of the Faculty of Engineering. He also has been the representative of the Faculty of Engineering in the Schleswig-Holsteinische Universitätsgesellschaft.

Prof. Klinkenbusch is a member of VDE, and an elected member of URSI Commission B, and a Fellow of IEEE. He serves in the IEEE Antennas and Propagation Education Committee. In 2012 he was elected as a member of the URSI Commission B Technical Advisory Board (B-TAB). In 2012, he was a Technical Reviewer, Chairman, and Organizer of Special Sessions for several international scientific journals and conferences.

# Digital Signal Processing and System Theory

In 2013 the group “Digital Signal Processing and System Theory” (abbreviated in the following as DSS), comprised two professors, Prof. Dr. Ing. Gerhard Schmidt (head) and Prof. Dr.-Ing. Ulrich Heute, a secretary, and a technician (both also working for the Information & Coding Theory group), two external lecturers, about 20 PhD students (internal and external), as well as several co-workers on a short-term job basis. As in the last year we focussed on two major research topics, namely, **speech and audio processing** and **medical signal processing**:

- The investigation of speech communication in automotive environments (e.g. hands-free or in-car communication systems) was continued in 2013, and both of our cars (a saloon and a convertible) were equipped with even more sensors and actuators as well as real-time signal processing capabilities, in order to verify our theoretical approaches in real automotive environments. Also the investigation of automatic evaluation schemes for in-car communication continued successfully, and we started a fruitful cooperation with the linguistics department of Kiel University (Prof. Niebuhr and colleagues). The evaluation of text-to-speech (TTS) systems was finalized successfully and Christoph Norrenbrock submitted his dissertation at the end of this year (defence will be in January). In addition, research on the (real-time) simulation of acoustic environments continued and a complete recording-and-playback system including calibration was finalized in 2013.
- We continued our cooperation with the Neurology and the Neuropaediatrics departments of the University Clinics Kiel with great success. In particular, we worked on automatic source analysis in the human brain with the groups of Prof. Deuschl and Prof. Stephani, within the large cooperative project SFB 855. Also Alina Santillán Guzmán finished her research on artifact suppression of EEG and MEG signals. She successfully defended her thesis in December. Now Jens Reermann has started to work on that subject. He began to improve the magneto-electric sensors concerning external distortions. Furthermore, research on our real-time brain-computer interface was continued and our first system is ready now (until now, only artifact-based, but it constitutes a starting point).

Besides our work in the two main focus areas, we continued our cooperation with the Federal-Navy Research Institute for Under-Water Acoustics and Geophysics (FWG) with two interesting research projects: marine mammal detection, and tracking of underwater objects. The large BMWi-funded project “PITAS” was successfully finished at the end of 2013. The project concerns detection and classification of pirate or terrorist attacks against ships; apart from DSS and three other groups of TF, it involved also teams from four industrial companies in Schleswig-Holstein.

Also in 2013, we were very happy that our external lecturers, Dr.-Ing. M. Krini (from Paragon in Delbrück) and Dr.-Ing. M. Muthuraman (from the Neurology Department of Kiel University), continued with their lectures. Dr.-Ing. M. Krini teaches neural networks, and Dr.-Ing. M. Muthuraman teaches medical signal processing with special emphasis on frequency-domain approaches.

## Results

On-going work led to numerous publications and presentations.

Prof. Schmidt co-organized the 6th Biennial Workshop on Digital Signal Processing for In-Vehicle Systems in September 2013. The workshop took place in Seoul, at Korea University. The workshop presented a unique opportunity for researchers working on different branches of in-vehicle signal processing to exchange and discuss cutting edge results. It also formed a communication platform between researchers, automotive manufacturers, and legislators for road safety on future in-vehicle technologies. The workshop featured world-class experts on:

- road safety, and

- in-vehicle technologies, as well as
- demonstrations of state-of-the-art systems.

In the various fields of DSS, of course, the co-workers presented their results also:

- **Speech quality:** As mentioned, this is still an item of DSS research within a continuous and extremely fruitful cooperation with "T-Labs" at TU Berlin, especially the group of Prof. Dr.-Ing. Sebastian Möller. Christoph Norrenbrock presented results at a quality workshop in Vienna. Furthermore, he was a co-author of two papers with our partners in Berlin, presented at Interspeech'13 in Lyon and at an international conference in Barcelona, Spain. As mentioned above, the project was finished successfully in December 2013, and we are looking forward to the thesis defence of Christoph Norrenbrock.
- **Real-time audio processing:** Meanwhile seven PhD students are using our real-time framework called "KiRAT" in their research projects. This tool is a soft- and hardware combination and the abbreviation "KiRAT" stands for Kiel Real-Time Audio Toolkit. It is used now for speech and audio research, in some of our SONAR projects, and for medical research.

In summer 2013 the DSS audio lab reached its second (of three) expansion stages. We have now a portable ambiance simulation system; it is also possible now to do 3D-auralizations of brain signals in our lab. Our in-car systems also were tested under "very hard conditions". Fig. 1 shows us during our driving training with one of our cars.



Fig. 1: Testing our real-time systems under "controlled extreme conditions".

- **Medical signal processing:** Noise and artifact reduction in EEGs, and in the future MEGs, are the central topics of the DSS part of the above mentioned SFB-855, to be carried out by Alina Santillán Guzmán. She presented the state of her work at an SFB seminar in Sankelmark in February 2013, as well as at an international conference in



Innsbruck, Austria. Her co-author A. Galka presented their collaborative results at an international conference in Osaka, Japan, and Prof. Schmidt showed common results at EUSIPCO'13 in Marrakesh, Morocco.

The same kinds of signals are also analyzed by Abdul Rauf Anwar, M.Sc., cooperating closely with our lecturer Dr.-Ing. M. Muthuraman who has been a member of the Neurology group of Kiel's University Clinics since 2010. The aim is to find a deeper understanding of tremor diseases, and especially the mis-led information flow in the brain. Kidist Gebremariam Mideksa, M.Sc., also works with these signals, aiming for a comparison between, and possibly, a combination of EEG and MEG information. The results of both scientists led to three conference publications, presented at Osaka, Japan, three co-authored national and international conference contributions, and four co-authored journal papers.

Research on brain computer interfaces continued in 2013. Jens Reermann started his thesis on this topic and continued our emphasis to help patients in the "REHA Haus Buchholz" (a nursing home specializing in patients with brain lesions) in simplifying their everyday life. Our portable EEG systems are now fully connected (see Fig. 2) and we have now the first brain interfaces ready that can be controlled via small movements (e.g. eye blinking). In addition, these interfaces can be used to detect absences of epileptic patients and determine if they are able to respond during an absence. This work was carried out in cooperation with our colleagues from the Neuropaediatrics department (Prof. Stephani) of the medical faculty of Kiel University.

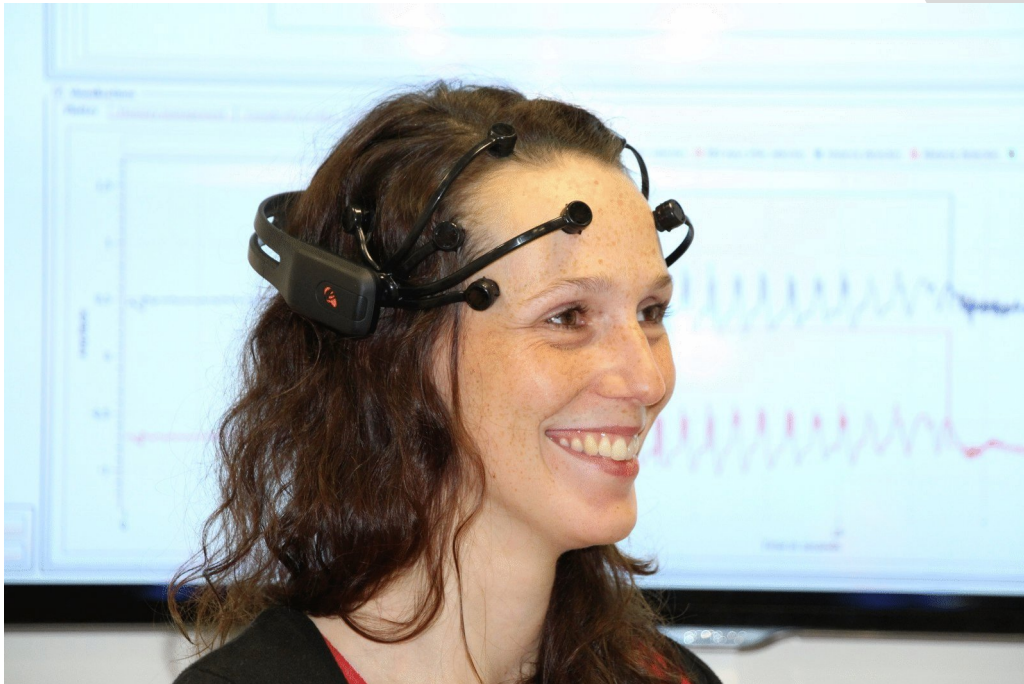


Fig. 2: Janika Puls wearing one of our EEG headsets with the KiRAT analysis window in the background.

- **SONAR signal processing:** Viet Duc Nguyen and Tim Claussen worked with PITAS, and their contributions concerned object tracking and sensor fusion as well as real-time beamforming. Viet Duc Nguyen also acted as the project coordinator as far as the TF parts of PITAS are concerned. The state of his and Tim Claussen's work is documented in various PITAS reports and in a conference contribution in Istanbul.

Kolja Pikora worked on detection and tracking of underwater objects, in particular on improving automatic tracking with sensor data fusion techniques and adaptive beamforming. The results have been presented at the International Conference on Information Fusion, Istanbul 2013, within a special session on multi-static tracking.

- **Marine-mammal detection and classification:** In close cooperation with FWG, a huge database was created and sorted by Roman Kreimeyer. The results of his classification approaches were published at various workshops of the international PoMM project (Protection of Marine Mammals), at an ITG workshop in Darmstadt, and at an international conference in Budapest, Hungary.
- **Real-time speech and audio processing:** This topic is the largest one in the DSS team. Currently five internal and five external PhD students are focusing on this topic. Jochen Withopf and also Sebastian Rohde are investigating so-called in-car communication systems that improve the communication between the passengers of a vehicle. Anne Theiß continued to investigate automatic evaluation procedures for in-car communication systems. Christian Lüke does research on acoustic environment simulation, allowing for reliable and reproducible testing of speech and audio equipment in virtual environments that are very close to reality. Vasudev Kandade Rajan investigates multi-channel speech-enhancement systems for automotive applications and teleconference systems. For the latter type of systems, we have now equipped some of our rooms with a multitude of compact microphone arrays, loudspeakers, cameras, and screens. The focus here is on the complexity-optimized processing (and transmission) of multi-channel HD audio streams.

In addition to that, we started a close cooperation with the linguistic research group (headed by Prof. Oliver Niebuhr) of our university. Within this cooperation, we had three common thesis projects in 2013 in which we created several new data bases that can be used for the analysis of the so-called Lombard effect. Fig. 3 shows the people involved from the technical and the philosophical faculty.



Fig. 3: The "Lombard" team (Rabea Landgraf, Tina John, Oliver Niebuhr, Anne Theiß, Christian Peters, Gerhard Schmidt [left to right]).

## Personnel

Head of the group: Prof. Dr.-Ing G. Schmidt; Secretary: S. Schuchardt (50%)

Technical Staff: Dipl.-Ing. T. Rabsch (50%)

Staff:

Prof. Dr.-Ing. U. Heute

01.01.-31.12.2013

PhD supervisor



Dr.-Ing. M. Krini	01.01.-31.12.2013	Lecturer
Dr.-Ing. M. Muthuraman	01.09.-31.12.2013	Lecturer
Scientific Staff:		
M. Sc. A. R. Anwar Brain Information Flow	01.01.-31.12.2013	DAAD / PhD student
M. Sc. H. Bakkari Automotive Signal Processing	01.10.-31.12.2013	External PhD student
Dipl.-Ing. M. Christoph Audio Signal Processing	01.01.-31.10.2013	External PhD student
Dipl.-Wirtsch.-Ing. T. Claussen Sonar-System Realization	01.01.-31.12.2013	PITAS / PhD student
Dipl.-Ing. S. Graf Robust Voice Activity Detection	01.01.-31.12.2013	External PhD student
M.Sc. M. Haide Environmental Signal Processing	01.01.-31.12.2013	External PhD student
M.Sc. P. Hannon Model-Based Speech Enhancement	01.01.-31.12.2013	External PhD student
M.Sc. V. Kandade Rajan Automotive Speech Enhancement	01.01.-31.12.2013	Industry / PhD student
Dipl.-Ing. R. Kreimeyer Marine-Mammal Protection	01.01.-30.11.2012	FWG / PhD student
Dipl.-Phys. C. Lüke Adaptive Ambiance Simulation	01.01.-31.12.2013	CAU / PhD student
M.Sc. Kidist G. Mideksa EEG and MEG Combination	01.01.-31.12.2013	SFB and SH Fell. / PhD st.
Dipl.-Wirtsch.-Ing. D. Nguyen Sensor Fusion and Tracking	01.01.-31.12.2013	PITAS / PhD student
Dipl.-Ing. C. Norrenbrock TTS Speech Quality	01.01.-31.12.2013	DFG / PhD student
M.Eng. K. Pikora Tracking of Underwater Objects	01.01.-31.12.2013	FWG / PhD student
M.Sc. J. Reermann MEG Signal Processing	01.11.-31.12.2013	DFG SFB / PhD student
Dipl.-Wirtsch.-Ing. S. Rohde Automotive Signal Enhancement	01.01.-31.12.2013	Industry / PhD student
M.Sc. A. Santillán Guzmán EEG and MEG Signal Enhancement	01.01.-31.12.2013	DFG SFB / PhD student

M.Sc. S. Senkbeil In-Car Communication	15.11.-31.12.2013	Industry / PhD student
M.Sc. S. Stenzel Multi-Channel Speech Enhancement	01.01.-31.12.2013	External PhD student
M.Sc. A. TheiB Automatic Evaluation of Automotive Speech Enhancement Systems	01.01.-31.12.2013	CAU / PhD student
Dipl.-Ing. J. Withopf In-Car Communication	01.01.-31.12.2013	CAU / PhD student
M.Sc. A. Wolf In-Car Communication	01.01.-31.12.2013	External PhD student

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

Advanced Digital Signal Processing, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ V. Kandade Rajan, S. Rohde)

Advanced Signals and Systems, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ A. TheiB)

Speech and Audio Processing - Recognition and Audio Effects, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ C. Lüke)

Signals and Systems II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ J. Withopf)

Communications Lab, 3 hrs Lab/Week,  
G. Schmidt (+ together with several members of the faculty)

Medical Signal Processing, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Muthuraman

Advanced Topics Lab, 3 hrs Lab/Week,  
G. Schmidt (+ together with several members of the faculty)

### *Summer 2013*

Speech and Audio Processing - Adaptive Filters, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ C. Lüke)

Digital Signal Processing, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ S. Rohde)

Signals and Systems I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ J. Withopf)

Neural Networks, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Krini

System Theory Lab, 3 hrs Lab/Week,  
G. Schmidt (+ A. TheiB)

Seminar on Topics in Digital and Optical Communications, 3 hrs Seminar/Week,  
G. Schmidt (+ together with several members of the faculty)

Real-Time Processing Lab, 3 hrs Lab/Week,  
G. Schmidt (+ C. Lüke)

*Winter 2013/2014*

Advanced Digital Signal Processing, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ V. Kandade Rajan, S. Rohde)

Advanced Signals and Systems, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ A. Theiß)

Speech and Audio Processing - Recognition and Audio Effects, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ C. Lüke)

Signals and Systems II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
G. Schmidt (+ J. Withopf)

Communications Lab, 3 hrs Lab/Week,  
G. Schmidt (+ together with several members of the faculty)

Medical Signal Processing, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Muthuraman

Advanced Topics Lab, 3 hrs Lab/Week,  
G. Schmidt (+ together with several members of the faculty)

### Third-Party Funds

Industry, *Research on the topics described before*, 01.01.-31.12.2013 (Adequate payment)  
Bundesamt für Wehrtechnik und Beschaffung (BMV), *New Concepts for Sonar Detection, Classification, and Tracking*,  
01.01.-31.12.2013 (Adequate payment)  
Bundesamt für Wehrtechnik und Beschaffung (BMV), *Detection and Classification of Marine Mammals by means of  
Speaker-Recognition Methods*, 01.01.-31.12.2012 (75 000 EUR)  
DFG, *Synthetic Speech-Signal Quality Measurement*, 01.01.-31.08.2013 (45 000 EUR)  
DFG / SFB-855, *Digital Signal Processing for New MEG Sensors*, 01.01.-31.12.2013 (68 000 EUR)  
BMW, *PITAS*, 01.01.-31.12.2013 (120 000 EUR)  
DAAD, *Brain Source Analysis*, 01.01.-31.12.2013 (18 000 EUR)  
Grad. Fellowship SH, *EEG and MEG Combination*, 01.01.-31.12.2013 (15 000 EUR)

### Diploma, Bachelor's and Master's Theses

Frederik Duchâteau, *Parametrierung der geräuschabhängigen Verstärkungssteuerung eines  
Fahrzeuginnenraumkommunikationssystems*, 31.03.2013  
Oliver Mittag, *Digitale Simulation von Gitarrenverstärkern*, 30.04.2013  
Grant Davtjan, *Identifizierung und Unterdrückung von Artefakten in EEG-Signalen in Echtzeit*, 30.06.2013  
Janika Puls, *Automatische Verifizierung von kognitiven Beeinträchtigungen während epileptischer Aktivität*,  
30.06.2013  
Merikan Koyun, *Complexity Management in a Real-Time, Ultra-Wideband, Multi-Channel Audio Conferencing System*,  
31.07.2013  
Julian Andrej, *Entwicklung und Analyse eines Echtzeit-Trackingsystems*, 31.07.2013

- Lukas Goßmann, *Entwicklung einer autonomen Echtzeit-Spracherzeugung unter Berücksichtigung des Lombard-Effekts*, 31.07.2013
- Simon Ohlendorf, *Entwicklung einer skalierbaren Sprachaktivitätsdetektion*, 30.09.2013
- Wiebke Schmidt, *Geräuschreduktion in EEG- und MEG-Signalen*, 30.09.2013
- Stephan Senkbeil, *Merkmalsextraktion und Mustererkennung für automatische Spracherkennung*, 31.10.2013
- Michael Brodersen, *Echtzeit-Signalverbesserung in Atemschutzmasken*, 30.11.2013
- Celina Schneider, *Evaluation von Sprachverbesserungsalgorithmen*, 30.11.2013
- Thi Thu Hi Vu, *System Design and Implementation for Simulating Time Variant Acoustics Channels in Real Time*, 31.12.2013

## Dissertations / Postdoctoral Lecture Qualifications

- Markus Christoph, *Untersuchung verschiedener Verfahren zur messtechnischen Bestimmung und Nachbildung der Akustik insbesondere von Fahrzeugsystemen*, 16.09.2013
- Alina Santillán Guzmán, *Digital Enhancement of EEG/MEG Signals*, 19.12.2013

## Publications

Published in 2013

- V.D. Nguyen, T. Claussen, *Reduced Computational Complexity of Gating Procedures Using Sorting Algorithms*, Proc. International Conference on Information Fusion 2013, Istanbul, Turkey, (2013)
- K. Pikora, F. Ehlers, *Analysis of the FKIE Passive RADAR Data Set with GMPHD and GMCPHD*, Proc. International Conference on Information Fusion 2013, Istanbul, Turkey, (2013)
- S. Ludwig, R. Kreimeyer, *Comparison of PAM Systems for Acoustic Monitoring and Further Risk Mitigation Application*, 3rd. International Conference on the Effects of Noise on Aquatic Life 2013, Budapest Hungary, (2013)
- R. Kreimeyer, S. Ludwig, *Automatic Classification of Marine Mammals with Speaker Classification Methods*, 3rd. International Conference on the Effects of Noise on Aquatic Life 2013, Budapest Hungary, (2013)
- T. John, O. Niebuhr, G. Schmidt, A. TheiB, *Phonetic Analyses vs. Dirty Signals: Fixing the Paradox*, Proc. ESSV 2013, Bielefeld, Germany, (2013)
- A. Santillán Guzmán, U. Heute, U. Stephani, H. Muhle, A. Galka, *Hybrid Filter for Removing Power-supply Artifacts from EEG Signals*, Proc. BioMed 2013, IAESTED, Innsbruck, Austria, (2013)
- A. Santillán Guzmán, U. Heute, M. Muthuraman, U. Stephani, A. Galka, *DBS Artifact Suppression using a Time-frequency Domain Filter*, Proc. EMBC 2013, IEEE-EMBS, Osaka, Japan, (2013)
- A. Santillán Guzmán, M. Fischer, U. Heute, G. Schmidt, *Real-time Empirical Mode Decomposition for EEG Signal Enhancement*, Proc. EUSIPCO 2013, Marrakesh, Morocco, (2013)
- C. Lüke, A. TheiB, G. Schmidt, O. Niebuhr, T. John, *Creation of a Lombard Speech Database using an Acoustic Ambiance Simulation with Loudspeakers*, Proc. 6th Biennial DSP Workshop for In-Vehicle Systems 2013, Seoul, Korea, (2013)
- V. Kandade Rajan, S. Rohde, G. Schmidt, J. Withopf, *Signal Processing for Microphone Arrays on Seat Belts*, Proc. 6th Biennial DSP Workshop for In-Vehicle Systems 2013, Seoul, Korea, (2013)
- F. Hinterleitner, C. Norrenbrock, S. Möller, *Is Intelligibility Still the Main Problem? A Review of Perceptual Quality Dimensions of Synthetic Speech*, Proc. 8th ISCA Speech Synthesis Workshop, Barcelona, Spain, (2013)
- F. Hinterleitner, C. Norrenbrock, S. Möller, U. Heute, *Predicting the Quality of Text-To-Speech Systems from a Large-Scale Feature Set*, Proc. Interspeech 2013, Lyon, France, (2013)
- C. Norrenbrock, F. Hinterleitner, U. Heute, S. Möller, *Quality Estimation Based on Regular Perception*, Proc. Fourth International Workshop on Perceptual Quality of Systems (PQS), Vienna, Austria, (2013)
- K.G. Mideksa, H. Hellriegel, N. Hoogenboom, H. Krause, A. Schnitzler, G. Deuschl, J. Raethjen, U. Heute, M. Muthuraman, *Dipole Source Analysis for Readiness Potential and Field using Simultaneously Measured EEG and MEG Signals*, Proc. EMBC 2013, IEEE-EMBS, Osaka, Japan, (2013)

- K.G. Mideksa, A. Khan, G. Deuschl, U. Heute, M. Muthuraman, *Dipole Source Analysis for Identifying the Location of Deep Brain Stimulation Electrodes in Parkinson's Patients*, Proc. EMBC 2013, JSMBE-EMBS, Osaka, Japan, (2013)
- M. Muthalib, A.R. Anwar, A. Galka, U. Heute, G. Deuschl, *Multimodal integration of fNIRS, fMRI and EEG neuroimaging*, Clin. Neurophysiol., **13**, (2013)
- L. Michels, M. Muthuraman, A.R. Anwar, M. Siniatchkin, *Developmental changes of functional and directed resting-state connectivity associated with neuronal oscillations in EEG*, NeuroImage, **13**, (2013)
- N. Japaridze, M. Muthuraman, A.R. Anwar, G. Deuschl, J. Raethjen, *Neuronal networks in west syndrome as revealed by source analysis and renormalized partial directed coherence*, Brain Topography, **26**, (2013)
- L. Elshoff, M. Muthuraman, A.R. Anwar, G. Deuschl, U. Stephani, *Dynamic imaging of coherent sources reveals different network connectivity underlying the generation and perpetuation of epileptic seizures*, Plos one, **10**, (2013)
- A.R. Anwar, M. Muthalib, A. Galka, G. Deuschl, U. Heute, *Comparison of causality analysis on simultaneously measured fMRI and NIRS signals during motor tasks*, IEEE Int. Conf. EMBC, Osaka, 2628 - 2631 (2013)
- M. Muthuraman, A.R. Anwar, G. Deuschl, J. Raethjen, *Differentiating unipolar and bipolar STN-DBS on Parkinsonian patients using source and directionality analysis*, Proc. Int. Conf. DBS, Düsseldorf, (2013)
- M. Muthuraman, A.R. Anwar, G. Deuschl, J. Raethjen, *Resolving the networks of deep brain stimulation on high resolution EEG*, Proc. Deutscher Parkinson-Kongress, Würzburg, (2013)
- S. Paschen, A.R. Anwar, G. Deuschl, M. Muthuraman, J. Raethjen, *Effective use of microelectrode recording for the implantation of deep brain electrodes into the Nucleus subthalamicus in advanced Parkinson's disease*, Proc. MDS Conf., Sydney, Austr., (2013)

Journal

# almanach 13

# Information and Coding Theory

The **research activities** of the Information and Coding Theory group (ICT) of the University of Kiel are in the general area of baseband signal processing for wireless digital communication and localization. Emphasis is on the design and evaluation of new digital transmission techniques and systems, the evolution of existing wireless standards, and the development of corresponding software algorithms. The proposed transmission/localization techniques are motivated by insights from applied information theory. Among our goals is to serve more users in future radio systems, to increase data rates, and to reduce transmission power and signal bandwidth per data bit.

The main expertise is in the area of channel coding (turbo codes, low-density parity check codes, decoding with reliability information, space-time codes), applied information theory (particularly multi-user information theory), digital modulation schemes (adaptive modulation and channel coding, superposition modulation, orthogonal frequency-division multiplexing), joint communication and localization, and development of modern receiver algorithms (equalization, channel estimation, synchronization, interference rejection). Among the applications are future radio systems, marine applications, in-body communications, and free-space optical transmission.

In 2013, ICT began activities in the area of underwater robotics. The goal is to design and build a swarm of autonomous underwater vehicles (AUVs), serving as a teaching and research platform. Advanced techniques like cooperative communication and cooperative localization are to be implemented and tested on this platform.

Concerning **teaching**, we offer lectures and exercises, mostly in English, on channel coding, information theory, wireless communications and advanced wireless communications with the emphasis on baseband processing. A lecture on time series analysis (with a stress on medical applications) is offered in the form of a teaching assignment. Furthermore, several labs and seminars are provided for our bachelor's and master's students.

## Results

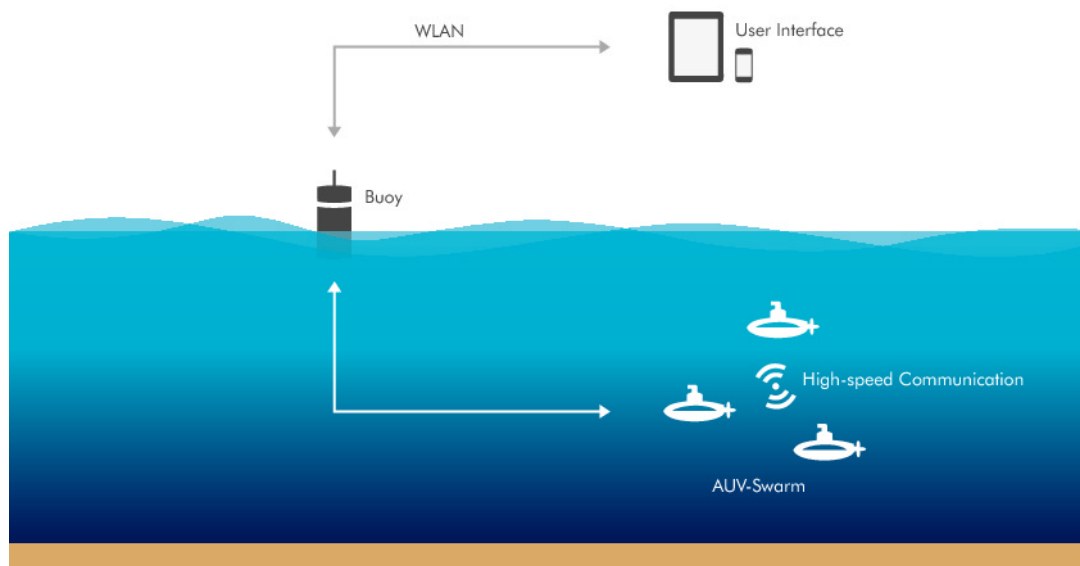


Fig. 1: cSwarm scenario.

**cSwarm: An AUV Education and Research Platform** (Gilbert J.M. Forkel, Meelis Noemm, Christopher Knievel, Rebecca Adam, Torge Rabsch). In this innovative student project, an *Autonomous Underwater Vehicle* (AUV) swarm is currently

being developed and implemented. The AUVs simultaneously serve as an education platform as well as a research platform. The project supports learning by doing, which is an important recipe particularly in engineering.

AUVs are unmanned and characterized by (i) an on-board power supply, (ii) on-board sensors and processing units, and (iii) autonomous navigation skills. In contrast to remotely operated vehicles (ROVs), which are also unmanned, AUVs are not supported by a cable. Hovering AUVs are designed for manoeuvrability, whereas torpedo-like or fish-like shapes are typical hull designs for larger distances.

Among the numerous applications of civil AUVs are oceanographic survey (including seabed mapping and resource exploration), marine sciences (including marine observation), inspection tasks (including pipelines and ship hulls), and environmental monitoring.

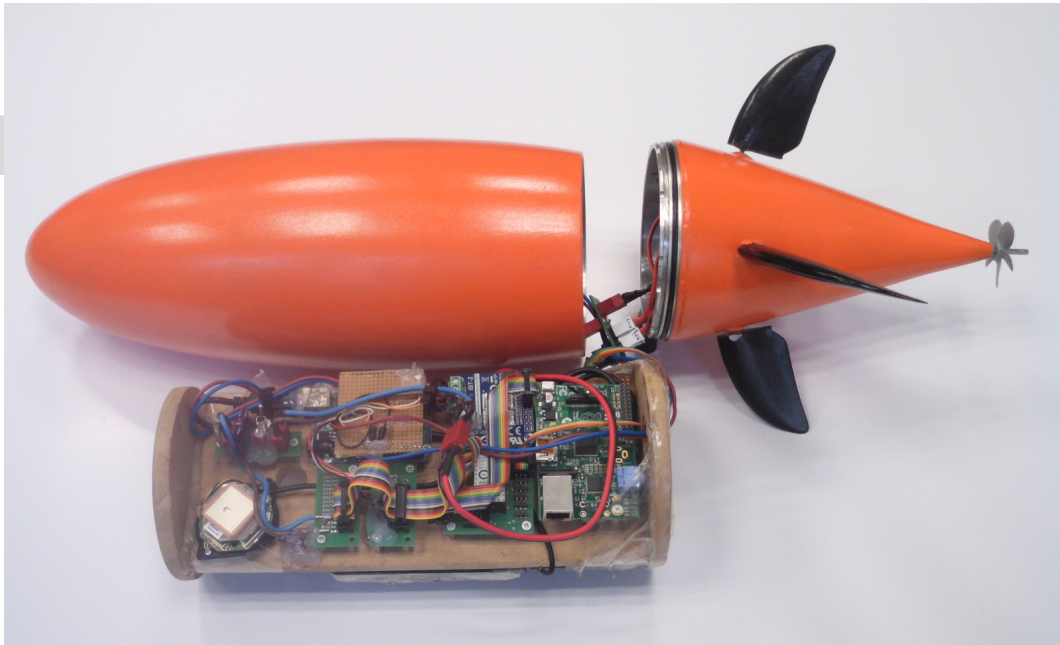


Fig. 2: Prototype AUV design.

When employing a swarm of AUVs, *swarm intelligence* can be exploited. Swarm intelligence is useful for communication purposes, localization, and sophisticated applications. Due to the huge path loss encountered in sonar and radio-wave transmission, high-speed communication is difficult in sea water given a peer-to-peer scenario. Having a swarm of AUVs however, intermediate AUVs may serve as relays. Swarm navigation is capable of enhancing the difficult task of 3D positioning in unknown terrain. Furthermore, many applications can be solved more efficiently if a swarm is available.

As an *education platform*, this interdisciplinary project joins students from different disciplines (particularly electrical engineering, computer sciences, management), with distinct levels (bachelor and master), skills and experience. Soft skills such as creativity, multi-cultural teamworking, problem-oriented working, communication and presentation skills, team-organization and student-based project management are supported. Most students are highly motivated, and develop and implement their own solutions.

As a *research platform*, our long-term theoretical experience in digital communications, applied information theory, signal processing, sonar processing, localization, as well as software-defined radio and cognitive radio can be realized and tested in a harsh environment. Particular emphasis is on exploiting swarm intelligence.

Established in 2013, this project has been sponsored within the pilot phase of the CAU PerLe Fond for innovations in teaching. Organized in 12 groups, 25 bachelor's and master's students performed tasks like hull and thruster design,



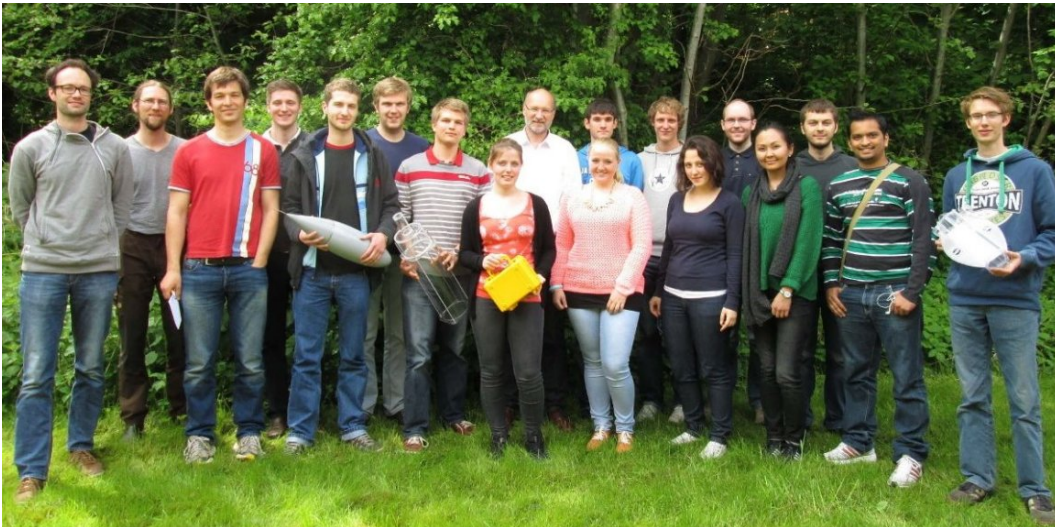


Fig. 3: AUV team in summer 2013.

inertial positioning, sonar ranging, amplifier design, leakage detection, WLAN access, graphical user interface, high-speed data communication, cooperative localization, and last but not least management.

**Ultra-High-Speed Wireless Indoor Communication** (Niklas Doose). Recent developments in industry and consumer electronic products demand reliable communication with very high data rates. Within the DFG Priority Programme SP 1655, data rates of 100 Gb/s and more shall be obtained, which is currently only feasible in wired and optical networks. A variety of advanced techniques are being examined to develop a wireless system that is able to deliver the required rate.

Possible enabling key techniques in the concept are the following: the implementation as a UWB system provides high bandwidth that can be utilised with multiple OFDM systems, and the deployment in a so-called Massive MIMO scenario promises great beamforming gains and the ability to offer an SNR that is needed for high-level modulation schemes. The application of multi-mode antennas gives additional degrees of freedom for beamforming, multiplexing and compactness of transceivers.

While we concentrate on the baseband signal processing, the project is a cooperation with the Wireless Communications group, who develop the multi-mode antennas and work on hardware issues of the system concept.

In an initial step, the suitability of multi-mode antennas for application in MIMO systems has been shown with respect to correlation of the elements and the channel capacity. Further research focuses on deriving system requirements and overall performance estimates.

**Superposition Modulation** (Zhenyu Shi, Meelis Noemm). Superposition modulation (SM) is a novel digital modulation scheme that can be used in high-rate mobile communications. The signal points of SM are derived by linearly superimposing binary antipodal symbols with proper power and phase allocation. Unlike conventional PSK/QAM modulation, the signal points of SM have a quasi-Gaussian distribution.

Power and phase allocation is an important issue for superposition modulation. The constellation diagram and the maximum achievable mutual information are highly influenced by the applied power and phase allocation. Different power and phase allocation schemes were investigated and compared. In the low-to-moderate signal-to-noise region, SM with equal power and uniform phase allocation shows higher potential to achieve the Shannon capacity compared to traditional power and phase allocation schemes.

Besides extensive investigations on power and phase allocation of SM, information theoretical properties of SM have been investigated. By means of an extensive analysis, the pros and cons of SM have been clarified, and also its potential, in the

sense of approaching the capacity of the Gaussian channel, and are now well understood. Theoretical limits for coded as well as uncoded SM systems were derived, which serve as guidelines for practical system design.

The most important result is in finding reasons for the previously known limit on the bandwidth efficiency of coded SM systems. Based on this finding, novel coding schemes have been investigated to further improve the system performance. With sophisticated channel coding employing long codewords, our results are less than 1 dB away from channel capacity even for large bandwidth efficiencies, which currently marks the world record.

**Multi-User Superposition Modulation** (Gilbert J.M. Forkel). High-order modulation schemes are necessary to cope with the increasing bandwidth demands in future communication systems. Superposition modulation is one promising solution, since its quasi-Gaussian shape allows the Shannon capacity bound to be approached. In dense wireless networks interference is the limiting factor on the overall system performance. By using the inherent multi-layer structure of superposition modulation, it has been shown that it will be possible to construct modulation-based multi-user communication systems with close to optimal performance given competitive computational complexity.

**Joint Communication and Navigation** (Rebecca Adam). Joint communication and positioning (JCAP) yields synergetic effects. Nowadays, in the age of quickly evolving smart phones and tablets, JCAP applications become more and more indispensable. They demand a high quality of service, a high throughput, and a high positioning accuracy. Some years ago, ICT proposed a prototype JCAP system approach based on a generic unified signal structure. By evaluating and optimizing the theoretical performance, in 2013 the group has developed design rules in order to find an overall optimal joint communication and positioning system design that is purely based on channel estimation and time-of-arrival based positioning, rather than on a predefined standardized communication signal structure. The framework is built upon the idea that channel estimates (an estimated sampled version of the wireless transmission channel) are doubly exploited for both communication and positioning purposes. Thus, the design is targeting scenarios in which global navigation satellite systems are known to fail without assistance from other systems. Typical scenarios would be urban or indoor environments. Such realistic, and in the case of joint communication and positioning, challenging environments demand special flexible modelling and estimation approaches, since in reality both too sophisticated and too simple modelling will result in an unacceptably bad estimation performance. A trade-off constrained to a certain resolution is sought. Design extensions, like multiple-input multiple output system approaches, influence the overall system performance and therefore have been investigated.

**Resource Allocation in Cognitive Radio** (Abdullah Yaqot). Due to increasing demands for new services and applications given the observation that nowadays the radio spectrum is scarcely used, reusing this partially occupied spectrum intelligently and opportunistically becomes a candidate solution: this is where the cognition concept comes in.

Cognitive radio (CR) is an intelligent communication strategy that adapts according to the surrounding environment. CR has the ability to reconfigure its transmission parameters such as modulation order, spectral allocation, bandwidth, transmission power, etc. through programmable modules based on the software-defined radio principle. However, CR has limitations due to interference, mainly because of the coexisting primary radio. Given a dynamic environment, CR has to offer reliable, seamless, and high-quality services in order to fulfil the requirements and to be able to become a reliable technology for upcoming 5G networks. Motivated by the aforementioned, the optimal resource allocation strategy (integrated with techniques such as multiuser MIMO-OFDM) can meet the required high data rates by means of developing capacity achieving allocation strategies for power and subcarriers as well as precoding designs. The main challenge is the trade-off between efficiency and optimality. Towards this goal, the first promising results have been obtained in 2013.

**Channel Estimation and Interference Cancellation for MIMO-OFDM** (Christopher Knievel). Multi-user multiple-input multiple-output (MIMO) transmission techniques in combination with orthogonal frequency-division multiplexing (OFDM) promise to provide the desired performance of next-generation cellular radio systems. MIMO-OFDM has been selected as a key technology for the IEEE 802.11n wireless local area network (WLAN) standard and for 3GPP Long Term Evolution (LTE), which is the successor of third generation cellular radio systems (such as UMTS). The successor of LTE, called LTE-Advanced

(LTE-A), is expected to close the gap between stationary and mobile communications by supporting high data rates.

Channel estimation, data detection, and interference cancellation are challenging tasks in multi-antenna scenarios. ICT developed a graph-based iterative receiver employing joint data detection and channel estimation, which utilizes correlation in time, frequency, and space in order to improve channel estimation and data detection quality. This graph-based receiver has lower computational complexity, expands the restriction of training symbols, and shows very good performance when compared to iterative as well as non-iterative state-of-the-art algorithms.

Recently, additional effort has been spent on graph-based soft channel estimation and data detection. By means of improving the initialization and by taking into account inherent correlation caused by the message exchange, the algorithm could be significantly improved to support higher-order modulation formats. The improved receiver supports a larger variety of channel codes and even copes with a very small number of training symbols. It has been tested for cellular environments taking co-channel interference into account. Emphasis has been on 3GPP LTE-A as a special application. In 2013, the project was completed; a Ph.D. thesis has been submitted.

**Diver Detection** (Meelis Noemm). Within the BMWi project PITAS, a piracy and terrorism defence system for vessels is being developed. In this framework, ICT proposed an advanced signal design for diver detection that is capable of discriminating between moving objects (like divers) and stationary objects (like the sea bed), while providing an improved range resolution compared to alternatives. In 2013, the project has been completed. A Ph.D. thesis will be completed soon.

**Time Series Analysis** (Andreas Galka). The work of A. Galka deals with the development and application of new tools for the analysis of time series from neuroscience, such as electroencephalograms (EEG) and functional magnetic resonance imaging (fMRI) data sets. In most cases the analysis is based on state-space modelling within a Kalman filtering and maximum-likelihood framework. Tasks such as artifact removal, noise reduction, decomposition into physiological components, source analysis, and estimation of task or stimulus related activations can be approached by this analysis.

**Hybrid Microwave/Free-Space Optical MIMO Transmission** (Mark Gregory). Driven by the demand for extremely high data rates but also secure data transmission and licence-free operation, free-space optical communication has been studied increasingly over the last few years. Broadband sensor performance needs high-speed interfaces for the data; sensitive data needs secure data transmission and a high availability.

To satisfy these demands, a hybrid transmission system has been studied, combining the advantages of radio frequency (RF) and free-space optical (FSO) systems. It has been shown and proven by field measurements that the complementary behaviour of both systems to channel impacts can increase highly the availability, particularly in a maritime environment.

A promising technique that increases the performance of both FSO links and RF links is the multiple-input multiple-output (MIMO) approach. It has been shown that this well-known technique to mitigate fading effects can be applied to the optical domain to decrease the impact of light wave distortion due to propagation in a turbulent medium. The project was completed in 2013; a Ph.D. thesis has been submitted

## Personnel

Head of the group: Prof. Dr.-Ing. P. A. Hoeher; Secretary: S. Schuchardt (50%)

Technical Staff: Dipl.-Ing. T. Rabsch (50%)

Scientific Staff:

Dipl.-Ing. R. Adam	01.04.2009-31.12.2013	DFG
Joint Navigation and Communication		
M.Sc. N. Doose	01.-31.12.2013	DFG
Ultrawideband Communication		

Dipl.-Ing. G. Forkel Cooperative Communication	01.10.2012-31.12.2013	CAU
Dr. rer. nat. A. Galka Time Series Analysis	01.06.2009-31.12.2013	Lecturer
Dipl.-Ing. M. Gregory Free-space Optical MIMO Communications	01.01.2010-31.12.2013	External PhD Student
Dipl.-Ing. Ch. Knievel 3GPP LTE-A	15.03.2009-30.11.2013	CAU
M.Sc. M. Noemm Sonar Signal Design	01.06.2009-31.12.2013	BMW
M.Sc. Z. Shi Superposition Modulation	01.01.2009-30.09.2013	DFG
M.Sc. L. Wolff Sonar Processing	01.-31.12.2013	External PhD Student
M.Sc. A. Yaqot Convex Optimization for Cognitive Radio	01.10.2012-31.12.2013	DAAD
Dipl.-Wirtsch.-Ing. V. Zeiger Underwater Navigation	01.01.2010-31.12.2013	External PhD Student

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Grundlagen der Kanalcodierung, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Information Theory and Coding I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Advanced Wireless Communications (DSP), 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Communications Lab, 4 hrs Practical/Week,  
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Advanced Topics Lab, 4 hrs Practical/Week,  
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Informationstechnik und Codierung, 1 hrs Seminar/Week,  
P.A. Hoeher

### Summer 2013

Theoretische Grundlagen der Informationstechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Information Theory and Coding II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Wireless Communications (DSP), 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Real-time Signal Processing Lab, 4 hrs Practical/Week,  
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Informationstechnik und Codierung, 1 hrs Seminar/Week,  
P.A. Hoeher

Time Series Analysis, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
A. Galka

Bachelor Projekt, 3 hrs Seminar/Week,  
P.A. Hoeher (+ and Research Assistants)

### *Winter 2013/2014*

Grundlagen der Kanalcodierung, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Information Theory and Coding I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Advanced Wireless Communications (DSP), 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
P.A. Hoeher (+ and Research Assistants)

Communications Lab, 4 hrs Practical/Week,  
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Advanced Topics Lab, 4 hrs Practical/Week,  
P.A. Hoeher (+ W. Rosenkranz, G. Schmidt, and Research Assistants)

Informationstechnik und Codierung, 1 hrs Seminar/Week,  
P.A. Hoeher

Bachelor Project, 3 hrs Seminar/Week,  
P.A. Hoeher (+ and Research Assistants)

### **Third-Party Funds**

DFG, *Joint Navigation and Communication based on Interleave-Division Multiple Access (HO 2226/11-1)*,  
15.03.2009-05.01.2014 (1xE13 + Working and Travelling Expenses)

DFG, *Superposition Mapping: Theory and Applications (HO 2226/12-2)*, 01.10.2012-30.09.2013 (1xE13 + Material  
and Travelling Expenses)

BMW, *PITAS (Piracy and Terrorism Defence System for Vessels)*, 01.09.2010-31.12.2013 (1x13 + Material and  
Travelling Expenses)

DFG, *Ultrawideband Communication based on Massive MIMO and Multimode Antennas for Mobile Terminals*,  
01.12.2013-30.11.2016 (1xE13 + Material and Travelling Expenses)

### **Further Cooperation, Consulting, and Technology Transfer**

Besides cooperation with other universities, the Information and Coding Theory Lab has collaborations with numerous companies and research institutes, including:

- DoCoMo Euro Labs, Munich,

- DLR, Oberpfaffenhofen,
- FGH IIS, Erlangen,
- GEOMAR Helmholtz Centre for Ocean Research, Kiel,
- L-3 Communications ELAC Nautik GmbH, Kiel,
- Raytheon Anschütz, Kiel,
- Tesat Spacecom, Backnang.

## Diploma, Bachelor's and Master's Theses

Sonja Steker, *Entwicklung von Methoden zur Evaluierung einer fahrzeugübergreifenden Umfelderkennung*, 02.01.2013

Rico Kelz, *Entwicklung eines Aktiv-Sonar-Simulators basierend auf MATLAB*, 04.02.2013

Lu Cheng, *Design and Implementation of a Generic Attack Detection and Response Mechanism for a Centralized V2X Credential Management*, 13.02.2013

Adham Mostafa, *Load Dependent Coordination of Femtocell Basestations for Energy Efficient Networks*, 06.05.2013

Niklas Doose, *Beamforming und Leistungskontrolle für Multi-Mode Massive MIMO Systeme*, 14.11.2013

## Publications

Published in 2013

P.A. Hoeher, *Grundlagen der digitalen Informationsübertragung: Von der Theorie zu Mobilfunkanwendungen*, Wiesbaden: SpringerVieweg, ISBN 978-3-8348-1784-6, 2nd ed., (2013)

P.A. Hoeher, *Grundlagen der digitalen Informationsübertragung: Von der Theorie zu Mobilfunkanwendungen*, Wiesbaden: SpringerVieweg, eBook, ISBN 978-3-8348-2214-7, (2013)

R. Adam, P.A. Hoeher, *Semi-blind channel estimation for joint communication and positioning*, Proc. Workshop on Positioning, Navigation and Communication (WPNC), Dresden, Germany, (2013)

Z. Shi, P.A. Hoeher, A.A. Saed, *Graph-based bit-wise soft channel estimation for superposition mapping*, Journal of Intelligent Computing, 4, 17 - 22 (2013)

Ch. Knievel, D. Hao, P.A. Hoeher, P. Weitkemper, H. Taoka, *Evaluation and extension of a multi-dimensional graph-based receiver concept for MIMO-OFDM*, Proc. IEEE International Conference on Communications (ICC), Budapest, Hungary, (2013)

M. Noemm, P.A. Hoeher, *CutFM: a novel sonar signal design*, Proc. Future Security Conference 2013, Berlin, Germany, (2013)

R. Martens, D. Manteuffel, P.A. Hoeher, *Ultra wideband communications based on massive MIMO and multi-mode antennas suitable for handheld devices - A project outlook*, Proc. of the 43. European Microwave Conference (EuMW 2013), Nuremberg, Germany, (2013)

## Further Activities and Events

Prof. Dr. Peter Adam Hoeher became an IEEE Fellow "for contributions to decoding and detection that include reliability information". Less than 0.1% of IEEE members are selected annually for this member grade elevation based on a strict selection process.

His textbook "Grundlagen der digitalen Informationsübertragung," Wiesbaden: SpringerVieweg has been published 2013 in its 2nd edition.

Dipl.-Ing. Rebecca Adam returned from a sabbatical at UCLA, Los Angeles. She received a best paper award at the IEEE Workshop on Positioning, Navigation and Communication for a contribution on Joint Communication and Positioning.

The ICT group has received a CAU PerLe Award for innovations in teaching for its Autonomous Underwater Vehicle (AUV) Teaching and Research Platform.

# tf PerLe Award for Innovation

# almanach 13



# Integrated Systems and Photonics

The research activities of the group for Integrated Systems and Photonics (ISP) focus on projects in the areas of nanotechnology, optical technologies, and integrated systems. The research covers the entire spectrum of modelling, design, fabrication, and experimental characterization. As Prof. Dr. Martina Gerken was taking a parental leave of absence, Dr.-Ing. Jost Adam has been heading the group from January until June 2013. Dr. Adam is a postdoctoral fellow with the Photonics Laboratory, University of California, Los Angeles, and an expert in numerical modelling, waveguide theory and high-throughput optical microscopy.

Very exciting for us in 2013 was the start of two new projects: one in basic research and one in the area of technology transfer to industry. In July, research on the ERC Starting Grant project „Photo-switching of smart surfaces for integrated biosensors (PhotoSmart)“ started. Smart surfaces with switchable properties hold great promise for future integrated sensors. Azobenzene molecules have been demonstrated to switch reversibly between the *trans* and *cis* isomer with picosecond time constants, when triggered with an external light source. Due to the different molecular geometries and electronic properties of the isomers, these may be used as molecular switches for realizing smart surfaces. The objective of this research project is to establish methods for integrating photo-switchable smart surfaces into miniaturized sensors. In the first part of the project we will focus on reversible switching of wettability between hydrophilic and hydrophobic. To this end we started by investigating the wettability of nanostructured surfaces and surface functionalization with azobenzene molecules.

In August the EXIST team began their efforts towards commercialization of research results in the area of label-free bioanalytics. The team of two electrical engineers (Dr. Nazirzadeh and Dr. Metz) and one biologist (Dr. Glorius) is being funded by the Federal Ministry for Economic Affairs and Energy (BMWi) in order to form a spin-off company. Currently, the team is building a demonstrator. In 2014 the interdisciplinary team will be complemented by a fourth member from economics. Details on this project are given below.

2013 was a successful research year with many results that are detailed below as well as in our publications. We further intensified our collaborations with other groups in Electrical Engineering and in Material Sciences in Kiel as well as with external partners. Six joint publications (out of a total of 13) in peer-reviewed journals are one visible result of these collaborations. We thank our collaborators for the many discussions and exchange of knowledge.

## Results

### Biosensors employing photonic crystal slabs

The detection of biological materials, e.g. biomarkers or microbial pathogens, is of high importance for human health. We investigate label-free biosensors employing a periodically nanostructured sensor surface (photonic crystal slab). In 2013 we developed a compact, label-free measurement setup using a CMOS camera for detection. A biofunctionalized photonic crystal slab is used as the transducer for optically detecting binding events. Resonances in the optical transmission spectrum of the photonic crystal slab are sensitive to binding events on the surface that cause a change in the refractive index. By aligning the resonance spectral position to the falling edge of a light emitting diode (LED), molecular binding processes result in a reduction of the transmitted light intensity. Imaging detection of the transmitted light with a camera allows for multiple measurements in parallel.

In collaboration with the group of Dr. Buhmann at the university hospital of the LMU in Munich we demonstrated experimentally label-free detection of the protein thrombin. We immobilized thrombin-specific aptamers locally on the surface of the photonic crystal slab. The signal and reference intensities are detected in parallel at different positions. The association, dissociation and regeneration kinetics of 250nM thrombin dissolved in buffer are clearly observed as changes of the intensity.

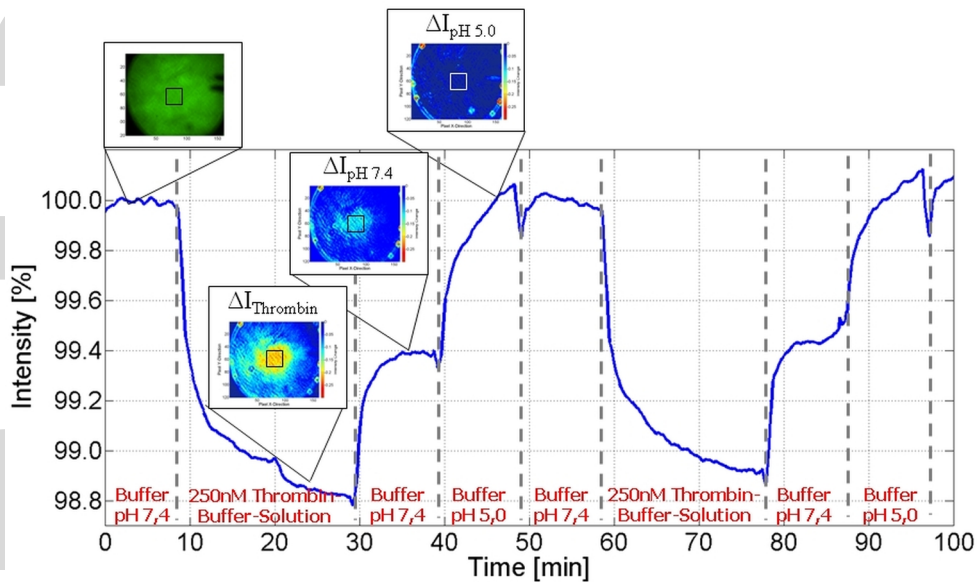


Fig. 1: Association, dissociation, and regeneration kinetics of 250nM thrombin to a bio-functionalized photonic crystal surface measured by evaluation of the filtered transmission intensity on a CMOS camera. In the insets intensity changes are visualized as colour changes revealing the anti-thrombin functionalized central area.

## Lab-on-a-chip

Compact lab-on-a-chip systems employing optical detection schemes require the integration of a light source and a detector close to the sensing volume. In 2013 we realized a system using a photonic crystal slab as the transducer, an organic light-emitting diode (OLED) as the light source, and an organic photo detector (OPD) as the detector. We integrated wet-processed OLEDs and OPDs on a single glass substrate in a lateral set-up at the Kieler Nanolabor. A compact sensor is obtained by realizing a stack structure with the OLED-OPD-substrate, the photonic crystal slab sensor surface, and the sensing volume. The latter is formed by squeezing an o-ring between the photonic crystal slab and a glass lid. Two butterfly cannulas are used for in- and outflow of the liquid.

Any refractive index change in the vicinity of the photonic crystal slab leads to a spectral shift of the characteristic resonances in transmission measurements. Using the falling edge of the OLED, the spectral shift of the resonance is transformed into an intensity decrease, which is measureable at the OPD. To demonstrate the refractive index dependency, we used two different refractive indices: air ( $n = 1$ ) and pure water ( $n = 1.33$ ). As expected, an increase of the refractive index leads to an intensity decrease in the OPD current. From these experiments we could estimate a detection limit of  $\Delta n = 2.32 \cdot 10^{-2}$ . These are promising results and we will investigate protein binding next.

## Integrated optics

Integrated optical systems are interesting for many applications. In 2013 we investigated two types of integrated optical systems: a pressure measurement system, and a thermally tuneable attenuator.

The 5-mm diameter pressure measurement chamber shown in Fig. 2 was realized by assembling a moulded polydimethylsiloxane (PDMS) chamber and membrane, a triangular photonic crystal slab, and a glass lid. By raising the pressure outside the chamber the membrane is deformed towards the inside and comes into contact with the photonic crystal slab. Using remote imaging of the photonic crystal surface, the contact area of the membrane with the photonic crystal slab is measured. For a higher pressure, more of the membrane is pressed against the photonic crystal slab and the dark spot visible in Fig. 2 becomes larger. A further miniaturization of this device is promising as an eye implant for regular measurement of the intraocular pressure to prevent glaucoma.

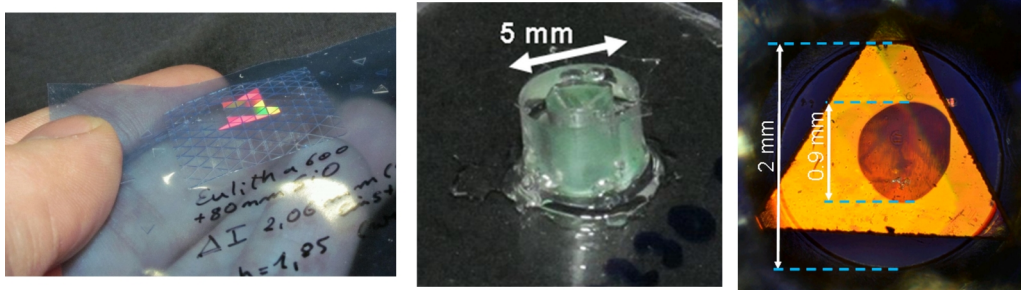


Fig. 2: Photographs of photonic crystal slabs fabricated by nanoimprint lithography (left) and assembled pressure measurement chamber (centre). The size of the dark spot visible in an optical transmission measurement is indicative of the pressure difference between chamber and outside (right).

Continuing the work on tuneable thin-film structures we investigated a thermally tuneable attenuator for monochromatic light. The tuneable attenuator is based on a thin transparent elastomer layer of PDMS sandwiched between two semi-transparent silver layers. Elastomer and silver layers form an optical cavity. Light passing this cavity is partially reflected at both silver layers causing interference in transmitted light. This interference depends on the cavity's thickness. Therefore, tuning the PDMS layer results in varying transmission intensity. As the interference condition is met for one specific wavelength, the cavity acts as attenuator for monochromatic light and allows the transmission intensity to be tuned to any level between constructive and destructive interference. Currently, tuning is achieved by Joule heating. The attenuator concept is suitable for wafer-level integration. In a joint project with the Fraunhofer Institute for Silicon Technology in Itzehoe we are working towards the demonstration of a tuneable system fabricated in a wafer-level process.

### Optical design

Spectrally encoded confocal microscopy and microsurgery (SECOMM) offers a way to implement miniaturized endoscopy, as only a small-diameter single fibre is needed to transport image information. Here, a specific wavelength to image position mapping is achieved. We proposed a compact, transmissive 2D spatial disperser design, based on a virtually imaged phased array (VIPA) spectral disperser, in conjunction with a perpendicularly arranged reflective diffraction grating embedded between two prisms (GRISM), and imaging optics (Fig. 3). Our systematic, fabrication-oriented parameter analysis yields design rules allowing for specific device tailoring. We found that a favourable design comprises a low grating period combined with a high source bandwidth and a low VIPA tilt. As an example, we demonstrated an optimized design producing a 50 by 50 pixels image resolution at a device diameter of 3.6 mm assuming a 20-nm bandwidth Ti:Sa laser centred at 800 nm.

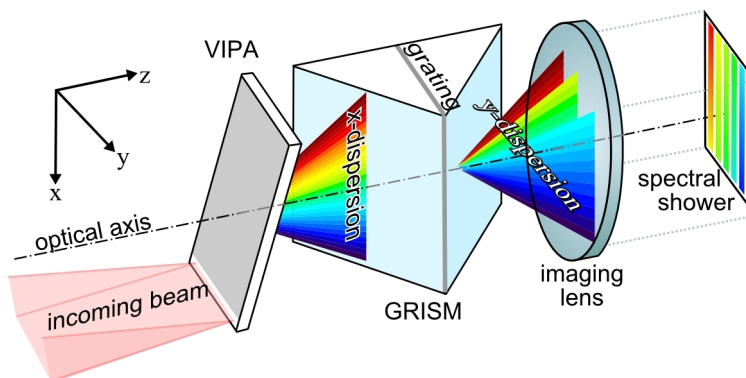


Fig. 3: Compact, transmissive 2D spatial disperser design with application in simultaneous endoscopic imaging and laser microsurgery.

## Modelling of magnetoelectric sensors

In 2013 we expanded our scientific simulation work on layered magnetoelectric nanocomposite sensors concentrating on the effects of novel layer sequences, elastic substrate compliance, resonant quality factor limiting loss mechanisms, and resonant line shape effects. Focussing on effects that enhance the sensitivity of magnetoelectric H-field sensors operating in resonant bending mode, we discovered significantly increased signals for bilayer sensors, if the magnetostrictive and piezoelectric layers are deposited on opposite rather than the same sides of the substrate. Furthermore, we found that the elastic compliance of the substrate greatly affects the ME response, whereby the enhancement or reduction depends on the layer sequence and whether resonant or static magnetic fields excite the cantilever. In addition, cantilever loss mechanisms were investigated comparing experimental data to viscous air damping and thermoelastic damping models. We discovered that for cantilevers operated in vacuum, i.e. without air damping losses, thermoelastic losses are not limiting sensor sensitivity and that other loss mechanisms, presumably mounting losses, are dominant.

Different kinds of structured magnetoelectric sensors were modelled using finite element method (FEM) simulations. The resonance line shape of such layered composite magnetoelectric sensors exhibit an asymmetric behaviour with a zero response frequency similar to the ones known from optical resonators called Fano resonances. The equivalence of a superposition function line shape to a Fano profile was derived and the superposition function could be fitted to the discrete values of the calculated FEM resonance line shapes in a post processing step. Thereby, the computational effort is decreased and losses can be included easily.

The results of FEM calculations with different layer sequences and material combinations were validated against analytical calculations of magnetoelectric sensors and show good agreement to experimental results. Ideal geometric parameters and material combinations were evaluated and were discussed and characterized by examining the associated stress and strain distributions.

## Commercialization of label-free bioanalysis

In the past few years our research in the fields of nano- and biophotonics has yielded novel technologies allowing for simple yet advanced label-free detection schemes. In 2013 we started the EXIST project to transfer these research results into marketable products. The EXIST project, funded by the Federal Ministry for Economic Affairs and Energy, supports outstanding research-based start-up projects.

Label-free bioanalysis is becoming an important tool for pharmaceutical research and development. Here, biological experiments can be performed in the absence of any labels such as fluorescence or radioactive markers. Instruments currently available on the market are rather bulky and expensive. Employing our technology and knowledge we can develop mobile and cost-efficient instruments that will enable new application scenarios for a wider user community. In particular we have developed a label-free reader device for 96-microwell plates. In the design process of this device the accurate matching of the optical and photonic components is the challenge. We designed and produced a first prototype, which we used to perform biological experiments. Beyond these technical aspects we have investigated the market for label-free technologies and plan the foundation of a spin-off company in 2014.

## **Personnel**

Head of the group: Dr.-Ing. J. Adam, Prof. Dr. M. Gerken; Secretary: S. Thielbörger (50%)

Technical Staff: Dipl.-Ing. J. Buschmann (50%), J. Greve

Scientific Staff:

Dipl.-Wi.-Ing. H. Block

Microoptical systems

01.01.-31.12.2013

DFG/CAU

M.Sc. M. Bremer Switching of nanostructured surfaces	01.04.-31.12.2013
Dr. rer. nat. P. Glorius EXIST: Biological experiments	09.08.-31.12.2013
Dipl.-Ing. J. L. Gugat Magneto-electric sensors	01.01.-31.12.2013
Dipl.-Wi.-Ing. S. Jahns Label-free biosensing	01.03.-31.12.2013
Dipl.-Wi.-Ing. T. Karrock Microoptical systems	01.01.-31.12.2013
Dipl.-Ing. C. Kluge Nanostructured organic optoelectronics	01.01.-31.07.2013
Dr. M.C. Krantz Magneto-electric sensors	01.01.-31.12.2013
Dr.-Ing. P. Metz EXIST: System engineering	01.01.-31.12.2013
Dr.-Ing. Y. Nazirizadeh EXIST: Project lead and system validation	01.01.-31.12.2013
M.Sc. A. Pradana Nanostructured organic optoelectronics	01.01.-31.05.2013
Dipl.-Wi.-Ing. D. Threm Lab-on-a-chip	01.01.-31.12.2013

PP/ERC

BMW

DFG

BMBF/ERC

DFG/CAU

CAU

DFG

DFG/BMW

BMBF/BMW

CAU

CAU

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

Grundgebiete der Elektrotechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
J. Adam (+ staff and student tutors)

Micro- and Nano-Optics, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
J. Adam

Seminar Integrierte Systeme und Photonik, 2 hrs Seminar/Week,  
J. Adam

Praktikum Optoelektronik, 4 hrs Exercise/Week,  
Scientific staff

### *Summer 2013*

Grundgebiete der Elektrotechnik II, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
J. Adam (+ staff and student tutors)

Optische Systeme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
J. Adam (+ H. Block)



Seminar Integrierte Systeme und Photonik, 2 hrs Seminar/Week,  
J. Adam

Praktikum Optoelektronik, 4 hrs Exercise/Week,  
Scientific staff

Bachelorpraktikum Mikro-Nano-Optosystemtechnik, 4 hrs Practical/Week,  
J. Adam (+ H. Kohlstedt, W. Benecke, scientific staff)

Winter 2013/2014

Grundgebiete der Elektrotechnik I, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
M. Gerken (+ staff and student tutors)

Photonic Components, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Gerken

Seminar Integrierte Systeme und Photonik, 2 hrs Seminar/Week,  
M. Gerken

Praktikum Optoelektronik, 4 hrs Exercise/Week,  
Scientific staff

## Third-Party Funds

DFG/SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt C1*,  
01.01.2010-31.12.2013 (477.000 EUR)

DFG, *Mikro-Auge basierend auf Glasoptiken und durchstimmbaren Dünnschichtfiltern herstellbar in waferbasierter Fertigung*, 30.09.2011-28.02.2015 (250.650 EUR)

BMBF, *Multiparametrische Biomarker-Bestimmung auf Wegwerfchips*, 01.04.2012-31.03.2014 (235.539 EUR)

ERC, *Photo-switching of smart surfaces for integrated biosensors*, 01.07.2013-30.06.2018 (1.499.878 EUR)

BMW, *Instrument für markerfreie Bioanalytik*, 01.08.2013-31.01.2015 (432.000 EUR)

## Diploma, Bachelor's and Master's Theses

Roger Kwee, *Charakterisierung nanostrukturierter Emissionsschichten für Chiplabore mit verbesserter Empfindlichkeit*,  
07.01.2013

Sabrina Jahns, *Photometrische Proteindetektion mittels photonischer Kristalle*, 05.02.2013

Parastou Rafiee-Yeganeh, *Entwurf und Realisierung eines Teststreifens mit integrierter nanooptischer Biosensorik*,  
21.02.2013

Semra Akyol, *Herstellung und Charakterisierung photonischer Kristalle in dehnbaren Polymermembranen*, 21.02.2013

Johannes von Fleischbein, *Signalformen und Auswerteverfahren zur Gasdetektion mit schnell modulierbaren IR-Dioden*,  
05.03.2013

Lars Thorben Neustock, *Simulation und Charakterisierung von Wellenleitern mit multi-periodischen Gittern*, 16.04.2013

Mareike Stoffel, *Optimierung eines thermisch durchstimmbaren, elastomerbasierten Virtually Imaged Phased Array (VIPA)*, 03.07.2013

Carolin Fink, *Aufbau eines Messstandes für IR-Kameras*, 01.08.2013

Jan Balke, *Entwicklung eines Messsystems zur Auswertung eines optischen Augeninnendruckensors*, 21.08.2013

Marlena Draheim, *Messaufsatz für eine Smartphonekamera zur optischen Proteindetektion*, 28.08.2013

Lazaros Sotiriou, *Vorrichtung zur Bestimmung von Oberflächenkontaktwinkeln bewegter Tropfen*, 08.10.2013



## Dissertations / Postdoctoral Lecture Qualifications

P. Metz, *Aktive Mikrooptiken auf Basis durchstimmbarer Dünnschichtresonatoren*, 25.06.2013

## Publications

Published in 2013

- J. Adam, E. Diebold, B. W. Buckley, B. Jalali, *Spectrally Encoded Angular Light Scattering*, Opt. Express, **21**, 28960 - 28967 (2013)
- Y. Nazirizadeh, F. von Oertzen, T. Karrock, J. Greve, M. Gerken, *Enhanced sensitivity of photonic crystal slab transducers by oblique-angle layer deposition*, Opt. Express, **21**, 18661 - 18670 (2013)
- A. Piorra, R. Jahns, I. Teliban, J. L. Gugat, M. Gerken, R. Knöchel, E. Quandt, *Magnetoelectric thin film composites with interdigital electrodes*, Appl. Phys. Lett., **103**, 032902 (2013)
- M. Krantz, J. L. Gugat, M. Gerken, *Resonant magnetoelectric response of cantilevers with magnetostrictive and piezoelectric layers on opposite sides of the substrate*, AIP Advances, **3**, 062135 (2013)
- M. Gerken, *Resonance line shape, strain and electric potential distributions of composite magnetoelectric sensors*, AIP Advances, **3**, 062115 (2013)
- C. Kirchhof, M. Krantz, I. Teliban, R. Jahns, S. Marauska, B. Wagner, R. Knöchel, M. Gerken, D. Meyners, E. Quandt, *Giant magnetoelectric effect in vacuum*, Appl. Phys. Lett., **102**, 232905 (2013)
- R. Jahns, A. Piorra, C. Kirchhof, D. Meyners, J. L. Gugat, M. Krantz, M. Gerken, R. Knöchel, E. Quandt, *Giant Magnetoelectric Effect in Thin-Film Composites*, J. Am. Ceram. Soc., **96**, 1673 - 1681 (2013)
- M. Krantz, M. Gerken, *Theory of magnetoelectric effect in multilayer nanocomposites on a substrate: Resonant bending-mode response*, AIP Advances, **3**, 052131 (2013)
- J. L. Gugat, M. Krantz, M. Gerken, *Two-Dimensional Versus Three-Dimensional Finite Element Method Simulations of Cantilever Magnetoelectric Sensors*, IEEE Transactions on Magnetics, **99**, 5287 - 5293 (2013)
- Y. Nazirizadeh, F. von Oertzen, K. Plewa, N. Barié, P. Jakobs, M. Guttman, H. Leiste, M. Gerken, *Sensitivity optimization of injection-moulded photonic crystal slabs for biosensing applications*, Opt. Mater. Express, **3**, 556 - 565 (2013)
- M. Krantz, M. Gerken, *Theory of magnetoelectric effect in multilayer nanocomposites on a substrate: Static bending-mode response*, AIP Advances, **3**, 022103 (2013)
- P. Metz, H. Block, C. Behnke, M. Krantz, M. Gerken, J. Adam, *Tunable elastomer-based virtually imaged phased array*, Opt. Express, **21**, 3324 - 3335 (2013)
- Y. Nazirizadeh, J. F. Reverey, U. Geyer, U. Lemmer, C. Selhuber-Unkel, M. Gerken, *Material-based three-dimensional imaging with nanostructured surfaces*, Appl. Phys. Lett., **102**, 011116 (2013)

## Presentations

- C. Kluge, L. T. Neustock, J. Adam, M. Gerken, *Calculation of leaky-wave radiation from compound binary grating waveguides*, XXIIth International Workshop on Optical Wave and Waveguide Theory and Numerical Modelling, Enschede, The Netherlands, 19.-20.04.2013
- D. Threm, Y. Nazirizadeh, M. Gerken, *Label-Free Biosensor with Integrated Organic Optoelectronic System*, 3rd International Conference on Bio-Sensing Technology, Sitges, Spain, 12.-15.05.2013
- M. Gerken, *Biomedizinische Sensoren basierend auf mikro- und nanotechnologischen Ansätzen*, Kolloquium in der Elektrotechnik und Informationstechnik, Technische Universität Darmstadt, Darmstadt, Germany, 07.06.2013
- M. Gerken, *Biomedical sensing with photonic crystal slabs*, Physikalisches Kolloquium, Universität Regensburg, Regensburg, Germany, 08.07.2013
- J. L. Gugat, M. Gerken, *Resonance Line Shape Behaviour of 2-2 Magnetoelectric Sensors on Cantilever Substrates*, Joint UFFC, EFTF and PFM Symposium, Prag, Czech Republic, 21.-25.07.2013

M.C. Krantz, J. L. Gugat, M. Gerken, *Effect of Substrate Materials on Bending-Mode Magnetoelectric Effects in Multilayer Composites: Si vs. Fused Quartz*, European Materials Research Society Fall Meeting, Warsaw, Poland, 16.-20.09.2013

J. L. Gugat, M.C. Krantz, M. Gerken, *Comparison of Analytic and FEM Simulations of Multiferroic Composite Magnetoelectric Sensors*, Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013

M.C. Krantz, J. L. Gugat, M. Gerken, *Magnetoelectric-Effect-Optimized Resonant Cantilever Bilayers: Simulations of FeCoBSi-PVDF, FeCoBSi-AlN, and FeCoBSi-PZT*, Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013

J. Adam, P. Metz, M. Gerken, *Miniaturized optical-fibre endoscope without inertial scan for simultaneous imaging and laser microsurgery*, Proc. SPIE 8842, Novel Optical Systems Design and Optimization XVI, 884204, 30.09.2013

J. Adam, L. Klinkenbusch, *Spherical-multipole based time-domain near-field to far-field transformation for the finite-difference time-domain method*, European Microwave Week, Nürnberg, Germany, 06.-11.10.2013

S. Jahns, Y. Nazirizadeh, B. Meyer, S. B. Gutekunst, C. Selhuber-Unkel, M. Gerken, *Photometric Aptasensor using Biofunctionalized Photonic Crystal Slabs*, Proc. IEEE Sensors 2013, Baltimore, USA, 03.-06.11.2013

M.C. Krantz, J. L. Gugat, M. Gerken, *Strong Enhancement of Bending-Mode Magnetoelectric Effect by Layer Sequence Choice in Thin Film Bilayer Composites on a Substrate*, Materials Research Society, Boston, USA, 01.-06.12.2013



## Microwave Group

The **Microwave Group** of the Christian Albrechts University of Kiel (CAU) has continued research in the areas of **ultra-wideband technology (UWB)**, and **high frequency materials and components**. The working area of **microwave sensors**, where highly recognized research has been carried out during the last few decades, has been further extended to field based sensors, which include for example eddy current sensors, low frequency capacitive sensors, and magnetoelectric sensors. Another working area is **molecular spectroscopy**, where work on spectrometer construction continues.

**UWB-technology** concentrates on sensors for the characterization of condition, composition, and history of natural materials. At present the research is focused on non-contacting determination of the properties of dielectric objects that may be much smaller than the footprint of the interrogating antenna. Over the years the laboratory has acquired considerable expertise in the application of dielectric spectroscopy and in the use of multivariate statistics to analyse the response of UWB signals.

**Industrial and medical microwave sensors** are areas where the microwave group has a long established experience. A wide range of sensors has been created in the past. Present work concentrates on millimetre wave Doppler radar sensors for the characterization of aerosols for example, on other radar sensors, and on sensors for medical applications. In addition, a novel density independent measurement method was enhanced; it is suited for moisture measurements up to very high moisture levels. Significant effort has been devoted to investigations concerning the characterisation of thin film magnetoelectric sensors in collaboration with others working in materials research at Kiel, and to low noise electronic circuits for interrogating such devices.

**Molecular spectroscopy** is focused not only on spectroscopy itself, but also on the development of new spectrometers in the millimetre and sub-millimetre wave region.

In October 2013 Prof. Dr.-Ing. Michael Höft became the new head of the microwave group.

### Results

#### Near range radar for the detection of small fast moving targets at sea

The near range radar has been designed in the framework of the PITAS-project as a sensor for an antipiracy and counterterrorism system that is aimed at warning and protecting the crew of a cargo ship against pirate attacks. The radar is capable of detecting small fast moving boats within one mile radius of the the ship. A lab designed solid-state radar transmitter, with an average radiation power of 140 mW provides safety and long operation time in comparison to traditional radar transmitters. Moreover, the sophisticated pulse coherent signal processing that has been realized using modern FPGA technology allows the recognition of a small target against the background of sea clutter with a very high detection probability. Finally, the full scale tests of the whole system, and particularly the near-range radar designed, have shown excellent results.

#### Microstrip Filter Design with Fuzzy Logic

Dielectric resonator filters are widely used in satellite communication systems and mobile base stations. They provide a mass reduction in comparison with other types of waveguide filters. The design procedure of this filter type is based on a coupling matrix. In order to accelerate the design procedure of these filters advantage was taken of a Fuzzy approach. Based on this method the behaviour of coupled resonators was extracted. Based on the extracted surfaces some filters were designed and the simulated results were compared with ideality. A good agreement shows the accuracy of the proposed method in the design of such filters. One of the demands in the area of satellite communication is the mass reduction of DR filters. The reason behind such a demand is that the number of channel filters has to be increased. Novel operation modes were taken into consideration. This idea is still under investigation. In mobile base stations, every improvement in the steepness of the filter response at the band edge of the transmission band is appreciated. This improvement can reduce the

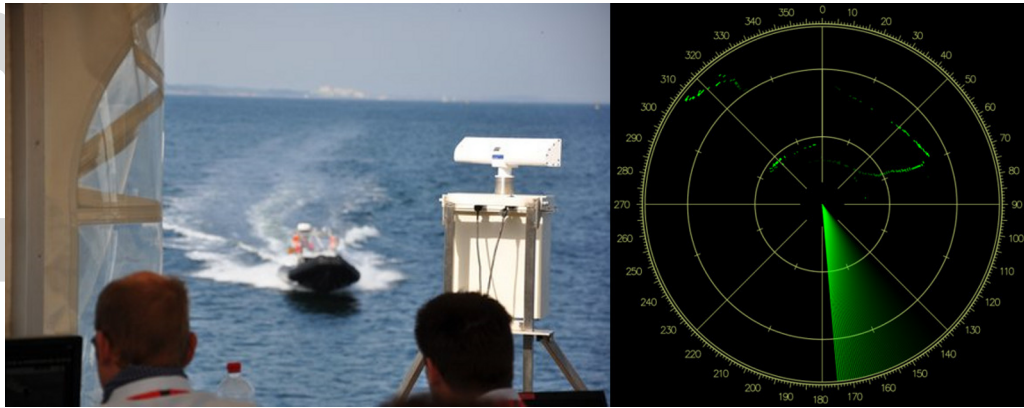


Fig. 1: Full scale test of the near range radar and PPI screen with target tracks

number of filter elements and as a consequence the cost will be decreased. It is important to produce an arbitrary number of out-of-band transmission zeros independent from the filter degree. To achieve such arbitrary adjustable out-of-band zeros, structural modification in the DR filters is investigated.

#### Metamaterial-loaded Slow Wave Structures for Spatial Harmonic Magnetrons (SHMs)

Spatial harmonic magnetrons are good candidates for the development of pulse sources operating in the low frequency part of the THz region. However they suffer from low efficiency and low average power. The main goal of this project is to improve the performance of the SHMs in terms of efficiency and output power. Using the equations of motion of electrons in the interaction space of SHMs, an approximate criterion for the assessment and comparison of different SWSs in a spatial harmonic scenario without being involved in complicated hot cathode analysis of magnetrons has been derived. This approximate criterion shows that the conventional slow wave structures impose fundamental limitations on the output power and efficiency of SHMs. Based on the approximate theory developed, it has been shown that loading the side resonators with a metamaterial unit-cell can remove the fundamental limitations of conventional SWSs. Hence a metamaterial unit-cell has been realized in the side resonators of a conventional SWS. The hot cathode operation of a metamaterial loaded SHM and a conventional SHM with similar operation frequencies, interaction space dimensions, and operating points showed that the electron power and the efficiency of the metamaterial loaded SHM are 2.37 and 1.8 times larger respectively than those of the conventional SHM.

#### Non-contacting characterization of the dielectric properties of objects of irregular shape

The aim of the DFG-project ISOPerm (irregular shaped objects permittivity) is to develop an UWB method for the measurement of the dielectric properties of irregularly shaped bodies by using a non-contacting approach. Industrial processes often require the determination of the process parameters, e.g. water content of bulk materials. Unlike existing methods, and as a novel approach, an attempt was made using multivariate analysis to separate those effects due to the geometry of the object from those due to its dielectric properties. It was successfully proven that the determination of the dielectric properties is possible, regardless of shape, size and orientation of the objects under test. It was also shown that related properties such as for example, the water content of water-ethanol mixtures, the carbon content of carbon loaded silicones, or the moisture content of moist clay granules, can be determined directly from the time domain data. A main focus was the hardware development and the improvement of system performance. An FPGA based system was brought into operation that offers superior performance regarding speed and accuracy. Novel components like an eight-fold UWB signal combiner were designed and installed. Besides the impulse technique a system using maximum-length-sequences as stimuli was developed. A novel approach using orthogonal codes for measurement purposes was also implemented successfully.

#### Moisture Measurements of Irregularly Shaped Objects using a Phased Array Antenna

Free space moisture measurements are often required for industrial applications. However, due to the complex scattering properties within the transmission path of the microwaves the measurements are often heavily perturbed. The solution to this problem is the use of a phased array for modifying the illumination of the objects in order to collect more information for multivariate data processing. The proposed system works only at one frequency; hence it has a high dynamic range and a relatively low hardware effort. A simple data processing of the transmitted signal from the sending to the receiving antenna is not applicable, especially when the objects to be characterized are irregularly shaped. With the phased array used the radiation characteristic can be changed and therefore the illumination of the irregular shaped objects alters also. Due to the complex scattering properties of the objects a receiving antenna collects a characteristic pattern depending on the permittivity, shape and orientation of the object. However, to create a physical model for the transmission channel from the received signals is very difficult so a multivariate signal processing procedure is applied here. Principal component analysis together with artificial neural networks (ANN) enables the measurement of the moisture content of irregular shaped objects independently of their shape and orientation.

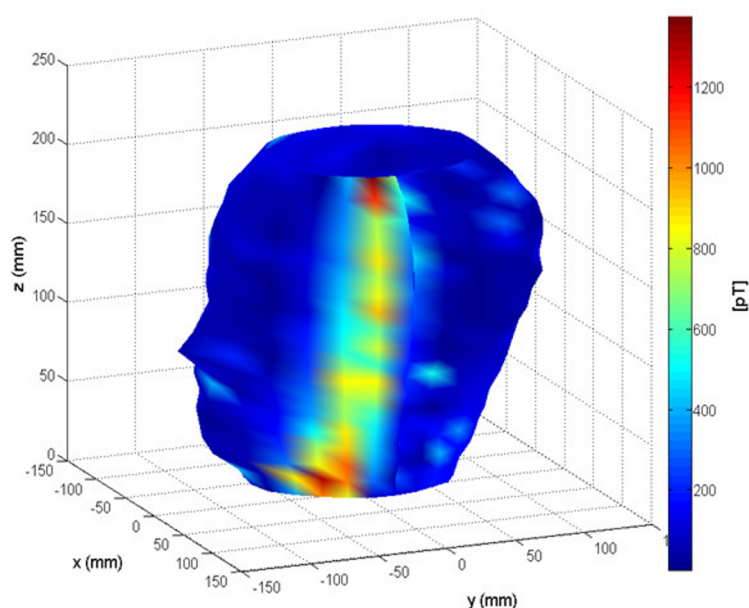


Fig. 2: Measurement of the magnetic field distribution around a head phantom with brain pacemaker

Collaborative Research Centre SFB 855 "Magnetolectric Composite Materials - Biomagnetic Interfaces of the Future"  
Subproject C3: Sensor Modelling and Electronic Signal Processing

The aim of the collaborative research centre SFB 855 is the development of a high sensitivity magnetoelectric (ME) detection unit that is able to measure biomagnetic signals in the picotesla range. In 2013 it was possible to reduce the influence of external mechanical vibrations significantly by developing a tuning fork approach. Therefore two identical ME sensors have been connected back to back with each other at their clamped ends. This leads to  $180^\circ$  phase shifted output signals with regard to mechanical vibration noise at the input and to in-phase output signals, having a magnetic signal at the sensor input. This technique allows easily the cancellation of disturbing mechanical vibration signals. Using this approach, it was possible to measure brain pacemaker signals from a head phantom in the picotesla range without any vibration isolation. With the use of a non-magnetic 3D scanner it was possible to map the entire magnetic field distribution around the head phantom (see Fig. 2). Further progress has been made in the measurement of broadband epilepsy signals in cooperation with the group of Prof. Schmidt. By using our previously reported modulation technique and signal post processing in Prof. Schmidts group, an artificially generated epilepsy signal could be shifted into the mechanical resonance

of the sensor at several hundred Hertz and demodulated again at the sensor output.

### Nanostructured Cocoon-PUFs

Numerous civil and military applications strongly demand secure hardware. Most present systems are incapable of fulfilling all security needs. Crypto-technology experts have known for some time how to do better; now these next generation technologies begin to leave the experimental phase and enter the preproduction stage. Among them are the Physical Unclonable Functions (PUFs). There are strong expectations that they will have a great role in securing hardware and integrated circuits, even in post NSA times. Throughout this research, the TF group uses microwave techniques along with PUFs in proposing a potential solution to data security and counterfeiting problems. We call this solution Cocoon-PUF technology. It is interesting to point out, that such a security technology remains resilient against the upcoming attack threat using quantum computing. This security technique is based on artificially-synthesized disordered micro and nano materials embedded into the IC-chip through the fabrication process. A proof-of-concept realization of such a concept is the result of the successful collaboration between the Microwave Group and the Functional Nanomaterials Group. Examples of some synthesized nano composites are the Tetrapodal Zinc Oxide (T-ZnO) and Baytubes C150P Carbon Nanotubes (CNTs). These materials have shown rather reliable results and have proven to be promising candidates for future on-chip embedded security.

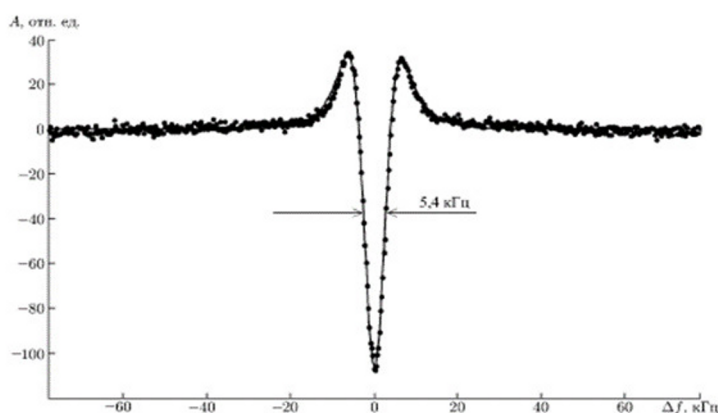


Fig. 3: Absorption line of the molecule OCS by 109463.064 MHz

### Molecular Spectroscopy

Molecular spectroscopy in the range of millimetre- and sub-millimetre wavelengths (carried out by Prof. Guarnieri) allows the investigation of free molecules in the gas phase. In this state the molecules are in continuous motion proportional to their thermal energy. A part of this energy is stored as rotational energy. The activity of the lab was concentrated on the improvement of the resolution of the millimetre- and sub-millimetre wave spectrometer to allow very precise measurements of transition frequencies between rotational energy states. Astronomical observations in millimetre- and sub-millimetre wavelengths have led to the discovery of many different molecules in the interstellar clouds. Laboratory spectra of such molecules in the millimetre- and sub-millimetre range measured with a precision  $\leq 1$  kHz are therefore needed for modern astrophysical investigations. To this purpose this laboratory's spectrometer has been supplemented with devices that have allowed the observation of absorption lines with Lamb-dip (a result of a saturated absorption process) accuracy. This method allows the measurement of the absorption lines with a precision  $\leq 1$  kHz. A corresponding paper was published in 2007 in Astrophysics Letters. Further to increase the sensitivity of the InSb-Detector-chip in the frequency range near 1 THz (0.3 mm wavelength) a suitable cryostat provided with a neodymium permanent magnet delivering a magnetic field of 1.4 Tesla around the InSb-chip, is under construction in the local workshop of the faculty. Within the scope of the DFG-cooperation project with the Institute of Applied Physics of the Russian Academy of Science (Nizhnii Novgorod) spectra of the HCCCN (propyne nitrile), NH<sub>3</sub> (ammonia), and various isotopologues of water have been

investigated with the goal of obtaining precise transition frequencies in the millimetre- and sub-millimetre range (accuracy  $\leq 1$  kHz) for investigation of the dynamics of interstellar clouds. Within the scope of cooperation with the Institute of Applied Physics of the Russian Academy of Science in Nizhnii Novgorod a new spectrometer in the range of millimetre- and sub millimetre-waves, based on the use of the Lamb-dip method for reaching a high resolving power, also has been set up in the above Institute. [See: Izvestija suzov.Radiofisica, LVI,8-9,666(2013)] As an example of the resolving power reached we give here the picture of the absorption line of the molecule OCS at 109463.064 MHz with a full width at half line maximum of 5.4 KHz which allows the measurement of the absorption peak of the line with a value better than 1 kHz (see Fig. 3).

## Personnel

Head of the group: Prof. Dr.-Ing. M. Höft, Prof. Dr.-Ing. R. Knöchel; Secretary: M. Bork  
Technical Staff: Dipl.-Ing. (FH) L. Ngongue, H. Runkowske, Dipl.-Ing. (FH) W. Taute

Scientific Staff:

Dr.-Ing. F. Daschner	01.01.-31.12.2013	CAU
Resonant stents / Microwave sensors / Early detection of dental pulp in inflammations		
Prof. Dr. A. Guarnieri	01.01.-31.12.2013	CAU
Molecular Spectroscopy		
Dr.-Ing. R. Jahns	01.01.-31.12.2013	DFG
Magnetolectric sensors		
Dr.-Ing. M. Kheir	01.02.-31.12.2013	CAU
Cocoon-PUF		
Dr.-Ing. H. Kreft	15.01.-31.12.2013	CAU
Cocoon-PUF		
Dr.-Ing. H. Mextorf	01.01.-30.09.2013	CAU
Non-contacting characterisation of irregular shaped objects		
M.Sc. N. Nasresfahani	01.01.-31.12.2013	DAAD / TUHH
Metamaterials in microwave structures		
M.Sc. P. Rezaee	01.01.-31.12.2013 (50%)	BMW / CAU
Microwave filter design with fuzzy logic		
Dipl.-Ing. W. Stellmach	01.01.-31.12.2013 (50%)	BMW / CAU
Near range radars		
I. Teliban	01.10.-31.12.2013	DFG
Magnetolectric sensors		
M.Sc. O. Teplyuk	01.01.-31.12.2013	CAU / BMW
Near range radars		
Dipl.-Ing. J. Wolff	01.01.-31.12.2013 (50%)	BMW / CAU
Near range radars		

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Leitungstheorie, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Knöchel (+ F. Daschner)

Nichtlineare Schaltungen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Knöchel (+ R. Jahns)

Hochfrequenzschaltungen und -systeme: Aktive Schaltungen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Knöchel (+ H. Mextorf)

Rauschen in Kommunikations- und Messsystemen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Knöchel (+ W. Stellmach)

Projekt, 3 hrs Practical/Week,  
R. Knöchel

Masterpraktikum Mikrowellen und EMV, 4 hrs Practical/Week,  
F. Daschner (+ R. Jahns, A. Teplyuk, H. Mextorf)

Seminar Hochfrequenztechnik, 2 hrs Seminar/Week,  
R. Knöchel

Hochfrequenz-Messtechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Daschner (+ F. Daschner)

### Summer 2013

Radar, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Knöchel (+ H. Mextorf)

Hochfrequenz-Messtechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Daschner (+ F. Daschner)

Hochfrequenzschaltungen und -systeme: Passive Systeme, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Knöchel (+ H. Mextorf)

Bachelorpraktikum Hochfrequenztechnik, 4 hrs Practical/Week,  
F. Daschner (+ R. Jahns, O. Teplyuk, H. Mextorf)

Projekt, 3 hrs Practical/Week,  
R. Knöchel

Seminar Hochfrequenztechnik, 1 hrs Seminar/Week,  
R. Knöchel

Hochfrequenztechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Knöchel (+ R. Jahns)

### Winter 2013/2014

Leitungstheorie, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Höft (+ F. Daschner)

Nichtlineare Schaltungen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Höft (+ R. Jahns, O. Teplyuk)

Hochfrequenzschaltungen und -systeme: Aktive Schaltungen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Knöchel (+ F. Daschner)

Rauschen in Kommunikations- und Messsystemen, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Jahns (+ R. Jahns)

Projekt, 3 hrs Practical/Week,  
M. Höft

Masterpraktikum Mikrowellen und EMV, 4 hrs Practical/Week,  
F. Daschner (+ R. Jahns, A. Teplyuk)

Seminar Hochfrequenztechnik, 2 hrs Seminar/Week,  
M. Höft

Hochfrequenz-Messtechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Daschner (+ F. Daschner)

### **Third-Party Funds**

Deutsche Forschungsgemeinschaft, *Kontaktlose Bestimmung der dielektrischen Eigenschaften unregelmäßig geformter Objekte (ISOPerm) - Folgeprojekt*, 01.02.2011-31.01.2013 (126300)

Deutsche Forschungsgemeinschaft, *Aufbau und Optimierung von Spektrometern für den Submillimeterwellen-Bereich sowie Fortsetzung der rotationsspektroskopischen Messungen an interstellaren Spezies*, 01.10.2008-31.03.2013 (53995 EUR)

Deutsche Forschungsgemeinschaft, *Sonderforschungsbereich 855, Subproject C3: Sensor Modelling and Electronic Signal Processing*, 01.01.2010-31.12.2013 (579100 EUR)

Bundesministerium für Wirtschaft und Technologie, *Verbundprojekt: PITAS - Piraterie und Terrorabwehr auf Seeschiffen; Sensorik und Tracking*, 01.07.2010-31.12.2013 (1029711 EUR)

Deutscher Akademischer Austauschdienst, *Leonhard-Euler Programm, Zielland: Ukraine*, 01.09.2012-31.08.2013 (8175)

Deutscher Akademischer Austauschdienst, *Leonhard-Euler Programm, Zielland: Ukraine*, 01.09.2013-31.08.2014 (6680)

Deutscher Akademischer Austauschdienst, *Leonhard-Euler Programm, Zielland: Russische Föderation*, 01.09.2013-31.08.2014 (7725)

Deutsche Bundesstiftung Umwelt, *Förderinitiative Nachhaltige Pharmazie: Prozessanalytische Technologie für die Hormon-Granulierung*, 01.11.2013-31.10.2014 (152000)

### **Further Cooperation, Consulting, and Technology Transfer**

There is close cooperation concerning magnetic nano composites for rf applications with the departments of Multicomponent Materials, (Prof. Faupel) and Inorganic Functional Materials, (Prof. Quandt) in the **Faculty of Engineering of CAU**.

With the latter department (Prof. Quandt) there is also cooperation with regard to magnetoelectric sensors.

There exists a cooperation concerning radiophysics and radioelectronics, radar technology, and biological effects of electromagnetic waves and fields, with the **Kharkov National University (KNU)**, Kharkov, Ukraine, in association with research institutes of the Ukrainian academy of science, the **Institute of Radiophysics (IRE)**, (Prof. Khlopov) and the **Institute of Radioastronomy (IRA)**, (Prof. Vavriv). There is also some cooperation within the framework of the **Leonard Euler Program of the German Academic Exchange Service (DAAD)**.

With the **Technische Universität Hamburg Harburg**, (Prof. Dr. A. Jacob), we cooperate in the areas of microwave components, microwave measurements, and radar technology.



With Prof. Dr. K. Schünemann, **Technische Universität Hamburg Harburg** and Prof. G. Khlopov, **Institute of Radiophysics**, Kharkov, Ukraine we cooperate in the area of industrial radar sensors.

Concerning sub-millimetre spectrometers and molecular spectroscopy we work in cooperation with the **Applied Physics Institute of the Russian Academy of Science** (Dr. Gera Golubjatnikov and Dr. Vladimir Markov) .

Cooperations with industry include: **AMS - Advanced Microwave Systems**, Hamburg, in the area of microwave sensors for density and moisture determination of materials,

**Thales**, Kiel, in the area of antennas,

and **Bikotronic Industrie-Elektronik GmbH**, Deidesheim.

A cooperation concerning resonant stents and other stent solutions is carried out together with the **Paediatric Cardiology Clinical Centre of the Christian-Albrechts-University** (PD Dr. Rickers). The project on early detection of dental pulp inflammation is a cooperation with the **Department of Conservative Dentistry of the Christian-Albrechts-University** (Prof. C. Dörfer).

As in previous years there is cooperation with **Dr. M. Kent**, a UK consultant, in the application of dielectric measurements and multivariate analysis.

## Diploma, Bachelor's and Master's Theses

- M. Shahryari, *Mikrowellenresonatoren zur Messung der Permittivität entzündeter Zahnwurzeln*, 21.02.2013
- S. Krepper, *Gleichzeitige Messung mehrerer Impulsantworten mit nur einem Empfänger*, 19.03.2013
- T. Kröger, *Entwurf und Aufbau von analogen Filtern für ein M-Sequenz Messverfahren*, 19.03.2013
- H. Nätke, *Entwicklung eines Mikrowellenresonators zum Detektieren entzündeter Zahnwurzeln*, 10.06.2013
- Jian Wen, *Entwicklung von offenen Resonatoren mit verminderter Abstrahlung für Permittivitätsmessungen*, 10.06.2013
- S. Schauer, *Selbstschwingendes Dielektrometer für präzise Messungen der Luftfeuchte*, 12.06.2013
- D. Baron, *Anwendung des Regenerativprinzips zur Sensitivitätssteigerung magnetoelektrischer Sensoren*, 12.06.2013
- Y. Huang, *Entwicklung eines Mikrowellen-Messverfahrens für hohe Materialfeuchten*, 25.07.2013
- N. Baligh, *Wirbelstromsensor zur Diagnose von Zahnwurzelentzündungen*, 23.08.2013
- N. Beck, *Rauscharmer Vorverstärker für ein 35 GHz Pulsradar*, 17.08.2013
- C. Ebner, *Entwicklung eines breitbandigen Vorwärtskopplers mit gekoppelten Leitungen*, 17.08.2013
- I. Keskin, *Entwicklung eines Mikrowellenresonators mit Meanderleitung*, 15.10.2013
- S. Salzer, *Untersuchung der Anwendbarkeit von magnetoelektrischen Sensoren in biomagnetischen Messsystemen*, 29.10.2013
- C. Plueschke, *Kohärente Radarsignalverarbeitung zur Sea-Clutter Unterdrückung mit FPGA*, 30.10.2013
- E. Tüfekci, *Entwicklung eines Mikrostreifensensors zur frühzeitigen Diagnose von Zahnwurzelentzündungen*, 20.11.2013

## Dissertations / Postdoctoral Lecture Qualifications

- R. Jahns, *Untersuchung und Optimierung von Empfindlichkeit und Rauschverhalten magnetoelektrischer Sensoren*, 11.06.2013
- H. Mextorf, *Ein Ultrabreitband Verfahren zur Charakterisierung beliebig geformter dielektrischer Objekte im Freiraum*, 18.06.2013

## Publications

Published in 2013



- R. Jahns, A. Piorra, E. Lage, C. Kirchhof, D. Meyners, J.L. Gugat, M. Krantz, M. Gerken, R. Knöchel, E. Quandt, *Giant magnetoelectric effect in thin film composites*, Journal of the American Society, **96**, 1673 - 1681 (2013)
- S. Marauska, R. Jahns, C. Kirchhof, M. Claus, E. Quandt, R. Knöchel, B. Wagner, *Highly sensitive wafer-level packaged MEMS magnetic field sensor based on magnetoelectric composites*, Sensors and Actuators A, **189**, 321 - 327 (2013)
- A. Piorra, R. Jahns, I. Teliban, L. Gugat, M. Gerken, R. Knöchel, E. Quandt, *Magnetoelectric Thin Film Composites with Interdigital Electrodes*, Appl. Phys. Lett., **103**, 032902 (2013)
- C. Kirchhof, M. Krantz, I. Teliban, R. Jahns, S. Marauska, B. Wagner, R. Knöchel, M. Gerken, D. Meyners, E. Quandt, *Giant magnetoelectric effect in vacuum*, Applied Physics Letters, **102**, 232905 (2013)
- G.Yu. Golubiatnikov, S.P. Belov, I.I. Leonov, A.F. Andrianov, I.I. Zinchenko, A.V. Lapinov, V.N. Markov, A.P. Shkaev, A. Guarnieri, *Precision Subdoppler Millimetre and Submillimeter Lamb-Dip Spectrometer*, Izvestija suzov. Radiofísica, **LVI**, 8 - 9 (2013)
- M. Kheir, H. Kreft, R. Knöchel, *RF identification and security technique for highly-secure UWB information systems*, IEEE 24th Symposium on Personal Indoor and Mobile Radio Communications, 164 - 168 (2013)
- M. Kheir, H. Kreft, R. Knöchel, *Nanostructured RFID technology: Attack-response and temperature-robustness investigations*, European Microwave Conference, 132 - 135 (2013)
- F. Daschner, H. Mextorf, M. Kent, R. Knöchel, *Moisture Measurement of Irregularly Shaped Objects using a Phased Array Antenna*, Proceedings of the 10th International Conference on Electromagnetic Wave Interaction with Water and Moist Substances, (2013)
- F. Daschner, B.E. Beck-Broichsitter, D. Christofzik, W. Stellmach, S.T. Becker, J. Wiltfang, R. Knöchel, *Sensor for Monitoring the Progress of Heterotopic Bone Induction*, Proceedings of the 10th International Conference on Electromagnetic Wave Interaction with Water and Moist Substances, (2013)
- H. Mextorf, C. Plueschke, F. Daschner, M. Kent, R. Knöchel, *UWB multi-channel m-sequence system for moisture measurements*, IEEE International Conference on Ultra-Wideband, 221 - 225 (2013)
- H. Mextorf, R. Knöchel, *Ultra-Wideband Loose Coupling Directional Couplers with High Directivity*, Proceedings of the European Microwave Conference, doi: 10.1109/ICUWB.2013.666385, (2013)

## Presentations

- F. Daschner, *Dielectric Measurements for the Determination of the State of Organic Materials*, Workshop Introduction to Advanced Measurement Techniques for Material Characterization, European Microwave Week, Nuremberg, Germany, 06.-11.10.2013
- F. Daschner, H. Mextorf, R. Knöchel, *Ultra-Wideband Sensors for Non-Contacting Material Characterization using Multivariate Calibration*, Workshop Microwave Sensors and Applications, European Microwave Week, Nuremberg, Germany, 06.-11.10.2013

## Further Activities and Events

**Prof. Knöchel** is active in the IEEE-MTT (Microwave Theory and Techniques) Society. He was chairman of subcommittee-29 "Broadband Microwave Systems" within the programme committee of the "International Microwave Symposium", IMS, which is the biggest conference worldwide in that area. He is also Chairman of the technical committee MTT-16, "Microwave Systems", and since 2007, a member of the selection committee for the "IEEE MTT Distinguished Microwave Lecturers". He also represents the MTT on the executive committee of the "International Conference on Ultra-Wideband, ICUWB". He is a member of the editorial board of "Frequenz" and a reviewer for the journals "IEEE Transactions on Microwave Theory and Techniques", "IEEE Microwave and Wireless Components Letters", as well as journals of the UK "Institute of Physics" (IOP) among others. He is also a member of VDE Expert Group 7.3, "Mikrowellentechnik". Apart from his membership of the IEEE he is also a member of the "European Microwave Association, EuMA" and of URSI, commission A.

# almanach 13

# Nanoelectronics

Exciting new opportunities for future information technology arise from unconventional and novel electronic materials, nanoscale phenomena and advanced processing technologies that start at the atomistic level. It is expected that, with the trend of aggressive downscaling of commercial electronic devices into the nanoscale regime, quantum mechanical effects will become steadily more important. This trend will lead to a change of paradigm, i.e. future nanoelectronic devices exploiting electron tunnelling and/or spin transport will rely on the fundamental laws of quantum mechanics rather than on classical electrodynamics. In this context, new materials and material combinations are urgently required in order to develop tunnel junctions with enhanced functionalities. The chair of Nanoelectronics is focusing on medium- term and long-term tasks, on emerging far-reaching concepts, and on issues of physics and technology well ahead of the mainstream development of the nanoelectronics industry. The research platform of the AG Nanoelectronics is supported by three main pillars, i. e. new device concepts based on quantum phenomena, interfacial studies and novel fabrication routes. For example we explore multiferroic tunnel junctions based on complex oxide materials, superconducting junctions for quantum bits, and lateral tunnel junctions (nanogaps). Therefore, a considerable technological and metrological infrastructure is needed. Part of the equipment such as an electron-beam-writer, a focused ion beam system, as well as a Pulsed Laser Deposition system is available via the Kieler Nanolabor. Various current-voltage acquisition systems, magneto- resistance set-ups, and ferroelectric thin films analyzers for a temperature range between 4.2 K and 300 K are part of our lab. On the system level neuromorphic circuits will lead in the future to parallel computing and low power dissipation. Recently our group became active in the development of neuromorphic circuits comprising a memristive device to mimic synaptic activities. Our activities are embedded in the recently founded Collaborative Research Centre SFB 855 on magneto-electric composites and heterostructures for medical sensor applications, as well as in the Focal Point of Support on Nano and Surface Science within the CAU Kiel.

## Results

### Memristive operation mode of floating gate transistors: a two-terminal MemFlash-cell

*Martin Ziegler, Hermann Kohlstedt*

During recent years the development of memristive (analogue) devices has received a tremendous boost. This is due to innovative applications in the field of non-volatile random access memories (RAMs) in the gigabit range, as a successor technology to flash memories, and furthermore by the possibility to provide a technology for emulating neuronal functionality in the field of neuromorphic engineering. Within this context, memristive devices are appealing, in particular due to their low power consumption, fast read/write cycles, low fabrication costs and their large scalability, which allows the realization of memristive devices on the nanometer scale. Moreover, due to their simple wiring scheme, memristive devices may reduce significantly the complexity of large electronic circuits and in addition provide a higher flexibility in circuit design. Such approaches are currently being discussed for applications in the field of neuromorphic circuits.

Despite the massive world-wide research activities during recent years and the manifold areas of applications, it has not been possible yet to develop memristive devices which comply with all application-relevant specifications. Important criteria for reliability, such as retention, reproducibility, and endurance, but also the reciprocal switching energy in particular in the field of memory applications, has not been reached so far. This gives rise to the question whether in future all desired device specifications can be met within a single device. Furthermore, despite many years of research in this field, a detailed physical understanding of the relevant physical effects on a mesoscopic and atomic scale is lacking. Within this context, quite different models have been developed. Moreover, most of the applied materials for memristive devices are only partly complementary metal oxide semiconductor (CMOS) compatible, which is another obstacle for commercialization. In this respect, a deep understanding and an appropriate control of the electrical parameters of memristive devices combined with Si-technology are highly appreciated. Floating gate (FG) transistors (i.e. electrically erasable programmable read only memory (EEPROM) cells) may serve as such a device, since their device resistance is dependent on the electronic

charge stored on the floating gate. However, in such common non-volatile Flash-type memories write, erase, and read cycles are time distinguishable and for each cycle a particular pulse sequence is applied. The common EEPROM-cell is a three-terminal or four-terminal device, which prevents at first glance a memristive operation mode. Therefore, advanced cell layouts are required if memristive I-V characteristics should be established.

In Ref. [maz1] we present a memristive operation mode of a single floating gate transistor, the MemFlash cell. The device resistance varied accordingly to the charge flow through the device. Hysteretic current-voltages including a resistance storage capability were observed, as shown in Fig. 1(a). To ensure the memristive operation mode, the three-terminal device was reduced to a two-terminal device in such a way that the device resistance varied accordingly to the charge flow through the device during source-drain voltage application (see Fig. 1(b,c)). Moreover in Ref. [maz2] we provide evidence that a single MemFlash cell can be used to mimic synaptic functionality. Furthermore, based on Hebbian learning, a synaptic analytical expression for the learning rate of this device is derived in Ref. [maz2]. The experimental findings are theoretically supported by a capacitive based model. The MemFlash cell can be considered as a potential substitute for any state-of-the-art memristive device in neuromorphic circuits, cross bar arrays, or reconfigurable logics, and is compatible with state-of-the-art Si-fabrication technology.

[maz1] M. Ziegler, Maria Oberländer, D. Schroeder, W. H. Krautschneider, and H. Kohlstedt, *Memristive operation mode of floating gate transistors: A two-terminal MemFlash-cell*, Appl. Phys. Lett. **101**, 263504 (2012).

[maz2] M. Ziegler and H. Kohlstedt, *Mimic synaptic behaviour with a single floating gate transistor: A MemFlash synapse*, J. Appl. Phys. **114**, 194506 (2013).

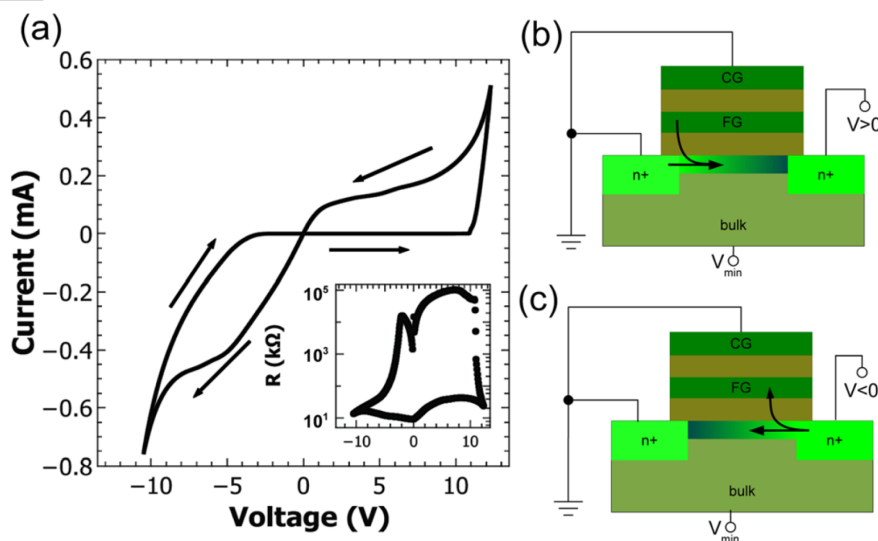


Fig. 1: (a) Typical current-voltage characteristic of our two-terminal circuitry, addressing a single EEPROM cell. At positive voltages, applied to the drain terminal ( $V > 0$ ), electrons are tunnelling from the floating-gate through the gate oxide layer to the conducting channel of the underlying MOS transistor, as illustrated in (b), while at negative voltages ( $V < 0$ ) the electrons are recaptured (c). Inset: Resistance-voltage characteristic. (Reproduced from [maz1])

## Tunable $\pi$ junctions – a fundamental element for superconducting circuits

Nico Ruppelt, Ondrej Vavra and Hermann Kohlstedt

Nb based Josephson junctions with aluminium oxide tunnel barriers (I) can be manufactured controllably with defined normal resistance and critical current. The high quality, low spread of parameters and excellent yield render these SIS type junctions interesting for many functional applications of superconductivity. Josephson junctions are used widely if the quantum nature of superconductivity is to be exploited beyond the dissipation-free transport of current. Their application

ranges from magnetic field sensors through sensitive detectors to solid state quantum computation and superconducting logic circuits e.g. RSFQ (see below). A special kind of Josephson junction where in the ground state a phase difference of  $\pi$  occurs between the wave functions of the electrodes can be realised in SFS structures (F= ferromagnet). This phase shifting property allows simpler operation modes and interesting new designs for applications. In particular such a  $\pi$  Josephson junctions would be complementary [1] to the standard Josephson junction with the potential to lead to a similar boost of performance in RSFQ as CMOS did in Si technology.

A variety of  $\pi$  SIFS structures that combine a technologically compatible tunnel barrier with an adjacent phase shifting ferromagnetic layer have been investigated in the past but they suffered from tiny critical current densities which make them less interesting for basic research and difficult to integrate into applications. We fabricated and characterised SIsFS junctions where (I) and (F) are separated by several nanometres of a superconductor (s). By variation of the F-layer thickness a transition between 0 and  $\pi$  coupling occurs for a thin (s) interlayer. A homogeneous current transport through the junctions plane was confirmed by critical current vs. in-plane magnetic field dependence which modulates in a Fraunhofer fashion. We experimentally verified (Fig. 2 b) that beyond a critical thickness of the intermediate layer (s) the critical current drastically increases and finally saturates at the value of a corresponding SIS junction. This is a potential method to tailor the electrical parameters of  $\pi$  junctions.

**Info:** Rapid single flux quantum logic (RSFQ) is a superconducting, inherently digital circuit design. The information is represented and transmitted by single flux quanta  $\Phi_0 = h/2e$  (elementary charge  $e$  and Planck's constant  $h$ ) that are stored in superconducting loops. Although the flux propagation through the circuit is mediated by an ultrashort voltage pulse the voltage does not control the behaviour of the circuit elements. Note that the superconducting charge carriers in a superconductor, called *Cooper pairs*, are described by a collective wavefunction which contains a phase  $\varphi$ . The phase difference over a circuit element  $\Delta\varphi$  becomes the important state variable that governs its dynamics. Standard RSFQ logic contains three components: inductors, current sources, and Josephson junctions (Fig. 2 a). The latter are the active elements similar to transistors in conventional electronics. An external control of clock frequency and bias occurs by means of the current. Advantages shown by Si devices are the extremely low power dissipation and very high clock frequencies of several hundred GHz, making RSFQ particularly interesting for large data processing systems. However cryogenic cooling is needed and despite some quite fundamental experiments severe limitations by yield, robustness of operation, and integration density remain.

[1] E. Terzioglu and M.R. Beasley, IEEE Trans. Appl. Supercond. 8, 48–53 (1998)

[2] K.K. Likharev and V.K. Semenov, IEEE Trans. Appl. Supercond. 1, 3–28 (1991)

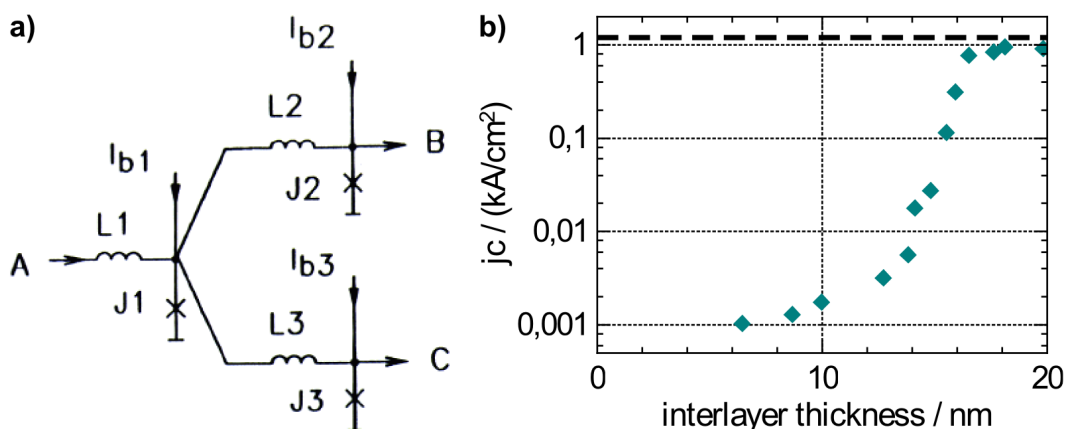


Fig. 2: a) A signal splitter in RSFQ logic contains the basic circuit elements inductance (L1, . . . ), current source ( $\downarrow$ ) and Josephson junction ( $\times$ ) (adapted from [2]); b) The critical current density of a SIsFS structure depends on the thickness of the interlayer superconductor (s). The horizontal dashed line indicates the limit given by the tunnel barrier (I).

Head of the group: Prof. Dr. H. Kohlstedt; Secretary: T. Bittner (50%)  
Technical Staff: Dipl.Ing.(FH) N. Röschmann

Scientific Staff:

M. Hansen	01.01.-31.12.2013	Stipendium
Dr. A. Petraru	01.01.-31.12.2013	CAU
N. Ruppelt	01.01.-31.12.2013	DFG
KO 1953/11-1, BA 521		
Dr. R. Soni	01.01.-31.12.2013	DFG
SFB 855		
Dr. O. Vavra	01.01.-31.10.2013	CAU
Dr. M. Ziegler	01.01.-31.12.2013	CAU

## Third-Party Funds

DFG, SFB 855, Teilprojekt A4, *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft*, 01.01.2009-31.12.2013 (268300 EUR)

DFG, *Semifluxons in ferromagnetic Josephson junctions*, 01.12.2010-30.11.2013 (211450)

BMBF era-nat, *Oxide Heterostructures*, 01.04.2013-31.03.2015 (24000)

## Diploma, Bachelor's and Master's Theses

Lasse Schenck, *Magnetoelektrische Sensoren mit epitaktischer Pufferschicht aus SrTiO<sub>3</sub>*, 06.02.2013

Alexander Chemnitz, *Simulation und Design eines lithographischen Prozesses zur Herstellung lateraler memristiver Bauelemente*, 10.03.2013

Mahal Sing Gill, *Digitale Nachbildung einer memristiven Schaltung zum Antizipationsverhalten einer Amöbe*, 17.03.2013

Philipp Keßler, *Fehleranalyse und Entwicklung eines Konzepts zur Fehlervermeidung von einer EMV-Belastung während Tieftemperatur-Messungen mit einem Thermostream*, 26.03.2013

Ole Thomsen, *Herstellung von Aluminiumnitrid-Tunnelbarrieren für memristive Josephson Tunnelkontakte*, 03.10.2013

Kay Robert Sörensen, *Signalerhöhung durch Reihenschaltung magnetoelektrischer Sensoren*, 25.10.2013

Fabian Matthes, *Entwicklung von hochohmigen AlN-Tunnelbarrieren für potentielle Anwendungen in Crossbar-Arrays und neuromorphen Schaltungen*, 26.03.2013

Matthias Bubolz, *Einfluss der Substratspannung auf den Metall-Isolator Übergang von dünnen Vanadiumoxidschichten*, 12.08.2013

Marina Ignatov, *Anwendung von Metall-Isolator-Übergangs-Kontakten für memristive Bauelemente*, 18.10.2013

## Publications

Published in 2013

N. Ruppelt, O. Vavra, H. Sickinger, E. Goldobin, D. Koelle, R. Kleiner, H. Kohlstedt, *Combinatorial sputtering in planetary type systems for alloy libraries with perpendicular gradients of layer thickness and composition realised by a timing approach*, Appl. Phys. A, (2013)

- M. Ziegler, H. Kohlstedt, *Mimic synaptic behaviour with a single floating gate transistor: A MemFlash synapse*, J. Appl. Phys., **114**, (2013)
- R. Soni, P. Meuffels, A. Petraru, M. Hansen, M. Ziegler, O. Vavra, H. Kohlstedt, D. S. Jeong, *Bipolar switching polarity reversal by electrolyte layer sequence in electrochemical metallization cells with dual-layer solid electrolytes*, Nanoscale, **5**, 12598 - 12606 (2013)
- E. Goldobin, H. Sickinger, M. Weides, N. Ruppelt, H. Kohlstedt, *Memory cell based on a  $\phi$  Josephson junction*, Appl. Phys. Lett., **102**, (2013)
- R. Soni, P. Meuffels, A. Petraru, O. Vavra, H. Kohlstedt, *Rate limiting step for the switching kinetics in Cu doped  $\text{GeO}_3\text{SeO}_7$  based memory devices with symmetrical and asymmetrical electrodes*, J. Appl. Phys., **113**, (2013)
- D.S. Jeong, I. Kim, M. Ziegler, H. Kohlstedt, *Towards artificial neurons and synapses: a materials point of view*, RSC Adv, **10**, 3169 - 3183 (2013)
- M. Ziegler, K. H. Ochs, M. Hansen, H. Kohlstedt, *An electronic implementation of amoeba anticipation*, Appl. Phys., (2013)
- N. Barrett et al., *Full field electron spectroscopy applied to ferroelectric materials*, J. App. Phys., **113**, 187217 (2013)
- O. Vavra, W. Pfaff, R. Monaco, M. Aprilli, C. Strunk, *Current-controllable planar S-(S/F)-S Josephson junction*, **102**, 072602 (2013)

## Presentations

- N. Ruppelt, *Towards  $\pi$  Josephson Junctions with Fe, Si based Barriers*, DPG-Frühjahrstagung, Regensburg, Germany, 10.-15.03.2013
- N. Ruppelt, *Josephson junctions with  $\text{Si/Fe}$  (ferromagnet) barriers*, International Summer School on Superconductivity - Theory, Experiments and Phenomena, Cargese, France, 05.-17.08.2013
- N. Ruppelt,  *$0-\pi$  Transitions in SIsFS Junctions*, Kryoelektronische Bauelemente 2013, Bad Herrenalb, Germany, 06.-08.10.2013
- A. Petraru, *Tuning the magnetoelectric properties of heteroepitaxial CFO/SRO/PZT/SRO films grown on piezoelectric PMN-PT substrates via strain*, MAMA-Trend: Trends, challenges and emergent new phenomena in multi-functional materials, Sorrento, Italy, 20.-23.05.2013
- M. Hansen, *An electronic implementation of amoeba anticipation*, DPG Frühjahrstagung, Regensburg, Germany, 10.-15.03.2013
- M. Hansen, *An electronic implementation of amoeba anticipation*, Arbeitskreistreffen für nicht-flüchtige Informationsspeicher, Kiel, Germany, 24.-24.04.2013
- M. Ziegler, *Memristive operation mode of floating gate transistors*, Arbeitskreistreffen für nicht-flüchtige Informationsspeicher, Kiel, Germany, 24.-24.04.2013
- H. Kohlstedt, *Digging Deep: A modified Total Electron Yield to Study Buried Material Properties in Oxide Devices by Soft X-Ray Absorption Spectroscopy*, 8th International Multifunctional Materials Workshop (MFM-8), Itamambuca, Brasil, 10.-14.11.2013
- H. Kohlstedt, *Memristive Devices in Analog Neuromorphic Circuits*, 4th Workshop on Nanotechnology for Microsystems, Bergen, Norway, 17.-19.06.2013
- M. Ziegler, *Memristive devices in analog neuromorphic circuits*, Universität Tübingen Physikalisches Institut, Experimental Physik II, Tübingen, Germany, 28.-28.08.2013
- M. Ziegler, *Memristive Bauelemente für analoge neuromorphe Schaltungen*, Kolloquium, Fakultät für Elektro- und Informationstechnik, Ruhr Universität Bochum, Bochum, Germany, 30.-30.10.2013
- H. Kohlstedt, *Artificial Nanocomposites: Towards Magnetoelectric Materials-by-Design: kick-off meeting*, Konferenz - era-net BMBF- No 133 NANO-C, Paris, France, 19.-19.02.2013
- H. Kohlstedt, *Resistive Switching*, International School of Oxide Electronics (ISOE 2013), Cargese, France, 02.-14.09.2013

## **Further Activities and Events**

N. Ruppelt, 44th IFF Spring School „Quantum Information Processing“, Jülich, 25.02 - 08.03.2013

Head of Examination Committee and Students Contact Person (W. Ing.)

Head of Engineering Branch Library (Technical Faculty, East Cost)

Representative of the ETIT (CAU Kiel) of the Fakultätsentag der Elektrotechnik und Informationstechnik (FTEI)

Member of the Examination Committee: Material Science

Member of the Examination Committee: Digital Communication

Host of the yearly workshop on the Non-Volatile Random Access Memories, held in the Technical Faculty of Kiel, 24.04.



## Power Electronics and Electrical Drives

The year 2013 has been a year of transition for the chair and the team and we think we managed it very well. On the 31st march 2013 Prof. Fuchs retired, officially, but in the following three years he will continue doing research (and teaching if necessary), managing his current research projects and team members, as well as supervision of students' theses. On the 16th of September 2013 Prof. Liserre took over the responsibility of the Chair of Power Electronics with new ideas and new projects. Prof. Liserre and Prof. Fuchs and their teams will work in future years in good cooperation. The name of the chair has slightly changed from the former name of Chair for Power Electronics and Electrical Drives.

The work of both professors and of their respective teams led the chair to expand its activities further, already starting in 2013. New research subjects are active thermal control of power converters, reliability and robust design, solid-state transformers and their impact on the power system, and multi-frequency and wireless power conditioning.

In fact in November 2013 Prof. Liserre was awarded a EU-funded ERC Consolidator Grant, „The Highly Efficient And Reliable smart Transformer (HEART)“, a new Heart for the Electric Distribution System; this is worth 2 MEuro to be spent over 5 years. This project will involve 5 PhDs and Post-Docs and many guest researchers and professors. It will be a flagship research project for the Chair of Power Electronics. It will be developed in a newly established High-Voltage and High-Power laboratory with facilities for reliability testing, efficiency and thermal verification of power converters, and grid-integration testing with an RTDS system. The project will benefit from cooperation with Aalborg University, and especially with the CORPE (Centre Of Reliable Power Electronics). The main findings of the project will be useful also for industries interested in high-power and high-voltage power electronics and in general for the industries of Schleswig-Holstein involved in power electronics, electric drives, and smart grid technologies.

The research fields of the chair are now expanded to: power conversion for renewable energy, grid integration for renewable energy, electromobility, converter control, reliability, and the Smart Transformer. The research results of the chair are documented in 12 publications at conferences and three in journals. Four doctoral theses (see internet) have been completed under the supervision of Prof. Fuchs. The research cooperation with industrial companies has been enhanced. Technology transfer is still an important aspect of our research work and has been continued, also in small projects with industry. There is again high activity of the chair in the competence centre of Innovation Cluster Renewable Energy. Concerning research infrastructure we have put into operation a microgrid for the analysis of the grid integration of renewables. Prof. Fuchs and Prof. Liserre have been very active managing the chair and research projects and acquiring projects. Prof. Fuchs and his team kept the chair full running in summer 2013 despite his retirement. Additionally both professors were supporting conferences, for example as topic chairs, and journals, for example as associate editors. Our teaching activities were continued at full volume, the responsibility being slightly transferred to Prof. Liserre and his team. Again a high number of 24 bachelor's and master's theses, (all very good and some excellent), have been finished. We continued our activities in motivating young people for the field of technology with a guided visit to the Hannover Industry Fair for 40 senior class pupils, and a three day event, Power Girls and Power Boys, for 10 to 12 year old pupils to get into contact with energy and renewables.

### Results

#### **ERC Consolidator Grant: The Highly Efficient And Reliable smart Transformer (HEART), a new Heart for the Electric Distribution System, 2014-2018**

The *Smart Transformer* will be based on a modular architecture of units made by power electronics converters; it will be able to manage the energy and the information flows among sources and loads in the distribution area with the goal of decoupling it from the rest of the bulk power system. Actual proposals of Smart Transformers cannot compete in terms of cost, efficiency and reliability with traditional transformers. This project has decided to take this challenge with a paradigm shift in how to approach it. The breakthrough results of this research will be obtained by taking the following high-risk,

high-gain bet: significantly influence the efficiency and the reliability of the Smart Transformer by routing the energy flows among its power converter units, and inside them among the power modules.

## Our Idea of future

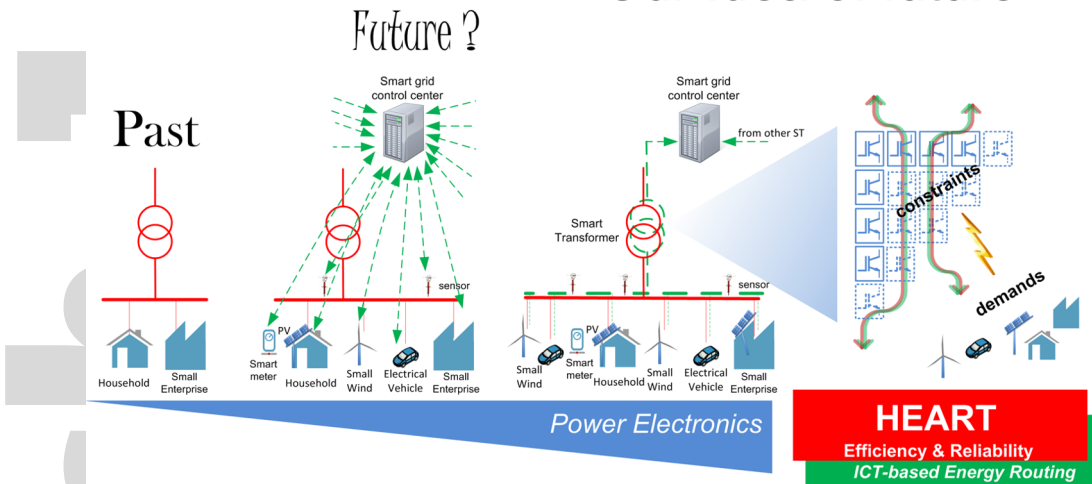


Fig. 1: The flagship research for the Chair of Power Electronics

### Grid-adaptive Control and Active-Filter Functionality of grid-connected PWM-inverters in Wind Energy Applications (Nils Hoffmann)

The performance of the mains with power fed in from distributed regenerative power generation is dependent on the line-impedance. This is usually not constant, but time and frequency dependent, especially in weak grid conditions. In this research project it has been investigated how different grid-adaptive control strategies for grid-connected PWM converters in distributed regenerative power generation applications are operating, by using conventional and modern control methods. The grid-adaptive converter control is based on an estimation of the line-impedance in a frequency range up to 10 kHz and leads to a reduction or elimination of current harmonics in the lower-frequency range (Active-Filter functionality), a compensation of reactive power components as well as grid-voltage and current unbalances, all in addition to the fundamental power feed-in. Furthermore, the grid-adaptive PWM converter control and hardware should be designed to reduce the feed-in of higher-frequency harmonic current components. The research project was successfully concluded in summer 2013.

### Development of a battery back-up system with power management in electric vehicles with 24/ 48 V, 5-20 kVA (Jens Schröder)

In this project, a battery back-up system has been developed for electrical drives which are fed by a battery via a converter. The system enables disburdening of the battery and smoothing of the supply voltage. It consists of a DC/DC converter and double layer capacitors in which the energy can be stored at braking. In addition, a higher-level power management has been developed, which controls the restoration of energy into the system at the proper time. An efficient multi-phase DC/DC converter with interleaved technique has been designed and a power management system has been developed. For optimization of the inductors of the system, the possible use of coupled inductors was analyzed and the properties were compared to the discrete case. A coupled inductor is designed and integrated in the DC/DC converter. The battery back-up system developed has been implemented in the laboratory and the operation of the drive system with and without battery back-up has been compared. It could be shown that the battery support system with active power management is able to relieve the vehicle battery strongly. Finally, the support system in a compact mobile version was constructed and tested successfully in a prototype vehicle.

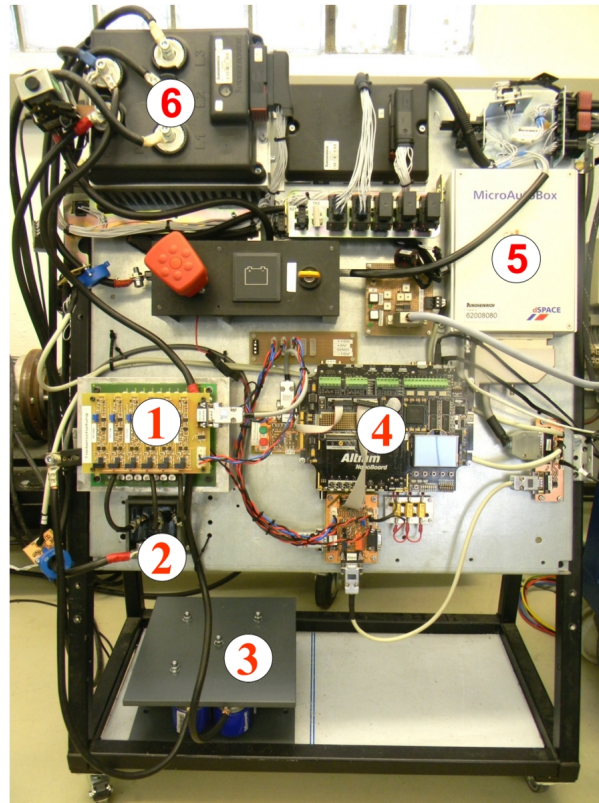


Fig. 2: Battery Buffer System for E-Vehicle: electronic components of the laboratory test bench (1: DC/DC converter and drivers, 2: coupled three phase inductor, 3: EDLC module, 4: FPGA board, 5: dSpace Autobox, 6: DC/AC-converter)

### Analysis of multilevel inverters and new power semiconductors for photovoltaic applications (Fabian Gebhardt)

Photovoltaic (PV) power plants will play a significant role in the future energy mix. Decreasing costs of PV modules allow the cost-effective installation of big PV plants. Limitations of classical two level inverters regarding power quality and efficiency can be eliminated with multilevel topologies. These topologies reduce the filter effort and so the total inverter costs, weight, and volume can be lowered in spite of the higher complexity. In this research project, different multilevel topologies for photovoltaic applications are investigated concerning efficiency, filter design, PWM techniques, and driver circuits. Furthermore, PV specific tasks (e.g. leakage currents) have to be solved. It has been shown that a MOSFET based Modular Multilevel Converter (M2C) is suitable even for the low voltage grid. This year, different modulation and balancing methods of the five level laboratory setup were investigated by simulation and experiment in the laboratory.

### Investigation on Autonomous Controlled Inverters in Microgrids to Improve Control Behaviour in Case of Grid Voltage Disturbances (Jan Reese)

To ensure voltage quality and the stable operation for decentralized power production and growing density of power converters in the distribution grid, new approaches for the control of each autonomous inverter are required. In this research work the improvement of the control behaviour of parallel acting, autonomous controlled inverters in microgrids has been investigated. A microgrid is a cluster of power converters (generation, consumption, storage) that can be operated in parallel or isolated from the main grid. For the analysis, interactions between parallel acting inverters are identified and used to enhance the voltage quality and stability of microgrids under stationary and transient grid faults, with conventional and modern control methods for the converters. Concerning harmonics and asymmetries in the grid voltage, improvements are revealed in stability, dynamics, and power quality. A laboratory test bench of a microgrid has been put into operation.

### **Grid Integration of Wind Turbines with Energy Storage System (Sönke Grunau)**

The aim of this research project is to analyze and compare possible applications and ratings of distributed and aggregated energy storage systems (ESS) and their concepts to improve the grid integration of wind turbines (WT). In 2013 it could be shown that power reserves for frequency regulation purposes by WTs can be provided economically by ESS, even with given conditions. Also the provision of an emulated inertial response by WTs was investigated by the use of the kinetic energy of the rotor. In the case of a frequency drop the overall behaviour in terms of grid stability can be improved. The inertial response can be emulated more freely, especially by the use of an ESS, and the impact on frequency stability can be optimized. Furthermore the potential of an ESS to reduce possible deficits resulting from an active power ramp-rate-limitation (RRL) was investigated. By means of the results the required size of an ESS can be deduced. Also an energy storage emulator (ESE) was constructed and built. It has a power rating of 10 kW and consists of a line side converter, a DC-link and a three level DC/DC converter. At the output terminals a voltage is controlled by means of a PM which behaves like an electrical storage unit. By means of a three phase interleaved DC/DC converter, which is under construction at present, the ESE will be connected to the DC link of a WT laboratory setup.

### **Design, construction, implementation, and use of a low voltage-medium frequency-current generator for grid impedance analysis (Sandro Günter)**

Due to the increasing number of distributed generation systems in the low voltage grid, their integration has to be well analysed. In order to determine and predict the effect of distributed generators on the low voltage grid the knowledge of the frequency-dependent grid impedance is necessary. The aim of this project is to measure the frequency-dependent grid impedance at frequencies from 0.1 up to 30 Hz and from 70 Hz up to 10 kHz. This is done by means of the feed-in of a defined current at a defined frequency and measuring the resulting voltage drop on the grid impedance. A special device for this feed-in is being developed with a maximum power of approximately 40 kVA. In 2013, a special gate-drive-circuit for high switching frequencies was developed that fulfils special requirements, e.g. EMC. There was a power unit designed and constructed. Furthermore, a special hysteresis current control for optimal inverter operation was developed.

### **Electric Propulsion Drive Train - highly efficient and robust electric propulsion drives including battery buffering system for working vehicle (Stephan Bröske)**

Global mobility and the oil shortages have moved electromobility, i.e. electrical propulsion into the focus of society, politics and research. The objective of this working package of Interreg 4a eMOTION project is to investigate and improve the electric propulsion drive train of an electric vehicle or a working vehicle. The drive power is chosen to be 40 kW and 800 V input voltage. Possible drive train topologies have been compared and one topology has been selected for further investigations. The selected topology consists of the battery, the motor, the inverter and an additional DC/DC converter. The DC/AC inverter is one of the main subjects. Two inverter topologies, the NPC and the T-type inverter, have shown great promise as an alternative for the common 2-level voltage source inverter. A simulative comparison revealed that the NPC is superior for switching frequencies above 20 kHz. The NPC was realized in the laboratory with IGBTs at the end of 2013. For the emulation of the battery voltage a grid converter with an interleaved buck converter is used. The variable DC input voltage provided by the DC/DC converter could be used to adapt the voltage level to the operating conditions of the machine, i.e. addressing other optimization objectives as loss minimization.

### **Analysis and optimization of a small wind turbine system (Kristina Buchert)**

The aim of this research project is the optimization of small wind turbines (SWT). Generator and converter topologies are analyzed for their suitability in small wind turbines and designed and tested in the laboratory. A focus is to exploit gusts of wind speed as well as the net integration. For the customer a cost-effective system has to be found, which has a high efficiency. Small wind turbine systems (SWTS) consist of a rectifier topology, a DC link circuit, and an inverter topology. Several converter topologies can be chosen such as diode rectifier, half or full bridge rectifier; these differ in the number of necessary power semiconductors and have been analysed in this project. Necessary for operation is a sufficient DC voltage, i.e. higher than 565 V for the 400 V mains, which determines the operation range of the different converter systems and

the possibility of Maximum Power point Tracking. The Maximum Power Point Tracking allows a high output power, whilst it has to react quickly to gusts of wind as well as provide low costs. Promising methods are analyzed and combinations of various methods are examined. The Switch Mode Rectifier has good properties to meet the requirements of low costs whilst providing a high output power and also will be analysed in the laboratory.

### **Optimization of Inductive Power Transfer Systems for Electric Vehicles in Vehicle-to-Grid Applications (Marinus Petersen)**

Inductive Power Transfer (IPT) Systems are a promising solution for recharging hybrid and electric vehicles. They can enhance the acceptability of such vehicles. The objective of this project is the further technical development of IPT systems with focus on Vehicle-to-Grid applications. Several optimization methods (new semiconductor materials, components, and topologies) will be analyzed to reach the highest possible efficiency, which should be above 90 %. Comprehensive investigations have been performed concerning the four basic resonant topologies SS, SP, PS and PP. It appeared that the SS topology especially is suitable for the bidirectional IPT system because of its advantages (zero phase angle at resonance frequency, load and coupling independence of primary capacity). Furthermore, a magnetic coupler (500x640 mm) for mounting under the vehicle's chassis was developed for nominal power of 5 kW. To maximize the coupling coefficient while keeping the ferrite volume as small as possible, a configuration of 16 concentrically arranged ferrite bars was chosen. Compared with a solid ferrite plate the volume could be decreased by 58 %. Apart from theoretical analyses, a lab setup is under operation.

### **Investigation of interactions between renewable energy resources in electrical power grids with high amount of converters (Lars Jessen)**

Due to growing feed-in of electrical energy from renewable sources and connection of converter control loads the behaviour of the power system in the steady-state operation as well as in the voltage sag transient response is changing. The goal of this research project is to analyze the voltage support capabilities during voltage sags by several parallel renewable energy resources. This will be done in a microgrid connected to the main grid. Especially, the interactions between the renewable energy resources and the interactions between the microgrid and the power system will be examined. Subsequently, strategies will be developed to increase the transient stability of microgrids and dampen transient phenomena due to voltage sags. The separation of microgrids during short voltage sags is prohibited, in order to simultaneously increase the robustness of the upstream network. Therefore, the power at the point of common coupling (PCC) should be similar before and after the voltage sag.

### **Optimization of a Power Stack for Wind Turbines (Berthold Benkendorff)**

In this research project the optimization of an inverter for a wind turbine generator, regarding volume, efficiency, reliability, and maintenance effort, is the main subject. Under these boundary conditions, a 1 MW power inverter needs to be designed, constructed, and tested. The construction of such an inverter consists of a power unit including cooling unit and a central control unit. In 2013, the electrical behaviour of a suitable topology for the base plate inverter was simulated. The losses of the inverter system were examined. The low-inductance design of the inverter and the integration of the driver circuit were designed together with project partners. The 3-level power semiconductor module of the inverter, developed by other partners in the project, was measured and characterized. The driver is now being put into operation; operation of the full inverter starts in 2014. To increase the energy density and to improve the efficiency research on active control of the switching behaviour of the power semiconductor is required. A comprehensive analysis will follow.

### **Active thermal control for power electronic modules (Markus Andresen)**

Some applications in power electronics have extremely high safety standards that set high demands on the reliability of the single devices. Examples of this are electric cars and airplanes, which have a lifetime of up to 20 years during which the modules have to operate fault free. To guarantee this, the errors need to be minimized. The aging and wearing out of the power electronic modules is strongly affected by heating and cooling. This can be explained with the multilayer structure

of the modules, which consists of copper for the heat transfer and substrate for the electrical isolation. These materials have different coefficients of thermal expansion, which affects mechanical stress between the layers in case of temperature variations. The result is aging, which leads to common failures like solder fatigue and bondwire lift off. For solder fatigue, this problem occurs between substrate and chip or between baseplate and substrate. A stress reduction can be achieved by reducing the number of thermal cycles and the accompanying temperature swings. In this project, the lifetime and the reliability of the power electronic modules has to be increased with active thermal control. The thermal cycles should be reduced with the controller, whereby either the losses can be minimized or additional losses can be generated. In multilevel inverters or in parallel devices it is also possible to share the power intelligently. On a test bench, several approaches for active thermal control should be implemented and tested. A possible lifetime extension should be evaluated.

### **Analysis of Smart Transformer features for electric distribution (Giovanni De Carne)**

The presence of distributed generations, as well as other renewable resources (batteries, flywheels, etc.), has changed the way that energy is provided to the user. The traditional transformer can no longer guarantee optimal performance, in terms of voltage and current profile, when a bidirectional power flux occurs. The Smart Transformer represents a more flexible system that adapts itself as a function of grid needs, and provides a good power quality to the users at the same time. The Smart Transformer can provide several services to the grid: on-line voltage profile optimization, current congestion management, and reduction of harmonics magnitude. The planned research field can be divided into three main topics. The first topic regards the static optimization of the network by means of a Smart Transformer. It aims to improve the voltage profile along the grid and solve the current congestion caused by the distributed generation. The Smart Transformer can also accomplish the reduction of the impact of harmonics on the grid. The second topic regards the dynamic optimization during a perturbation caused by faults or voltage drops. The Smart Transformer can dampen any perturbations thanks to the high dynamic control. The third topic regards the validation of the Smart Transformer by means of RTDS, that allows the substitution of the real grid by means of hardware. The Smart Transformer will be connected in the hardware in-loop mode. This analysis will validate the simulation findings.

### **Condition Monitoring for Frequency Inverter and Control of Generators in Wind Turbines (Matthias Böttcher)**

Fault tolerance of wind turbines, particularly in hard-to-reach areas such as offshore, is of increasing importance. The converter there has a particular importance as it shows statistically a higher probability of failure compared to other components. This project deals with strategies with regard to offshore applications of wind turbines to increase the availability of the converter in wind turbines. Fault-tolerant converter topologies and control methods as well as methods for early fault detection and prognosis are in the focus of these investigations. Within the project various fault tolerant converter topologies have been studied in terms of their suitability for use in wind turbines. It was shown that with the help of a specially modified three-level neutral-point-clamped (NPC) inverter nearly as large an increase in reliability can be reached as in a fully redundant drive, but at lower total cost. Furthermore, there are advantages in the performance of the inverter by additional degrees of freedom in the control. Studies on control of fault tolerance have deepened and the simulations are compared with laboratory measurements.

## **Personnel**

Head of the group: Prof. Dr.-Ing. F.W. Fuchs, Prof. Dr.-Ing. Marco Liserre; Secretary: P. Bekendorf, M. Marter  
Technical Staff: B. Doneit

Scientific Staff:

M.Sc. M. Andresen

23.09.-31.12.2013

CAU

Active thermal control for power electronic modules



Dipl. - Wirtsch.-Ing. B. Benkendorff	01.01.-31.12.2013	Zukunftsprogramm SH/Industrie
Optimization of a Power Stack for Wind Turbines		
Dipl. - Wirtsch.-Ing. St. Brüske	01.01.-31.12.2013	Interreg
Electric propulsion drive trains - high efficient and robust electric propulsion drives including battery buffering system for working vehicles and cars		
Dipl. - Wirtsch.-Ing. K. Buchert	01.01.-31.12.2013	EKSH/ Industrie
Analysis and optimization of a small wind turbine system		
Dipl.- Ing. M. Böttcher	01.01.-31.03.2013	Zukunftsprogramm SH/ Industrie
CEwind - Kompetenzzentrum Windenergie S-H Phase II: Condition Monitoring for frequency inverters and control of generators in wind power stations		
M.Sc. G. De Carne	01.-31.12.2013	CAU
Analysis of Smart Transformer features for electric distribution		
Dipl.- Ing. F. Gebhardt	01.01.-31.12.2013	CAU
Analysis of Multilevel Inverters and New Power Semiconductors for Solar Applications		
Dipl. - Wirtsch.-Ing. S. Grunau	01.01.-31.12.2013	CAU
Wind Turbines and Energy Storage Systems		
M.Sc. S Günter	01.01.-31.12.2013	BMU
Development of a current generator to measure the frequency dependent low voltage grid impedance		
Dipl.- Ing. N. Hoffmann	01.01.-31.12.2013	Zukunftsprogramm SH/Industrie
CEwind - Kompetenzzentrum Windenergie S-H Phase II: Grid-adaptive control and active-filter functionality of grid-connected converters in wind turbine applications		
M. Eng. L. Jessen	01.01.-31.12.2013	Stipendiat
Investigation of interactions between distributed generation in electrical power systems with a high penetration of converters		
Dipl. - Wirtsch.-Ing. M. Petersen	01.01.-31.12.2013	EKSH/ Industrie
Inductive Charging for Electric Vehicles		
Dipl. - Wirtsch.-Ing. J. Reese	01.01.-31.12.2013	CAU
Investigation on autonomous controlled inverters in microgrids		
Dipl.-Ing. J. Schröder	01.01.-31.03.2013	Frauenhofer ISIT/Land SH
Battery Buffer System and Power Management		

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2012/2013*

Power Electronics I- Basics, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F.W. Fuchs (+ M. Petersen)

Power Electronics III- Electrical drives, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F.W. Fuchs (+ B. Benkendorff)

Control of Electrical Drives, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F.W. Fuchs (+ K. Buchert)

Power Electronics - laboratory course, Master´s, 4 hrs Lab/Week,  
F. W. Fuchs (+ F. Gebhardt, J. Reese, S. Grunau, B. Benkendorff, K. Buchert, S. Günter, L. Jessen)

Seminar on Power Electronics, 2 hrs Seminar/Week,  
F.W. Fuchs (+ J. Reese, K. Buchert, M. Petersen, St. Bröske, S. Grunau, B. Benkendorff)

Power Electronics - excursion, 1 hrs excursion/Week,  
F.W. Fuchs (+ K. Buchert, B. Benkendorff)

Power Electronic Generator Systems for Wind Turbines, 3 (+ 1) hrs Masters Study course Wind Engineering in CEwind  
(+ Exercises)/Week,  
F.W. Fuchs (+ S. Grunau, F. Gebhardt, St. Bröske, B. Benkendorff, K. Buchert)

Renewable Energy Systems II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F.W. Fuchs (+ J. Reese, F. Gebhardt)

### *Summer 2013*

Basics of electrical energy systems and power engineering, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
Michael Bierhoff (+ S. Grunau)

Power Electronics II - Advanced, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
F.W. Fuchs (+ St. Bröske)

Renewable Energy Systems I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F.W. Fuchs (+ S. Grunau)

Power Electronics - laboratory course, Bachelor´s, 4 hrs Lab/Week,  
F.W. Fuchs (+ F. Gebhardt, J. Reese, K. Buchert, St. Bröske, S. Günter, M. Petersen)

Seminar on Power Electronics, 2 hrs Seminar/Week,  
F.W. Fuchs (+ J. Reese, K. Buchert, St. Bröske)

Power Electronics - excursion, 1 hrs excursion/Week,  
F. W. Fuchs (+ J. Reese)

Microprocessors for real-time control, 1 (+ 1) hrs Lecture (+ Exercises)/Week,  
T. Leifert (+ S. Günter)

### *Winter 2013/2014*

Power Electronics I- Basics, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F.W. Fuchs (+ M. Petersen)

Power Electronics III- Electrical drives, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F.W. Fuchs (+ B. Benkendorff, K. Buchert, St. Bröske, M. Petersen, M. Andresen, S. Günter)

Control of Electrical Drives, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Marco Liserre (+ M. Andresen, G. De Carne)

Power Electronics - laboratory course, Master´s, 4 hrs Lab/Week,  
Marco Liserre (+ M. Andresen, B. Benkendorff, K. Buchert, S. Günter, G. De Carne, H. Jedtberg)

Seminar on Power Electronics, 2 hrs Seminar/Week,  
Marco Liserre (+ K. Buchert, M. Petersen, St. Bröske, M. Andresen, B. Benkendorff, S. Günter)



Power Electronics - excursion, 1 hrs excursion/Week,  
Marco Liserre (+ K. Buchert, B. Benkendorff)

Power Electronic Generator Systems for Wind Turbines, 3 (+ 1) hrs Masters Study course Wind Engineering in CEwind  
(+ Exercises)/Week,  
F.W. Fuchs (+ St. Bröske, B. Benkendorff, K. Buchert, M. Petersen)

Renewable Energy Systems II, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Marco Liserre (+ M. Andresen, G. De Carne, H. Jeditberg, S. Bröske)

## Third-Party Funds

EU/State SH (CE wind combined project), *Grid-adaptive control and active-filter functionality of grid-connected converters for wind-turbine applications*, 01.10.2008-30.06.2013 (361.978 EUR)

EU/State SH (CE Wind combined project), *Condition Monitoring for frequency converters at wind turbine generators*, 01.10.2008-31.03.2013 (100.000 EUR)

BMU/Industry, combined project FH Kiel, *Low voltage Grid Analysis - Power current generator for grid impedance measurement*, 01.02.2012-31.01.2015 (326.000 EUR)

Interreg (EU), *Optimization of the drive for electric cars*, 01.02.2012-31.01.2013 (270.000 EUR)

Fraunhofer/State Schleswig-Holstein/Industry, combined project FH Kiel, FH Westküste, ISIT, Innovation cluster Renewable Energy, *Optimization of a 1 MW power converter for wind turbines*, 01.07.2012-31.08.2015 (250.000 EUR)

EKSH/Industry, *Analysis and optimization of power converter systems for small wind turbines*, 15.02.2012-31.03.2015 (178.300 EUR)

EKSH/ Industry, *Optimization of inductive charging for E-vehicles and vehicle to grid technology*, 01.04.2012-31.07.2015 (160.000 EUR)

Industry, *Grid adaptive control of Active Rectifiers*, 01.04.2011-31.03.2013 (9.000 EUR)

Industry, *Grid adaptive control of Active Rectifiers*, 01.06.2010-31.03.2013 (12.000 EUR)

Industry, *Influence of regenerative power feed in on grid performance/current control*, 15.05.2012-31.01.2013 (55.000 EUR)

Industry, *Control of a brake*, 01.11.2012-31.03.2013 (40.000 EUR)

Industry, *Battery back-up system for E-vehicles*, 01.01.2013-30.06.2015 (15.900 EUR)

Industry, *Analysis of a converter fed six-phase generator for wind turbines*, 01.02.-30.06.2013 (19.000 EUR)

## Diploma, Bachelor's and Master's Theses

R. Kulpe, *Untersuchung und Optimierung von Regelungsverfahren für interleaved betriebene bidirektionale DC/DC-Umrichter*, 15.01.2013

A. Wutzke, *Analyse und Verbesserung dynamischer Netzstützung parallel arbeitender Energieerzeuger*, 13.02.2013

K. Genzmer, *Theoretische, simulative und experimentelle Untersuchungen zur Übertragungsfrequenz eines induktiven Ladesystems für Elektrofahrzeuge*, 19.02.2013

H. Günther, *Untersuchungen zum Konzept eines Messstromgenerators für die Netzanalyse im Mittelspannungsnetz*, 28.02.2013

J. Kickstein, *Einfluss von Frequenzregelung und Spannungshaltung durch Windenergieanlagen mit Energiespeichersystem und FACTS-Funktionalität auf das Stromnetz*, 29.04.2013

D. Janning, *Oberschwingungskompensation durch parallele Umrichter in schwachen und isolierten Netzstrukturen*, 06.05.2013

T. Plöhn, *Entwicklung und Implementierung einer Frequenzregelung für ein induktives Ladesystem von Elektrofahrzeugen*, 06.05.2013

- J. Falk, *Regelung einer elektrischen Last zur Erzeugung eines ohmsch-induktiven Verhaltens durch einen Umrichter*, 08.05.2013
- St. Suhr, *Untersuchung der Ausbreitung und Überlagerung von Harmonischen und Interharmonischen in einem Windpark*, 15.05.2013
- J. Hein, *Auslegung und Optimierung von Primär- und Sekundärspule eines induktiven Ladesystems für Elektrofahrzeuge mittels 3D-Simulation*, 26.06.2013
- F. Hahn, *Analyse und Vergleich zweier DC/AC-Umrichtervarianten für den Einsatz im Elektrofahrzeug*, 28.06.2013
- H.S. Steude, *Untersuchung des Einsatzes eines DC/DC-Stellers zwischen Batterie und Fahrumrichter im elektrischen Fahrantriebsstranges eines Elektrofahrzeuges*, 28.06.2013
- S. Münzberg, *Untersuchung und Charakterisierung von Speicher-technologien zur Anwendung in einem Energiespeichersystem an Windenergieanlagen*, 08.07.2013
- H. Jedtberg, *Netzintegration von Windenergieanlagen mit Doppelt-Gespeister Asynchronmaschine und Emulated Inertia Control*, 08.07.2013
- F. Palm, *Untersuchung von Maximum Power Point Tracking Verfahren beim Einsatz in Kleinwindenergieanlagen*, 19.07.2013
- V. Varain, *Entwicklung einer Gate-Treiber Schaltung für hohe Schaltfrequenzen*, 24.07.2013
- H. Kuhlmann, *Konzeption und Realisierung einer Active-Gate-Control-Treibereinheit für Superjunction MOSFETs durch eine veränderliche Gatespannung*, 29.07.2013
- F. Gärtner, *Untersuchung von Einspeisebegrenzungen durch maximale Einspeise-Steigerungsraten in Netzanschlussregeln und Nutzungspotentiale durch Energiespeichersysteme*, 29.07.2013
- L. Wunderlich, *Simulative und praktische Untersuchung resonanter Topologien von induktiven Ladesystemen für Elektrofahrzeuge*, 23.09.2013
- C. Wacker, *Untersuchungen von SiC-MOSFETs bezüglich der Verlustleistung bei hohen Schaltfrequenzen*, 27.09.2013
- A. Göken, *Untersuchung von Regelstrategien und diskontinuierliche PWM-Verfahren für die permanenterregte Synchronmaschine*, 16.10.2013
- C. Krawczyk, *Entwicklung und Inbetriebnahme einer schnellen, hochauflösenden AD-Wandlerschaltung für ein induktives Ladesystem für Elektrofahrzeuge*, 18.10.2013
- S. Brüske, *Entwicklung einer hocheffizienten netz- und fahrzeugseitigen Leistungselektronik mit übergeordneter Regelung für ein induktives Ladesystem mit Rückspeisefunktionalität (Vehicle-to-Grid)*, 31.10.2013
- H. Martens, *Untersuchung von Modulationsverfahren für den Halbbrückengleichrichter beim Einsatz in Kleinwind-energieanlagen*, 05.11.2013

## Dissertations / Postdoctoral Lecture Qualifications

- W.-T. Franke, *Vergleich von Siliziumkarbid-Leistungshalbleitern und ihre Anwendung in einem wirkungsgradoptimierten PVWechselrichter*, 14.01.2013
- S. Thomsen, *Drehzahlregelsverfahren für Antriebssysteme mit schwingungsfähiger Last unter Berücksichtigung verschiedener mechanischer Antriebsparameter, Auslegung, Analyse und Vergleich*, 01.02.2013
- O. Mühlfeld, *Charakterisierung und Optimierung parasitärer Elemente in Umrichtern mit niedrigen Zwischenkreisspannungen und hohen Betriebsströmen*, 19.02.2013
- A. Knop, *Entwicklung eines schnelltaktenden Umrichters für die Netzimpedanzanalyse*, 12.07.2013

## Publications

Published in 2013

- R. Peña-Alzola, M. Liserre, F. Blaabjerg, R. Sebastián, J. Dannehl, F.W. Fuchs, *Analysis of the Passive Damping Losses in LCL-Filter-Based Grid Converters*, Power Electronics, IEEE Transactions on, **6**, 2642 - 2646 (2013)

- M. Böttcher, J. Reese, F.W. Fuchs, *Reliability Comparison of Fault-Tolerant 3L-NPC Based Converter Topologies for Application in Wind Turbine Systems*, Proc. of IECON, (2013)
- S. Brüske, F.W. Fuchs, *Active Gate Control Methods for the Turn-On of High-Voltage Power MOSFETs in Hard Switching Applications*, PCIM Europe, (2013)
- T. Endres, J. Schröder, F.W. Fuchs, *Reduction of switching losses in bidirectional DC/DC converters for automotive use*, Power Electronics and Applications (EPE), (2013)
- F.W. Fuchs, J. Schröder, B. Wittig, *State of the technology of power loss determination in power converters*, Power Electronics and Applications (EPE), (2013)
- S. Günter, F.W. Fuchs, *A Method to Measure the Network Harmonic Impedance*, PCIM Europe, (2013)
- S. Grunau, J. Reese, L. Jessen, F.W. Fuchs, *Aspects of Grid Integration of Renewable Energy Sources in Weak Power Systems*, ETG, (2013)
- S. Grunau, F. Gaertner, F.W. Fuchs, *Quantification of Losses Regarding Active Power Injection due to New Grid Code Requirements*, Wind Integration Workshop London, (2013)
- M. Petersen, F.W. Fuchs, *Comparative Study on Optimal Core Design for Maximizing the Coupling Coefficient in Electric Vehicle Inductive Power Transfer Systems*, PCIM Europe, (2013)
- J. Reese, D. Janning, F.W. Fuchs, *Evaluation of Harmonic Compensation Algorithms with Parallel Autonomously Controlled Inverters in Isolated Microgrids*, Proc. of IECON, (2013)
- C. Wessels, N. Hoffmann, M. Molinas, F.W. Fuchs, *StatCom control at wind farms with fixed-speed induction generators under asymmetrical grid faults*, Industrial Electronics, IEEE Transactions on, **7**, 2864 - 2873 (2013)
- R. Peña-Alzola, M. Liserre, F. Blaabjerg, R. Sebastián, J. Dannehl, F.W. Fuchs, *Systematic Design of the Lead-Lag Network Method for Active Damping in LCL-Filter Based Three Phase Converters*, Industrial Informatics, IEEE Transactions on, **1**, 43 - 52 (2014)

## Presentations

- B. Benkendorff, *Optimierung eines Stromrichtersatzes - Entwicklungspotential der Komponenten des Stromrichters*, Industrie, 25.01.2013
- B. Benkendorff, *Optimierung eines Stromrichtersatzes - Forschungs- und Entwicklungsarbeiten*, Industrie, 04.02.2013
- B. Benkendorff, *Fortschritte der Leistungselektronik - Themenbereich Leistungshalbleiter*, Industrieseminar, 19.03.2013
- B. Benkendorff, *Optimierung eines Stromrichtersatzes - Verlustleistungssimulation*, Industrie, 08.05.2013
- B. Benkendorff, *Optimierung eines Stromrichtersatzes - Verlustleistungssimulation*, intern, 23.05.2013
- B. Benkendorff, *Optimierung eines Stromrichtersatzes - Zwischenkreis, Verschienungskonzept und Treiber*, Industrie, 12.07.2013
- B. Benkendorff, *Optimierung eines Stromrichtersatzes - TMB-Treffen*, Industrie, 13.09.2013
- B. Benkendorff, *Konzipierung, Optimierung und Realisierung eines Drei-Level-Niederspannungs-umrichters für MW-Windenergieanlagen*, 1. Workshop: Innovationscluster Leistungselektronik für Regenerative Energieversorgung, 26.11.2013
- B. Benkendorff, *Konzipierung, Optimierung und Realisierung eines Drei-Level-Niederspannungs-umrichters für MW-Windenergieanlagen - P3L NPC IGBT-Treiber*, intern, 17.12.2013
- St. Brüske, *Untersuchung des elektrischen Antriebsstrang von Elektrofahrzeugen*, Industrie, 20.02.2013
- St. Brüske, *Untersuchung des elektrischen Antriebsstrang von Elektrofahrzeugen*, Industrie, 19.04.2013
- St. Brüske, *Konzept und Auslegung des elektrischen Fahrantriebsstranges*, intern, 07.05.2013
- St. Brüske, *Untersuchung des elektrischen Antriebsstrang von Elektrofahrzeugen*, Industrie, 30.05.2013
- St. Brüske, *Untersuchung des elektrischen Antriebsstrang von Elektrofahrzeugen*, Industrie, 01.07.2013
- St. Brüske, *NPC für den Einsatz als Antriebsumrichter in Elektrofahrzeugen*, intern, 17.12.2013
- K. Buchert, *Aufbau und Inbetriebnahme einer elektrischen Last*, intern, 07.05.2013
- K. Buchert, *Vergleich von Gleichrichtertopologien für den Einsatz in Kleinwindenergieanlagen*, intern, 12.12.2013

- F.W. Fuchs, *Antriebstechnik für Elektrofahrzeuge*, 1. Elektromobilitätsforum Schleswig-Holsteins, Kiel, 12.03.2013
- F.W. Fuchs, *Offshore Windenergie*, Universitätsgesellschaft, St. Peter Ording, 06.05.2013
- F.W. Fuchs, *State of Technology of Powerloss Determination in Power Converters*, EPE-Konferenz, Lille, France, 04.09.2013
- F.W. Fuchs, *Offshore Windenergie*, Universitätsgesellschaft, Geesthacht, 18.11.2013
- F.W. Fuchs, *Konzipierung, Optimierung und Realisierung eines Drei - Level - Niederspannungsumrichters für MW - Windenergieanlagen*, Innovationscluster Leistungselektronik für Regenerative Energieversorgung, Itzehoe, 26.11.2013
- F. Gebhardt, *Hardware-Projekte am Lehrstuhl für Leistungselektronik und Elektrische Antriebe*, Industrie, 20.02.2013
- F. Gebhardt, *M2C-Funktionsweise und Herausforderungen*, intern, 23.05.2013
- F. Gebhardt, *Analyse von Multilevel Umrichtern und modernsten Leistungshalbleitern für Photovoltaik*, Statusseminar: Regenerative Energien, 10.06.2013
- S. Grunau, *Netzintegration von Windenergieanlagen mit Energiespeichersystem*, intern, 07.05.2013
- S. Grunau, *Windenergieanlagen und Energiespeichersysteme*, LE-Nord, Magdeburg, 07.06.2013
- S. Grunau, *Netzintegration von Windenergieanlagen mit Energiespeichersystem*, Statusseminar: Regenerative Energien, 10.06.2013
- S. Grunau, *Quantification of Losses Regarding Active Power Injection due to New Grid Code Requirements*, Wind Integration Workshop, London, United Kingdom, 23.10.2013
- S. Günter, *Fortschritte der Leistungselektronik - Themenbereich Schaltungen*, Industrieseminar, 19.03.2013
- S. Günter, *Hysteresestromregelung für 3-Level Umrichter*, intern, 07.05.2013
- S. Günter, *Entwurf, Aufbau, Inbetriebnahme und Einsatz eines Niederspannungs-Mittelfrequenz-Messstromgenerators zur Netzanalyse*, Statusseminar: Regenerative Energien, 10.06.2013
- S. Günter, *Schaltnetzteilschaltungen für die galvanisch getrennte Versorgung einer Gate-Treiberschaltung*, intern, 12.12.2013
- N. Hoffmann, *Netzadaptive Regelung und Aktiv-Filter Funktionalität von Netzpulsstromrichtern in der regenerativen Energieerzeugung*, Industrie, 05.03.2013
- N. Hoffmann, *Modellierung von Verkopplungseffekten für die zeitdiskrete Stromregelung bei niedrigen Verhältnissen von Schalt- zur Grundschnwingungsfrequenz*, intern, 25.04.2013
- N. Hoffmann, *Grid-adaptive control and active-filter functionality of grid-connected PWM-inverters in distributed renewable-energy applications*, Industrie, 10.06.2013
- L. Jessen, *Netzparallelbetrieb von Erzeugungsanlagen*, intern, 17.05.2013
- L. Jessen, *Netzstützung bei Spannungseinbrüchen mit parallelen Umrichtern*, intern, 17.12.2013
- M. Petersen, *Induktive Ladeverfahren für Elektrofahrzeuge I*, Industrie, 20.02.2013
- M. Petersen, *Dosierte Regelung einer Lamellenbremse I*, Industrie, 28.02.2013
- M. Petersen, *Induktive Ladeverfahren für Elektrofahrzeuge II*, Industrie, 19.04.2013
- M. Petersen, *Dosierte Regelung einer Lamellenbremse I*, intern, 21.05.2013
- M. Petersen, *Induktive Ladeverfahren für Elektrofahrzeuge III*, Industrie, 30.05.2013
- M. Petersen, *Dosierte Regelung einer Lamellenbremse II*, Industrie, 05.06.2013
- M. Petersen, *Induktive Ladeverfahren für Elektrofahrzeuge IV*, Industrie, 01.07.2013
- M. Petersen, *Induktive Ladeverfahren für Elektrofahrzeuge V*, Industrie, 24.10.2013
- M. Petersen, *Auslegung eines bidirektionalen induktiven Ladesystems*, intern, 17.12.2013
- J. Reese, *Analyse und Simulationserweiterung eines 6-Phasen-Generators für Windenergieanlagen*, Industrie, 28.02.2013
- J. Reese, *Fortschritte in der Leistungselektronik - Regelung von Leistungselektronik und elektrischen Antrieben*, Industrie, 19.03.2013
- J. Reese, *Analyse und Simulationserweiterung eines 6-Phasen-Generators für Windenergieanlagen*, Industrie, 17.04.2013

- J. Reese, *Analyse und Simulationserweiterung eines 6-Phasen-Generators für Windenergieanlagen*, intern, 25.04.2013
- J. Reese, *Modellierung, Analyse und Synthese des Systemverhaltens von Dezentralen Erzeugereinheiten*,  
Statusseminar: Regenerative Energien, 10.06.2013
- J. Reese, *Analyse und Simulationserweiterung eines 6-Phasen-Generators für Windenergieanlagen*, Industrie,  
01.07.2013
- J. Reese, *Evaluation of Harmonic Compensation Algorithms with Parallel Autonomously Controlled Inverters in Isolated  
Microgrids*, IECON, Vienna, Austria, 11.11.2013
- J. Reese, *Reliability Comparison of Fault-Tolerant 3L-NPC Based Converter Topologies for Application in Wind Turbine  
Systems*, IECON, Vienna, Austria, 13.11.2013

# almanach 13

# Technology of Silicon-Based Micro- and Nano-Systems

Since October 2008 Prof. Dr.-Ing. Wolfgang Benecke has been Managing Director of the Fraunhofer-Institut für Siliziumtechnologie (ISIT) in Itzehoe.

Fraunhofer ISIT develops and manufactures components in microelectronics and microsystems technology, from the design phase, including system simulation, through prototyping and fabrication of samples, up to series production. Even though components manufactured at Fraunhofer ISIT, such as acceleration sensors, valves, and deflection mirrors are often just a fraction of a millimetre in size, there is a wide range of applications: the devices are implemented in areas like medical care, environmental and traffic engineering, communication systems, automotive industry, and mechanical engineering. Working under contract, ISIT develops these types of components in accordance with customer requirements, also creating the application specific integrated circuits (ASICs) needed for the operation of sensors and actuators. Included in this service is the system integration using miniaturized assembly and interconnection technology.

Together with Vishay Siliconix Itzehoe GmbH, the institute operates a professional semiconductor production line which is up-to-date in all required quality certifications (e. g. ISO 9001, TS 16949). This line is used in parallel for PowerMOS and microsystem production, and for R&D projects developing new devices and technological processes.

Other fields of activity at ISIT focus on assembly and packaging techniques for microsystems, analysis of the quality and reliability of electronic components, and development of advanced power-supply components for electronic systems.

The institute employs a staff of around 150 people.

Further information about Fraunhofer ISIT is available on the web: [www.isit.fraunhofer.de](http://www.isit.fraunhofer.de).

In addition the Institute publishes an Annual Report which can be ordered at ISIT.

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# Wireless Communications

The research of the Wireless Communications group (CWC) focuses on the physical aspects of wireless communications, i.e. antennas and channel modelling.

Antennas are key components of many rf systems for wireless communications and sensing, as they perform the transition from guided waves to free space propagating waves. Antenna design is often seen as an art in applying basic electromagnetic principles to create real structures with the required properties. Nowadays, applications offer limited space for the integration of the wireless modules and therefore, are dominated by obstacles to integration; this is especially true for antenna performance. The group's research activities aim particularly to master this integration challenge. Applications range from reconfigurable multiband antennas for SDR (software defined radio), multiple antenna systems for small MIMO (multiple input multiple output) terminals, UWB (ultra wideband) antennas for combined communication and localization, and antenna implantation into the human body for medical implants and BAN (body area networks).

Detailed knowledge of the electromagnetic propagation channel is essential to gain optimum performance in all wireless communication, sensing, and locating applications. In terms of wireless communications the channel properties set the upper bound of the capacity for a given SNR (signal to noise ratio). While channel models of typical urban or indoor environments are already standardized for common mobile communication systems, such as GSM, UMTS, and IEEE 802.11, more specific environments such as aircraft cabins, or in and on the body wireless channels, become an interesting research topic.

## Results

### UWB Communication and Localization

The Wireless Communications group works on design and integration of UWB antennas for a combined communication and localization system. Application areas range from airborne systems, search and rescue and implantable medical devices. The antennas designed cover the frequency range from 3.1 GHz to 10.6 GHz. In the framework of a BMWi project grant and in cooperation with Airbus, multiple two antenna systems are integrated into the cabin's ceiling while a miniature mobile device contains a single antenna that is specifically designed to work in close proximity to the human body.

Currently, the CWC evaluates the RF localization of medical implants and surgical instrumentation in cooperation with the Department of Neurosurgery of the Kiel University hospital.

### Reconfigurable MIMO Antenna Integration into Small Terminals

MIMO (Multiple Input Multiple Output) is a technique to utilize multiple antenna systems to increase the capacity of modern communication systems. The integration of multiple low correlated antennas is especially challenging if we look at small terminals such as mobile phones. Our results are well received by both the scientific community and industry. They indicate a relationship between the element correlation and the characteristic modes established on the common finite ground plate. It can already be foreseen that these promising findings will have the potential to derive design rules for the integration of multiple antennas into small terminals. Meanwhile CWC won funding for multiple projects in this area including a new focus area of the DFG with emphasis on 100 GBit wireless systems.

Recently the CWC won research grants from the DAAD, DFG, the BMBF and the ENIAC European framework. Furthermore, cooperation with the Fraunhofer ISIT in Izehoe in the area of piezoelectric MEMS for reconfigurable antennas is ongoing.

### Implanted Antennas and RF propagation within the human body

A Body Area Network (BAN) is a combination of several electronic applications that are worn on or in the body, preferably having a wireless interconnection with each other, or with external peripheral devices. The applications can range over consumer electronic devices, security equipment, medical devices for telemedicine, and electronic implants. In order to allow

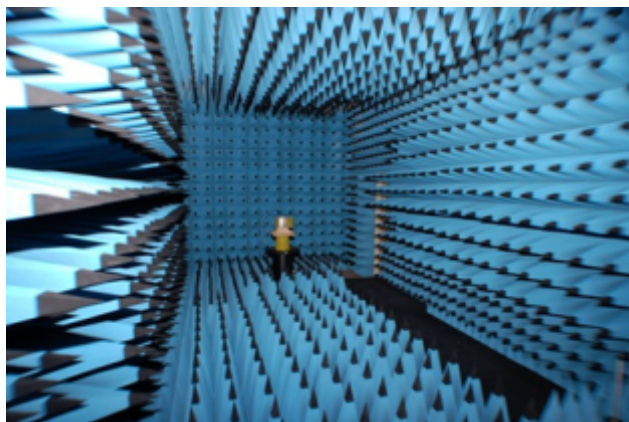


Fig. 1: Shielded absorber room for antenna measurements.

for high data rates, reliable links, and low power consumption, UWB (Ultra WideBand) technology has been considered recently for future BANs. The CWC aims at developing and integrating new miniaturized antennas and channel models for BANs of different applications. The antennas are developed and optimized taking into account realistic integration into the chassis of the application and realistic implantation into the body.

Recently the CWC won a project grant of the DFG in the area of analytic path loss modelling of On-Body wireless propagation.

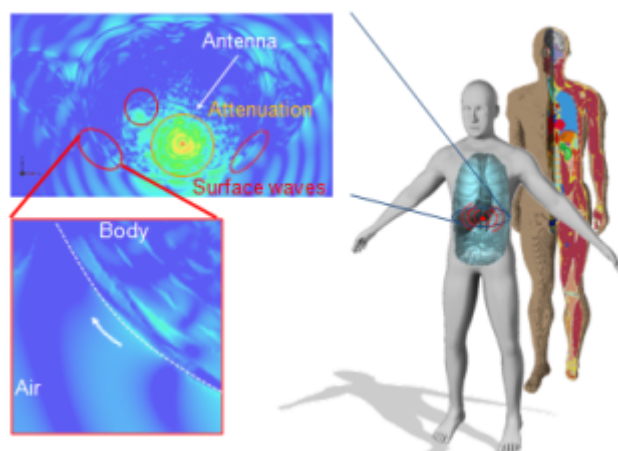


Fig. 2: In and on body radio propagation of wireless medical implants.

## Personnel

Head of the group: Prof. Dr.-Ing. D. Manteuffel; Secretary: M. Bork  
Technical Staff: Dipl.-Ing. W. Taute

### Scientific Staff:

Dipl.-Ing. Y. Chen  
EPAMO

01.01.-31.12.2013

BMBF / EU

Dipl.-Ing. M. Grimm  
UWB BAN

01.01.-31.12.2013

DFG

Dipl.-Wirtsch.-Ing. R. Martens  
MIMO

01.01.-31.12.2013

DFG

Dipl.-Ing. E. Safin

01.01.-31.12.2013

CAU

Dr. Sc. R. Valkonen  
KoAMo

01.08.-31.12.2013

BMBF

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

Grundgebiete der Elektrotechnik III, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
D. Manteuffel

Antennas, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Manteuffel

Funkbasierte Kommunikation und Sensorik in der Medizintechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Manteuffel

Projekt, 3 hrs Practical/Week,  
D. Manteuffel

Masterpraktikum Mikrowellen und EMV, 4 hrs Practical/Week,  
D. Manteuffel

### *Summer 2013*

Wireless Communication (RF), 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Manteuffel

Seminar EM Modelling, 3 hrs Seminar/Week,  
D. Manteuffel

Projekt, 3 hrs Practical/Week,  
D. Manteuffel

Antennas, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Manteuffel

### *Winter 2013/2014*

Grundgebiete der Elektrotechnik III, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
D. Manteuffel

Funkbasierte Kommunikation und Sensorik in der Medizintechnik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Manteuffel

Projekt, 3 hrs Practical/Week,  
D. Manteuffel

Masterpraktikum Mikrowellen und EMV, 4 hrs Practical/Week,  
D. Manteuffel



## Third-Party Funds

- Deutsche Forschungsgemeinschaft, *Antennen und Wellenausbreitung für am und im Körper betriebene Funkanwendungen basierend auf ultra breitbandiger Technologie (Schwerpunktprogramm UKoLoS)*, 01.10.2010-31.01.2013 (124960 EUR)
- Deutsche Forschungsgemeinschaft, *Integration von Mehrantennensystemen in kleinen mobilen Endgeräten auf Basis der Theorie der Charakteristischen Moden*, 01.12.2010-28.02.2015 (187440 EUR)
- Bundesministerium für Bildung und Forschung, *ENIAC-Verbundprojekt EPAMO - Teilvorhaben: MEMS basierte rekonfigurierbare Antennen für mobile Terminals*, 01.04.2011-30.09.2014 (353713 EUR)
- Bundesministerium für Bildung und Forschung, *Numerische 3D-Feldsimulationen für Konzeptentwicklung und Integration der Antennen für Aufbau mobiler Demonstratorplattformen (Verbundprojekt KoAmo)*, 01.03.2012-28.02.2015 (213948 EUR)

## Further Cooperation, Consulting, and Technology Transfer

The Wireless Communications group (CWC) cooperates with several international universities, such as the University of Nice, Helsinki University of Technology, and Loughborough University. Industrial cooperation has been conducted with I2R Singapore, IMST GmbH, Airbus and Draeger. Within the Institute CWC has a strong collaboration with the ICT group. In a joint initiative they recently won a project within a newly founded DFG focus area with the subject of multi-mode massive MIMO.

## Diploma, Bachelor's and Master's Theses

- Y. Topp, *Herleitung und Bewertung der Norton-Theorie zur Beschreibung körperbezogener Funknetzwerke*, 08.02.2013
- I. Heilemann, *Evaluierung eines Mehrantennensystems für mobile MIMO-Endgeräte*, 07.04.2013
- C. Arendt, *Skalierbarkeit von hybriden Kommunikationstechnologien für sicherheitskritische Applikationen*, 21.07.2013

## Publications

Published in 2013

- Y. Chen, D. Manteuffel, *Miniaturizing of a Distributed MEMS Impedance Matching Network*, International Workshop on Antenna Technology, 303 - 306 (2013)
- E. Safin, D. Manteuffel, *Resonance Behaviour of Characteristic Modes Due to the Presence of Dielectric Objects*, 7th European Conference on Antennas and Propagation, (2013)
- M. Grimm, D. Manteuffel, *Discussion of Body Worn Dipole Antennas based on an Improved De-embedding Approach*, 7th Conference on Antennas and Propagation, (2013)
- R. Martens, D. Manteuffel, *Improved Radiation Pattern Measurements of MIMO Handheld Mobile Terminals*, 7th European Conference on Antennas and Propagation, (2013)
- E. Safin, D. Manteuffel, *Reconstruction of the Characteristic Modes on an Antenna Based on the Radiated Far Field*, IEEE Transactions on Antennas and Propagation, 61, 6, 2964 - 2971 (2013)
- E. Safin, R. Martens, R. Capek, M. Eichler, P. Hazdra, D. Manteuffel, M. Mazanek, *Discussion and Evaluation of Modal and Radiation Q-Factors for MIMO Antennas Based on Theory of Characteristic Modes*, COST IC1102, 3. WG Meeting and Technical Workshop, (2013)
- T. Hadamik, R. Martens, D. Manteuffel, *Comparison of Two Matching Networks for a LTE2600 Handset Antenna*, Loughborough Antennas and Propagation Conference, (2013)
- R. Martens, J. Holopainen, E. Safin, D. Manteuffel, *Small Terminal Multi-Antenna System Based on Two Different Types of Non-Resonant Coupling Elements*, COST IC1102, 4. WG Meeting and Technical Workshop, (2013)

- R. Martens, D. Manteuffel, P.A. Höher, *Ultra Wideband Communications based on Massive MIMO and Multi-mode Antennas Suitable for Handheld Devices - A Project Outlook*, Proceedings of the 43. European Microwave Conference, (2013)
- T. Metzger, T. Ebefors, T. Pudas, A. Haapalinna, R. Martens, T. Lisec, *RF Solutions for Future Generation Mobile Phones*, European Nanoelectronic Forum, (2013)
- R. Martens, J. Holopainen, E. Safin, J. Ilvonen, D. Manteuffel, *Optimal Dual-Antenna Design in a Small Terminal Multi-Antenna System*, IEEE Antennas and Wireless Propagation Letters, 12, 1700 - 1703 (2013)

## Further Activities and Events

VDE ITG Fachausschuss 7.1 "Antennen": appointed national committee member.

EurAAP (European Association on Antennas and Propagation): member of the Board of Directors

EurAAP WG on Small Antennas: chairman of the working group.

IEEE AP-S AdCom member (term 2013 - 2015)

ESoA - European School of Antennas: member of the board of directors.

Standardization: ICES working group TC34 member.

Editor of the IET Proceedings on Microwave, Antennas and Propagation and IEEE Transactions on Antennas and Propagation

Steering Committees and Technical Programme Committees. In 2013 Prof. Manteuffel served as a TPC chair of iWAT 2013 - International Workshop on Antenna Technology and as a member of the TPC of the following international conferences: EuCAP 2013 - European Antennas and Propagation Conference, LAPC 2013 - Loughborough Antennas and Propagation Conference, ISAP 2013 - International Symposium on Antennas and Propagation.

# almanach

## Institute for Materials Science

The Institute for Materials Science consists of 9 professorships, 2 honorary professorships, and one extraordinary professorship. Prof. Wolfgang Jäger, the head of the "Microanalysis of Materials" group, retired from his teaching duties at the end of March 2013. The Institute thanks Prof. Jäger for his great and pioneering work in electron microscopy over the last eighteen years. Dr. Mikhail Zheludkevich has recently been appointed Professor of "Electrochemistry of Metallic Biomaterials". His main scientific interests are on multi-functional active surfaces for biomedical and hybrid structural components. The emphasis of his research is given to coatings which combine an active protection with additional functions, such as self-health monitoring or controllable drug delivery. The research is planned to be performed in close collaboration with the Helmholtz-Zentrum Geesthacht, where Prof. Zheludkevich heads the department of "Corrosion and Surface Technology" at the Institute of Materials Research in Geesthacht.

The Institute for Materials Science offers 2 degree programmes, a Bachelor's course "Materials Science" (currently 189 students), and a Master's course "Materials Science and Engineering" (currently 111 students) with increasing numbers of students still and with up to 37 % of female students: a very high percentage. The establishment of a new degree programme in "Business Materials Science" is planned in the near future. Funds from the *Hochschulpakt 2020* were used to improve the university teaching facilities. In 2013, these funds were spent for the repair of the scientific equipment used in the basic and advanced lab courses, in order to make sure that in the future the excellent quality of our training courses for the students can be maintained.

The research infrastructure of the Institute is becoming more complex and, of course, more valuable. Consequently, individual areas are summarized into equipment centres, like the TEM centre, which is listed as the first DFG core facility of the Faculty. In this context, the establishment of the *Kompetenzzentrum Nanosystemtechnik* (coordinator: Prof. Eckhard Quandt) represents another important milestone, which is funded with approximately € 1.3 million from the state of Schleswig-Holstein. The competence centre forms an essential basis for the current but also for future third-party funding activities of the Institute. It will also be a focal point for companies of Schleswig-Holstein and non-university research institutions to carry out research in nanotechnology and thus forms an excellent platform for technology transfer. In this regard, the competence centre especially strengthens the cooperation with the Fraunhofer Institute for Silicon Technology in Itzehoe.

In 2013, the members of the Institute for Materials Science were again very successful in attracting third-party funding. Of particular note here is the project "CellInspired" of Prof. Christine Selhuber-Unkel that is funded from 2013 - 2018 with € 1.5 million by the European Research Council in the framework of an ERC Starting Grant. It supports excellent scientists at an early stage of their scientific career. This award was granted, for the first time, to a member of the Institute for Materials Science.

Unfortunately, the renewal proposal for the Collaborative Research Centre SFB 855 "Magnetoelectric Composites - Future Biomagnetic Interfaces" was not granted, despite a very good evaluation. Nevertheless, the research in this important and scientifically successful research area will be continued by using other grants. The submission of a new SFB proposal on a similar topic is scheduled for 2015.

### Results

The high scientific quality of the Institute's members became visible in 2013 by several excellent scientific results, some of which are summarized briefly below. Further details can be found in the chapters of the respective groups.

- Prof. Mady Elbahri and his group developed a spectacularly simple method for the synthesis of nanomaterials that largely dispensed with toxic chemicals. In this case, a simple drop of water is used as a floating reactor to carry

out chemical reactions and to arrange the products as porous or complex nanostructures. The method and some application examples have been published in the highly renowned journal Nature Communications.

- A novel concept on self reporting materials by Prof. Adelung's group "Functional Nanomaterials" received considerable international attention. The original work was published in Advanced Materials in collaboration with the TU Munich.
- Prof. Kienle's group "Synthesis and Real Structure" discovered an extended new group of gold containing minerals by means of electron microscopy.
- A breakthrough in magneto-optical magnetic domain imaging was achieved in the group "Nanoscale Magnetic Materials - Magnetic Domains" headed by Prof. Jeffrey McCord. By the new technique magnetic domain features concealed from standard domain imaging techniques are directly exposed. The novel method was published in Applied Physics Letters.
- During the last year, within the framework of the Collaborative Research Centre SFB 855, the chair for "Multicomponent Materials" held by Prof. Franz Faupel developed a new magnetoelectric magnetic field sensor involving a piezoelectric co-polymer that achieved the highest magnetoelectric coefficient ever observed at low frequencies. The results were reported in Applied Physics Letters.
- Also in the framework of the SFB 855 a new 2-2 magnetoelectric thin film composite was developed by the Chair for "Inorganic Functional Materials" held by Prof. Eckhard Quandt that does not require a direct interface between the magnetostrictive and piezoelectric thin film. This approach allows the use of interdigital electrodes which increase significantly the magnetoelectric voltage and thus decrease the detection limit to  $1 \text{ pT/Hz}^{1/2}$ . An international patent was applied and the results were published in Applied Physics Letters.

In collaboration with the German Society for Materials Science (DGM) Prof. Christine Selhuber-Unkel and Prof. Eckhard Quandt organised the conference "Euro Intelligent Materials 2013" in Kiel. From September 25th to 27th, leading international experts from a variety of disciplines discussed the latest developments in the field of intelligent materials. Layer systems for measuring tiny magnetic fields, gecko-inspired micro-adhesive structures, and stretchable optics: these were just some of the topics highlighted at the conference, which included more than 100 lectures and posters. There were 13 invited speakers from universities and research institutions in Milan, Kansas, Zurich, Bayreuth, Tohoku, Portsmouth, Darmstadt, Stuttgart, and Kiel, who presented current highlights of intelligent materials during the three-day programme. A second conference is scheduled for 2015, again to be held in Kiel.

As an innovation in 2013, a joint graduation ceremony of the Institute of Electrical Engineering and Information Technology and the Institute for Materials Science honoured the Bachelor's and Master's graduates on November 29, 2013. The event attended by about 150 students and their family members was held in this form for the first time at the Faculty of Engineering. Before the actual ceremony laboratory tours were offered at the Institute, in order to demonstrate to the interested general public some of the current research topics. Following the solemn ceremony, the *Förderverein* (Friends) of the Faculty and the Institutes invited everybody to a social gathering in the cafeteria. The event was very well received and will be held in this form again in 2014.

As a final point, Prof. Lorenz Kienle was elected for an additional 2 year term as the executive director of the Institute for Materials Science and Prof. Jeffrey McCord as the deputy executive director.



## Biocompatible Nanomaterials

Research in the group “Biocompatible nanomaterials” focuses on investigating cell-material interactions with an interdisciplinary approach, by combining methods from materials science, physics, chemistry, and biology. The long-term goal is to control living cells with nano- and microstructures from the level of single molecules to many cells. Furthermore, we develop methods to quantitatively investigate cell adhesion mechanobiology. This includes experiments with force microscopy techniques and optical microscopy. In September 2013 we started our project “Cell-inspired: Mechanotransduction mediating cell adhesion - towards cell-inspired adaptive materials”, which is funded by an ERC Starting Grant and is intended to transfer cellular adhesion principles to intelligent materials.

### Results

#### Microtopographic substrates for controlling cell adhesion at the micro-nanoscale

Diblock-copolymer Micelle Nanolithography is a powerful technique used for mediating cell adhesion through controlling the spacing variation in binding sites of single cell adhesion receptors. Recently, we have developed a novel method to additionally control binding site spacing on regular micropatterns. We use a micro-structured topography on Si substrates that can be produced easily with photolithography followed by wet etching. Performing a diblock-copolymer micelle nanolithography procedure on such substrates introduces nanoparticle arrays of different densities and spacings in the pattern provided by the microtopography in a single-step (figure 1). With this technique, we have so far achieved spacing variations in the micropattern of up to 25 nm (1). The microstructured domains patterned with nanoparticle arrays were biofunctionalized with RGD ligands to make them attractive for integrin binding in order to further study the effect of ligand spacing on cell adhesion. Thus, our micro-patterned nanostructured surfaces now provide a versatile platform for studying cellular adhesion processes that are influenced by micro-nanostructured ligand spacings and density.

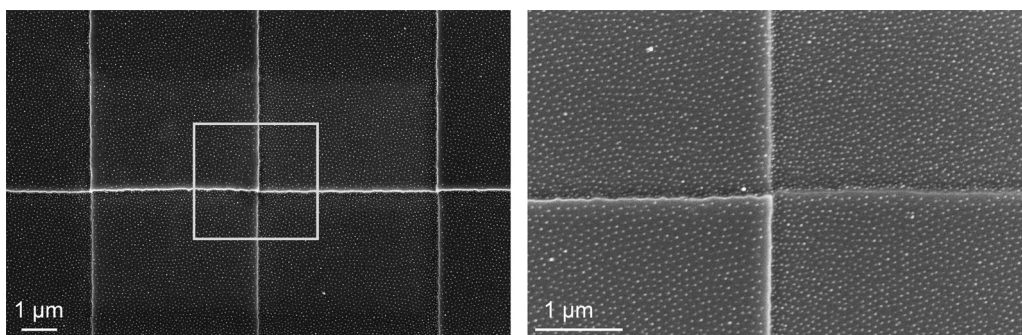


Fig. 1: Left: SEM image of a Si wafer with microtopography. The white rectangle is the area shown enlarged to the right. Right: Zoom into the SEM image showing the distribution of nano-particles on a micro-topography.

#### Influence of gold nanostructures on the adhesive properties of *Acanthamoeba castellanii*

*Acanthamoeba castellanii* is a human pathogen, which can cause *Acanthamoeba* keratitis. The critical step in an infection with *Acanthamoeba castellanii* is the adhesion of the amoebae to the host cells. A major virulence factor is the mannose-binding protein, which is responsible for the amoebic adhesion by binding mannose residues on the target-cell surface. The adhesion of *Acanthamoeba castellanii* to substrates with molecularly defined patterns of mannose molecules was investigated with functionalized nanostructures. These nanostructures were produced via diblock-copolymer-micelle-nanolithography and consist of a quasi-hexagonal pattern of gold nano dots with an interparticle distance of 104 nm and 127 nm. By passivating the surface with polyethylene glycol and functionalizing the gold particles with mannose disulphide (figure 2), it could be shown that the adhesion of *Acanthamoeba castellanii* to target-cells can be mimicked by biofunctionalized nanostructures. The influence of the ligand patch spacing on the cell spreading, used as an indicator for

adhesion, was also investigated. *Acanthamoeba castellanii* could adhere very well to the nanostructured substrates with spacings 104 and 127 nm, which is amazing, as for many cell types a binding site spacing of smaller or equal to 60 nm is required.

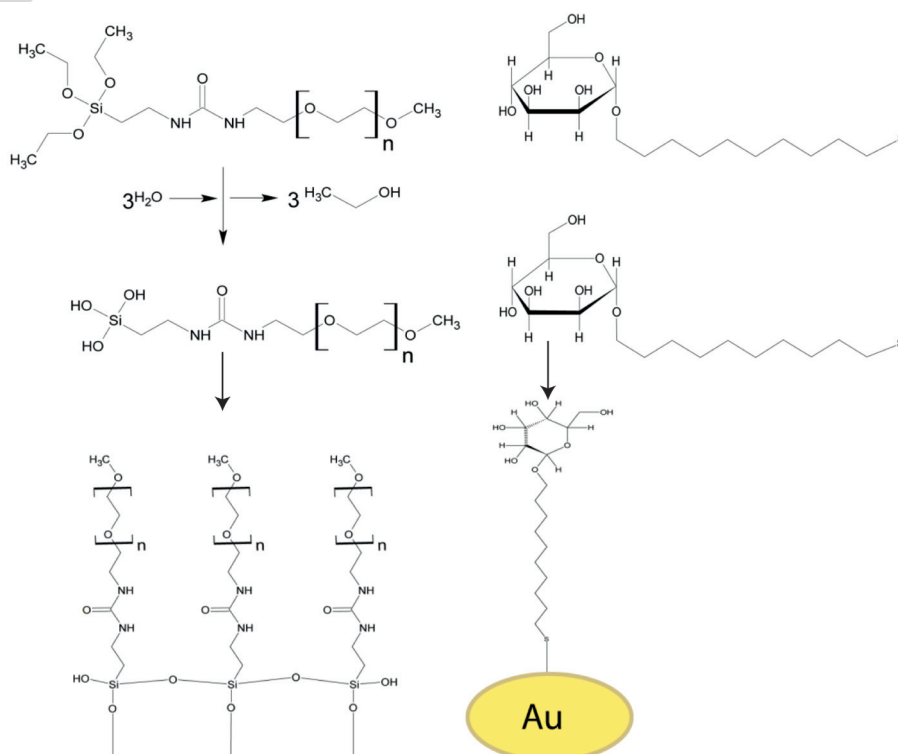


Fig. 2: Sketch of passivation and functionalization strategy of a nanostructured surface. To the left, the passivation with methoxyl PEG silane is shown, including a hydrolysis step to activate the silane groups and oligomer formation on the surface of the substrate; To the right, the functionalization of a gold dot with mannose disulphide is illustrated.

## " Graphite4Med"

In April, Dr. Constanze Lamprecht started the project „Graphite4Med“ with a Marie Curie Intra-European Fellowship . The goal of this 2-year project „Graphite4Med-Aerographite as scaffold material for regenerative medicine“ is to explore the feasibility of aerographite as scaffold material for biomedical applications. A special focus is the potential use in regenerative medicine with the aim to promote and direct cell growth, a feature that is highly desired in repair and functional restoration of injured nerve tissue (e.g. spinal cord injuries). Aerographite provides a stable porous scaffold, which offers accessibility of surfaces and penetrability. These are key features for 3D tissue engineering applications. Moreover, its close physicochemical (mechanical, chemical, electronic properties) relation to carbon nanotubes, which have been studied extensively in the biomedical context and proven biocompatible and permissible for neuronal regeneration when properly functionalized, make aerographite a very promising candidate. We were already able to identify successful wetting agents to transfer and keep aerographite in physiological conditions. Furthermore, we are conducting biocompatibility experiments. The results will allow first conclusions regarding environmental risks associated with this novel material and will explore potential biological applications.

## Adhesion of *Acanthamoeba castellanii* to soft contact lenses

The main cause of an infection with *Acanthamoeba castellanii* is the use of contact lenses, especially if they are not carefully handled. To determine if contact lens material parameters have an influence on adhesion of acanthamoebae, different soft hydrogel contact lenses were incubated with *Acanthamoeba castellanii* and their adhesion was quantified.

Parameters such as elastic modulus, silicone content, ionic properties and swelling did not have any influence on the adhesion of *Acanthamoeba castellanii*. The only significant influence was shown for the water content of the contact lens. The adhesion of *Acanthamoeba castellanii* increased nonlinearly with the water content of the lens. In addition, the effect of standard cleaning procedures for contact lenses was tested. Both solutions tested, a multipurpose solution and a peroxide solution, were capable of removing all adherent amoebae from the lenses after the recommended incubation time. However, only the treatment with the peroxide solution and the neutralization pellet killed most of the amoebae (figure 3).

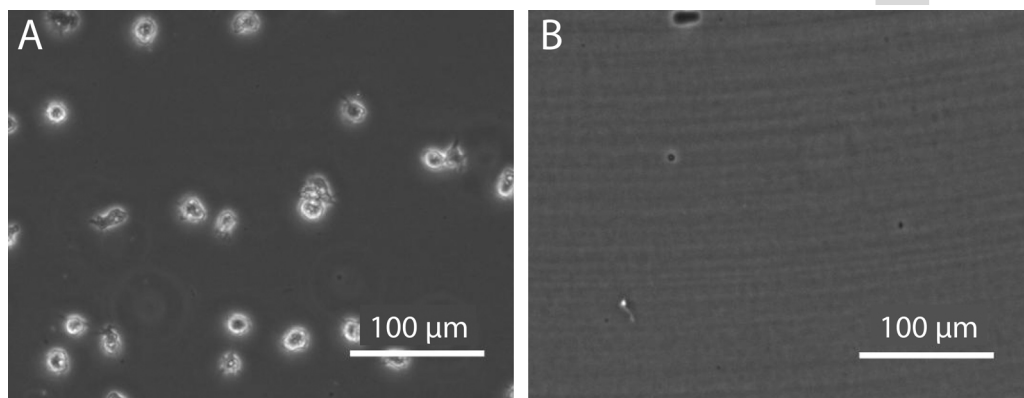


Fig. 3: Effects of contact lens treatment on acanthamoeba adhesion in phase contrast microscopy. (A) *Acanthamoeba castellanii* on an Aerofilcon A contact lens after 24 h of incubation at room temperature. (B) Aerofilcon A contact lens after subsequent treatment with contact lens care solution and disinfection with peroxide solution in combination with a neutralizing tablet.

## Personnel

Head of the group: Prof. Dr. C. Selhuber-Unkel; Secretary: E. Riemer (50%)  
 Technical Staff: M. Lieb (50%)

Scientific Staff:

Dr. C. Grabosch	01.08.-31.12.2013	CAU
Mechanosensitive polymer materials		
M.Sc. S. Gutekunst	01.01.-31.12.2013	DFG
A nanobiophysical Approach to Elucidate Target-Cell Killing by amoebic parasites.		
M.Sc. L. Kadem	01.01.-31.12.2013	DFG
SFB 677, Teilprojekt B11, Schaltbare Zelladhäsion		
Dr. C. Lamprecht	01.01.-31.12.2013	Materials for Life Award/EU
Atomic force microscopy on single molecules and live cells/Graphite4Med-Aerographite as scaffold material for regenerative medicine		
M. Sc. Q. Li	01.01.-31.12.2013	CAU/EU
CellInspired		
M.Sc. J. Revery	01.01.-31.12.2013	DFG/EU
A nanobiophysical approach to elucidate target-cell killing by amoebic parasites/CellInspired		

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Cell Mechanics, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
C. Selhuber-Unkel

Chemistry and Physics of Biomaterials, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
C. Selhuber-Unkel

Biokompatible Nanomaterialien, 2 hrs Seminar/Week,  
C. Selhuber-Unkel

### Summer 2013

Grundlagen der Optik und Lichtmikroskopie, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
C. Selhuber-Unkel

Bioinspired Materials, 2 hrs Lecture/Week,  
C. Selhuber-Unkel

Nano Medicine, 2 hrs Lecture/Week,  
C. Lamprecht

Biokompatible Nanomaterialien, 2 hrs Seminar/Week,  
C. Selhuber-Unkel

### Winter 2013/2014

Bioinspirierte Materialien, 2 hrs Lecture/Week,  
C. Selhuber-Unkel

Cell Mechanics, 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
C. Selhuber-Unkel

Chemistry and Physics of Biomaterials, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
C. Selhuber-Unkel (+ C. Grabosch, C. Lamprecht)

Biokompatible Nanomaterialien, 2 hrs Seminar/Week,  
C. Selhuber-Unkel

## Third-Party Funds

DFG, *Sachbeihilfe zur Einrichtung einer Nachwuchsgruppe im Emmy Noether-Programm zum Thema: A nanobiophysical approach to elucidate target-cell killing by amoebic parasites*, 01.06.2010-30.05.2015 (1.244.542 Euro)

DFG, *Schaltbare Zelladhäsion: SFB 677/B11*, 01.07.2011-30.06.2015 (237.600 Euro)

Marie Curie IEF, *Graphite4Med - Aerographite as scaffold material for regenerative medicine*, 01.04.2013-31.03.2015 (161.968,80 Euro)

EU, *CellInspired: Mechanotransduction mediating cell adhesion - towards cell-inspired adaptive materials*, 01.09.2013-31.08.2018 (1.467.483 Euro)

DAAD, *Reisebeihilfe zum MRS Spring Meeting and Exhibit, San Francisco*, 01.-05.04.2013 (1.447,20 Euro)

## Further Cooperation, Consulting, and Technology Transfer

- Prof. D. Adam, UKSH: adhesion forces of Jurkat cells on biopolymer surfaces.  
 Prof. R. Adelung, Universität Kiel, Lehrstuhl für Funktionale Nanomaterialien: Aerographite for medical applications.  
 Dr. R. Fromme, Wöhlk Contactlinsen, Schönkirchen.  
 Prof. M. Gerken, Universität Kiel, Lehrstuhl für Integrierte Systeme und Photonik: cell adhesion on photonic crystals.  
 Prof. S. Gorb, Universität Kiel, Zoologisches Institut: common projects on investigating adhesion with AFM.  
 Prof. Größner-Schreiber, UKSH and CAU, Zahnerhaltungskunde und Parodontologie: Biocompatibility of ceramic and dental materials.  
 Prof. R. Herges, Prof. T. K. Lindhorst, Universität Kiel, Otto-Diels-Institut: Switchable cell adhesion (SFB 677 „Function by switching“ ).  
 Prof. M. Leippe, Universität Kiel, Zoologisches Institut: Characterizing Biophysical properties of amoebae.  
 Prof. R. Metzler, University of Potsdam, Dr. Jae-Hyung Jean, University of Tampere, Finland: diffusion and ageing in cells.  
 Prof. E. Quandt, Universität Kiel, Lehrstuhl für Anorganische Funktionsmaterialien: NiTi and magnesium thin films.  
 Prof. K. Schwarz, Dr. Y. Serfert, Universität Kiel, Institut für Humanernährung und Lebensmittelkunde: nanotopography and nanostructure of biopolymer fibrils.  
 Prof. J. Spatz, MPI für Intelligente Systeme: nanostructure fabrication.

## Diploma, Bachelor's and Master's Theses

- A. Raza, *Fabrication of micro-nanostructured surfaces*, 30.07.2013

## Publications

Published in 2013

- J. Reverey, R. Fromme, M. Leippe, C. Selhuber-Unkel, *In vitro adhesion of Acanthamoeba castellanii to soft contact lenses depends on water content and disinfection procedure*, Contact Lens and Anterior Eye, published online Dec. 19, 2013, doi: 10.1016/j.clae.2013.11.010, (2013)  
 Y. Nazirizadeh, J. Reverey, U. Geyer, U. Lemmer, C. Selhuber-Unkel, M. Gerken, *Material-based three-dimensional imaging with nanostructured surfaces*, Applied Physics letters, **102**, 011116 - 011116 (2013)  
 S. Jahns, Y. Nazirizadeh, B. Meyer, S. Gutekunst, C. Selhuber-Unkel, M. Gerken, *Photometric Aptasensor using Biofunctionalized Photonic Crystal Slabs*, Proc. IEEE Sensors 2013, Baltimore (USA), (2013)  
 Y. Serfert, R. Kleinhans, C.-P. Tan, C. Lamprecht, C. Selhuber-Unkel, S. Drusch, K. Schwarz, *Einsatz von beta-Lactoglobulin-Fibrillen zur Herstellung mikrostrukturierter Trägersysteme*, Fraunhofer ICT, Pfinztal, 139 - 147 (2013)

## Presentations

- C. Selhuber-Unkel, *Investigating cellular interactions with force microscopy (invited talk)*, 6th North-German Biophysics meeting, Research Centre Borstel, Borstel, Germany, 25.01.2013  
 C. Lamprecht, *Microencapsulation of lipophilic ingredients by spray drying/Ancient DNA-process of selective decay and preservation (talk)*, Seminar New Materials and Biosystems, Antholz, Italy, 03.-09.03.2013  
 C. Selhuber-Unkel, *Biocompatible nanomaterials (talk)*, Seminar New Materials and Biosystems, Antholz, Italy, 03.-09.03.2013  
 S. Gutekunst, *Novel elastic force sensors for live cell investigations (talk)*, Seminar New Materials and Biosystems, Antholz, Italy, 03.-09.03.2013  
 L. Kadem, C. Selhuber-Unkel, *Varying gold inter-dot distances on structured microtopographies (talk)*, New Materials and Biosystems, Antholz, Italy, 03.-09.03.2013

- Q. Li, D. Adam, C. Selhuber-Unkel, *Adhesion Forces of Jurkat T Lymphocytes on Fibronectin (-TNF/+TNF) Measured by Atomic Force Microscopy (talk)*, Seminar New Materials and Biosystems, Antholz, Italy, 03.-09.03.2013
- L. Kadem, Q. Li, M. Holz, R. Herges, C. Selhuber-Unkel, *Photo-induced switchable cell adhesion on nanostructured surfaces (poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM), Universität Regensburg, Regensburg, Germany, 10.-15.03.2013
- S. Gutekunst, J. Reverey, C. Selhuber-Unkel, *Novel elastic force sensors for live cell investigations (poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM), Universität Regensburg, Regensburg, Germany, 10.-15.03.2013
- Q. Li, D. Adam, C. Selhuber-Unkel, *Adhesion Forces of Jurkat T Lymphocytes on Fibronectin Measured by Atomic Force Microscopy (poster)*, International Joint Meeting of the German Society for Cell Biology (DGZ) and the German Society for Developmental Biology (GfE), Heidelberg, Germany, 20.-23.03.2013
- L. Kadem, Q. Li, C. Lamprecht, J. Reverey, C. Selhuber-Unkel, *Controlling cell adhesion by precise ligand positioning at the nanoscale (talk)*, MRS Spring meeting, San Francisco, USA, 01.-05.04.2013
- J. Reverey, V. Chandrasekaran, M. Leippe, T. K. Lindhorst, C. Selhuber-Unkel, *Carbohydrate Functionalization of Nanostructured Surfaces for Biological Adhesion Applications (poster)*, MRS Spring Meeting, San Francisco, USA, 01.-05.04.2013
- C. Selhuber-Unkel, *Investigating dynamic processes in parasitic Acanthamoeba (invited talk)*, Seminar of the SFB 937 Collective behaviour of soft and biological matter, Göttingen, Germany, 28.05.2013
- C. Selhuber-Unkel, *Controlling cell adhesion at the molecular scale with biofunctionalized nanostructures (invited talk)*, Biochemie Kolloquium, University of Hamburg, Hamburg, Germany, 01.07.2013
- C. Selhuber-Unkel, *Biophysics at the nanoscale - watching molecules at work (invited talk)*, Boehringer Ingelheim Fonds Alumni Seminar, Ertstadt/Liblar, Germany, 19.-21.07.2013
- L. Kadem, Q. Li, M. Holz, R. Herges, C. Selhuber-Unkel, *Photo-induced switchable cell adhesion on nanostructured surfaces (poster)*, SFB 677 Summer School, Schleswig, Germany, 13.-14.08.2013
- C. Lamprecht, *Strategic planning of your scientific career (invited talk)*, SFB 677 Summer School, Schleswig, Germany, 14.08.2013
- C. Lamprecht, *Multifunctional carbon nanotubes for targeted drug delivery (invited talk)*, Institute of Physical Chemistry, Johannes Gutenberg University Mainz, Mainz, Germany, 18.08.2013
- Y. Serfert, C.-P. Tan, C. Lamprecht, C. Selhuber-Unkel, S. Drusch, K. Schwarz, *Use of fibrillar beta-lactoglobulin for microencapsulation of lipophilic ingredients by spray drying (poster)*, XXI. International Conference on Bioencapsulation, Berlin, Germany, 28.-30.08.2013
- S. Gutekunst, *Optical Tweezers (talk)*, Forces and Dynamics in Cells, Bayreuth Summer School on Biophysics, University of Bayreuth, Bayreuth, Germany, 09.-12.09.2013
- J. Reverey, V. Chandrasekaran, M. Leippe, T. K. Lindhorst, C. Selhuber-Unkel, *Mannose Functionalized Nanostructures for Mimicking Cell Surface Properties (talk)*, Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013
- L. Kadem, M. Holz, Q. Li, C. Lamprecht, R. Herges, C. Selhuber-Unkel, *Varying gold inter-dot distances on structured microtopographies (talk)*, Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013
- C. Selhuber-Unkel, *Biophysical studies of cell-material interactions (invited talk)*, Biophysics Seminar, Humboldt University Berlin, Berlin, Germany, 10.10.2013
- C. Selhuber-Unkel, *Intracellular motion in non-motile and motile cells (invited talk)*, Dynamics in crowded systems workshop, Potsdam, Germany, 23.-25.10.2013
- G. Zoch, *The influence of different nanostructures on the adhesive properties of Acanthamoeba castellanii (talk)*, Life Science Studierendentagung, Kiel, Germany, 05.12.2013

## Further Activities and Events

C. Selhuber-Unkel: Co-chair at the DGM-Conference "Intelligent Materials", Kiel, Germany, September 25-27, 2013.

Session chair “Materials Science/Chemistry” at the Japanese-German Frontiers of Science Meeting (Alexander von Humboldt Foundation and JSPS), Kyoto, Japan, October 31-November 3, 2013.

Guests in 2013:

18.02. - 15.04.2013

Carolina Herranz, BIBITE, Dep. Of Materials Science and Metallurgical Engineering Universitat Politècnica de Catalunya, Spain: cell adhesion forces on novel titanium alloys.

19.09. - 22.12.2013

Yasaman Ganji, Amirkabir University of Technology, Tehran, Iran (travel grant from the Boehringer Ingelheim Foundation, topic: design and fabrication of a conductive nano-wired polyurethane cardiac patch for regeneration of myocardial infarction (MI)).

14.10. - 30.11.2013

Fabian Czerwinski: research on optical tweezers.

14.10. - 16.12.2013

Julia Purtov: controlling cell adhesion by micro-nanotopographics.





# Functional Nanomaterials

In "Functional Nanomaterials" nanostructured materials are synthesized and investigated for research, teaching and technology transfer. This covers aspects over the full range from basic research to application. In 2013, all such aspects were covered, and again the work from the group found national and international recognition.

Novel interdisciplinary projects started; the group is now a partner in the EU graphene flagship project. A DFG-Project about the toxicity of nanostructures in collaboration with Dr. Röhl and the Institute of Toxicology began in the summer. A further technology transfer project with industry received funding by the BMWi and covers the topic of diamond-like carbon coatings.

The research on aerographite found further interest (see Almanach 2012); a nomination for the Diesel medal in the category "most sustainable Innovation achievement" was given. As in previous years, several invited talks were given, and plenary lectures were delivered at the clean room user meeting in Upsalla, Sweden, and at the ICNBME in Moldova. As in 2011, the SPIE nanotechnology conference was organized, this time in Grenoble, France, where the number of participants doubled. Public talks included again a contribution to the "Night of the Profs" series, where the opening lecture was given to a very high number of participants, with a positive resonance.

International attention was given to an article in Advanced Materials about a novel concept of self reporting materials. The mechanical state and history of the composite can be read out optically. Even though it was a basic research concept developed with Prof. Cordt Zollfrank from the Technological University Munich, scientific news pages like physweb.org or materials views, reported it in detail. Another article concerning a flexible ceramic was chosen as cover story of the Particle and Particle Systems Characterization journal. In general, the scientific outcome was covered by several lab journals like GIT as well as newspaper reports. Within the framework of the SFB 677, a podcast on the new material linker technology was created by the IPN group of Prof. Ilka Parchmann. Further scientific achievements are reported in the results section.

The group grew again; in December 16 researchers and one technician were employed. Among them, Dr. Oleg Lupan joined the group; he received an advanced researcher grant from the Alexander von Humboldt foundation. As an expert on ZnO he has contributed significantly to the output of the group.

## Results

In 2013 the scientific results of the group could be published again in prominent scientific journals like Advanced Materials, Applied Physics Letters, or PLoS ONE. Besides the basic research aspect, several techniques like flame transport synthesis led to novel applications. A first prototype of a low power light scattering element could be transferred to a commercial company. This is the first commercial demonstrator in which ZnO tetrapods formed by the flame transport synthesis process have been included. In the following discussion, three selected examples should give a more detailed insight into the research and technology transfer carried out by the functional nanomaterials group. All these projects are part of the teaching and education, as all projects include and are based on bachelor's, master's and PhD-theses.

### UV-Sensors from the baking oven

Placed in fire detectors and water treatment units UV-sensors can save lives: in many areas of industry and the environment the demand for these devices is rising steadily. This was a motivation to develop a recipe for the simple and fast fabrication of nanostructure based UV-sensors. This statement and the following text about the UV-sensors which were developed in 2013 is taken from the Kiel University Press news items that were written for online publication of the corresponding Advanced Materials article. It appears very suitable for explaining the importance of UV-sensors to a broader audience. The process enables the "baking" of the nanostructures on a microchip within milliseconds. The nanostructure design enables a fast UV-sensor response time. This new technique diminishes the need to use sophisticated equipment and toxic chemicals.

When building a sensor device from nanostructures in the form of wires, one of the challenges, because of their extremely

small dimensions, is to integrate the nanostructures between electrical contacts on the chips. Most of the existing synthesis methods, such as chemical vapour deposition or vapour-liquid-solid (VLS) growth allow synthesis of different nanostructures only under specific conditions. For instance, the presence of catalytic particles, particular substrates, complex temperature, atmospheric conditions, and many more factors must be met. Furthermore, to integrate the synthesized nanostructures with these techniques in the chips requires another very sophisticated step. There are of course already silicon or gallium nitride based UV detectors available in the market but they lack a certain level of selectivity and also they cannot function in harsh environments. More important, high production costs, multistep processes, and the requirement of specific operating conditions limit the field of application for these sensors. On the other hand, nanostructures made from zinc oxide are highly interesting for multifunctional applications, not only due to their sensitivity to UV light and their electrical and mechanical properties, but also their simple formation process. A network of interconnected zinc oxide nano-tetrapods as a bridge between electrodes on a chip can be fabricated by a new single step flame transport synthesis process: in a simple oven or airbrush gun-type burner it only needs high temperature to convert zinc microparticles into nano-micro tetrapods (see Figure 1). This process takes place in an ambient air environment and the necessary amount of oxygen is regulated by the flame itself. The high temperature of the flame ensures contacts of good quality between chip and the nanostructures, which is highly desirable for a better performance of the device. The sensor reacts to UV light within milliseconds of its exposure. Additionally, it also works in rather rough environments. These simple and inexpensive manufacturing conditions as well as the use of cost efficient zinc microparticles make this production method highly attractive to manufacturing companies. It might be a small step towards the utilization of the inexpensive but multifunctional ZnO semiconductor.

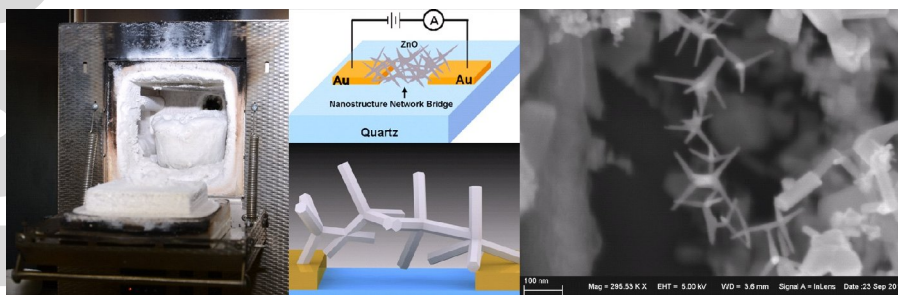


Fig. 1: Zinc oxide for gas sensors from a simple oven process. Left: ZnO snow after synthesis, middle: sketch of the microchip connection, right: electron microscopy of a ZnO nano-bridge

### Interpenetrating nanostructures for flexible ceramic assisted composite materials

The remarkable characteristics of nanostructures are typically the result of their nanoscopic dimensions. One of them is the high flexibility of macroscopic brittle materials. Forming 3D nano- and microstructured network materials is a way to transfer these special properties to the macroscopic world. Classical semiconductors or ceramics exhibit important fundamental properties including a certain chemical inertness and especially high-temperature stability. State-of-the-art applications include sensory properties (see above) or high Li storage capability. However, their rigidity on the macroscopic scale hinders applications as flexible, high-temperature materials, for example in advanced battery electrodes that cope with large quantities of Li without breaking, or as ceramic stents, which would require elastic properties on a macroscopic scale. The magazine cover image on the left in Figure 2 shows a three dimensional network of interpenetrating crystals. This network enables a high flexibility and at the same time high temperature stability as the network is made from ZnO micro and nanocrystals. The article in 'Particle and Particle Systems Characterization' describes the effect of porosity on the flexibility of the material. With a space filling of 100%, i.e. full solid ceramic, the elastic modulus corresponds to more than 100 GPa, which is the bulk modulus and comparable with a ridged and brittle material like a glass plate. The viewgraph in the middle in Figure 2 shows the effect of free space in the network. The wider the openings in the network, the higher the flexibility, expressed by the softer modulus. A porosity of 75% means already a modulus decrease of more than a factor of 5000. The flexibility can be increased up to a wool-like behaviour; even if the material is bent by more than 90 degree it will not break. With a porosity of more than 98%, the material has a modulus of less than 1 kPa. As

ZnO is a semiconductor, the multifunctional properties of the network can be utilized, e.g. a current conducted through the network corresponds with the mechanical behaviour. The viewgraph on the right shows the electromechanical properties of the porous networks. The network can be deformed elastically up to about 2% compression while the current continues to increase up to a deformation of 3%. This can be explained by two competing processes. In the elastic behaviour regime, the network is compressed, which causes the formation of additional junctions by touching crystals and thus results in an increase in the electrical conductivity. As soon as plastic deformation sets in at larger deformations, tetrapods in the network start to break and thus the conductivity decreases. This implies that beyond the elastic limit (at a compression of about 3% in this case) the conductivity increase due to additional junctions becomes overcompensated by broken tetrapods. If the flexible ceramic networks are utilized as parts of a polymer composite material, the conductivity can provide valuable information about the internal structure, e.g. for damage detection.

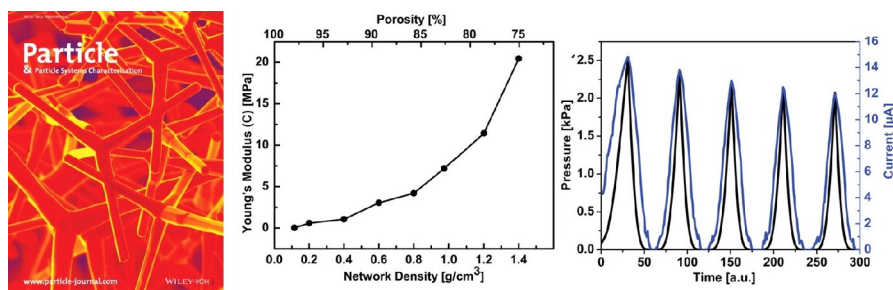


Fig. 2: Flexible ceramics. Left: Cover illustration showing interpenetrating ZnO, (Figure reproduced with permission, Copyright Wiley). Middle: influence of the porosity of the network. Right: correlation between mechanical and conductive properties

## Toxicity of nanostructures

As mentioned in earlier issues of the Almanac, there are pronounced biomedical properties of zinc oxide such as an anti-viral effect. The nano-microstructures (NMS) of zinc oxide have multifunctional applications ranging from nanoscale electronic devices, lasers, sensors, and significantly in biomedical engineering as consumer products. The main advantages of ZnO include its biocompatible nature, low costs availability, and possible fabrications of its nanostructures by very simple growth processes. For example, due to their interesting antibacterial properties, ZnO nano-microstructures have served as promising prophylactic agents against bacterial infections; it is currently in use in dental treatments. In our case, if ZnO structures of different size ranges as well as with complex shapes have been, and are going to be utilized for various applications, including the biomedical field, an understanding about the potential effects (like toxicity levels) caused by these structures are highly important. Material properties like size, shape, method by which they have been synthesized etc. as well as cell culture conditions play equally important roles in determining the nanostructure's effect on cells. Synthesis by chemical routes involves different chemicals and thus the nanostructures obtained exhibit chemically modified surfaces. In this regard, direct fabrication methods (e.g. physical vapour deposition, lithography techniques, etc.) are better as the obtained structures do not involve complex chemicals; however precise control over size, shape and cost-effectiveness are major issues. The ZnO tetrapods used in this work were synthesized by a recently introduced flame transport synthesis (FTS) approach. The main advantage of this technique is that it offers versatile synthesis of ZnO-T with dimensions ranging from nanoscale to microscale and large amounts (up to kilograms) can be easily synthesized in a very effective manner. Nevertheless, the questions about the cytotoxicity include shape and size of the particles. A recent study, published in collaboration with the toxicology department showed that tetrapodal zinc oxide has a significant lower toxicity than zinc salts and zinc nanoparticles. It was found that the cell toxicity depends indeed on the shape. Figure 3 shows some images from this study: the tetrapodal particles especially show a surprisingly good cell compatibility. Only very high amounts of more than 4 g/l cause significant cytotoxicity.

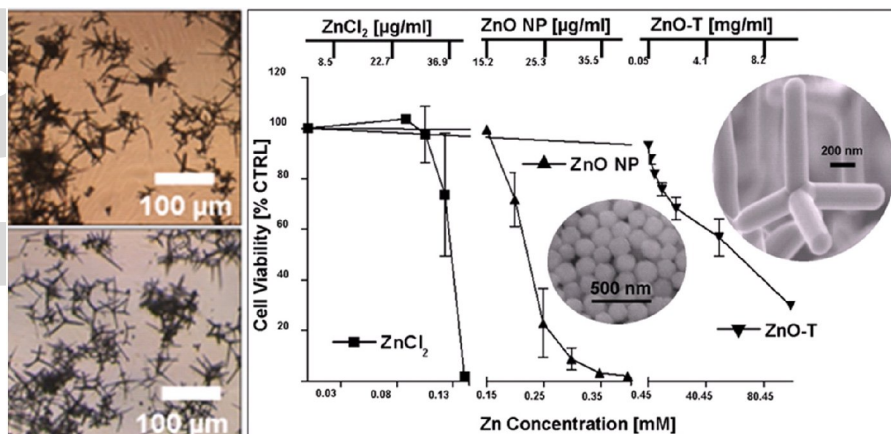


Fig. 3: Cell toxicity data: Very large amounts of tetrapodal zinc oxides are necessary to slow down cell growth

## Personnel

Head of the group: Prof. Dr. R. Adelung; Secretary: Dipl.-Geol. B. Minten (50%)

Technical Staff: Technician C. Ochmann (50%), Dipl.-Ing. S. Rehders (50%), Dipl.-Inf. P. Sommer (50%)

Scientific Staff:

M.Sc. M. Baytekin-Gerngroß	17.06.-31.12.2013	(50%)	DFG
Nanostructures and toxicity			
M.Sc. S. Freitag	01.07.-31.12.2013		BMWi
Analytics of nanocoatings			
M.Sc. D.M. Gedamu	01.01.-31.12.2013		DFG, CAU
Nanowire electronics			
M.Sc. J. Gröttrup	01.11.-31.12.2013	(50%)	EU
Graphene like structures			
Dipl.-Wi.-Ing. M. Hoppe	01.03.-31.12.2013		BMWi
Conductivity of nanocomposites			
M.Sc. I. Hölken	01.01.-31.12.2013		BMWi, CAU
Anwendung und Eigenschaften oxidischer Nanomaterialien			
M.Sc. X. Jin	01.01.-31.12.2013		SFB 677, CAU
Piezo composites			
M.Sc. V. Kaidas	01.10.-31.12.2013	(50%)	CAU
Biomedical research			
Dipl.-Ing. S. Kaps	01.01.-31.12.2013		SFB 855
Piezomaterials			
PhD O. Lupan	01.05.-31.12.2013		AvH Grand
ZnO nanostructures			

Dr. Y.K. Mishra	01.01.-31.12.2013	CAU, AvH Grand
Nanowires and nanostructures		
M.Sc. S. Nöhren	01.-31.12.2013	CAU, BMWi
Herstellung und Theorie poröser Nanomaterialien		
M.Sc. I. Paulowicz	01.01.-31.12.2013	CAU
Synthesis and characterization of nanostructures		
M.Sc. A. Schuchardt	01.01.-31.12.2013	CAU
Aeromaterials and electrical properties		
M.Sc. D. Smazna	01.11.-31.12.2013 (50%)	EU
Graphene like structures		
M.Sc. E.S.E.S.A. Zarie	01.01.-31.07.2013	Grant Government Egypt, CAU
Drug evaporation		

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

mawi-929: Chemistry and Physics of Biomaterials, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
R. Adelung (+ C. Selhuber-Unkel, L. Kienle)

mawi-102: Mathematik für Materialwissenschaftler I, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. Adelung

mawi-503: Halbleitertechnik und Nanoelektronik, 4 hrs Lecture/Week,  
R. Adelung (+ H. Föll)

mawi-503: Halbleitertechnik und Nanoelektronik, 1 hrs Seminar/Week,  
R. Adelung (+ H. Föll)

mawi-E010: Technologie und Gesellschaft 2, 2 hrs Seminar/Week,  
R. Adelung (+ W. Theobald)

mawi-907: Semiconductor, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Y.K. Mishra

Seminar Funktionale Nanomaterialien, 2 hrs Seminar/Week,  
Y.K. Mishra

Solid State Physics I, 2 (+ 1) hrs Exercise (+ Exercises)/Week,  
F. Faupel (+ A. Schuchardt)

### *Summer 2013*

Mathematik für Materialwissenschaftler II, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. Adelung (+ S. Harms, T. Strunskus)

mawi-414: Voraussetzungen und Auswirkungen Nanotechnologie, 2 hrs Lecture/Week,  
R. Adelung

mawi-414: Voraussetzungen und Auswirkungen Nanotechnologie, 1 hrs Seminar/Week,  
R. Adelung

Seminar Funktionale Nanomaterialien, 2 hrs Seminar/Week,

Y.K. Mishra

mawi-E010: Technologie und Gesellschaft 2, 2 hrs Seminar/Week,

R. Adelung (+ W. Theobald)

Winter 2013/2014

mawi-929: Chemistry and Physics of Biomaterials, 3 hrs Lecture/Week,

R. Adelung (+ C. Selhuber-Unkel, L. Kienle)

mawi-102: Mathematik für Materialwissenschaftler I, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

R. Adelung

mawi-503: Halbleitertechnik und Nanoelektronik, 4 hrs Lecture/Week,

R. Adelung (+ H. Föll)

mawi-503: Halbleitertechnik und Nanoelektronik, 1 hrs Seminar/Week,

R. Adelung (+ H. Föll, Y.K. Mishra)

mawi-907: Semiconductor, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

Y.K. Mishra

Seminar Funktionale Nanomaterialien, 2 hrs Seminar/Week,

Y.K. Mishra

## Third-Party Funds

Botschaft der Arabischen Republik Ägypten, *Ägyptisches Regierungsstipendiat in Long Term Mission System für Zarie für vier Jahre*, 07.03.2009-06.03.2013 (66.000 EUR)

DFG (SFB 855/1-2010 Teilprojekt IGK), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: Integriertes Graduiertenkolleg*, 01.01.2010-31.12.2013 (378.272 Euro)

DFG (SFB 855/1-2010 Teilprojekt A5), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: Herstellung von vertikal freistehenden magnetoelktrischen Kompositen*, 01.01.2010-31.12.2013 (339.840 Euro)

DFG (SFB 855/1-2010 Teilprojekt Z), *Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft: wiss. Hilfskräfte*, 01.01.2010-31.12.2013 (29.600 EURO)

DFG (SFB 677/2 2011 C10), *Funktion durch Schalten: Photoaschaltbare Adhäsive*, 01.07.2012-30.06.2015 (474.240 EURO)

EU (Interreg-Projekt), *Technet Nano (074)*, 29.12.2011-28.03.2014 (112.925 EURO)

ETSH, *Transferprämie 2012*, 26.11.2012-31.12.2013 (5.000 EURO)

BMW (16KN015421), *Nanobasierte Beschichtungstechnologie für den Erosions- und Vereisungsschutz von Offshore-Windenergieanlagen (DKL:WEA)*, 01.11.2012-31.10.2014 (159.963 EURO)

AvH-Stiftung (3.3-MOL/1148833 STP), *Stipendium an Prof. Dr. Oleg Lupan*, 01.-31.05.2013 (56.700 EURO)

AvH-Stiftung (3.3-MOL/1148833 STP), *Forschungskostenzuschuss an Gastgeber für 18 Monate*, 01.-31.05.2013 (14.400 EURO)

BMW (16KN015428), *NanoMarin / Analysen der DLC Beschichtungen (DLC4marin)*, 01.06.2013-30.11.2015 (173.407 EURO)

DFG (Ad183/10-1), *Differentielle Untersuchungen zur Rolle der Oberflächeneigenschaften und der zellulären Aufnahme von Metalloxiden in ihrer Nanoform für ihre Zytokompatibilität (AOBJ: 602565)*, 17.06.2013-16.06.2015 (87.200 EURO)

EU, *Graphene Flagship (Projekt Nr. 604391)*, 01.10.2013-31.03.2016 (205.800 EURO)

## Further Cooperation, Consulting, and Technology Transfer

### *University:*

Dr. D. K. Avasthi, Materials Science Group, Inter University Accelerator Centre New Delhi, India: experiments with composite materials.

Prof. Dr. T. Bosch, Zoologisches Institut und Museum (Sektion Biologie), Allgemeine Zoologie, CAU Kiel: viral experiments with nanostructures.

Prof. Dr. F. Faupel, Institut für Materialwissenschaft - Materialverbunde, CAU Kiel: various projects ranging from nanostructures to superhydrophobicity.

Prof. Dr. S. Gorb, Institut für Zoologie, CAU Kiel: switchable adhesion.

Prof. Dr. M. Kern, Universitätsklinikum Schleswig-Holstein, Klinik für Zahnärztliche Prothetik, Propädeutik und Werkstoffkunde, CAU Kiel: chemical and microscopy on dental materials.

Prof. Dr. L. Kienle, Institut für Materialwissenschaft - Synthesis and Real Structure, CAU Kiel, Transmission electron microscopy.

Prof. Dr. H. Kohlstedt, Institut für Elektrotechnik und Informationstechnik - Nanoelektronik, CAU Kiel: nanowires field effect transistors.

Prof. Dr. E. Quandt, Institut für Materialwissenschaft - Anorganische Funktionsmaterialien, CAU Kiel: magnetoelectric materials.

PD Dr. C. Röhl, Institut für Toxikologie, CAU Kiel: toxicity of nanostructures of ZnO.

Prof. Dr. C. Ronning, Universität Jena: photoluminescence ZnO Nanobridges.

Prof. Dr. D. Shukla, University of Illinois, Chicago, USA: antiviral properties of ZnO nanostructures.

Dr. F. Spors, Western University of Health Sciences, Pomona CA, USA: antiviral studies of nanostructures.

Prof. Dr. Anne Staubitz, Institut für Organische Chemie, CAU Kiel: switchable polymers.

Prof. Dr. H. Steckel, Pharmazeutisches Institut, CAU Kiel: nanostructured pharmaceuticals.

Prof. Dr. K. Schulte, TU Hamburg: aerographite.

Prof. Dr. I. Tiginyanu, TU of Moldova: galliumnitride.

Dr. V. Tiwari, Midwestern University, Illinois, USA: antiviral properties of ZnO nanostructures.

Prof. Dr. C. Zollfrank, TU München: self reporting materials.

### *Research Institutes:*

Prof. Dr. H.-G. Rubahn, Mads Clausen Institute, University of Southern Denmark, EU Interreg project: Technet Nano.

### *Industry:*

IRATEC, Institut für Rohrleitungs- und Apparatechnik GmbH, Magdeburg: Forschung und Entwicklung zu Materialsynthese und -analytik.

Materion thin films and sensors GmbH, Wismar, DLC4marin: Forschung und Entwicklung zu Materialsynthese und -analytik.



nanoproofed r&d GmbH, Scharbeutz (Gleschendorf), DKL:WEA: photocatalytic substances, Forschung und Entwicklung zu Materialsynthese und -analytik.

OIS, Offshore Industrie Service GmbH, Rostock: Forschung und Entwicklung zu Materialsynthese und -analytik.

Wöhlk, Schönkirchen: Examination of contact lenses.

## **Diploma, Bachelor's and Master's Theses**

- T. Behrendt, *Characterization and manufacturing of transparent conductive oxides for silicon hetero junction solar cells*, 15.04.2013
- S. Scheffler, *Untersuchungen von oberflächenmodifiziertem Lithiumtitanat*, 03.05.2013
- S. Freitag, *Multifunktionale Komposite aus organischen und anorganischen Funktionswerkstoffen auf Basis von Aerographit*, 04.06.2013
- S. Sachau, *Untersuchungen der Haft- und Zugfestigkeit von tetrapodalen Zinkoxid-Kompositlacken auf Polyurethanbasis*, 05.08.2013
- S. Dittich, *Einfluss von Platin-Modifizierungen auf die katalytischen Eigenschaften von Cer(IV)oxid-Beschichtungen*, 05.09.2013
- P.H. Mösel, *Influence of ceramic particles on the mechanical characteristics of different polymeric materials*, 12.09.2013
- M. Hesebeck, *Optimierung von Manganphosphatschichten auf gasnitrierten Stahlbauteilen*, 11.09.2013
- L. Bumke, *Auswirkung von Zinkoxidmikrostrukturen auf die mechanischen und strukturellen Eigenschaften von PET*, 04.10.2013
- C. Hänel, *Einfluss von spärlichem und tetrapodalem Zinkoxid sowie Zirkoniumoxid auf die mechanischen Eigenschaften von Polythiourethan*, 08.10.2013
- A. Omelcenko, *Characterization of electrical conductivity of aluminium doped ZnO tetrapod structures and their suitability as filler material for polyurethane composites*, 17.10.2013
- H. Wolff, *Analyse des Einflusses von Werkzeug-Beschichtungen beim MIM (Metal injection molding) von Titan*, 23.10.2013
- J. Gröttrup, *Fabrication and characterisation of 3D interconnected networks of ZnO tetrapods*, 30.10.2013
- D. Smazna, *Growth of core-spike ZnO sea-urchins and their scope for antiviral applications*, 31.10.2013
- S. Schlüter, *Untersuchung des Gefüges und des Korrosionsverhaltens von Reibschweißverbindungen aus austenitischen CrNi-Stahl*, 31.10.2013
- M. Lohmann, *Optimierung von 1-1 ME-Sensoren im Rahmen des Sonderforschungsbereiches 855*, 20.09.2013
- F. Gerds, *Optimierung und Entwicklung von Methoden zur Herstellung sinterbarer poröser Beschichtungen von Titanimplantaten*, 21.10.2013
- J. Rupsch, *Strukturierung von Zn-Flächen*, 29.08.2013
- R. Keitel, *Morphologieuntersuchungen an organischen n-type Transistoren*, 10.09.2013
- D. Krüger, *Entwicklung und Analyse von pulvermetallurgisch hergestellten Titan-Keramik-Verbundmaterialien*, 30.09.2013
- T. Burgdorf, *Analyse des Einflusses der Pulvermorphologie auf den Metallpulverspritzguss von Titan*, 21.10.2013

## **Dissertations / Postdoctoral Lecture Qualifications**

E.S.E.S.A. Zarie, *Vacuum evaporation of pharmaceutical molecules for the creation of medically active nanostructures with enhanced activities*, 13.06.2013



Published in 2013

- X. Jin, M. Götz, S. Wille, Y.K. Mishra, R. Adelung, C. Zollfrank, *A novel concept for self-reporting materials: Stress sensitive photoluminescence in ZnO tetrapod filled elastomers*, *Advanced Materials*, **25**(9), 1342 - 1347 (2013)
- V. Hrkac, L. Kienle, S. Kaps, A. Lotnyk, Y.K. Mishra, U. Schürmann, V. Duppel, B.V. Lotsch, R. Adelung, *Superposition twinning supported by texture in ZnO nanospikes*, *Journal of Applied Crystallography*, **46**, 396 - 403 (2013)
- I.M. Tiginyanu, O. Volciuc, M.A. Stevens-Kalceff, V. Popa, J. Gutowski, S. Wille, R. Adelung, H. Föll, *The impact of the discreteness of low-fluence ion beam processing on the spatial architecture of GaN nanostructures fabricated by surface charge lithography*, *Surface Engineering and Applied Electrochemistry*, **49**(1), 1 - 3 (2013)
- Y.K. Mishra, R. Adelung, G. Kumar, M. Elbahri, S. Mohapatra, R. Singhal, A. Tripathi, D.K. Avasthi, *Formation of self-organized silver nanocup-type structures and their plasmonic absorption*, *Plasmonics*, **8**(2), 811 - 815 (2013)
- Y.K. Mishra, S. Kaps, A. Schuchardt, I. Paulowicz, X. Jin, D. Gedamu, S. Freitag, M. Claus, S. Wille, A. Kovalev, S.N. Gorb, R. Adelung, *Fabrication of macroscopically flexible and highly porous 3D semiconductor networks from interpenetrating nanostructures by a simple flame transport approach*, *Particle and Particle Systems Characterization*, **30**(9), 775 - 783 (2013)
- S.B. Hrkac, M. Abes, C.T. Koops, C.T. Krywka, M. Müller, S. Kaps, R. Adelung, J. McCord, E. Lage, E. Quandt, O.M. Magnussen, B.M. Murphy, *Local magnetization and strain in single magnetoelectric microrod composites*, *Applied Physics Letters* (doi: 10.1063/1.4821443), **103**(12), (2013)
- S. Bhowmick, D. Stauffer, H. Guo, S. Kaps, Y.K. Mishra, V. Hrkac, O. Warren, R. Adelung, A. Minor, L. Kienle, *In situ electromechanical study of ZnO nanowires*, *Microscopy and Microanalysis*, **19**, 434 - 435 (2013)
- O. Lupan, Y.K. Mishra, I. Paulowicz, D. Gedamu, R. Adelung, L. Ghimpu, I. Tiginyanu, *Effect of Al, Sn-doping on properties of zinc oxide nanostructured films grown by magnetron sputtering*, *IEEE Proceedings of the 2013 International Semiconductor Conference*, **1**, 133 - 136 (2013)
- H. Kaur, G. Pujari, A. Sharma, Y.K. Mishra, K.M. Jin, B.K. Nirala, N.K. Gohil, R. Adelung, D.K. Avasthi, *Study of in-vitro toxicity of glucose capped gold nanoparticles in malignant and normal cell lines*, *Advance Materials Letters*, **4**, 888 - 894 (2013)

## Patent Applications

- X. Jin, R. Adelung, *Polymerlaminat und Verfahren zu seiner Herstellung*, Deutsches Patentamt, 23.07.2013, DE 10 2013 107833.8

## Presentations

- R. Adelung, *Use of polymers in a non chemical manner (talk)*, 9. Emmy-Noether-Nachwuchsgruppenleitertreffen Chemie, CAU, Kiel, 09.-10.02.2013
- R. Adelung, *Impulsvortrag: Mikrofüllerbasierte Verklammerung als Adhäsionsstrategie für inkompatible Werkstoffe (invited talk)*, 2. Sitzung DGM-Fachausschuss: Hybride Werkstoffe und Strukturen, Bremen, 28.02.2013
- Y.K. Mishra, *Fabrication of different nano-microstructures by flame transport synthesis: From electronic to biomedical applications (invited talk)*, Inter University Accelerator Centre, New Delhi, India, 14.03.2013
- Y.K. Mishra, *Fabrication of different nano-microstructures by flame transport synthesis: From electronic to biomedical applications (invited talk)*, Department of Physics, University of Lucknow, Lucknow, India, 09.04.2013
- R. Adelung, *ZnO based nanomaterials (invited talk)*, Reinraumvortrag Nils Nordell, Stockholm, Sweden, 16.-17.04.2013
- R. Adelung, *Production, properties and perspective of ultra porous materials like flexible ceramics and aerographite (invited talk)*, 2nd International Conference on Nanotechnologies and Biomedical Engineering, Chisinau, Moldova, 18.-20.04.2013

- M. Baytekin, M.-D. Gerngross, Q. Li, S. Viebig, C. Selhuber-Unkel, J. Carstensen, H. Föll, R. Adelung, *Surface modification of Ti by chemical etching and HA sputtering for dental applications (poster)*, 2nd International Conference on Nanotechnologies and Biomedical Engineering, Chisinau, Moldova, 18.-20.04.2013
- R. Adelung, *Semiconductors as flexible ceramics, as antiviral materials and as both (invited talk)*, SPIE Microtechnologies, Grenoble, Switzerland, 23.-26.04.2013
- X. Jin, Y.K. Mishra, R. Adelung, *Role of shape: ZnO tetrapods in fabrication of smart composites (poster)*, SPIE Microtechnologies, Grenoble, Switzerland, 23.-27.04.2013
- A. Schuchardt, *Aerographite: mechanical, electrical and optical properties of a cellular carbon nanomaterial with densities below 0.2 mg/ccm (talk)*, SPIE Microtechnologies, Grenoble, Switzerland, 23.-27.04.2013
- R. Adelung, *Von Theorie zum Markt: Nanotechnologische Entwicklungen (invited talk)*, Kieler Salon, KiWi GmbH, Kiel, 02.05.2013
- R. Adelung, *Von Theorie zum Markt: Nanotechnologische Entwicklungen (invited talk)*, 14. Kieler Salon, Kiel, 14.05.2013
- R. Adelung, *Extreme Materialien für Energie und Medizin (invited talk)*, Kieler Woche Vorträge, Kiel, 28.06.2013
- R. Adelung, *Cytocompatibility of artificial viral barrier systems from ZnO micro-nanostructures (poster)*, Retreat Exzellenzcluster Inflammation at Interfaces, Schleswig, 02.-03.08.2013
- R. Adelung, *Nanomaterialien in der Meerestechnik (invited talk)*, Cluster Future Ocean, Schleswig, 10.09.2013
- R. Adelung, *Neue Materialien zusätzliche Effizienz - Potentiale aus der Forschung (invited talk)*, WTSH Ressourceneffizienz - Wege zum effizienten Produzieren, Kiel, 10.09.2013
- Y.K. Mishra, S. Kaps, A. Schuchardt, I. Paulowicz, X. Jin, D. Gedamu, S. Wille, R. Adelung, *Fabrication of different nano-microstructures by flame transport synthesis: From electronic to biomedical applications (invited talk)*, Advanced Materials World Congress, Cesme, Izmir, Turkey, 15.-20.09.2013
- Y.K. Mishra, S. Kaps, A. Schuchardt, I. Paulowicz, X. Jin, D. Gedamu, S. Wille, R. Adelung, *Fabrication of different nano-microstructures by flame transport synthesis: From electronic to biomedical applications (invited talk)*, University of Sabanci, Istanbul, Turkey, 15.-20.09.2013
- R. Adelung, *Von Aerographit bis Antiviral: Zinkoxid macht's möglich (invited talk)*, 47. Herbsttagung des Vereins MNU-SH, Kiel, 24.09.2013
- R. Adelung, *Multifunctional ZnO - from self reporting materials to self stiffening ultralightweight materials (invited talk)*, Euro Intelligent Materials, DGM, Kiel, 25.-27.09.2013
- I. Hölken, M. Hoppe, R. Adelung, *Enhancement of mechanical and electrical properties of tetrapod-like zinc oxide filled polymer coatings (poster)*, Euro Intelligent Materials, DGM, Kiel, 25.-27.09.2013
- S. Nöhren, H. Föll, *Electrochemical study of size effects in Si microwire anodes for Li ion batteries (talk)*, Euro Intelligent Materials, DGM, 25.-27.09.2013
- R. Adelung, *Zinkoxid als funktionales Nanomaterial: Vom Aerographit bis zum UV-Sensor (invited talk)*, Herbstschule Nanowissenschaften, Lüneburg, 12.11.2013
- R. Adelung, *Extrem poröse Materialien, deutlich mehr als heiße Luft (invited talk)*, Stryker Academy, Schönkirchen, 14.11.2013
- R. Adelung, *Wie intelligenter Sand im Getriebe beschleunigt: Von neuen Materialien und alter Forschungspolitik (invited talk)*, night of the profs, CAU, Kiel, 15.11.2013
- D. Gedamu, *ZnO nanostructure based UV-photodetectors: In-situ integration on chips and their fast response to UV (talk)*, Workshop Technet nano, Kista, Stockholm, Sweden, 26.-28.11.2013

## General Materials Science

The approved BMU proposal concerning novel ways of processing solar cells (with ISFH GmbH Hameln) could not be started since the partners refused to sign the contract as proposed by the CAU. The group lost not only entry into a promising new technology but 180.000 € of third party funding by the BMU.

Work on the Si nanowire anode for Li ion batteries, together with the Fraunhofer Institutes for Chemical Technology (ICT) and Material and Beam Technology (IWS) as part of the AlkaSuSi project (BMBF) has been finished successfully: the main researcher, Enrique Quiroga-Gonzales, left the group on Dec. 31st for a Professorship in Mexico. A continuation of this work is impossible due to the CAU patent politics.

A joint proposal of Prof Kienle and Prof Föll concerning basic research on Si wire anodes was granted by the DFG in Sept. 2013; the group receives 153.000 € for 2 years.

The DFG CELLO project was finished; the results exceeded expectations. A proposal concerning SHALUM ("SHAded LUMinescence") has been forwarded to the DFG (in agreement with Prof. Adelung).

The BMU "SolarWinS" (Solarforschungscluster zur Ermittlung des maximalen Wirkungsgradniveaus von multikristallinem Silicium) project progressed rather nicely. Meanwhile it became clear that it will be continued ("SolarLife") and that AMAT is expected to participate. The present patent politics of the CAU will most likely not allow AMAT participation however.

The work for the SFB 855 has produced further remarkable results but not yet a functioning sensor.

The "Mold Nanonet" project, an EU funded partnership with the Technical University of Moldova, proceeds smoothly.

A new project together with the "Landesmuseum; Schloss Gottorf in Schleswig" has been started. It concerns the rapid desalination by electrochemical means of archaeological finds that have been submerged in salt water for a long time. The object in this case is a cannon from the sunken 16<sup>th</sup> century Danish flagship "Lindormen".

Phasing out or transferring the research activities of the group proceeds smoothly. The retirement of Prof. Föll in 2014 will thus not cause disruptions or resource conflicts.

## Results

*New projects started in 2013:*

For all new projects started it was assured beforehand that they can be continued after the retirement of Prof. Föll.

The new DFG project "Electrochemical and microstructural analysis of the processes of anodes for high capacity lithium-ion batteries based on Si microwire arrays" (together with Prof. Kienle) started in December 2013. First experiments aimed at a better understanding of the structural changes of the Si microwire anodes after cycling at a specific rate. Upon cycling, the anodes are supposed to become amorphous. It is not yet clear how our Si anodes change from crystalline to amorphous Si with the number of cycles, or from which side the Li ions are incorporated first into the wires.

The new BMU project "CuMeMo" concerning novel ways of processing solar cells (with ISFH GmbH Hameln) was abandoned after the project management finally refused to agree to the contract demands of the CAU concerning patents. The group thus could not start work on this very interesting topic that was considered to open a new and exciting research area for the successor of Prof. Föll.

The new project with the "Landesmuseum" so far runs on an informal base. AMAT supplied the "Landesmuseum" with a complete electrochemical high-performance apparatus that allows huge objects such as a medieval cannon to be kept at a constant potential in a desalination bath. This is absolutely necessary to avoid excessive corrosion in (humid) air. First

results indicate the viability of the approach. It is expected that the desalination time (at present several years) can be reduced substantially.

*Cooperation projects* started or running in 2013:

Work within the AlkaSuSi project (BMBF) has led to what is currently the very best Si wire anodes with respect to all performance criteria. Progress depended essentially on the capability of AMAT to record in-situ impedance spectra (IS) with its unique FFT technique and to extract data about the detailed electrochemical processes from the measurements. This resulted, for example, in an understanding of the crucial role of the PEG (Polyethylene-Glycol) additions to the electrolyte, and based on this, an optimization of the necessary pore diameter variations.

Solar cell activities within the running BMU project "SolarWinS" involved mostly detailed CELLO analysis of solar cells from project partners plus improvements concerning the techniques and the interpretation of the results. The outstanding result was that lateral current flow could be caused by certain inhomogeneities of the solar cells. These currents flow through the series resistance network and cause substantial losses. This is a new insight that was deeply appreciated by the project partners.

*Internal projects:*

Significant advances were reached with the SHALUM ("SHAded LUMinescence") technique. New hardware was constructed (temperature controlled sample stage using vacuum suction and extremely flat contacting of the solar cells), allowing standard luminescence measurements at well-determined working points along the solar cell's  $I$ - $V$  curve; the new set-up is now thoroughly tested and further improved by a master's student.

## RESEARCH DETAILS

### Battery Research:

To extend the lifetime of the Si microwire anodes, it is necessary to know the voltage limits for charging the battery. If the limits are exceeded, severe damage inside the battery will occur. Voltammetric measurements revealed at which potentials the phase transformations take place and to which potential the battery can be charged.

The Si microwire anodes of different thickness and length as fabricated by the AMAT group showed a severe change in the lithiation/delithiation process when lithiating thin and long wires. The voltage range for charging therefore depends clearly on the thickness and length of the wires of the anode. Short and thick wires show the easiest lithiation/delithiation due to smaller resistances of the Si wires. This is a new and important insight that has not been previously reported in the literature.

The amorphization process starts from the walls of the wires and not from the top. First results indicate that the inner core of the Si microwire anodes remains crystalline after the first two cycles. The preparation of the Si samples with the Focused Ion Beam method (FIB) for the TEM proved to be a challenge. The samples have to be as thin as 10 - 50 nm for good high resolution TEM images. During the thinning of the samples with the FIB, the wires are only attached to the transfer needle by Pt and tend to collapse because they do not have a stabilizing material.

A crucial factor in the production of Si microwire anodes is the ability to control the diameter of the pores initially etched. In practice under "normal" pore etching conditions this is not possible. The trick is to manipulate the passivation of the pore walls by, for example, supplying the "right" additions to the electrolyte, controlling the temperature, and optimizing the electrical parameters. Since the parameter space is very large, in-situ measurements of what is going on are necessary, and FFT-IS is the only method that can be applied. The in-situ results are converted in real time into plots of parameters of equivalent circuit diagrams; typically resistances and time constants are evaluated. The results showed that one of the three time constants obtained by FFT-IS measurements relates directly to the critical passivation state of the pore walls as well as the roughness of the pore walls (Fig. 1) and can thus be used to control the process. This work was carried out and published in cooperation with an internationally renowned Irish group (O'Dwyer, Raman Scattering) [E. Quiroga-González,

J. Carstensen, C. Glynn, C. O'Dwyer, and H. Föll, "Pore size modulation in electrochemically etched macro-porous p-type silicon monitored by FFT impedance spectroscopy and Raman scattering", *Phys. Chem. Chem. Phys.* 16, 255 (2014)].

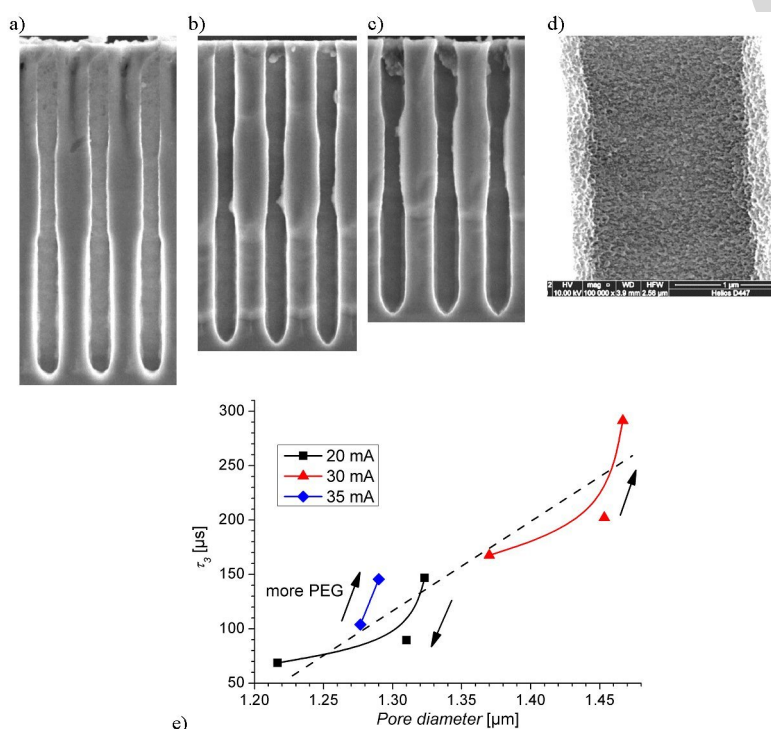


Fig. 1: a) - d) Experiments to pore diameter variation and the roughness of the pore walls. e) Relation between a time constant  $\tau_3$  obtained from FFT impedance and pore diameters and PEG additions. PEG reduces micro-turbulences in the electrolyte, resulting in smoother pore walls with better passivation properties.

The basic patent for the AMAT Si microwire anodes has been sold to Samsung for 300.000 € and accounts for more than 10 % of the total income of the PVA. While this is gratifying for the inventors, it makes future projects with German companies or Federal funding agencies like the BMBF, BMW, or BMU virtually impossible.

#### SFB 855 Research:

The experimental work concerning the SFB 855 (magneto-electric composite materials) has focused on the electrochemical deposition of magnetic metals inside macroporous InP membranes, in particular Ni and FeCo. In the case of Ni, the galvanic growth of Ni nanowires inside InP membranes was investigated using FFT impedance spectroscopy. The electrochemical fabrication of these ultra-high aspect ratio membranes was part of the research of the last few years. The galvanic deposition in high and even ultra-high aspect ratio membranes is a very complex process and has almost nothing to do with standard galvanic processes known for planar structures.

The *in-situ* FFT impedance spectroscopy allows an inside view to be gained in the processes involved during the growth of Ni nanowires that cannot be obtained by any other technique. The impedance data are recorded for a frequency range from 75 Hz - 18 kHz simultaneously. An electric equivalent circuit model involving a series resistor and three *RC* elements can describe the recorded impedance data completely. The full complexity of the galvanic deposition becomes visible in Fig. 1a, where the time dependence of the seven fit parameters for Ni deposition is depicted. The Ni nanowire growth process can be separated into three different processes: a catalytic process supporting the Ni deposition (fit parameters  $R_p$  and  $\tau_p$ ), the Ni deposition itself (fit parameters  $R_a$  and  $C_a$ ), and a diffusion-limited passivation process (fit parameters  $R_b$  and  $C_b$ ).

The knowledge gained helps to optimize the electrolyte and deposition conditions for tuning the magnetic properties of the Ni nanowires. Of course, this is not limited to Ni nanowires, but can also be applied to other materials.

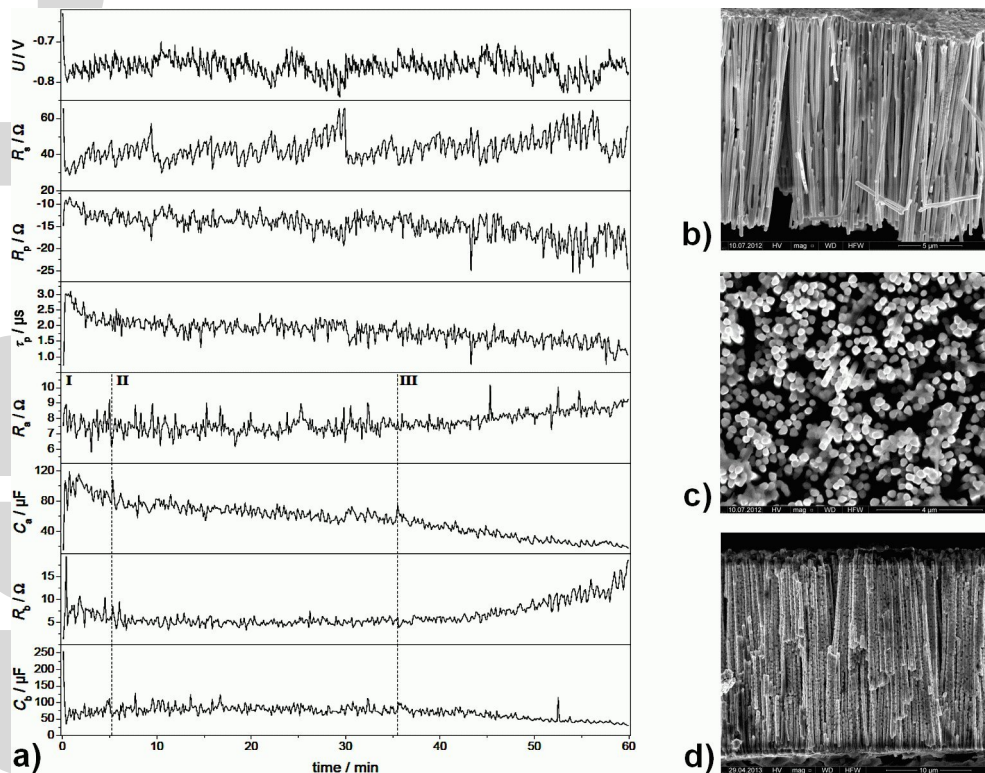


Fig. 2: FFT impedance spectroscopy: a) time dependence of the fit parameters describing the galvanic Ni deposition inside InP membranes. SEM images of freestanding Ni nanowires b) in cross-section, c) in top view, and d) embedded in PZT by a sol-gel process.

Besides the work related to the porous InP approach a different approach based on the free-standing Ni nanowires was followed. Ni nanowires were grown on an Au plating base in a porous aluminium oxide membrane. In the subsequent step the aluminium oxide membrane was dissolved and a free-standing Ni nanowire array was obtained (Fig. 2a and b). This Ni nanowire array could then be embedded into PZT by a sol-gel process. The PZT / Ni nanowire composite is shown in Fig. 2d.

#### Solar cell characterization using CELLO und SHALUM:

The following pictures (Fig. 3) show some relevant CELLO short-circuit current and series resistance maps of selected commercial solar cells. Two multicrystalline (mc) Si cells are compared, differing in the distribution of recombination-active defects. The cell with large defect clusters (top row) has larger efficiency losses than expected from the average photocurrent; its series resistance map shows increased values that are inhomogeneously distributed and correlate with the areas of reduced photocurrent. This can be explained by lateral balancing currents flowing as a consequence of the inhomogeneous photocurrent. These currents pass through the series resistance network, causing significant ohmic losses only in the case where they have to flow over large distances. The latter is much less relevant for the cell without defect clusters (bottom row). This can explain the observed differences in the open-circuit voltage and illustrates an intrinsic limitation of state-of-the-art mc-Si cells compared to mono-Si cells that has been analyzed in this quantitative manner for the first time.

SHALUM has proved to be a valuable characterization method for solar cells, complementing the injection-level range reached by CELLO. An example for information obtained from the injection level dependence of the series resistance is shown in Fig. 3 (last column). In sum, SHALUM series resistance maps are shown, taken under high-injection conditions



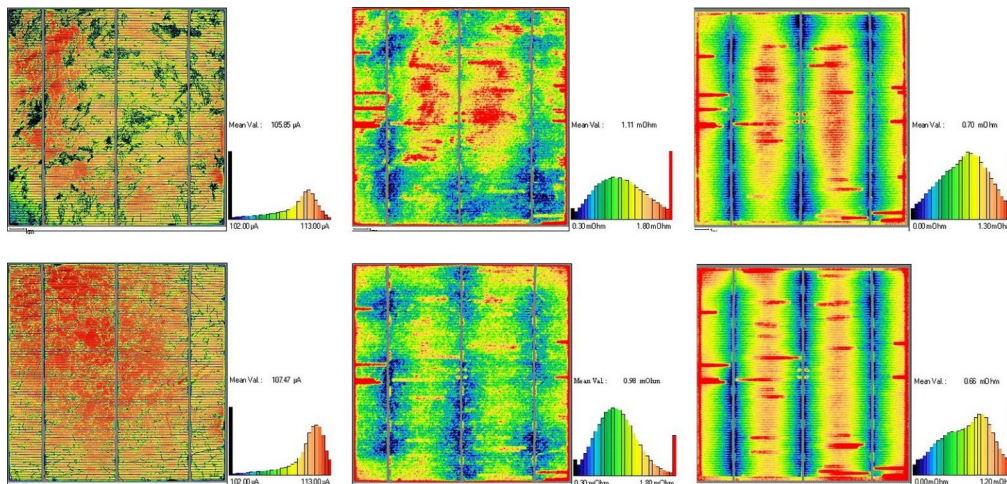


Fig. 3: CELLO maps of short-circuit current (left column) and series resistance at low injection (middle column) as well as SHALUM high-injection series resistance maps (right column) of two mc-Si solar cells (top row: with lower open-circuit voltage, bottom row: with higher open-circuit voltage).

where lateral balancing currents are practically negligible. As a consequence of the injection-level dependence of the series resistance, the average series resistance values of both cells are smaller, and the series resistance images mainly show the “technical” resistance of the solar cell grid (being identical for the two cells, coming from the same production run). SHALUM series resistance maps taken at MPP conditions (not shown) agree very well with the CELLO series resistance maps, both qualitatively and quantitatively.

**Teaching:** The AMAT Hyperscripts still enjoy some popularity around the world as shown by the following statistics:

2012: 19.7 million hits, 940 GByte downloads.

2013: 19.4 million hits, 5.4 TByte downloads. Around 100.000 different users visit the hyper-scripts per month.

Equally gratifying is the Google ranking of all relevant search strings (e.g. chapter and sub-chapter headings) where the AMAT Hyperscripts usually are found in first or second place (then after Wikipedia).

## Personnel

Head of the group: Prof. Dr. Helmut Föll; Secretary: Katrin Brandenburg (50%)

Technical Staff: Dipl.-Ing. (FH) Jörg Bahr

Scientific Staff:

M.Sc. Melike Baytekin	17.06.-31.12.2013	Unterauftrag Uni Konstanz
1/5 SolarWinS		
Dr. Jürgen Carstensen	01.01.-31.12.2013	CAU
Theory, software development, supervision of teaching		
M.Sc. Mark-D. Gerngroß	01.01.-31.12.2013	DFG
SFB 855 Magnetoelectric Composites - Future Biomagnetic Interfaces		
M.Sc. Iris Hölken	01.-14.01.2013 (50%)	CAU
Dr. Yogendra Mishra	01.01.-31.12.2013	CAU

M.Sc. Sandra Nöhren	01.-14.01.2013	(50%)	CAU
M.Sc. Emmanuel Ossei-Wusu	01.01.-31.12.2013		Drittmittel und CAU
Macroporous Si for solar cell uses; optimization of pore etching			
Dr. Enrique Quiroga-González	01.01.-31.12.2013		BMBF
Si nanowire anode for Li ion battery			
Dr. Jan-Martin Wagner	01.01.-31.05.2013		DFG
Theory and development for multi-color CELLO (incl. impedance and non-linear behaviour) and for shaded luminescence techniques			

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

- Quantenmechanische Aspekte in der Materialwissenschaft, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Jürgen Carstensen
- Aktuelle Fragen der Forschung, 2 hrs Seminar/Week,  
Helmut Föll (+ Jürgen Carstensen)
- Materialwissenschaft I, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ Mark-D. Gerngroß)
- Advanced Mathematics - Computational Mathematics (2 groups), 2 (+ 2) hrs Lecture (+ Exercises)/Week,  
Jürgen Carstensen (+ Jan-Martin Wagner)
- Basic Laboratory Course for Master's Students, 4 hrs Practical/Week,  
Emmanuel Ossei-Wusu (+ S. Nöhren, et al.)
- Halbleitertechnik und Nanoelektronik, 4 (+ 1) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ Rainer Adelson)
- Grundlagen der Materialwissenschaft, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ Jan-Martin Wagner, Mark-D. Gerngroß)
- Advanced Mathematics - Mathematics for Material Science, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Jürgen Carstensen
- Defects, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ S. Nöhren)
- Semiconductors, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Yogendra Mishra (+ Helmut Föll)
- Materialanalytik 2, 4 hrs Practical/Week,  
Enrique Quiroga-González (+ et al.)
- Allgemeine Chemie, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
W. Bensch (+ S. Nöhren)

### Summer 2013

- Materialwissenschaft II, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ Mark-D. Gerngroß)



Aktuelle Fragen der Forschung, 2 hrs Seminar/Week,  
Helmut Föll

Computergestützte Mathematik, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Jürgen Carstensen

Advanced Materials B, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ Jeffrey McCord, Enrique Quiroga-González)

Advanced Laboratory Course for Master's Students, 4 hrs Practical/Week,  
Emmanuel Ossei-Wusu (+ et al.)

Grundpraktikum für Ingenieure, 4 hrs Practical/Week,  
Yogendra Kumar Mishra (+ et al.)

### Winter 2013/2014

Quantenmechanische Aspekte in der Materialwissenschaft, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Jürgen Carstensen

Aktuelle Fragen der Forschung, 2 hrs Seminar/Week,  
Helmut Föll (+ Jürgen Carstensen)

Materialwissenschaft I, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ Mark-D. Gerngroß)

Advanced Mathematics - Computational Mathematics (2 groups), 2 hrs Lecture/Week,  
Jürgen Carstensen (+ Jan-Martin Wagner)

Basic Laboratory Course for Masters Students, 4 hrs Practical/Week,  
Emmanuel Ossei-Wusu (+ S. Nöhren, et al.)

Halbleitertechnik und Nanoelektronik, 4 (+ 1) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ Rainer Adelung, Yogendra Kumar Mishra)

Grundlagen der Materialwissenschaft, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
Helmut Föll (+ Mark-D. Gerngroß, Jan-Martin Wagner)

Advanced Mathematics - Mathematics for Material Science, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Jürgen Carstensen

Defects, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Helmut Föll

Materialanalytik 2, 4 hrs Practical/Week,  
Enrique Quiroga-González (+ et al.)

### Third-Party Funds

Alexander von Humboldt-Stiftung, *Institutspartnerschaft mit der TU Moldova*, 01.07.2010-30.04.2013 (55.000 EUR)

DFG, *SFB 855, TP A3 Magnetoelektrische 1-3-Komposite*, 01.01.2010-31.12.2013 (350.700 EUR)

BMBF, *AlkaSuSi Neue Materialkonzepte für Alkalimetall-Schwefel-Batterien bzw. Alkalimetall-Silizium-Batterien*,  
01.05.2011-30.04.2014 (259.769 EUR)

BMBF, *Projektpauschale zu: AlkaSuSi Neue Materialkonzepte für Alkalimetall-Schwefel-Batterien bzw. Alkalimetall-Silizium-Batterien*, 01.05.2011-30.04.2014 (25.976,90)

Unterauftrag BMU-Projekt Universität Konstanz, *SolarWinS, TP 6: Herstellung und Analyse von Solarzellen aus hochreinem kristallinem Silizium*, 01.02.2011-31.01.2014 (87.000 EUR)

EU 7th Framework Programme, *MOLD-NANONET*, 01.12.2011-31.05.2014 (47.658 EUR)

DFG, *Schnelle quantitative und orts aufgelöste Komplettcharakterisierung von Solarzellen durch Kombination von "CELLO" und FFT-Impedanzspektroskopie*, 01.06.2012-31.05.2013 (71.180 EUR)

DFG, *Programmpauschale zu: Schnelle quantitative und orts aufgelöste Komplettcharakterisierung von Solarzellen durch Kombination von "CELLO" und FFT-Impedanzspektroskopie*, 01.06.2012-31.05.2013 (14.200 EUR)

DFG, *Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen*, 17.09.2013-16.09.2015 (127.825 EUR)

DFG, *Programmpauschale zu: Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen*, 17.09.2013-16.09.2015 (25.600 EUR)

## Further Cooperation, Consulting, and Technology Transfer

**Bosch AG**, Stuttgart, Germany

Ongoing shared supervision of bachelor's and master's theses. Continuous cooperation based on the CELLO technique (measurements on various Bosch specimens); external PhD student.

**Centrosolar**, Hamburg, Germany

CELLO investigations of cells and modules (i) regarding the influence of module-making with respect to potential-induced degradation and (ii) for yield engineering issues.

**Condias**, Itzehoe, Germany

Explorative experiments (based on an AMAT patent) concerning electrochemical processing of large Si wafers.

**Dispatch Energy Innovations GmbH**, Itzehoe, Germany

Loose scientific cooperation with respect to Li-Ion Batteries.

**Fraunhofer-Institut ICT**, Pfinztal, Germany / **IWS**, Dresden, Germany

Cooperation within the "AlKaSuSi" project (see above).

**Fraunhofer-Institut ISE** (Solare Energiesysteme), Freiburg / Gelsenkirchen, Germany

Scientific cooperation with Dr. Warta and Prof. Dr. Schindler within the framework of the SolarFocus / SolarWinS project.

**INFICON GmbH**, Köln, Germany (world market leader for vacuum leak detection)

AMAT produces prototype of novel sensors based on porous Si. Results are encouraging.

**Hanwha Q Cells** (formerly Q-Cells), Bitterfeld-Wolfen, Germany

Based on previous CELLO measurements on cells made from different feedstock material and contact via SolarWinS project: evaluation of further collaboration.

**ISFH GmbH**, Hameln/Emmerthal, Germany

Cooperation within the framework of the SolarFocus / SolarWinS project. Informal cooperations with respect to Si nanowire formation and application of porous Si membranes in Li ion batteries.

**Lund University**, Sweden

Scientific cooperation with Prof. Christelle Prinz. Samples with different microwire array structures are provided to make biological tests. Especially, growth of optical cells is planned.

**Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany**

Scientific cooperation with Dr. Breitenstein within the framework of the SolarFocus / SolarWinS projects. CELLO and SHALUM measurements in comparison to thermography measurements.

**CSP Halle (Centre for Silicon Photovoltaic), Halle, Germany**

Scientific cooperation within the SolarWinS project and bilateral cooperation with respect to solar cell characterization using the CELLO technique.

**Nanoproofed GmbH, Scharbeutz (S.-H. Start-up), Germany**

CELLO measurements for the characterization of novel AR coatings on modules. General cooperations on other topics via Prof. Adelung's group.

**Nanotechnology Research Centre, Cairo, Egypt**

Proposal to A. v. Humboldt foundation concerning 2-year stay of senior researcher Dr. Osama Tobail at AMAT. Mr. Tobail was a guest in 2012 and in 2013. The common research topic is nanostructuring of materials by electrochemical means for Li ion battery electrodes.

**SolarWorld, Freiberg, Germany**

CELLO measurements in respect to some special questions concerning high-efficiency solar cells.

**Technical University of Moldova, Chisinau, Moldova**

Scientific cooperation with Prof. Dr. I.M. Tiginyanu for more than 10 years. Joint EU project (€ 48,000.—).

**University College Cork, Ireland**

Scientific cooperation with Dr. Colm O'Dwyer. Different kinds of Si porous membranes and porous pieces with different structures have been supplied to Cork with the aim to test their application in thermoelectrics and antireflection coatings, and to make some Raman microscopy studies.

**University Konstanz, Germany**

Partner within the "SolarWinS" project; possible new direct cooperation concerning large-area pore etching.

**University New South Wales, Australia (Prof. Green)**

Participation in "round robin" concerning quantitative solar cell characterization.

**University of Stanford, USA, California**

Application for synchrotron beam time for characterization of silicon nanowires for Li-ion batteries, the common project has been accepted meanwhile.

**Institut für Verbundwerkstoffe GmbH, Kaiserlautern, Germany**

Scientific cooperation with Prof. Dr. Ulf Breuer and Dipl.-Ing. Sebastian Nissle. Surface treatment of NiTi-wire smartflex and NiTi-wire alloy for SMA-FRP composites.

**Stryker GmbH, Schölkirchen, Germany**

Surface treatment and analysis of Stryker titanium nail implants.

**Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Köln, Germany**

Scientific cooperation with Dipl.-Ing. (FH) Karola Schulze. Surface roughening of Ti alloy turbine blades.

In most cases, the cooperation is motivated because there is either some interesting research or because the partially unique methods and processes of AMAT could be beneficial to a partner. In many first encounters with companies, "proof of principle" is the first goal, typically without direct remuneration. Instead, partners might supply specimens and technologies that are not available elsewhere. In this context it is necessary to point out that no university or research organization (short of large "national centres") is capable of producing solar cells that could rival the ones mass-produced by industry. State-of-the-art research with solar cells thus is only possible by cooperation with industry.

First cooperations with companies concerning possible novel products are always hoped to blossom eventually into fully-fledged funded projects. That happens, but not too often. Instead, the rewards are scientific insights and publications. Projects concerning prototypes invariably rely on the possibility of some technology transfer, and that needs "interface" companies like ET&TE. Since the CAU administration is opposed to this concept, many of the projects above are doomed to fail.

## Diploma, Bachelor's and Master's Theses

Jamal U. Channa, *Investigation of breakdown mechanism for high voltage (HV) devices based on GaN-on-Silicon*, 27.06.2013

Usman Ilyas, *Fabrication of a Magnetoelectric (ME) 1-3 Composite by Galvanic Metal Deposition and Sol-Gel Process*, 08.07.2013

Chima O. Kalu, *Study of Diffusion Limitation Mechanisms During Chemical Over-etching of Deep Pores with KOH Solutions*, 04.12.2013

Johann Rupsch, *Strukturierung von Zn-Flächen*, 29.08.2013

## Publications

Published in 2013

M. Leisner, H. Föll, J. Carstensen, *A meta model for electrochemical pore growth in semiconductors*, Nanostructured semiconductors: from basic research to applications, eds. P. Granitzer and K. Rumpf, Pan Stanford Publishing Pte Ltd, ISBN 9789814316503, London, (2013)

M.-D. Gerngross, S. Chemnitz, B. Wagner, H. Föll, *Ultra-high aspect ratio Ni nanowires in single-crystalline InP membranes as multiferroic composite*, Phys. Status Solidi RRL, DOI 10.1002/pssr.201307026, **7(5)**, 352 - 354 (2013)

M.-D. Gerngross, J. Carstensen, H. Föll, *How to make single-crystalline membranes in indium phosphide*, ECS Trans., **50(37)**, 121 - 130 (2013)

M.-D. Gerngross, E. Quiroga-González, J. Carstensen, H. Föll, *Characterization of three-dimensional single-crystalline porous InP anodes for Li-ion batteries*, ECS Trans., **50(26)**, 139 - 150 (2013)

J.-M. Wagner, J. Carstensen, A. Schütt, H. Föll, *Qualitative and quantitative evaluation of thin-film solar cells using solar cell local characterization*, J. Appl. Phys., **113**, 064503 (2013)

C. Shen, H. Kampwerth, M. Green, T. Trupke, J. Carstensen, A. Schütt, *Spatially resolved photoluminescence imaging of essential silicon solar cell parameters and comparison with CELLO measurements*, Sol. Energy Mater. Sol. Cells, **109**, 77 (2013)

E. Quiroga-González, J. Carstensen, H. Föll, *Structural and electrochemical investigation during the first charging cycles of silicon microwire array anodes for high capacity lithium ion batteries*, Materials, **6**, 626 - 636 (2013)

J.-M. Wagner, M. Hoppe, A. Schütt, J. Carstensen, H. Föll, *Injection-level dependent series resistance: Comparison of CELLO and photoluminescence-based measurements*, Energy Procedia, **38**, 199 - 208 (2013)

E. Ossei-Wusu, J. Carstensen, E. Quiroga-González, M. Amirmaleki, H. Föll, *The role of Polyethylene Glycol in Pore Diameter Modulation in Depth in p-type Silicon*, ECS Journal of Solid State Science and Technology, P243, **2(6)**, 243 - 247 (2013)

- E. Ossei-Wusu, J. Carstensen, E. Quiroga-González, M. Amirmaleki, H. Föll, *Investigation of Pore Diameter Modulation in Depth in p-type Silicon*, ECS Trans., **50(37)**, 3 (2013)
- M. Nguyen, A. Schütt, J. Carstensen, H. Föll, *Quantitative Defect Analysis on Solar Cells by Laser Beam Induced Current (LBIC) Measurements and 3D Network Simulations*, Mater. Res. Soc. Symp. Proc. 1493, DOI: 10.1557/opl.2013.232, Boston, (2013)
- J.-M. Wagner, J. Bauer, O. Breitenstein, *Comment on "Origin of breakdown mechanism in multicrystalline silicon solar cells"*, Appl. Phys. Lett., **102**, 246101 (2013)
- O. Breitenstein, J. Carstensen, A. Schütt, J.-M. Wagner, *Comparison of local solar cell efficiency analysis performed by DLIT and CELLO*, Proc. 28th European Photovoltaic Solar Energy Conference, 2CV.3.15, Paris, (2013)
- A. Schütt, J. Carstensen, J.-M. Wagner, H. Föll, *Influence of surface and process induced defects on potential-induced degradation and regeneration*, Proc. 28th European Photovoltaic Solar Energy Conference, 2B0.3.2, Paris, (2013)
- A. Schütt, J. Carstensen, J.-M. Wagner, H. Föll, *Local characterization of co-firing-induced inhomogeneities of conventional mc-Si solar cells*, Proc. 28th European Photovoltaic Solar Energy Conference, 2CV.3.13, Paris, (2013)
- E. Quiroga-González, J. Carstensen, H. Föll, *Optimal conditions for fast charging and long cycling stability of silicon microwire anodes for Lithium ion batteries, and comparison with the performance of other Si anode concepts*, Energies, **6(10)**, 5145 - 5156 (2013)
- M. Baytekin, M.-D. Gerngross, Q. Li, S. Viebig, C. Selhuber-Unkel, J. Carstensen, H. Föll, R. Adelung, *Surface modification of Ti by chemical etching and HA sputtering for dental applications*, Proc. ICNBME, 17. - 20.04.2013, Chisinau, Moldova, **2**, 56 (2013)
- M.-D. Gerngross, V. Hrkac, L. Kienle, J. Carstensen, H. Föll, *Formation and characterization of Ni nanostructures in porous InP - from crystallites to wires*, Proc. ICNBME, 17. - 20.04.2013, Chisinau, Moldova, **2**, 43 (2013)
- H. Föll, E. Quiroga-González, J. Carstensen, M. Amirmaleki, *Making and using macroporous p-type silicon with modulated pore diameters*, Proc. ICNBME, 17. - 20.04.2013, Chisinau, Moldova, (2013)
- C. Glynn, M. Osiak, W. McSweeney, O. Lotty, K. Jones, H. Geaney, E. Quiroga-González, J.D. Holmes, C. O'Dwyer, *Semiconductor nanostructures for antireflection coatings, transparant contacts, junctionless thermoelectrics and Li-Ion batteries*, ECS Trans., **53**, 25 - 44 (2013)
- E. Quiroga-González, J. Carstensen, H. Föll, *Good cycling performance of high-density arrays of Si microwires as anodes for Li ion batteries*, Electrochim. Acta, **101**, 93 - 98 (2013)

## Presentations

- J. Carstensen, A. Schütt, J.-M. Wagner, H. Föll, *What you get is how you etch?!?*, Solar WinS project meeting, Ochsenfurt, Germany, 23.01.2013
- E. Quiroga-González, J. Carstensen, H. Föll, *In situ impedance spectroscopy on high capacity Si microwire anodes for Li-ion batteries*, Kraftwerk Batterie, Aachen, Germany, 25.-26.02.2013
- S. Nöhren, E. Quiroga-González, H. Föll, *Size dependency study of Si microwire anodes by cyclic voltammetry (poster)*, Kraftwerk Batterie, Aachen, Germany, 25.-26.02.2013
- E. Quiroga-González, J. Carstensen, H. Föll, *Study of the effects in high Li storage capacity silicon microwire array anodes during the first charging cycles*, International Battery Association Meeting 2013, Barcelona, Spain, 11.-15.03.2013
- J.-M. Wagner, M. Hoppe, A. Schütt, J. Carstensen, H. Föll, *Injection-level dependent series resistance: Comparison of CELLO and photoluminescence-based measurements (poster)*, Silicon PV 2013: 3rd International Conference on Silicon Photovoltaics, Hameln, Germany, 25.-27.03.2013
- M. Baytekin, M.-D. Gerngross, Q. Li, S. Viebig, C. Selhuber-Unkel, J. Carstensen, H. Föll, R. Adelung, *Surface modification of Ti by chemical etching and HA sputtering for dental applications*, 2nd International conference on nanotechnology and biomedical engineering (ICNBME), Chisinau, Moldova, 17.-20.04.2013
- M.-D. Gerngross, V. Hrkac, L. Kienle, J. Carstensen, H. Föll, *Formation and characterization of Ni nanostructures in porous InP - from crystallites to wires*, 2nd International conference on nanotechnology and biomedical engineering

- (ICNBME), Chisinau, Moldova, 17.-20.04.2013
- E. Quiroga-González, *Advances in the fabrication of anodes based on Si wire arrays for Li-ion batteries*, 5th AlkaSuSi project meeting, Pfalz, Germany, 30.04.2013
- J.-M. Wagner, J. Carstensen, *CELLO - "solar cell local characterization"*, Vorlesungsreihe: "Moderne Methoden der Charakterisierung von Solarzellen und Halbleitermaterial" am MPI für Mikrostrukturphysik, Halle (Saale), Germany, 23.05.2013
- J. Carstensen, A. Schütt, J.-M. Wagner, H. Föll, *Majoritätseigenschaften bestimmt aus CELLO-Messungen und "What you get is how you etch?!?"*, SolarWinS project meeting, Apolda, Germany, 10.07.2013
- E. Quiroga-González, J. Carstensen, H. Föll, *Extraordinary Li-Storage Performance of Si Microwire Array Anodes Using Electrolytes for Li-S Batteries*, International Society of Electrochemistry meeting 2013, Querétaro, Mexico, 08.-13.09.2013
- E. Quiroga-González, *Photoactive materials based in compounds of the indium-sulfur system and in silicon rich oxide*, Invited Talk at Institute for Physics of the University of Puebla, Puebla, Mexico, 17.09.2013
- E. Quiroga-González, *Silicon microwire arrays as anodes of next generation Li ion batteries*, Invited talk at National Institute for Astrophysics, Optics and Electronics, Tonantzintla, Mexico, 18.09.2013
- M.-D. Gerngross, J. Carstensen, H. Föll, *Galvanic fabrication of a 1-3 multifunctional composite based on Ni nanostructures deposited in porous InP*, Conference on Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013
- M.-D. Gerngross, E. Quiroga-González, J. Carstensen, H. Föll, *Characterization of Li-ion battery anodes from single-crystalline InP membranes (poster)*, Conference on Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013
- S. Nöhren, E. Quiroga-González, H. Föll, *Electrochemical study of size effects in Si microwire anodes for Li ion batteries*, Conference on Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013
- E. Quiroga-González, J. Carstensen, H. Föll, *Fabrication of monodisperse Si micro/nano-rods in a wide range of morphologies and dimensions for biological applications*, Conference on Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013
- A. Schütt, J. Carstensen, J.-M. Wagner, H. Föll, *Influence of surface and process induced defects on potential-induced degradation and regeneration*, 28th European Photovoltaic Solar Energy Conference, Paris, France, 30.09.-04.10.2013
- O. Breitenstein, J. Carstensen, A. Schütt, J.-M. Wagner, *Comparison of local solar cell efficiency analysis performed by DLIT and CELLO (poster)*, 28th European Photovoltaic Solar Energy Conference, Paris, France, 30.09.-04.10.2013
- A. Schütt, J. Carstensen, J.-M. Wagner, H. Föll, *Local characterization of co-firing-induced inhomogeneities of conventional mc-Si solar cells (poster)*, 28th European Photovoltaic Solar Energy Conference, Paris, France, 30.09.-04.10.2013
- E. Quiroga-González, J. Carstensen, H. Föll, *Long cycling stability of Si microwire anodes with electrolytes for Li-S Batteries (invited)*, 2nd Workshop "Lithium-Schwefel-Batterien", Dresden, Germany, 06.-07.11.2013
- E. Quiroga-González, *Advances in the fabrication of anodes based on Si wire arrays for Li-ion batteries*, 6th AlkaSuSi project meeting, Dresden, Germany, 08.11.2013
- M. Nguyen, A. Schütt, J. Carstensen, H. Föll, *Quantitative Defect Analysis on Solar Cells by Laser Beam Induced Current (LBIC) Measurements and 3D Network Simulations (poster)*, MRS Fall Meeting, Boston, U. S. A., 01.-06.12.2013

## Further Activities and Events

Prof. Dr. H. Föll is a member of the executive board of the "Förderverein der Technischen Fakultät" at Christian-Albrechts-University Kiel.

Prof. Dr. H. Föll is the "Vertrauensdozent für Angelegenheiten der Deutschen Forschungsgemeinschaft" at Christian-Albrechts-University Kiel.

# Inorganic Functional Materials

The research of the Chair “Inorganic Functional Materials” concentrates on research on smart and multifunctional thin film materials and their applications in micro- and nanotechnology. Examples include research on:

- superelastic shape memory films for medical implants and for elastocaloric applications,
- magnetostrictive films, multilayers and structures for mechanical sensing applications,
- magnetoelectric composites: a combination of magnetostrictive and piezoelectric thin films for highly sensitive magnetic field sensors, and
- biodegradable Mg- or Fe-based films for medical implants.

The films and devices are fabricated in the cleanroom facility “Kieler Nanolabor” that provides thin film technologies such as magnetron sputtering, pulse laser deposition, and lithography as well as different dry and wet-etching techniques.

## Results

The idea of ferroic cooling utilizes the externally induced phase transformation of the magneto-, electro- or elastocaloric effects which are related to a temperature change of the material. These effects are promising for highly efficient and environmentally friendly cooling devices. Therefore a DFG priority program SPP 1599 programme has been created to expedite the research and development of this technology. As part of this project, the elastocaloric effect in thin films that could be used for small scale cooling applications is investigated in Kiel in collaboration with the KIT, Karlsruhe.

Major parameters for the stress induced transformation in elastocaloric materials are the fatigue behaviour, the transformation enthalpy, and the transformation temperature. The fatigue resistance of the transformation is related to composition microstructure and precipitates. For fine-grained TiNiCuCo films a high transformation stability up to  $10^6$  cycles has been achieved. Important factors for high fatigue resistance are the composition and the surface quality of the thin films (s. Fig. 1). Quaternary alloys like TiNiCuFe, TiNiCuCo and TiNiCuPd have been investigated to tailor the adiabatic

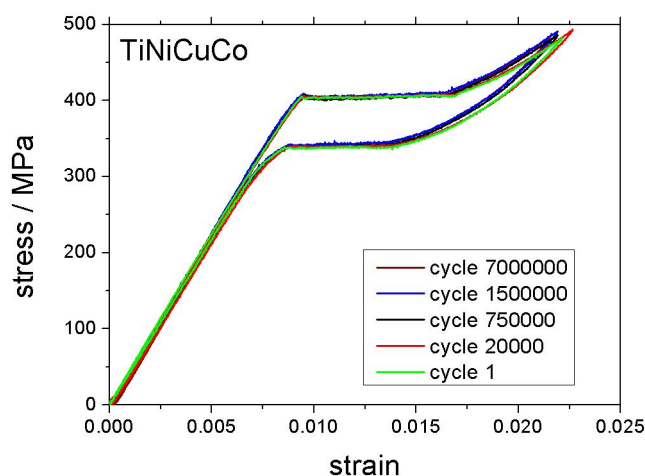


Fig. 1: High cycle tensile test of TiNiCuCo with outstanding functional and structural fatigue behaviour

temperature change and the transformation temperature of the elastocaloric material. The transformation temperature,



which has to match the heat sink temperature, could be adjusted from  $-40$  to  $70^{\circ}\text{C}$  with adiabatic temperature changes from  $6$  to  $9$  K.

Future work will concentrate on the investigation of the composition and structure of the precipitates in order to explain their role in high-fatigue resistant materials.

### Magnetoelectric Composites

The subjects of this research are new 2-2 thin film composites that exhibit a low limit of detection for biomagnetic fields. This work is part of the Collaborative Research Centre SFB 855 "Magnetoelektrische Composites - Future Biomagnetic Interfaces". In 2013 one new approach was investigated: the use of interdigital transducers to increase the magnetoelectric voltage.

The employment of interdigital transducers is attractive as the magnetoelectric voltage for a given materials combination and sensor design scales with the electrode spacing. Thus using interdigital instead of a plate capacitor design allows an increase in the magnetoelectric voltage of at least one order of magnitude; however, this new design requires the deposition of the piezoelectric phase on an insulating substrate. As a consequence new magnetoelectric composites without direct interphase between the piezoelectric and the metallic magnetostrictive layer were successfully developed. Magnetoelectric composites with PZT as the piezoelectric layer and amorphous FeCoBbi as the magnetostrictive layer were investigated. These composites show a 15-fold higher magnetoelectric voltage and a factor of 2.3 lower limit of detection (Figure 2), both results being in good agreement with theoretical models.

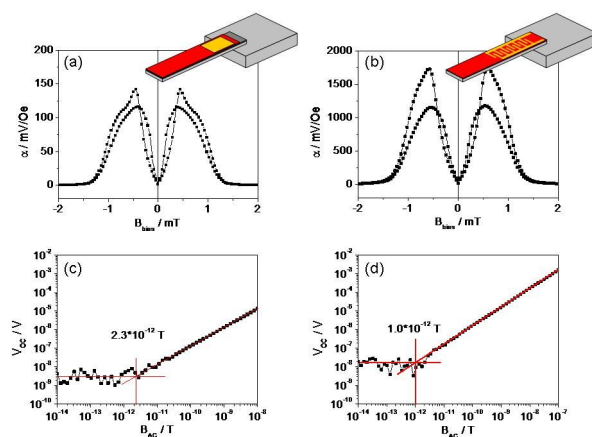


Fig. 2: Properties of ME composites with a  $2 \mu\text{m}$  thick PZT as piezoelectric and a  $4 \mu\text{m}$  FeCoSiB film as magnetostrictive phase, (a) ME voltage  $V_{ME}$  vs. bias field  $B_{Bias}$  of a composite with plate capacitor type electrodes, (b) ME voltage  $V_{ME}$  vs. bias field  $B_{Bias}$  of a composite with interdigital electrodes, (c) ME voltage  $V_{ME}$  vs. magnetic AC field  $B_{AC}$  of a composite with plate capacitor type electrodes, and (d) ME voltage  $V_{ME}$  vs. magnetic AC field  $B_{AC}$  of a composite with interdigital electrodes.

### Magnetostrictive magnetic tunnel junctions

Aside from the application as highly sensitive magnetic field sensors or magnetic storage devices, tunnel magnetoresistive (TMR) junctions are promising candidates for miniaturized strain sensors. For the latter purpose it is a precondition that a magnetostrictive material such as CoFeBSi can be used as a material for the sense electrode of the junction. Within the framework of the DFG funded project *Miniaturized magnetostrictive strain sensors for novel applications of atomic force microscopy* such magnetostrictive TMR junctions are patterned with lateral dimensions in the  $10$  micron range. Using MEMS fabrication techniques these strain sensors are integrated onto cantilevers. The goal of the project is to replace the commonly used optical and therefore bulky readout of an atomic force microscope (AFM) by such self-sensing cantilevers



(s. Fig. 3(a)).

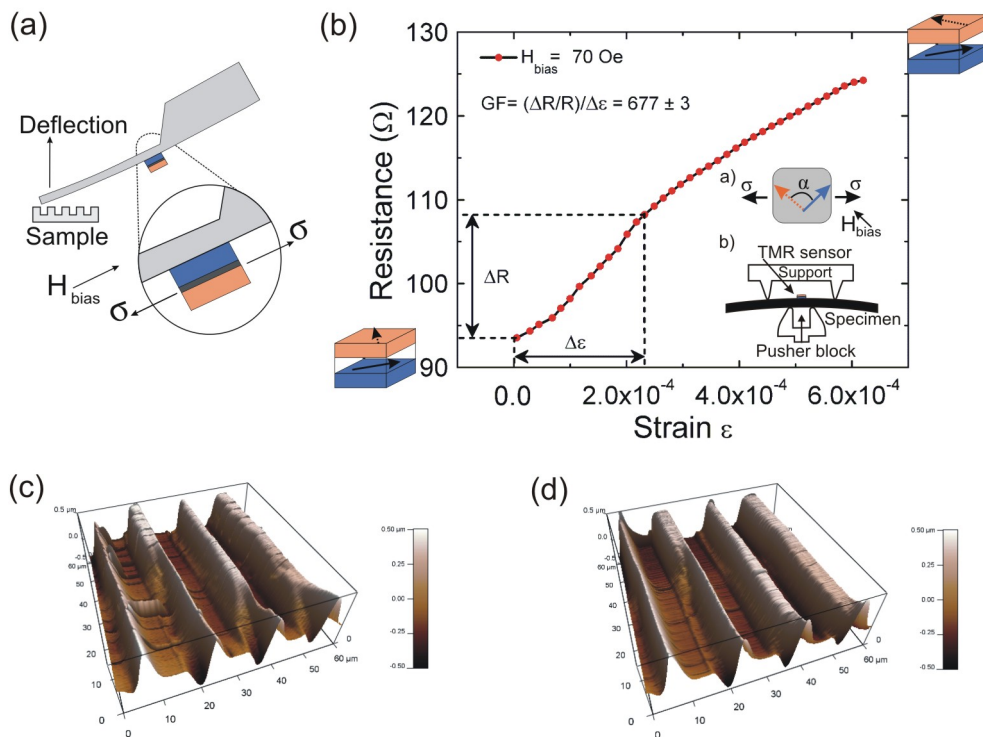


Fig. 3: (a) Self-sensing cantilever for atomic force microscopy. During sample scanning the deflection is detected by a magnetostrictive TMR junction placed at the cantilever position with maximum mechanical stress. (b) Resistance vs. strain curve of a 10 μm x 10 μm sized TMR junction. The TMR stack was prepared by project partners from Bielefeld University (Prof. G. Reiss, Dr. K. Rott). It comprises Ta (5 nm)/Ru (30 nm)/Ta(10 nm)/Ru (5 nm)/MnIr (12 nm)/CoFe (3 nm)/Ru (0.9 nm)/CoFeB (3 nm)/MgO (1.8 nm)/CoFeB (3 nm)/Ta (5 nm)/Ru (5 nm). In the presence of a magnetic DC bias field a high gauge factor  $GF = 677$  is observed. (c-d) AFM pictures of a grating using either (c) TMR (37 μm x 37 μm,  $H_{bias} = 57$  Oe) or (d) optical readout. Images by the courtesy of PD Dr. H. Hölscher and T. Meier from the Karlsruher Institut für Technologie (KIT).

Fig. 3(b) shows the course of the tunnel resistance of a 10 μm x 10 μm sized TMR junction as a function of mechanical strain evoked by a 4-point bending device. By inverse magnetostriction, application of mechanical stress leads to a change of the magnetization in the sensing layer. Accordingly a resistance change happens that can be used as a measure of cantilever deflection as can be seen in Figures 3(c,d) where a comparison of AFM measurements is shown performed by either using TMR or optical readout.

### Biodegradable Mg- or Fe-based films for medical implants

Biodegradable materials are subjects of intense scientific research in recent years, in particular for their application as temporary medical implants. The two most important metallic materials in this respect are magnesium and iron. Whereas the bio-corrosion of magnesium in the human body proceeds through the formation of hydrogen with high rate leading to premature device failure, bio-corrosion of iron proceeds too slowly. However, by alloying additional elements, corrosion as well as mechanical properties can be tuned. Within this project, structured foils of highly pure iron and iron based alloys will be fabricated and characterized for their intended use as microimplants. These foils will be deposited and structured using magnetron sputtering and microsystem technology processes, respectively. Since mechanical properties and corrosion behaviour are critical factors, the corrosion rate will be increased by generating local elements in the form of precipitates that simultaneously influence mechanical behaviour. The distribution and size of the precipitates are decisive in this

respect. Hence, the investigation of the influence of different heat treatments on the microstructure is of great importance. Promising systems that will be investigated in this project are iron-manganese, iron-manganese-silicon, iron-magnesium, iron-silver, and iron-zinc, among others. Alloys under investigation can be classified into two subgroups. The first subgroup contains alloys that are soluble up to a certain content of the additional element; the second group contains those that are completely insoluble. Alloying will be carried out using two approaches. On the one hand foils will be sputtered from alloy targets with different chemical compositions (first group), and on the other hand, mixtures of insoluble elements will be fabricated by sputtering multilayers (second group); a subsequent heat treatment will be employed to obtain a homogenization of the multilayers.

## **Personnel**

Head of the group: Prof. Dr.-Ing. Eckhard Quandt; Secretary: Ellen Riemer (50%), Gislinde Schroeder  
Technical Staff: Dipl.-Ing. (FH) Thomas Metzling

### Staff:

Stefanie Braunreuther-Rix SFB 855, Z2 und IGK	01.01.-15.02.2013	DFG
Boris Gudschun SFB 855, Z2 und IGK	01.01.-31.12.2013	DFG

### Scientific Staff:

Dr.-Ing. Angela Büttner SFB 855, Z2 und IGK	01.01.-31.12.2013	CAU
M.Sc. Christoph Chluba Elastocaloric Ti-Ni based Films and Devices - Materials	01.01.-31.12.2013	DFG
M.Sc. David Haffner Herstellung von Bioresorbierbaren Dünnschicht Gefäßstützen	01.01.2013-31.12.2013	DFG
M.Sc. Till Jurgeleit Fe-based biodegradable materials	15.-31.12.2013	DFG
M.Sc. Christine Kirchhof SFB 855, Teilprojekt C2	01.01.-31.12.2013	DFG
Dipl.-Ing. Enno Lage SFB 855, Teilprojekt Z1	01.01.-31.12.2013	DFG
Dr.-Ing. Rodrigo Lima de Miranda	01.01.-31.12.2013	CAU
Dipl.-Phys. Klaas Loger TiNi Dünnschicht Herzklappen	01.01.-31.12.2013	DFG
Dr. Antonio Malavé	01.01.-31.12.2013	CAU
Dr. Dirk Meyners	01.01.-31.12.2013	CAU
Dipl.-Ing. André Piorra SFB 855, Teilprojekt A1	01.01.-31.12.2012	DFG

M.Sc. Volker Röbisch SFB 855, Teilprojekt A1	01.01.-31.12.2013	DFG
Dipl.-Ing. Kristina Schlüter Herstellung von Bioresorbierbare Dünnschicht Gefäßstützen	01.01.-15.06.2013	DFG
M.Sc. Ali Tavasollizadeh Magnetoresistive Tunnelstrukturen	01.02.-31.12.2013	DFG
Dipl.-Phys. Claas Thede SPP 1299, Industrieprojekte	01.01.-31.12.2013	DFG
M.Sc. Erdem Yarar SFB 855, Teilprojekt A1	01.01.-31.12.2013	DFG
Dr. Christiane Zamponi Fe-based biodegradable materials	01.01.-31.12.2013	DFG
Dr.-Ing. Ahmed Zayed Fatigue in TiNi Thin Films	01.01.-31.07.2013	DFG

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

Smart Materials, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
E. Quandt

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,  
E. Quandt

Micro/Nanosystems Technology and Processes, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Meyners

Laboratory Course: Basic Lab Course for Master's Students, 3 hrs Lab/Week,  
D. Meyners (+ A. Zayed, C. Thede, A. Piorra)

Grundpraktikum I, 3 hrs Practical/Week,  
D. Meyners

### *Summer 2013*

Analytics 2, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
E. Quandt (+ A. Malavé)

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,  
E. Quandt

Advanced Lab Course for Master's Students, 4 hrs Lab/Week,  
D. Meyners (+ C. Chlubas, Ch. Kirchhof, Ali Tavasollizadeh)

### *Winter 2013/2014*

Analytics 1, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
E. Quandt (+ E. Quandt)



Smart Materials, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
E. Quandt (+ Ch. Kirchhof)

Anorganische Funktionsmaterialien, 2 hrs Seminar/Week,  
E. Quandt

Micro/Nanosystems Technology and Processes, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
D. Meyners

Laboratory Course: Analytik, 4 hrs Lab/Week,  
D. Meyners (+ D. Haffner)

Laboratory Course: Basic Lab Course for Master´s Students, 3 hrs Lab/Week,  
D. Meyners (+ K. Loger, E. Yarar, A. Piorra)

## Third-Party Funds

DFG, *Herstellung von bioresorbierbaren Dünnschicht Gefäßstützen (Stents) aus Magnesiumlegierungen durch Magnetron-Sputter-Technologie*, 09.11.2012-08.11.2015 (231.214 EUR)

DFG, *SPP 1599 - Elastocaloric Ti-Ni based Films and Devices - Materials*, 15.11.2012-14.11.2015 (281.234 EUR)

DFG, *TiNi Dünnschicht-Herzklappen*, 01.02.2012-31.01.2015 (239.748 EUR)

DFG, *SPP 1299 HAUT, Nanostrukturierte magnetische Dünnschicht-Komposite für Anwendungen in der Hochtemperatur-Sensorik*, 01.09.2010-31.08.2013 (184.143 EUR)

DFG, *Magnetoresistive Tunnelstrukturen mit magnetostriktiven Elektroden als Sensor für die Rastermikroskopie*, 01.02.2011-31.01.2013 (174.969 EUR)

SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt A 1*, 01.01.2010-31.12.2013 (603.200 EUR)

SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt C2*, 01.01.2010-31.12.2013 (289.200 EUR)

SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt Z1*, 01.01.2010-31.12.2013 (557.600 EUR)

SFB 855, *Magnetoelektrische Verbundstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt Z2*, 01.01.2010-31.12.2013 (1.185.000 EUR)

Industrie, *Forschungs- und Entwicklungsvertrag*, 01.09.2012-31.08.2015 (180.000 EUR)

EFRE, *Kompetenzzentrum Nanosystemtechnik*, 01.03.2013-30.09.2015 (1.297.300,00)

DFG, *Biodegradierbare eisenbasierte Schichten für medizinische Anwendungen*, 01.04.2013-31.03.2016 (435.700,00)

Bundeswehr WTD 71, *Piezoelektrischer Dünnschicht-Wasserschallsensor*, 01.09.-30.11.2013 (39.999.99)

Industrieprojekt, *Dehnungssensor*, 01.05.-30.12.2013 (43.694,14)

## Further Cooperation, Consulting, and Technology Transfer

Prof. Dr. F. Faupel, CAU

PD Dr. H. Hölscher, KIT, Karlsruhe

Dr. N. Hort, Helmholtz-Zentrum, Geesthacht

Prof. Dr. K.U. Kainer, Helmholtz-Zentrum, Geesthacht

Prof. Dr. R. Knöchel, CAU

PD Dr. M. Kohl, KIT, Karlsruhe

Prof. Dr. G. Lutter, UKSH

Prof. Dr. J. McCord, CAU

Dr. W. J. Quadakkers, FZ Jülich

Prof. Dr. M. Schütze, Dechema, Frankfurt

Prof. Dr. C. Selhuber-Unkel, CAU

Dr. M. Stüber, KIT, Karlsruhe

Prof. Dr. F. Tuzcek, CAU

Prof. Dr. B. Wagner, FHI ISIT

Prof. Dr. R. Willumeit HZG

Prof. Dr. M. Wuttig, University of Maryland, USA

## Diploma, Bachelor's and Master's Theses

Till Jurgeleit, *Herstellung und Charakterisierung von biodegradierbaren eisenbasierten Dünnschichtfilmen*, 12.11.2013

Patrick Hayes, *Investigation of magnetostrictive magnetic tunneling junctions for strain sensing applications -*

*Experimental determination of size and shape dependence of strain sensitivity and micromagnetic simulations.*,  
15.12.2013

## Dissertations / Postdoctoral Lecture Qualifications

A. Zayed, *Investigation of fatigue life characteristics of micropatterned freestanding NiTi thin Films*, 23.08.2013

## Publications

Published in 2013

- S. Maraуска, R. Jahns, C. Kirchhof, M. Claus, E. Quandt, R. Knöchel, B. Wagner, *Highly sensitive wafer-level packaged MEMS magnetic field sensor based on magnetoelectric composites*, Sensors & Actuators, A. Physical, **189C**, 321 - 327 (2013)
- K. Schlüter, C. Zamponi, C. Hapke, N. Hort, K.-U. Kainer, E. Quandt, *Mechanical properties and corrosion behaviour of freestanding, precipitate-free magnesium WE43 thin films*, Int. J. Mat. Res., **103**, 286 - 292 (2013)
- M. Abes, C. T. Koops, S.B. Hrkac, H. Greve, E. Quandt, S.P. Collins, B. Murphy, O.M. Magnussen, *Direct Measurements of Field-induced Strain at Magnetoelectric Interfaces by Grazing Incidence X-ray Diffraction*, Appl. Phys. Lett., **102**, 011601 (2013)
- R. Lima de Miranda, C. Zamponi, E. Quandt, *Micropatterned Freestanding Superelastic TiNi Films*, Advanced Engineering Materials, **15**, 1 - 2 (2013)
- A. Tavassolizadeh, T. Meier, K. Rott, K. Reiss, E. Quandt, H. Hölscher, D. Meyners, *Self-sensing atomic force microscopy cantilevers based on tunnel magnetoresistance sensors*, Appl. Phys. Lett., **102**, 153104 (2013)
- C. Kirchhof, M. Krantz, J. Teliban, R. Jahns, S. Maraуска, B. Wagner, R. Knöchel, M. Gerken, D. Meyners, E. Quandt, *Giant magnetoelectric effect in vacuum*, Appl. Phys. Lett., **102**, 232905 (2013)
- M. Helou, M. Reisbeck, S.F. Tedde, L. Richter, L. Bär, J. Bosch, R.H. Stauber, E. Quandt, E. Hayden, *Time-of-flight magnetic flow cytometry in whole blood with integrated sample preparation*, Lab on a chip, **13**, 989 - 1184 (2013)
- E. Lage, F. Woltering, E. Quandt, D. Meyners, *Exchange biased magnetoelectric composites for vector field magnetometers*, J. Appl. Phys., **113**, (2013)
- J. McCord, B. Erkartal, T. von Hofe, L. Kienle, E. Quandt, O. Roshchupkina, J. Grenzer, *Revisiting magnetic stripe domains - anisotropy gradient and stripe asymmetry*, J. Appl. Phys., **113**, 073903 (2013)

- M. Abes, C.T. Koops, S.B. Hrkac, E. Quandt, S.B. Bouchenoire, B.M. Murphy, O.M. Magnussen, *Direct measurements of field-induced strain in magnetoelectric composites by X-ray diffraction studies of forbidden reflections*, J. Appl. Phys., **113**, 124303 (2013)
- R. Jahns, A. Piorra, E. Lage, C. Kirchhof, D. Meyners, J. Gugat, M. Krantz, M. Gerken, R. Knöchel, E. Quandt, *Giant magnetoelectric effect in thin film composites*, Journal of the American Ceramic Society, **96**, 1673 - 1681 (2013)
- K. Krüger, C. Thede, K. Seemann, H. Leiste, M. Stüber, E. Quandt, *Thermal stability of the ferromagnetic in-plane biaxial anisotropy of Fe-Co-Hf-N/Ti-N multilayer films for high-frequency sensor applications*, IEEE Transactions on Magnetics, **49**, 7 (2013)
- A. Piorra, R. Jahns, I. Teliban, J.L. Gugat, M. Gerken, R. Knöchel, E. Quandt, *Magnetoelectric Thin Film Composites with Interdigital Electrodes*, Appl. Phys. Lett., **103**, 032902 (2013)
- T. Hofe, N.O. Urs, B. Mozooni, T. Jansen, C. Kirchhof, D. Bürgler, E. Quandt, J. McCord, *Dual wavelength magneto-optical imaging of magnetic thin films*, Appl. Phys. Lett., **103**, 123111 (2013)
- S.B. Hrkac, M. Abes, T. Koops, C. Krywka, M. Müller, S. Kaps, R. Adelung, J. McCord, E. Lage, E. Quandt, O.M. Magnussen, B.M. Murphy, *Local magnetization and strain in single magnetoelectric microrod composites*, Appl. Phys. Lett., **103**, 142410 (2013)
- E. Lage, A. Piorra, C. Kirchhof, E. Yarar, D. Meyners, E. Quandt, *(Invited) Giant magnetoelectric effect in thin film composites*, ECS Transactions, **50(10)**, 231 - 234 (2013)
- R. Lima de Miranda, G. Siekmeyer, A. Schübler, E. Quandt, *Comparison of the Fatigue Performance of Commercially Produced Nitinol Samples Versus Sputter Deposited Nitinol*, SMST 2013 Conference Proceedings, 143 - 144 (2013)

## Presentations

- C. Thede, K. Krüger, M. Stüber, E. Quandt, *Thermische Stabilität der uniaxialen Anisotropie in funktionalisierten Viellageschichten (Poster)*, Edgar-Lüscher Seminar, Klosters, Switzerland, 02.-08.02.2014
- E. Quandt, C. Bechtold, C. Chluba, R. Lima de Miranda, M. Wuttig, *Cyclic Stability and Elastocaloric Effect Size in Sputtered TiNi and TiNiCu films (invited)*, MRS 2013 Spring Meeting, San Francisco, USA, 01.-04.04.2013
- Ali Tavasollizadeh, T. Meier, K. Rott, G. Reiss, E. Quandt, H. Hölscher, D. Meyners, *Self-sensing Atomic Force Microscopy Cantilevers based on Tunnel Magnetoresistance Sensors*, MRS 2013 Spring Meeting, San Francisco, USA, 01.-05.04.2013
- E. Quandt, R. Lima de Miranda, C. Zamponi, K. Loger, A. Zayed, K. Schlüter, *Dünnschicht-Stents*, Nano meets MedTech (NINA), Hamburg, 11.04.2013
- E. Quandt, *Magnetoelektrische Komposite als hochempfindliche Magnetfeldsensoren*, 37. Edgar-Lüscher-Physikseminar am Gymnasium Zwiesel, Zwiesel, 12.-14.04.2013
- A. Schübler, R. Lima de Miranda, E. Quandt, G. Siekmeyer, *Comparison of the Fatigue Performance of Commercially Produced Nitinol Samples Versus Sputter Deposited Nitinol Samples Versus Sputter Deposited Nitinol*, SMST 2013, Prague, Czech Republic, 21.-24.05.2013
- E. Quandt, E. Lage, A. Piorra, C. Kirchhof, E. Yarar, D. Meyners, *Giant Magnetoelectric Effect in Thin Film Composites (invited)*, ECERS 2013, Limoges, France, 23.-27.06.2013
- E. Quandt, E. Lage, A. Piorra, C. Kirchhof, E. Yarar, D. Meyners, *Giant Magnetoelectric Thin Film Composites (invited)*, JEMS 2013, Rhodes, Greece, 25.-28.08.2013
- D. Haffner, *Freitragende gesputterte Mg-Legierungen*, VI. MetBioMat 2013, Hamburg, 24.09.2013
- Ali Tavasollizadeh, T. Meier, K. Rott, G. Reiss, E. Quandt, H. Hölscher, D. Meyners, *Atomic force microscopy using tunnel magnetoresistance sensors integrated with microcantilevers*, Euro Intelligent Materials 2013, Kiel, 25.-27.09.2013
- E. Yarar, E. Quandt, *Sandwich Type AlN-FeCoSiB Thin Film Magnetoelectric Composites (Poster)*, Euro Intelligent Materials 2013, Kiel, 25.-27.09.2013
- K. Loger, R. Lima de Miranda, E. Quandt, *Development of a TiNi Thin Film Heart Valve*, Euro Intelligent Materials 2013, Kiel, 25.-27.09.2013

- C. Kirchhof, R. Jahns, N. Urs, D. Meyners, R. Knöchel, J. McCord, E. Quandt, *Magnetoelectric sensors with reduced Barkhausen noise for frequency-conversion*, Euro Intelligent Materials 2013, Kiel, 25.-27.09.2013
- A. Piorra, J. Teliban, R. Jahns, R. Knöchel, E. Quandt, *Magnetoelectric composites based on PZT and FeCoSiB thin films with ID electrodes*, Euro Intelligent Materials 2013, Kiel, 25.-27.09.2013
- D. Meyners, E. Lage, C. Kirchhof, R. Jahns, R. Knöchel, E. Quandt, *Exchange biased magnetoelectric composites for magnetic field sensor application*, Euro Intelligent Materials 2013, Kiel, 25.-27.09.2013

## Further Activities and Events

- E. Quandt: Vice Dean of the Faculty of Engineering.
- E. Quandt: Speaker of the DFG Collaborative Research Centre (SFB 855) "Magnetoelectric Composites - Biomagnetic Interfaces of the Future".
- E. Quandt: Member of the Materials Science and Engineering Expert Committee (MatSEEC) of the European Science Foundation (ESF).
- E. Quandt: Member of "Deutsche Akademie der Technikwissenschaften (acatech)"
- E. Quandt: Member of the Executive Board and speaker of the Advisory Board of the Deutsche Gesellschaft für Materialkunde (DGM).
- E. Quandt: Member of the Scientific Advisory Board of the Acandis GmbH and Co. KG, Pfinztal.
- E. Quandt: Member of the Review Board of the DFG
- R. Lima de Miranda, E. Quandt: Co-Founder of the company Acquandas GmbH, Kiel.
- E. Quandt: Speaker of the Advisory Board of the Fraunhofer Institute ISIT

## Competence Centre "Nanosystem Technology"

The Competence Centre "Nanosystem Technology" was officially launched by the Minister of Economic Affairs of Schleswig-Holstein, Andreas Meyer, with an opening ceremony in November 2013.

The Competence Centre has four main objectives:

- 1) to serve as a research platform in nanosystem technology for the CAU and other public research institutions in Schleswig-Holstein,
- 2) to provide dedicated education in materials science and electrical engineering and related topics,
- 3) to perform research in third party funded (joint) research projects, and
- 4) to provide research and development capacities for industrial partners including spin-offs.

The outstanding equipment and the competence of the scientists at the competence centre will be a good basis for an effective support of all of the four mentioned goals.





# Materials and Processes for Nanosystem Technologies

Prof. Dr. Bernhard Wagner is the Deputy Director of the Fraunhofer-Institute für Siliziumtechnologie (ISIT) in Itzehoe.

Fraunhofer ISIT develops and manufactures components in microelectronics and microsystems technology, from the design phase (including system simulation), through prototyping and fabrication of samples, up to series production. Even though components manufactured at Fraunhofer ISIT, such as acceleration sensors, valves, and deflection mirrors, often measure just a fraction of a millimetre in size, there is a wide range of applications: the devices are implemented in areas like medical care, environmental and traffic engineering, communication systems, automotive industry, and mechanical engineering. Working under contract, ISIT develops these types of components in accordance with customer requirements, also creating the application specific integrated circuits (ASICs) needed for the operation of sensors and actuators. Included in this service is system integration using miniaturized assembly and interconnection technology.

Together with Vishay Siliconix Itzehoe GmbH, the institute operates a professional semiconductor production line which is up-to-date in all required quality certifications (e. g. ISO 9001, TS 16949). This line is used in parallel for PowerMOS and microsystem production and for R&D projects developing new devices and technological processes.

Other fields of activity at ISIT focus on assembly and packaging techniques for microsystems, analysis of the quality and reliability of electronic components, and development of advanced power-supply components for electronic systems.

The institute employs a staff of around 150 people

Further information about Fraunhofer ISIT is available on the web: [www.isit.fraunhofer.de](http://www.isit.fraunhofer.de).

In addition the Institute publishes an Annual Report which can be ordered at ISIT.

Fraunhofer-Institut für Siliziumtechnologie,  
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## Microanalysis of Materials

The reports for 1996 - 2013 are available for downloading at [www.tf.uni-kiel.de/matwis/matan](http://www.tf.uni-kiel.de/matwis/matan)

The Microanalysis of Materials Group (AG Mikrostrukturanalytik) of the Institute for Materials Science at the CAU Kiel started with the appointment of Dr. Wolfgang Jaeger as Professor in Oct 1996, (since 1997 also a member of the Physics Section at the CAU Kiel, and since 2006 appointed Director at the Institute for Materials Science, as are all group leader colleagues) and ceased to exist with his formal retirement from part of his duties in April 2013. His teaching duties at the Faculty of Engineering terminated at the end of the winter term 2012 / 2013. A contract with the CAU Kiel allows him to continue and finish on-going research projects and start new collaborative research projects. Please see also the acknowledgment at the end of the section on 'Research Results'.

The research areas and activities of the Microanalysis Materials Group are summarized in the reports 1997 - 2001, in the contributed reports published in the tf almanach 2002 - 2012, and in this report for 2013. (for download please see [www.tf.uni-kiel.de/matwis/matan](http://www.tf.uni-kiel.de/matwis/matan))

**Research Focus and Methods:** Our research projects aim at the understanding of microstructure-property relationships of functional materials and the synthesis of fundamental research, quantitative methodological approaches, and their applications in technology-oriented material developments. Particular emphasis is put on:

- Microstructure research of thin film systems, interfaces, defects, and nanomaterials,
- Quantitative methods of high-resolution and analytical transmission electron microscopy,
- Nanoanalytics with electrons in materials and surface science (technology transfer for industry).

The Centre of Materials Analysis (CMA) and the "Kieler Nanolabor" of the CAU provide access to numerous methods for the nanoanalysis of materials. Techniques predominantly used in our research projects are the advanced high-resolution imaging (HRTEM, STEM/HAADF, EFTEM) and spectroscopic (EELS/ELNES, EDXS) methods of transmission electron microscopy (TEM), state-of-the-art image simulation, digital image analysis methods, as well as dual-beam FIB / SEM / EDX methods for focussed ion beam (FIB) TEM specimen preparation. The central instrument of the TEM laboratory is a FEI TECNAI F30 analytical transmission electron microscope equipped with a GATAN GIF / TRIDIEM 863 Imaging Energy Filter, with Multi-Scan CCD Cameras, and with specimen holders for in situ TEM under temperature control or for electron tomography for 3D object reconstruction, which also enables Lorentz microscopy of magnetic materials. Software packages for state-of-the-art image simulation, digital image analyses, spectral data analyses, and exit-wave reconstruction from focal series assist in the evaluation of the experimental data.

**Course Teaching and Research Thesis Projects:** Study courses for Bachelor's and Master's Students (teaching languages English and German according to requirements) in the subject areas Materials Science, Analytical Methods in Materials Science, and Advanced Methods of Transmission Electron Microscopy. Offers for thesis projects in Bachelor's and Master's education and for Dissertation projects.

**Collaboration Offers for Research and Technology:** R&D collaboration with research institutions and with industry. Funded project research and transfer. Continuing education in subject areas 'Analytics of Materials for Research and Industry' and 'Electron Microscopy in Materials Science' (Prof. Wolfgang Jaeger, teaching languages English and German as required). Consulting and expert advice.

## Results

In 2013 we have continued with the experimental investigations of energy materials and finished some projects by publishing results of our studies that applied advanced high-resolution imaging and spectroscopic techniques of transmission electron microscopy (conventional and aberration-corrected high-resolution TEM, electron diffraction,

high-resolution STEM, and spectroscopic EDXS and EELS analyses) in comprehensive microstructure research on interfaces, surfaces, and nanomaterials.

#### TEM AND *in situ* TEM FOR IMPROVED HIGH-EFFICIENCY SOLAR CELLS

Dr. Dietrich Häussler, CAU. Cooperations: Dr. F. Dimroth, Dipl. Phys. S. Essig, Dr. A.W. Bett, Fraunhofer, Institute for Solar Energy Systems FhG-ISE Freiburg. Dr. L. Houben, Prof. Rafal Dunin-Borkowski, Ernst-Ruska Centre, Research Centre Juelich, Germany.

Multi-junction solar cells are of interest for power generation in space applications and in terrestrial concentrator photovoltaics (CPV). Efficiencies well above 40 % have been obtained for concentrator solar cells grown by metal-organic vapour deposition on Ge substrates. In multijunction solar cells, several cells of different III-V compound semiconductor materials are stacked on top of each other. Each cell absorbs a different wavelength range of the solar spectrum and converts it into electric power. In September 2013, a new record efficiency for the conversion of sunlight into electricity of 44.7 % was measured at a concentration of 297 suns using a new solar cell structure with four solar subcells. Frank Dimroth, Project Leader in charge of this development at the Fraunhofer ISE Freiburg says: "This four-junction solar cell contains our collected expertise in this area over many years. Besides improved materials and optimization of the structure, a new procedure called wafer bonding plays a central role. With this technology, we are able to connect two semiconductor crystals, which otherwise cannot be grown on top of each other with high crystal quality". See full text at: [www.ise.fraunhofer.de/en/press-and-media/press-releases/presseinformationen-2013/world-record-solar-cell-with-44.7-efficiency](http://www.ise.fraunhofer.de/en/press-and-media/press-releases/presseinformationen-2013/world-record-solar-cell-with-44.7-efficiency)

High-resolution imaging and spectroscopic techniques of transmission electron microscopy were applied throughout the last decade to support the development of novel multi-junction solar cell concepts through comprehensive analyses of microstructure and layer interfaces. Our research aimed at understanding and controlling defects and layer strains in lattice-mismatched epitaxial layer growth on Ge and on Si, and at analyzing interface structures after thin layer transfer combined with semiconductor wafer bonding for solar cells on Si substrates. The optimized solar cell concepts result in active cell regions with significantly reduced defect densities. The success of such concept developments led to a GaInP/GaAs/Ge cell with a record efficiency of 41.1 % at 454 suns concentration of AM1.5d in 2009 and a GaInP/GaAs/Si solar cell in 2013 with an AM1.5g efficiency of 26.1 %. - Furthermore, *in situ* TEM experiments have been performed in order to study influences of annealing at elevated temperatures ( $T \leq 400$  °C) on the structure of interfaces in wafer-bonded solar cells. The measurements support assessing the effect of the microstructure near the GaAs/Si interface on the electrical properties of the solar cell.

In methodologically oriented investigations, we explored the potential of combining HRTEM and EDX spectroscopy with aberration-corrected STEM and EELS (at the ER-C Juelich) to investigating the structure and the elemental distributions of near GaAs / Si bond interfaces of wafer-bonded GaInP/GaAs/Si multi-junction solar cells. **Figure 1** shows an example of the element distribution analysis by EDXS and by EELS at the GaAs / Si interface of a wafer-bonded solar cell, demonstrating that EELS in aberration-corrected scanning transmission electron microscopy reveals fluctuations of element concentrations within the amorphous interface layer of nanometer extension, including those of light elements, and thus extends by far the analytical capabilities with respect to an EDXS analysis using a non-corrected TEM. The measurements support assessing the influence of the interface on the measured current-voltage characteristics of a multi-junction solar cell.

#### TEM OF NANOMATERIALS FOR HIGH-CAPACITY HYDROGEN STORAGE

Dr. D. Häußler, CAU. Collaboration: Dr. C. Pistidda, Dr. M. Dornheim, Prof. Dr. Th. Klassen, Department Nanotechnology, Helmholtz Zentrum Geesthacht.

Various methods of TEM (BF and DF TEM imaging, high-resolution TEM, high-resolution TEM phase contrast imaging, electron diffraction (SAED), and energy-dispersive X-ray spectroscopy (EDXS) measurements) were applied in a first study to characterize the individual phases, and the sizes and distributions of phase particles for a ball-milled

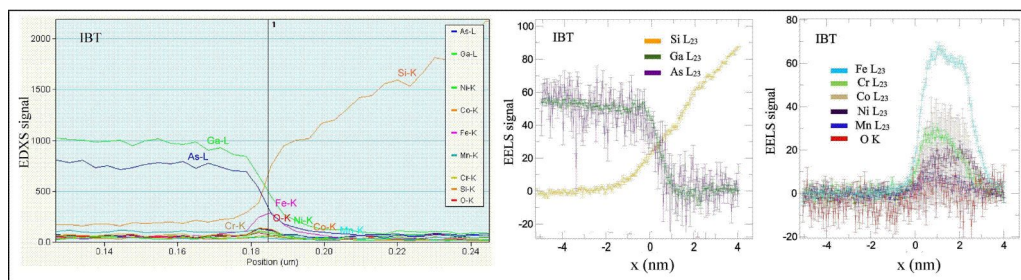


Fig. 1: Comparison of element profiles extracted from STEM-EDX line scans (TECNAI F30 G2, left) and from STEM-EELS line profiles (Titan 80-300 FEG, middle and right) taken across the identical GaAs-Si interface of a wafer-bonded GaInP/GaAs/Si multi-junction solar cell. Taken from: Ultramicroscopy 134, 55 (2013).

Ca(BH<sub>4</sub>)<sub>2</sub>-MgH<sub>2</sub>-0.1NbF<sub>5</sub> material system. The experiments for the H-desorbed state reveal clustering of nanoparticles (sizes < 10 nm). Analyses of the electron diffraction and lattice images corroborate the crystalline nature of particles of different phases. Composition analyses confirm qualitatively the presence of the EDXS-detectable elements in the expected nominal fraction. It is expected that such experiments contribute to understanding the optimum design and the structure of the absorbed and desorbed state of H-storage materials.

#### TEM OF NANOSCALE PHENOMENA IN MAGNETIC Cu-Co MULTILAYER AND Cu-Co ALLOY SYSTEMS

Dr. D. Häußler, CAU. Cooperation: Prof. Guillermo Solórzano, Dr. Natasha M. Suguhiro, Dept. Materials Science and Metallurgy, PUC-Rio Pontificia Universidade Católica do Rio de Janeiro, Rio de Janeiro, Brazil. Prof. E. B. Saitovitch, CBPF Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro - RJ, Brazil.

The investigations on melt-spun magnetic Cu-Co alloys and on several Cu-Co multilayer systems have been finalized and summarized for publication in 2 manuscripts. \* In these studies, TEM diffraction contrast imaging and STEM-EDXS analyses have been applied in systematic studies to characterize the microstructure and interfaces of layer systems in order to gain quantitative understanding of the microstructure-property relationships.

\* L. Liu, U. D. Chacón Hernandez, Y. T. Xing, N. M. Suguhiro, D. Haeussler, W. Jaeger, E.B. Saitovitch, I. G. Solórzano-Naranjo: Effect of interface roughness on superconducting transition temperatures of Nb/Co multilayers. J. Appl. Phys. (2013), submitted.

\* N. M. Suguhiro, Y. T. Xing, D. Haeussler, W. Jaeger, D. Smith, E. B. Saitovitch, I. G. Solórzano, E. B. Saitovitch: Discontinuous Reactions in Melt-Spun Cu-10at%Co Alloy and Their Effect on Magnetic Anisotropy. Manuscript in preparation.

#### ANALYTICAL STEM AND *in situ* TEM OF ZINC OXIDE NANOMATERIALS

Dr. D. Häußler, CAU. Cooperation: Prof. Y. Ortega Villafuerte, Prof. Dr. J. Piqueras, Physics Department, Universidad Complutense de Madrid, Spain.

We have finalized and published the fundamental studies of the behaviour of liquid metal in core regions of ZnO nanotubes with Sn cores by *in situ* TEM experiments, combined with element analyses by STEM HAADF imaging and spatially resolved STEM-EDXS measurements. By applying variable thermal load through changing the electron-beam flux of the electron microscope, melting of the metallic core can be induced, and the local behaviour of the liquid metal in the nanotubes can be monitored. It is feasible to produce nanodrops with volumes of 10<sup>-20</sup> - 10<sup>-18</sup> l that emerge from nanotube tip regions. In situ TEM allows initiating and monitoring changes of the nanodrop radius in a controlled way.

## ABERRATION-CORRECTED STEM OF Sn-Pd CORE-SHELL NANOPARTICLES

Dr. D. Häußler, CAU. Cooperation: Dr. B. Schaffer, Dr. F. Hofer, Institute for Electron Microscopy, Graz University of Technology, Graz, Austria and SuperSTEM Facility Daresbury, UK.

The fundamental study of the structure of polycrystalline Sn-Pd core-shell nanoparticles (typical sizes  $< 50\text{nm}$ ) using STEM-HAADF imaging, EDX and EELS spectroscopy in STEM, and STEM diffraction imaging (DI), has been finalized. Being of potential interest in catalysis, a comprehensive and quantitative particle structure characterization for various fabrication parameters is of basic interest. The particles of the chosen material are characterized by a high degree of structural complexity due to the presence of various crystallographic phases. Composition mappings show that Pd is not present in the shell regions. By applying the STEM-DI method which combines high-resolution STEM imaging with local Fourier analyses of the image contrast it can be shown that individual core-shell nanoparticles can contain a large number of different nanocrystallites that often possess locally strained lattice regions. The results are being prepared for publication.

## Microanalysis of Materials Group 1997 - 2013: Short Summary of Activities

[www.tf.uni-kiel.de/matwis/matan](http://www.tf.uni-kiel.de/matwis/matan)

### Microstructure and Electron Microscopy Research

Semiconductor materials for nanoelectronics and sensors: epitaxial growth of Si-Ge semiconductor heterostructures, epitaxial CVD growth of diamond on Si and on SiC, diffusion and defects in III-V semiconductors.

Energy materials: materials for high-capacity H absorption, TEM for defect engineering in high-efficiency solar cells, oxide semiconductor nanomaterials, quantitative STEM-EELS analyses of light element distributions in nanometre-scale interface layers.

Layered chalcogenide materials: growth, interface, and nanostructure phenomena.

Magnetic materials: magnetic layer and nanoparticle materials, magnetic nanostructures in melt-spun alloys.

Nanomaterials: multilayer materials for X-ray optics, nanoparticle materials for catalysis, functionalized diamond nanoparticles for bio-medical applications

Quantitative and nanoanalytical methods of TEM-development and applications to microstructure research in materials science: high-resolution TEM (HRTEM) of Si-Ge and of InP-GaAs alloys and interfaces, polarity analyses of III-V semiconductors by Convergent Beam Electron Diffraction (CBED), bend contour, and large-angle CBED (LACBED) methods for defect, interface, and nanostructure studies, electron beam induced behaviour of liquid metal in ZnO nanotubes with Sn cores by in situ TEM, layer thickness of ultrathin layers by STEM, atom column position determination in NbS-PbS layered misfit compounds by aberration-corrected HRTEM.

From 1997 to 2013 the group published about 180 publications in scientific journals (78 publications in refereed journals, 102 in conference publications), including articles in data review books and in Proceedings of Advanced Research Schools. The scientific results have been recognized by several journal cover page illustrations. The group contributed to international scientific conferences with numerous contributed as well as invited and plenary speaker presentations, the organisation of workshops and of symposia, and the international Microscopy Conference MC2011 Kiel (participation of 950 attendees and 50 companies, publications of scientific papers in Conference Proceedings). Further publications are concerned with the Engineering Education in Kiel and with the presentation of scientific methods and results for the public. Parts of the activities were presentations that were given for high-school students, for the 'Saturday Morning Physics' events of the CAU Kiel, and for the SHUG Schleswig-Holsteinische Universitätsgesellschaft.

### Lectures, Seminars, Laboratory Courses, Research Supervisions

Mandatory and elective study courses, including exercises, for B.Sc., M.Sc., and PhD course teaching (teaching language English) were given regularly in the following subject areas: Materials Science III (mandatory BSc course), Introduction

to Analytical Methods in Materials Science (mandatory BSc course), Analytical Methods in Materials Research (mandatory 2-semester MSc course), Advanced Methods of Transmission Electron Microscopy (elective MSc 2-semester course). The group contributed also regularly in basic lab classes and with experiments to the Advanced Laboratory Courses for Master's students. Furthermore, research supervisions for Doctorate and Habilitation Theses, for Diploma Theses, for Master's theses, and for Bachelor's theses were part of the continuing activities.

### Acknowledgement

As Head of the Microanalysis of Materials Group, it is with great pleasure and delight that I acknowledge the fruitful collaboration and exchange with all the members of our group over the years. Their contributions have been essential and enabled the scientific success of the group (see reports in the annual issues of the 'almanac' of the Faculty of Engineering of the CAU Kiel, <http://www.tf.uni-kiel.de/matwis/matan/>). Special thanks go to the secretary of our group, Katrin Brandenburg (**Figure 2**). Her smile and her always friendly, positive, highly efficient, and competent support in all matters when handling the finances of the group as well as her support in many aspects of the day-to-day work have been of utmost importance. Katrin also contributed continuously to the work of shaping a team spirit and creating a positive working environment. I am deeply grateful for all the good experiences and the fruitful collaboration, and I wish her all the best for her future!



Fig. 2: Katrin Brandenburg

Furthermore, I would like to acknowledge the continuous support that the Microanalysis of Materials Group has received over many years by Dr. Frank Paul, the members of the Dean's office, and by the various teams of the Central Services of the Faculty of Engineering, such as the library, the computer service group, the service centre, the building services, and the workshop. Many thanks also go to those of my friends and colleagues from the Faculty of Engineering and from the Christian-Albrechts-University of Kiel who supported, in a constructive manner, our scientific projects or contributed to our various project initiatives and their coordination being of general interest for the Faculty.

As a university teacher, one of the most invaluable and wonderful experiences, which I always will remember, is that of interacting with young students and to contributing to their scientific education. This has been great fun and a true privilege. Teaching, working in teams, discussing scientific and sometimes personal issues with the students of Materials Science from Germany and from abroad, who attended my courses and whom I had the pleasure to interact with, were for me always a source of great joy.

Representing all these students, I would like to express my thanks especially to the group of students (**Figure 3**) who attended my last lecture courses at the TF and who arranged and invited me to a farewell party with (a moderate amount of) sparkling wine and a tasty barbecue in the TF park - this was a truly special and invaluable experience for me! - Many thanks to all of you!





Fig. 3: Materials Scientists at CAU-TF

## Personnel

Head of the group: Prof. Dr. Wolfgang Jäger; Secretary: Katrin Brandenburg (50%)

Scientific Staff:

Dr. Dietrich Häußler	01.01.-31.03.2013	CAU
Analytical TEM of layer systems and nanomaterials		
M.Sc. Burcu Ögüt	01.-30.01.2013	MPI Stuttgart
Investigations of surface plasmon resonances of metallic nanomaterials by energy-filtering TEM (co-supervision of external Dissertation in collaboration with Max-Planck-Institute for Intelligent Systems, Stuttgart, Prof. Dr. P. Van Aken)		

## Lectures, Seminars, and Laboratory Course Offers

Winter 2012/2013

Analytics I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Wolfgang Jäger

Analytical Methods in Materials Research, 2 hrs Seminar/Week,  
Wolfgang Jäger

Transmission Electron Microscopy, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
Wolfgang Jäger



Materialwissenschaft III, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
Wolfgang Jäger

Materialanalytik, 4 hrs Practical/Week,  
Dietrich Häußler (+ Dirk Meyners, Klaus Rätzke, Mady Elbahri, Marlies Schwitzke)

### Third-Party Funds

EU, MACAN - *Merging Atomistic and Continuum Analysis of Nanometre Length-Scale Metal-Oxide Systems for Energy and Catalysis Applications*, 01.06.2009-31.05.2013 (29.158 EUR)

### Further Cooperation, Consulting, and Technology Transfer

*Technology-oriented collaborations with industry and external research institutes*

Continued collaboration with the Helmholtz Zentrum Geesthacht, Dept. Nanotechnology, Dr. C. Pistidda, Dr. M. Dornheim, Prof. Th. Klassen, on the application of advanced TEM methods for the development of nanomaterials for high-capacity hydrogen storage.

Continued collaboration with Fraunhofer Institute for Solar Energy Systems ISE, Dr. F. Dimroth, Dipl. Phys. S. Essig, Dr. A. W. Bett, Prof. Dr. E. Weber, on the development of concepts for defect engineering in high-efficiency solar cells. Recent results: F. Dimroth, T. Roesener, S. Essig, Ch. Weuffen, A. Wekkeli, E. Oliva, G. Siefer, K. Volz, Th. Hannappel, D. Häussler, W. Jäger, A. W. Bett: Comparison of Direct Growth and Wafer Bonding for the Fabrication of GaInP/GaAs Dual-Junction Solar Cells on Silicon, IEEE Journal of Photovoltaics, accepted for publication (2014).

Continued collaboration with the Ernst Ruska Centre for Microscopy and Spectroscopy with Electrons, Research Centre Juelich GmbH, Dr. L. Houben, Prof. R. Dunin-Borkowski, on aberration-corrected electron microscopy including EELS investigations of wafer-bonded tandem solar cells.

*Collaborations with Universities*

Continued co-supervision (Prof. W. Jäger) of PhD thesis research work at the Max-Planck-Institute for Intelligent Systems (formerly MPI for Metals Research), Stuttgart, Germany (Stuttgart Centre for Electron Microscopy, Dr. P. A. van Aken, Dr. W. Sigle) on TEM characterisations of plasmonic properties of metal nanostructures.

Continued research collaboration with Department of Materials Science and Metallurgy, PUC-Rio Pontificia Universidade Católica do Rio de Janeiro, Rio de Janeiro, Brazil (Professor Guillermo Solórzano) on TEM investigations of microstructure-property relationships of Cu-Co alloy and multilayer systems.

### Dissertations / Postdoctoral Lecture Qualifications

Burcu Ögüt, *Investigations of surface plasmon resonances by energy-filtering transmission electron microscopy methods*, 30.01.2013

### Publications

Published in 2013

D. Häussler, L. Houben, S. Essig, M. Kurttepeli, F. Dimroth, R.E. Dunin-Borkowski, W. Jäger, *Aberration-corrected transmission electron microscopy analyses of GaAs/Si interfaces in wafer-bonded multi-junction solar cells*, Ultramicroscopy, **134**, 55 - 61 (2013)

K. Derendorf, S. Essig, E. Oliva, V. Klinger, T. Roesener, S.P. Philipps, J. Benick, M. Hermle, M. Schachtner, G. Siefer, W. Jäger, F. Dimroth, *Fabrication of GaInP/GaAs//Si Solar Cells by Surface Activated Direct Wafer Bonding*, IEEE

Journal of Photovoltaics, DOI : 10.1109/JPHOTOV.2013.2273097, **3(4)**, 1423 - 1428 (2013)

J. Schöne, E. Spiecker, F. Dimroth, A.W. Bett, W. Jäger, *Defect Formation and Strain Relaxation in graded GaPAs/GaAs, GaNAs/GaAs and GaInNAs/Ge Buffer Systems for high-efficiency Solar Cells*, Journal of Physics: Conference Series, DOI: 10.1088/1742-6596/471/1/012008, **471**, 012008 (2013)

Y. Ortega, W. Jäger, J. Piqueras, D. Häussler, P. Fernández, *In situ TEM and analytical STEM studies of ZnO nanotubes with Sn cores and Sn nanodrops*, J. Phys. D: Appl. Phys., DOI: 10.1088/0022-3727/46/39/395301, **46**, 395301 - 395308 (2013)

E. Olsson, R. Sinclair, W. Jäger, *NorTEM net 2013 Workshop on Advanced Transmission Electron Microscopy*, MICROSCOPY AND ANALYSIS Editorial. [www.microscopy-analysis.com/editorials/editorial-listings/nortemnet-2013-workshop-advanced-transmission-electron-microscopy](http://www.microscopy-analysis.com/editorials/editorial-listings/nortemnet-2013-workshop-advanced-transmission-electron-microscopy), (2013)

E. Olsson, R. Sinclair, W. Jäger, *NorTEMnet meeting in Gothenburg, Sweden*, MICROSCOPY AND ANALYSIS, **9**, 30 (2013)

W. Jäger, *'Institut für Materialwissenschaft, Mikrostrukturanalytik'*, EKSH FORSCHUNGS- UND TRANSFERBERICHT, CAU Kiel, Technische Fakultät. Ed. Gesellschaft für Energie und Klimaschutz Schleswig-Holstein GmbH, 24118 Kiel. Download: [www.eksh.org](http://www.eksh.org), (2013)

## Presentations

W. Jäger, *Defect and polarity characterization in compound semiconductors (invited lecture)*, MACAN - IFX/KAI Idea Exchange Meeting, Infineon Technologies Austria AG, Villach, Austria, 15.-17.01.2013

W. Jäger, *Transmission Electron Microscopy for Functional Materials (invited lecture)*, Workshop on 'Applications of EM in Materials Science', NZCM 2013 26th New Zealand Conference on Microscopy, Christchurch, New Zealand, 12.02.2013

W. Jäger, *Transmission Electron Microscopy for High-Efficiency Solar Cells (invited lecture)*, NZCM 2013 26th New Zealand Conference on Microscopy, Christchurch, New Zealand, 13.-15.02.2013

W. Jäger, *Transmission Electron Microscopy of Nanostructured Semiconductor Materials (invited lecture)*, NZCM 2013 26th New Zealand Conference on Microscopy, [microscopynz.co.nz](http://microscopynz.co.nz), Christchurch, New Zealand, 13.-15.02.2013

W. Jäger, *Transmission Electron Microscopy of Surface and Interface Phenomena of Nanoscale Functional Layer Materials (invited lecture)*, NorTEMnet 2013 Workshop on Advanced Transmission Electron Microscopy, Chalmers University, [www.chalmers.se/en/about-chalmers/calendar/Pages/NorTEMnet-workshop-on-advanced-transmission.aspx](http://www.chalmers.se/en/about-chalmers/calendar/Pages/NorTEMnet-workshop-on-advanced-transmission.aspx), Gothenburg, Sweden, 25.-27.03.2013

W. Jäger, *Transmission Electron Microscopy for High-Efficiency Solar Cells (invited lecture)*, 18th MSM 2013 Microscopy of Semiconducting Materials Meeting (MSMXVIII), St Catherine's College, [www.rms.org.uk/events/pastevents/index/msmxviii](http://www.rms.org.uk/events/pastevents/index/msmxviii), Oxford, United Kingdom, 07.-11.04.2013

B. Ögüt, N. Talebi, R. Vogelgesang, W. Sigle, W. Jäger, P.A. van Aken, *Toroidal Plasmonic Eigenmodes in Oligomer Nanocavities for the Visible (invited lecture)*, MACAN Capstone Conference, Dan Carmel Hotel, Haifa, and HaGoshrim Hotel, Kibbutz HaGoshrim, [macan.technion.ac.il/conferences.html](http://macan.technion.ac.il/conferences.html), Haifa and Kibbutz HaGoshrim, Israel, 20.-26.04.2013

W. Jäger, *Transmission Electron Microscopy of Nanoscale Multilayer Materials*, Colloquium at CBPF Centro Brasileiro de Pesquisas Físicas, URCA, Rio de Janeiro, Brazil, 16.05.2013

W. Jäger, *Transmission Electron Microscopy of Nanoscale Multilayer Materials*, Colloquium at UFF Fluminense Federal University, Niteroi, Brazil, 21.05.2013

W. Jäger, *Transmission Electron Microscopy of Nanoscale Multilayer Materials*, Colloquium at INMETRO National Institute of Metrology, Standardization and Industrial Quality, Rio Comprido Rio de Janeiro, Brazil, 24.05.2013

W. Jäger, *Transmission Electron Microscopy of Nanoscale Functional Layer Materials*, ER-C Kolloquium, Research Centre Juelich, Jülich, Germany, 12.06.2013

D. Häußler, L. Houben, S. Essig, M. Kurttepeli, R. Dunin-Borkowski, F. Dimroth, W. Jäger, *Aberration-corrected STEM and EELS analyses of interfaces in wafer-bonded tandem solar cells*, MC 2013 Microscopy Conference 2013, [www.mc2013.de](http://www.mc2013.de), Regensburg, Germany, 26.-30.08.2013

W. Jäger, *Transmission Electron Microscopy of Nanoscale Semiconductor Materials (invited lecture)*, CIASEM 2013, 12th Inter-American Congress of Microscopy, [www.ciasem2013.com](http://www.ciasem2013.com), Cartagena de Indias, Colombia, 24.-28.09.2013

W. Jäger, *Transmission Electron Microscopy of Diffusion-Induced Phenomena in III-V Semiconductors (plenary lecture)*, YUCOMAT 2013, organized by the Materials Research Society of Serbia, under the auspices of the Federation of European Materials Societies (FEMS), [www.mrs-serbia.org.rs](http://www.mrs-serbia.org.rs), Herceg Novi, Montenegro, 01.-06.09.2013

W. Jäger, *Transmission electron microscopy for high-efficiency solar cells (invited lecture)*, PICO 2013 2nd Conference on Frontiers of Aberration Corrected Electron Microscopy, [www.er-c.org/pico2013](http://www.er-c.org/pico2013), Kasteel Vaalsbroek, The Netherlands, 09.-12.10.2013

## Further Activities and Events

### Further Activities of General Interest (Professor Wolfgang Jäger)

Acquisition of 2,988,000 EUR in third party funds.

Contribution to several successful proposals aiming at the acquisition of modern laboratory equipment being of general interest for the university (1997 - 2008).

Foundation and Head of the 'CMA Centre for Materials Analysis' (1999 - 2003).

Proposal for an 'Institute for Materials Development' as a regional competence cluster (2000).

Contributions to the development of the study course systems in Materials Science, of the international MSc Study course system, and of the Erasmus exchange program of the Faculty of Engineering of the CAU Kiel (1997 - 2006).

Initiative and project coordination of the interdisciplinary project 'Nanoanalytics with electrons for materials science and surface science' and of an interdisciplinary CAU Laboratory for Analytical TEM, now: TEM Centre in the 'Kiel Nanolaboratory' (2003 - 2006).

Host of numerous guest scientists with their contributions to the Colloquium programme of the Faculty of Engineering and to other colloquia, e. g. colloquium of DFG Research Group (1997 - 2013).

Organization of numerous workshops, of symposia at international conferences, and of Advanced Scientific Schools (1997 - 2013).

Support of numerous projects in universities, research institutes, research centres, and in industry with analytical services, mainly with methods of transmission electron microscopy and scanning electron microscopy, including spectroscopic analyses (1997 - 2013).

Organisation of the international Microscopy Conference MC 2011 Kiel, Chair Professor Wolfgang Jäger, with a participation of 950 attendees and 50 companies (2009 - 2011). [www.mc2011.de](http://www.mc2011.de)

Some further professional activities of Professor Wolfgang Jäger: Reviewer for numerous international scientific journals. Reviewer for various national and international funding bodies (Germany, EU, US, and others). Member of advisory committees and organiser and session chair for international conferences. 2006 - 2009 Editor of Springer Journal of Materials Science. Member of nomination committees. Jury Member of EMS Outstanding Paper Award Committee of the European Microscopy Society. Elected Member of Executive Committee of European Materials Research Society. Chairman of the E-MRS Fall Meeting Warsaw 2013.

2012 EMS Outstanding Paper Award for Dr. Burcu Ögüt

Dr. Burcu Ögüt (at present: Max-Planck-Institute for Intelligent Systems Stuttgart) was winner of the 2012 *EMS Outstanding Paper Award* of the European Microscopy Society (EMS) in the category "*Materials Sciences*" for the publication with the title "*Toroidal Plasmonic Eigenmodes in Oligomer Nanocavities for the Visible*", Burcu Ögüt, Nahid Talebi, Ralf Vogelgesang, Wilfried Sigle, and Peter A. van Aken; *Nano Letters* 12, 5239-5244 (2012). Further information: [www.imaging-git.com/news/ems-outstanding-paper-award-2012-0](http://www.imaging-git.com/news/ems-outstanding-paper-award-2012-0) and [www.euremicsoc.org/prizes-opa.htm](http://www.euremicsoc.org/prizes-opa.htm). Burcu Ögüt graduated from the Faculty of Engineering, CAU Kiel, with a master's thesis on 'Multilayers for X-ray optics: TEM characterization of aperiodic W-B4C multilayers' which she performed in the AG Microanalysis of Materials (Prof. Dr. W. Jäger). She conducted her PhD thesis research work on TEM characterisations of plasmonic properties of metal nanostructures at the Max-Planck-Institute for Intelligent Systems (formerly MPI for Metals Research) Stuttgart, Germany, in the Stuttgart Centre for Electron Microscopy under the supervision of Prof. Dr. Peter A. van Aken and Dr. Wilfried Sigle, co-supervised by Prof. Dr. Wolfgang Jäger. On Jan 30, 2013, Burcu Ögüt received her degree 'Dr. rer. nat.' (equivalent to Ph.D.) from the Faculty of Engineering, Christian-Albrechts-Universität zu Kiel. At the moment (2014) she is a postdoctoral research fellow at the Department of Materials Science and Engineering, Stanford University, USA.

### Guests in 2013

Professor Eva Olsson, Department of Applied Physics, Chalmers University of Technology, Gothenburg, Sweden, "Correlating charge transport properties to structure on the nanoscale and beyond using in situ electron microscopy", Colloquium of the Faculty of Engineering, January 7, 2013, <http://www.tf.uni-kiel.de/de/das-dekanat/aktuelles-termine/kolloquien>. Preparation Meeting Kiel for Workshop Organisation, June 24 - 26, 2013

Professor Robert Sinclair, Chairman, Materials Science and Engineering, Stanford University, USA, Preparation Meeting Kiel for Workshop Organisation, June 24 - 26, 2013

Professor James Wittig, Vanderbilt University, Nashville, Tennessee, USA, Preparation Meeting Kiel for Workshop Organisation, June 24 - 26, 2013

### Activities Professor Wolfgang Jäger

*In 2013 Professor Wolfgang Jäger accepted invitations to be a member of various international scientific advisory boards and programme committees at several international conferences and workshops on materials science and on advanced electron microscopy in materials science, see following list:*

Chair of the E-MRS 2013 European Materials Research Society Fall Meeting, University of Technology Warsaw, Poland, September 16 - 20, 2013. 14 thematic symposia, plenary session and satellite events. Organisation and chairpersons: George Kiriakidis, Physics Dept., University of Crete, Heraklion, Crete, Greece, Giuseppina Padeletti, ISMN - CNR, Monterotondo-Roma, Italy, Witold Lojowski, Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw, Poland, and Wolfgang Jäger, Institute of Materials Science, Christian-Albrechts-University of Kiel, Germany. [www.european-mrs.com](http://www.european-mrs.com)

NZCM 2013, 26th New Zealand Conference on Microscopy, Christchurch, New Zealand, February 13 - 15, 2013.

'NorTEMnet 2013 Workshop on Advanced Transmission Electron Microscopy', Chalmers University of Technology, Gothenburg, Sweden, March 25 - 27, 2013. [www.chalmers.se/en/about-chalmers/calendar/Pages/NorTEMnet-workshop-on-advanced-transmission.aspx](http://www.chalmers.se/en/about-chalmers/calendar/Pages/NorTEMnet-workshop-on-advanced-transmission.aspx) (see also Publications)

MACAN Capstone Conference, MACAN - Merging Atomistic and Continuum Analysis of Nanometre Length-Scale Metal-Oxide Systems for Energy and Catalysis Applications, Dan Carmel Hotel, Haifa, and HaGoshrim Hotel, Kibbutz HaGoshrim, Israel, April 20 - 26, 2013. [macan.technion.ac.il/conferences.html](http://macan.technion.ac.il/conferences.html)

CIASEM 2013, 12th Inter-American Congress of Microscopy, Cartagena de Indias, Colombia, September 24 - 28, 2013. [www.ciasem2013.com](http://www.ciasem2013.com)

YUCOMAT 2013, organized by the Materials Research Society of Serbia, under the auspices of the Federation of European Materials Societies (FEMS), Herceg Novi, Montenegro, September 1 - 6, 2013. [www.mrs-serbia.org.rs](http://www.mrs-serbia.org.rs)

*Professor Wolfgang Jäger participated upon invitation at the following workshops, conferences, and events:*

M&M 2013 Microscopy and Microanalysis Conference, Indianapolis, USA, August 4 - 9, 2013: Meeting of the Chairpersons for the preparation of a symposium on 'Microscopy and spectroscopy of materials for power generation and for energy conversion and storage' at the M&M 2014 Microscopy and Microanalysis Conference, Hartford CT, USA, August 3 - 7, 2014. [microscopy.org/MandM/2014](http://microscopy.org/MandM/2014)

SALVE I-II Sub-Angstrom Low-Voltage Electron Microscopy Workshop, Ulm University, Ulm, Germany, October 15, 2013.

ISE Solar Summit Conference, Freiburg, Germany, October 23, 2013. [www.solar-summit-2013.org](http://www.solar-summit-2013.org)

INT Physics Days, Karlsruhe Institute of Technology (KIT), Institute for Nanotechnology, Eggenstein-Leopoldshafen, Germany, November 14 - 15, 2013.

Participation upon invitation at the reception to honour the Nobel prize winners 2013, at the Nobel Prize Award Ceremony 2013, and at the Nobel Banquet 2013 in Stockholm, Sweden, December 10, 2013. [www.nobelprize.org](http://www.nobelprize.org)

*Further Activities Professor Wolfgang Jäger*

Reviewer for research funding bodies (Germany, USA, and other countries).

Reviewer for various international scientific journals.

Jury Member of the EMS Outstanding Paper Award Committee of the European Microscopy Society. [www.eurmicsoc.org](http://www.eurmicsoc.org)

Elected Member of Executive Committee of European Materials Research Society. [www.emrs-strasbourg.com/index.php](http://www.emrs-strasbourg.com/index.php)

Member of EU-funded MACAN Consortium (2008 - 2013).

Guest professor, Department of Applied Physics, Chalmers University of Technology, Gothenburg, Sweden, hosted by the Eva Olsson Group (since October 2013). [www.chalmers.se/en](http://www.chalmers.se/en)



## Multicomponent Materials

For several years, the Chair for Multicomponent Materials headed by Prof. Franz Faupel has participated actively in three Collaborative Research Centres (SFBs) and has third party funds from the German Research Foundation (DFG), the BMBF (Ministry for Education and Research), the AIF (Working Group Industrial Research) and others. Concerning the scientific output, the work of the group continues to be highly cited. Prof. Faupel is listed with more than 4200 citations in the Web of Science. Many additional citations are listed from group members. Here, only a few aspects of last year's research can be discussed. For more details we refer to our website <http://www.tf.uni-kiel.de/matwis/matv/> and the papers listed below. More information on the different research topics are also given in previous Almanac editions which can be downloaded from our website.

As in the year before, working in three Collaborative Research Centres (SFBs), the group strongly benefited from the joint interdisciplinary work with partners ranging from fundamental physics and organic chemistry to electrical engineering and medicine. The Collaborative Research Centre SFB 677 "Function by Switching" continued its very successful work of the last few years and now prepares for a second extension. Here our group strongly benefits from a close cooperation with the group of Prof. Elbahri from the Institute of Materials Science in the field of plasmonic nanocomposites (see Prof. Elbahri's Almanac chapter). Many new results on formation of nanoparticles in plasmas were obtained in our joint project "Plasma Processes for the Deposition of Nanostructured Composite Materials" within the Collaborative Research Centre SFB TR 24 on complex plasmas together with the group of Prof. Kersten from the physics department of the CAU. In 2013, the SFB TR24 was very successfully evaluated and is now in its third funding period. Although the Collaborative Research Centre SFB 855 on magneto-electric nanocomposites for medical applications can also look back to a very productive year in 2013 and a very successful evaluation, despite this its existence was only extended by the DFG for one more year. Much research of the Chair for Multicomponent Materials was also performed outside the three collaborative research centres, e.g. within the DFG priority program "Polymer-solid contacts: Interfaces and Interphases", and several other projects. The group also performed investigations at large scale facilities particularly at the electron storage ring BESSY in Berlin, at the DESY synchrotron source in Hamburg, at the positron beam facility of the Research Reactor Garching, and at the positron beam at Tsukuba in Japan. Besides direct cooperation with companies, joint work with industry was performed within projects of the BMBF.

Over the years, the group has been strongly involved in teaching and makes great efforts to inspire pupils for materials science and engineering in various ways, including visits to schools in Schleswig-Holstein.

### Results

#### a) Nanocomposites for functional applications

A main activity of our group during the last years centred around functional nanocomposites, which consist of metallic nanoparticles embedded in an insulating matrix, either polymeric or ceramic in nature. The size of the nanoparticles is in between that of atoms and macroscopic materials and thus gives rise to new properties, not observed in conventional materials, which are explored in a broad range of applications ranging from high frequency magnetic materials to antimicrobial coatings. The nanocomposites are mostly deposited as thin films by vapour phase deposition methods, in particular evaporation and sputtering from solid targets.

During the last year, plasma polymerization and physically enhanced chemical vapour deposition (PECVD) have also been employed in a joint project of the above mentioned Collaborative Research Centre SFB TR 24. This transregional collaborative research centre of the universities of Greifswald and Kiel addresses fundamentals of complex plasmas and their applications to nanoscience. As mentioned above, the TR 24 very successfully passed the evaluation after the second funding period and is now in its last period. Within the TR 24, our group established a joint project with Prof. Kersten from the department of physics of the CAU, focusing on the use of plasma processes for the deposition of nanostructured



composite materials. Details on the activities of our group within the TR 24 were reported in the Almanacs 2011 and 2012. In the new funding period, the investigations will inter alia be extended to atmospheric pressure plasmas, which are particularly attractive for applications because no vacuum equipment is needed. Moreover an additional joint project with Prof. Kersten was launched by Dr. Thomas Strunskus. This project aims at exploring the early stages of nanoparticle nucleation and growth using synchrotron based X-ray scattering and spectroscopy techniques at the large scale facilities DESY in Hamburg and BESSY in Berlin.

Within the framework of the SFB TR 24, our group also cooperates with the group of Prof. Michael Bonitz from the Institute of Theoretical Physics and Astrophysics on computer simulations of nanoparticle formation in the gas phase and on a substrate. In this connection, earlier approaches of our group based on kinetic Monte Carlo simulations were extended to describe the formation of highly anisotropic magnetic Fe-Ni-Co nanorods in a protecting fluoropolymer matrix during co-evaporation of the metallic and organic components (see Fig. 1). Based on the simulations, which also turned out to exhibit predictive capabilities, it was possible to identify the conditions for the transition from the growth of spherical nanoparticles to anisotropic growth.

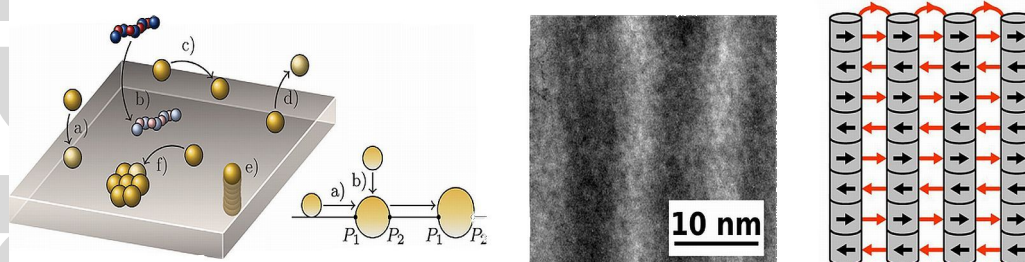


Fig. 1: Formation of Fe-Ni-Co nanorods in a protecting fluoropolymer matrix: (left) scheme used for the simulations, (middle) transmission electron micrograph of nanorods (dark) in fluoropolymer matrix (bright), (right) scheme showing magnetic domain formation in closely spaced nanorods.

Nanocomposites also play a key role in our projects within the Collaborative Research Centre SFB 677 "Function by Switching" which are now carried out jointly with Prof. Elbahri from our Institute of Materials Science (see also Almanac 2012 and his report) in the second funding period. Here, the nanocomposites are combined with photoswitchable molecules. These so-called chromophores change their properties reversibly upon irradiation with light of two different wavelengths. Very interesting new electro-optical properties arise through interactions between chromophores and the so-called surface plasmon resonance of the metallic nanoparticles. These resonances are collective oscillations of the conduction electrons in the electrical field vector of electromagnetic radiation. Recently, we also developed new photoswitchable devices that contain carbon nanotubes (CNTs) instead of metallic nanoparticles and allow light-induced conductivity switching. Last year, these investigations were extended from multiwalled carbon nanotubes to single-walled CNTs, where switching amplitudes close to 30% could be achieved. Interestingly, in the composites with single-walled CNTs the switching mechanism turned out to be different.

Concerning the Collaborative Research Centre SFB 855 on magneto-electric nanocomposites for medical applications, our work has shown that in this case, layered composites are much more promising than particulate composites. As reported in the Almanac 2011, we developed a novel magnetic field sensor that was presented to a wide readership in a Nature Research Highlight. The sensor is based on the so-called giant Delta-E-Effect, i.e. the huge change of Young's modulus of special magnetostrictive alloys in a magnetic field. Presently, various approaches ranging from new materials, through alternative read out and operation principles, to active control are explored together with partners within the SFB 855. Last year, together with Prof. Bernd Wagner from the Fraunhofer Institute for Silicon Technology (ISIT) and Dr. Robert Jahns from the Department of Electrical and Information Engineering (group of Prof. Reinhard Knöchel), a fully integrated sensor with a largely improved sensitivity was developed.



Moreover, magnetoelectric layered composites involving piezoelectric polymers appear to show great potential. This was demonstrated last year with a sensor made up of a cantilever of a highly magnetostrictive metallic glass covered with a thin film of a piezoelectric co-polymer (Fig. 2). The sensor achieved the highest magnetoelectric coefficient ever observed at low frequencies (around 28 Hz). In its second resonant mode at about 170 Hz, a detection limit as low as  $10 \text{ pT/Hz}^{1/2}$  was obtained.

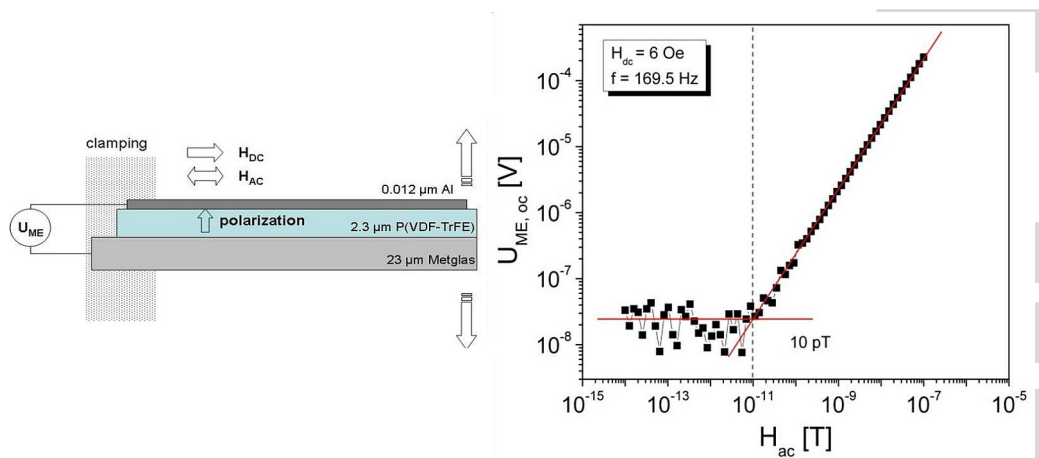


Fig. 2: (left) Sketch of the magnetic field sensor, developed within the SFB 855, consisting of a metglas cantilever and a spin-coated PVDF layer. (right) Sensitivity plot showing an almost linear response down to magnetic fields as low as 10 pT.

In several projects we explore the large specific surface area of the finely dispersed nanoparticles and the strong influence of the surface or interfacial energy on the material's properties. This is particularly the case in antibacterial coatings with nanoparticles of silver and other noble metals where a high metal ion release rate is strived for because the antimicrobial activity originates from the released metal ions. Here, research has been carried out in cooperation with Prof. Podschun from the Institute of Infection Medicine of the University Hospital Schleswig-Holstein/Campus Kiel. Toxicity of nanoparticles is investigated in cooperation with PD Röhl from the Institute for Toxicology and Pharmacology for Natural Scientists of the CAU. In addition, among other partners, we cooperate with Prof. Grundmeier from the Chemistry Department of the University at Paderborn in a joint DFG project addressing fundamental issues of silver ion release from nanocomposites.

Antimicrobial nanocomposites have been studied intensively with respect to their medical applicability, for example as functional coatings for implants. For such applications understanding of the so-called therapeutic window is essential in order to achieve a therapeutic effect without inflicting undesired damage to the treated organism. In a systematic study conducted in close cooperation with PD Dr. Röhl and Prof. Podschun much progress in the understanding of the therapeutic window in antimicrobial nanocomposites was achieved. As discussed in the Almanac 2012, it was found that the toxicity of silver for human cells and bacteria differs strongly for silver in solution and silver at surfaces, respectively. While in solution only a small therapeutic window exists in which silver is sufficiently toxic against bacteria but non-toxic to human cells, the situation is much more favourable at surfaces of silver containing nanocomposite coatings. Here human cells grow essentially undisturbed up to fairly high silver loadings of the coatings, and the toxicity for human cells can roughly be estimated by the measured silver release of the coating into distilled water. Bacteria, on the other hand, were already killed at fairly low silver loadings. This at first sight surprising observation could be understood considering the different metabolisms of human cells and bacteria.

Last year emphasis was put on controlling the release behaviour of nanocomposite consisting of reactively sputtered  $\text{TiO}_2$  and silver. In this work, care was taken to avoid direct exposure of Ag nanoparticles to the environment due to surface segregation of silver nanoparticles on titania coatings. It could be shown how the kinetics of surface segregation can be controlled via the process parameters in reactive sputtering and how surface segregation can be avoided.

Reactively sputtered  $\text{TiO}_2$  was also used in a BMBF project together with the Fraunhofer Institute Umsicht and several industrial partners for its photocatalytic properties which are here applied to water purification and waste water treatment.

The group also investigates various other functional properties of nanocomposites with metallic nanoparticles and an organic or ceramic matrix. Interested readers are referred to our publications and earlier Almanac editions. Concerning optical and plasmonic properties and so-called metamaterials, we refer to the Almanac chapter of Prof. Elbahri and the joint publications. He initiated some exciting new applications pursued together with our group.

Finally we mention that the nanoworkshop series "Polymer-Metal-Nanocomposites" which was initiated 2003 by Prof. Faupel in Kiel proceeded in 2013 with the 6th nanoworkshop in Toulouse. Prof. Faupel was invited to give an opening plenary overview on functional nanocomposites. The next nanoworkshop of the series will take place in Jaipur, India, in 2015.

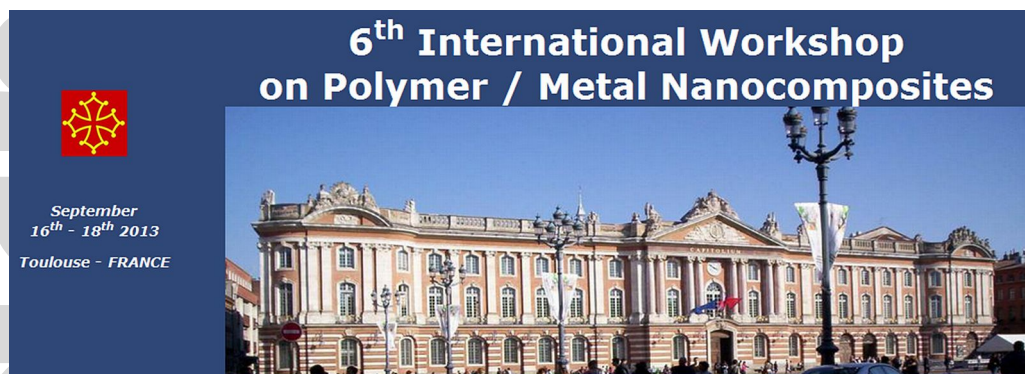


Fig. 3: In September 2013, the 6th nanoworkshop on "Polymer-Metal-Nanocomposites" took place in Toulouse. The workshop series was initiated 2003 by Prof. Faupel in Kiel, who was invited to give an opening plenary overview on functional nanocomposites.

## b) Metallic glasses and glass forming melts

Metallic glasses are mixtures of metals and non-metals which can be employed in a vast range of applications from ultra-thin electronic housings to biodegradable implants. Although the appearance of metallic glasses resembles that of ordinary metals, their atomic structure differs completely. While the atoms in a conventional metal arrange in a periodic lattice, there is no such order in metallic glasses. This disordered state, which is similar to a frozen liquid, can be created by rapid quenching of a melt. However, only for certain mixtures of elements will the glassy state be accessible with technically reasonable cooling rates. During the last years, we investigated the diffusion behaviour, glass forming ability, and the transition from the undercooled melt to the glassy state. Details were reported in previous Almanac editions.

Recently, we found very interesting deviations from the Stokes-Einstein relation in glass-forming Zr-Cu-Ni-Ti-Be melts. According to the Stokes-Einstein relation, all atoms are expected to participate in the Brownian motion with approximately the same mobility in the equilibrium melt far above the melting point. In contrast, the majority component Zr, which is also the largest atom of the alloy, proved to have a much lower mobility compared to the other components. This gives important clues to the excellent glass forming ability of this also technologically important bulk glass forming alloy. Ongoing investigations are performed in a joint DFG project with the group of Prof. Meyer from the DLR (Deutsches Zentrum für Luft- und Raumfahrt) in Cologne (formerly TU Munich).

## c) Polymer-solid contacts

Within the DFG priority programme "Polymer-solid contacts: Interfaces and Interphases" which was co-initiated by Prof. Faupel, we studied the structure and formation of interfaces between polymers and solid materials like metals and ceramics, which are important in many technological applications including polymer nanocomposites where solid nanoparticles are

embedded in a polymer matrix. We refer to previous Almanac editions and our publications for more information. Recently, we succeeded in probing the free volume, i.e. the packing density of the polymer chains, at the interface between the fluoropolymer Teflon AF and silicon with high resolution using the moderated positron beam at Tsukuba in Japan. Details of these ongoing investigations will be reported in the next Almanac.

## **Personnel**

Head of the group: Prof. Dr. F. Faupel; Secretary: N. Gühlke (50%), Dipl.-Chem. S. Kastaun (50%)  
 Technical Staff: Dipl.-Ing. (FH) R. Kloth (on leave), Techn. C. Ochmann (DFG, BMBI), Dipl.-Ing. (FH) S. Rehders, Dipl.-Inf. P. Sommer

Scientific Staff:

M.Sc. A. M. Ahadi Nanoparticles from plasmas	01.01.-31.12.2013	Fellowship Iran, CAU
M.Sc. N. Alissawi Ag-ion transfer	01.01.-31.07.2013	CAU
M.Sc. S. W. Basuki Diffusion in complex melts	01.01.-31.12.2013	DFG
Dipl.-Phys. B. Gojdka Magneto-electric nanocomposites	01.01.-14.02.2013	SFB 855, CAU
M.Sc. B. Henkel Functional nanocomposites	01.01.-31.12.2013	BMBF, CAU
M.Sc. A. Hinz Nanoparticle Formation	01.07.-31.12.2013	SFB TR24
M.Sc. T. Koschine Positron beam, polymers	01.01.-31.12.2013	BMBF, CAU
Dr. A. Kulkarni Magneto-electric nanocomposites	01.01.-31.03.2013	SFB 855, CAU
Dipl.-Ing. K. Meurisch Magneto-electric nanocomposites	17.02.-31.12.2013	CAU, SFB 855
M.Sc. C. Ohrt Polymer-Solid-Interphases	01.01.-31.12.2013	DFG SPP 1369
Dipl.-Phys. T. Peter Nanoparticles from plasmas	01.01.-31.03.2013	SFB TR24
Dr. O. Polonsky Nanoparticles from plasmas	01.01.-31.12.2013	SFB TR24, visiting scientist
Prof. Dr. K. Rätzke Supercooled melts, positron annihilation	01.01.-31.12.2013	CAU
Dipl.-Phys. V. Schneider Photoswitchable nanocomposites	01.01.-31.12.2013	SFB 677

Dr. T. Strunskus  
Functional nanocomposites

01.01.-31.12.2013

SFB 855

M.Sc. J. Xiong  
Functional nanocomposites

01.01.-31.12.2013

Fellowship China

Dipl.-Phys. S. Zabel  
Magneto-electric sensors

15.02.-31.12.2013

SFB 855

## Lectures, Seminars, and Laboratory Course Offers

### *Winter 2012/2013*

Advanced Organic Materials, 2 hrs Seminar/Week,  
F. Faupel

Übungen zur Physik I, 2 hrs Seminar/Week,  
K. Rätzke

Thin Films, 4 (+ 1) hrs Lecture (+ Exercises)/Week,  
K. Rätzke (+ V. Schneider)

Einführung in die Materialwissenschaft 1, 2 hrs Lecture/Week,  
K. Rätzke

Werkstoffe - Metalle, 2 hrs Lecture/Week,  
F. Faupel

Solid State Physics 1, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Faupel

Advanced Materials A - Polymers, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Faupel (+ T. Strunskus)

Seminar for Members Group of Rätzke, 2 hrs Seminar/Week,  
K. Rätzke

Seminar for Members of the Chair for Multicomponent Materials, 2 hrs Seminar/Week,  
F. Faupel

### *Summer 2013*

Einführung in die Materialwissenschaft II, 2 hrs Lecture/Week,  
K. Rätzke

Advanced Metallic Materials, 2 hrs Seminar/Week,  
F. Faupel

Seminar for Members of the Chair for Multicomponent Materials and interested guests, 2 hrs Seminar/Week,  
F. Faupel

Übungen zur Physik II, 2 hrs Exercise/Week,  
K. Rätzke

Seminar for Members Group of Rätzke, 2 hrs Seminar/Week,  
K. Rätzke

Solid State Physics 2, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Faupel

Winter 2013/2014

Advanced Organic Materials, 2 hrs Seminar/Week,  
F. Faupel

Übungen zur Physik I, 2 hrs Seminar/Week,  
K. Rätzke

Thin Films, 4 (+ 1) hrs Lecture (+ Exercises)/Week,  
K. Rätzke (+ V. Schneider)

Einführung in die Materialwissenschaft 1, 2 hrs Lecture/Week,  
K. Rätzke

Werkstoffe - Metalle, 2 hrs Lecture/Week,  
F. Faupel

Solid State Physics 1, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Faupel

Advanced Materials A - Polymers, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
F. Faupel (+ T. Strunskus)

Seminar for Members Group of Rätzke, 2 hrs Seminar/Week,  
K. Rätzke

Seminar for Members of the Chair for Multicomponent Materials, 2 hrs Seminar/Week,  
F. Faupel

### Third-Party Funds

DFG, SFB TR24/2, *Fundamentals of Complex Plasmas: Plasma processes for the deposition of nanostructured composite materials*, 01.07.2009-30.06.2013 (287.603 Euro)

DFG SFB 855, *Magnetoelectric Composites - Future Biomagnetic Interfaces: Gasphasenabscheidung von magnetoelektrischen 0-3 Nanokompositen*, 01.01.2010-31.12.2013 (635.280 Euro)

DFG, *Ion transfer reactions at Ag-nanoparticle/polymer interfaces*, 17.02.2010-30.04.2013 (190.424 Euro)

BMBF, *Development of advanced materials and methods for water and sewage treatment by means of functional nanocomposites*, 01.05.2010-31.10.2013 (221.004 Euro)

BMBF, *Verbundprojekt POSIMETHOD: Teilprojekt 5: "Charakterisierung nanoskopischer Leerstellen in dünnen Polymerfilmen mittels Positronenlebensdauerspektroskopie"*, 01.07.2010-30.08.2013 (213.300 Euro)

China Scholarship Council, *Stipendium für Jian Xiong für 4 Jahre*, 15.11.2010-15.11.2014 (48.000 Euro)

Iran Government, *Stipendium für Amir Mohammad Ahadi für 3,7 Jahre*, 25.11.2010-25.07.2014 (45.000 Euro)

DFG, *Polymer-Solid contacts: Interfaces and Interphases: Verteilung des freien Volumens an Polymer-Festkörper Grenzflächen*, 25.02.2011-30.11.2014 (257.800 Euro)

DFG, *Structural Arrest in Multicomponent Glass-forming Zr-melts*, 06.04.2011-06.04.2014 (278.450 Euro)

DFG SFB 677/2, *Function by Switching: Photoswitchable Metal-Polymer Nanocomposites*, 01.07.2011-30.06.2015 (363.220 Euro)

DFG, *In-situ Untersuchungen zu Kondensation, Nukleation und Wachstum von Metallfilmen und Nanostrukturen auf organischen Oberflächen während Sputterbeschichtung*, 05.06.2013-05.06.2016 (328.050 Euro)

DFG, SFB TR24/3, *Fundamentals of Complex Plasmas: Plasma processes for the deposition of nanostructured composite materials*, 01.07.2013-30.06.2017 (250.750 Euro)

## Further Cooperation, Consulting, and Technology Transfer

### University:

Prof. Dr. R. Adelung, Functional Nanomaterials, Memristive Materials and magnetic field sensors

Prof. M. Bauer, F. Tuczek, O. Magnussen, Prof. W. Herges: Combination of switchable molecules and nanocomposites close to the percolation threshold (SFB "Function by Switching")

Prof. Dr. M. Bonitz, Theoretical Physics, Kiel University, Theory and simulation of formation of nanostructured materials

Prof. Dr. R. Busch, Dr. Z. Evenson, Uni Saarland. Relaxation in bulk metallic glasses

Prof. Dr. A. Chandra, Dehli, India, Conductance and free volume in polymer electrolyte composites

Prof. Dr. G. Dollinger, Dr. W. Egger, Bundeswehr University, Munich, PLEPS at FRM II

Prof. Drusch, Food Processing Technology and Materials Science, TU Berlin, Encapsulation of food products

Prof. Dr. M. Elbahri, Institute for Material Science: several topics with hybrid organic/inorganic materials

Prof. Dr. M. Es-Souni, FH Kiel, Characterisation of Functional Materials

Prof. Dr. M. Gerken, Integrated Systems and Photonics, Simulation of magnetoelectric sensors

Prof. Dr. G. Grundmeier, Paderborn University, Silver Release from Nanocomposites

Prof. Dr. H. Herges, Organic Chemistry, Prof. Dr. F. Tuczek, Inorganic Chemistry, Kiel University, and other partners, NEXAFS investigations at the Berlin storage ring BESSY, Berlin

Dr. Chr. Hugenschmidt, TU Munich and FRM II, NEPOMUC

Dr. Stuart James, U. Belfast, free volume in porous liquids

Prof. Dr. Chr. Janiak, U. Düsseldorf, free volume in mixed-matrix membranes

Prof. Dr. M. Kern, Dental Clinic, Kiel University, Zirconia ceramics for dental applications

Prof. Dr. H. Kersten, Atom and Plasma Physics, Kiel University, Formation of nanostructured materials in complex plasmas

Prof. Dr. L. Kienle, Synthesis and Real Structure, TEM analysis of nanoparticles and nanocomposites

Prof. Dr. H. Kohlstedt, Nano Electronics, Memristive Materials

Prof. Dr. T. Meurer, Automatic Control, Nonlinear  $\Delta E$  Sensors

Prof. Dr. P. Müller-Buschbaum, Technical University Munich, PALS-Thin Films and DFG project "Growth of sputtered metal on organic surfaces" with Roth (DESY)

Prof. Dr. R. Podschun, Institute for Infection Medicine, Kiel University, Antibacterial Coatings

Prof. Dr. E. Quandt, Inorganic Functional Materials, Faculty of Engineering, Functional magnetic nanocomposites

Prof. Dr. J. Sievers, Institute for Toxicology and Pharmacology for Natural Scientists, Toxicological effects of metallic nanoparticles on human cells

Prof. Dr. C. Staudt, Düsseldorf, Block copolymers

Prof. Dr. N. Stock, Chemie, Univ. Kiel. Positron spectroscopy in Metal-Organic Frameworks

Dr. Tobias Vossmeier, Institut für Physikalische Chemie, Universität Hamburg. Free volume in polymer-gold nanocomposites

#### *Research Institutes:*

Prof. Dr. V. Abetz, Dr. V. Filiz, HZG, free volume in aged PIM-CNT Membranes

Dr. D. K. Avasthi, Materials Science Group, Nuclear Science Centre New Delhi, India, High energy ion beam effects in polymer-metal nanocomposites

Prof. Dr. A. Meyer, Dr. Fan Yang, DLR, Köln, Diffusion in glass forming metallic melts

Dr. Thomas Neubert, Dr. Michael Vergöhl Fraunhofer-Institute for Surface Engineering and Thin Films (IST), Braunschweig, Sputtered titania layers for photocatalysis

Dr. Nagayasu Oshima (AIST), focussed Positron lifetime beam for interphase analysis

Dr. G.J. Schneider, FRZ Jülich und FRM II, free volume in polymer-nanocomposites

#### *Industry:*

KHS Plasmax GmbH, Coatings on PET samples

#### *Partners in BMBF project Nanopurification:*

Fraunhofer Institute for Environmental, Safety and Energy Technology (UMSICHT), Oberhausen

Enviro Chemie GmbH, Roßdorf

Kryschi Wasserhygiene, Kaarst

Cornelsen Umwelttechnologie GmbH, Essen

Gelsenwasser AG, Gelsenkirchen

Ferdinand Braun-Institut, Berlin

### **Diploma, Bachelor's and Master's Theses**

D. Haffner, *Functional nanocomposites prepared by a combination of magnetron sputtering with a gas aggregation source*, 07.01.2013

S. Zabel, *Herstellung dünner gesputterter Titandioxidschichten und Untersuchung auf deren photokatalytische Wirksamkeit*, 08.01.2013

A. Hinz, *Field Enhanced Ion Mobility in Polymers*, 14.05.2013

M. Z. Ghori, *Thema Influence of barrier thickness and barrier deposition rate on Ag release for reactively sputtered Ag-TiO<sub>x</sub> nanocomposites*, 01.07.2013

M. Pfeifer, *Untersuchung von Einflüssen auf die Rissbildung bei Drei-Komponenten-Verdampfern nach 6  $\sigma$ -Methode*, 07.10.2013

I. Barg, *Production and Characterization of  $\Delta E$  Effect Magnetic Field Sensors*, 11.10.2013

S. Schlüter, *Reibschweißen von Edelstahl (Dockweiler, external)*, 31.10.2013

V. van Broeck, *Quantitative Bestimmung von Verunreinigungen durch zwei verschiedene Fließsilikone (Fit Checker) auf dichtgesinterter Zirkonoxidkeramik Mittels XPS bei unterschiedlicher Reinigung (with Prof. Kern, University Medical Center Schleswig-Holstein)*, 29.11.2013

N. Sawangboon, *Optimization of the electrical poling procedure of PCVDF-TrFE thin films fabricated by spin coating*, 20.12.2013



## Dissertations / Postdoctoral Lecture Qualifications

- K. L. Kolipaka, *Deposition and Characterization of functional cobalt-polymer nanocomposites prepared by a hybrid plasma process* (INP Greifwald e.V, external), 05.03.2013
- T. Peter, *Gas phase cluster aggregation and its application to the deposition of functional thin films*, 31.05.2013
- N. Alissawi, *Ion release from silver/polymer nanocomposites*, 12.07.2013
- S. Wicklein, *Defect engineering of SrTiO<sub>3</sub> thin films for resistive switching applications* (Helmholtz-Zentrum Jülich, external), 19.11.2013
- F. Dams, *Mikrotechnologische Strukturen zur Bestimmung druckabhängiger Gaseigenschaften für Anwendungen in der Vakuummessstechnik* (FH Regensburg, external), 29.11.2013

## Publications

Published in 2013

- N. Alissawi, L. Kienle, V.S.K. Chakravadhanula, I. Kocabas, D. Garbe-Schönberg, T. Strunskus, V. Zaporojtchenko †, F. Faupel, *Effect of gold alloying on stability of silver nanoparticles and control of silver ion release from vapour-deposited Ag-Au/polytetrafluoroethylene nanocomposites*, *Gold Bull*, **46**, 3 - 11 (2013)
- T. Hrkac, C. Röhl, R. Podschun, V. Zaporojtchenko †, T. Strunskus, H. Papavlassopoulos, D. Garbe-Schönberg, F. Faupel, *Huge increase of therapeutic window at bioactive silver/titania nanocomposite coating surface compared to solution*, *Materials Science and Engineering C*, **33**, 2367 - 2375 (2013)
- T. Peter, S. Rehders, U. Schürmann, T. Strunskus, V. Zaporojtchenko †, F. Faupel, *High Rate Deposition System for Metal-Cluster / SiO<sub>x</sub>C<sub>y</sub>H<sub>z</sub> - Polymer Nanocomposite Thin Films*, *Journal Nanoparticle Research*, **15**, 1710 (2013)
- O. Polonskyi, T. Peter, V. Zaporojtchenko †, H. Biedermann, F. Faupel, *Huge increase in gas phase nanoparticle generation by pulsed direct current sputtering in reactive gas admixture*, *Applied Physics Letters*, **103**, 033118 (2013)
- L. Rosenthal, H. Greve, V. Zaporojtchenko †, T. Strunskus, F. Faupel, M. Bonitz, *Formation of magnetic nanocolumns during vapour phase deposition of a metal-polymer nanocomposite: experiments and kinetic Monte Carlo simulations*, *Journal of Applied Physics*, **114**, 044305 (2013)
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- H. Jacob, K. Kathirvel, F. Petersen, T. Strunskus, A. Bannwarth, S. Meyer, F. Tuzek, *Grafting of Functionalized [Fe(III)(salten)] Complexes to Au(111) Surfaces via Thiolate Groups: Surface Spectroscopic Characterization and Comparison of Different Linker Designs*, *Langmuir*, (2013)
- J. Lee, M. M. Miró, C. K. Akkan, A. Haidar, W. Metzger, L. K. Schwarz, V. Zaporojtchenko †, K. H. Schäfer, H. Abdul-Khaliq, M. Veith, C. Aktas, *Development of Multi Scale Structured Al/Al<sub>2</sub>O<sub>3</sub> Nanowires for Controlled Cell Guidance*, *Journal of Biomedical Nanotechnology*, **9**, 295 - 295 (2013)
- P. Diwan, S. Dollinger, K. Rätzke, A. Chandra, *Conductivity modification in polymer electrolyte-crown ether complexes*, *Solid State Ionics*, **247-248**, 71 - 75 (2013)
- E. Ludwig, T. Strunskus, S. Hellmann, A. Nefedov, C. Wöll, L. Kipp, K. Rossnagel, *Electronic structure, adsorption geometry, and photoswitchability of azobenzene layers adsorbed on layered crystals*, *Phys. Chem. Chem. Phys.*, **15**(46), 20272 - 20280 (2013)
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## Patent Applications

- M. Elbahri, V. Zaporojtchenko /dag, T. Strunskus, F. Faupel, M. Keshavarz Hedayati, V.S.K. Chakravadhanula, *Omni-directoral Transparent Conducting Metal based Plasmonic Metamaterials*, German Patent and Trade Mark Office (GTPÖ), 27.02.2013, PCT/DE2007/001176
- M. Elbahri, M. Keshavarz Hedayati, F. Faupel, T. Strunskus, V. Zaporojtchenko /dag, *Absorberschicht für den VIS- und/oder NIR-Spektralbereich*, German Patent and Trade Mark Office (GTPÖ), 01.08.2013, DE 10 2011113571B4
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- F. Faupel, T. Strunskus, V. Zaporojtchenko †, J. Zabel, B. Henkel, *Herstellung und Charakterisierung von reaktiv gesputterten Titandioxidschichten für die Photokatalyse (Poster)*, Clustertreffen der BMBF-Fördermaßnahme NanoCare und NanoNature, Frankfurt / Main, Germany, 14.-15.01.2013
- F. Faupel, *Neue Werkstoffe durch Nanotechnologie (Invited Talk)*, Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Oldenburg / Holst., Germany, 16.-16.01.2013
- H. Biederman, A. Choukourou, P. Solar, O. Kylián, M. Petr, O. Polonsky, *Barrier properties of polymeric foils coated by plasma polymers and nanocomposite thin films (Poster)*, International Workshop COST-, Prague, Czech Republic, 07.-08.02.2013
- F. Faupel, *Funktionelle Nanokomposite (Invited Talk)*, 2. Diskussionstagung, Frankfurt / Main, Germany, 28.02.-01.03.2013
- F. Faupel, K. Rätzke, A. Meyer, F. Yang, S. W. Basuki, *Decoupling of component diffusivities in glass-forming Zr-Ni-Ti-Cu-Be alloys above the melting temperature (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013
- F. Faupel, T. Strunskus, V. Zaporojtchenko †, N. Alissawi, *Tuning of silver ion release properties of silver-polymer nanocomposites (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013
- F. Faupel, F. Lehmann, Lorenz Kienle, Ulrich Schürmann, T. Strunskus, V. Zaporojtchenko †, J. Xiong, *Influence of the sputter parameters on surface segregation and silver ion release properties of reactively sputtered Ag/TiO<sub>x</sub> nanocomposites (Poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013
- G. Schneider, L. Willner, F. Faupel, K. Rätzke, S. Rautenberg, T. Koschine, C. Ohrt, *Investigation of particle-induced confinement effects on free volume in PEP-Silica Nanocomposites (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013
- F. Faupel, M. Elbahri, T. Strunskus, V. Schneider, *Optical switchable properties of polymer-carbon-nanotubes nanocomposites based on photochromic molecules (Poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013

- S. James, N. Giri, K. Rätzke, T. Koschine, *Positron annihilation lifetime spectroscopy in a porous liquid (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013
- F. Faupel, T. Strunskus, J. Zabel, B. Henkel, *Nanostructured TiO<sub>2</sub> Thin Films and Structural Composites for Photocatalysis (Poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013
- F. Faupel, H. Biederman, V. Zaporozhchenko †, T. Strunskus, A. Hinz, A. M. Ahadi, T. Peter, O. Polonsky, *High deposition of metal (oxide) nanoclusters generated in pulsed DC magnetron sputtering system (Poster)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013
- F. Faupel, T. Strunskus, O. Polonsky, T. Peter, A. Hinz, V. Zaporozhchenko †, A. M. Ahadi, *Role of oxygen on stabilization of TiO<sub>x</sub> cluster production by gas aggregation cluster source (Talk)*, DPG-Frühjahrstagung der Sektion Kondensierte Materie (SKM) 2013, Regensburg, Germany, 10.-15.03.2013
- O. Polonsky, *Formation of Nanoparticles for Deposition of Thin Film Coatings from a Gas Aggregation Cluster Source (Talk)*, Seminar, Prague, Czech Republic, 16.-19.03.2013
- F. Faupel, T. Strunskus, B. Goidka, A. M. Ahadi, V. Zaporozhchenko †, T. Peter, O. Polonsky, *Formation of Nanoparticles for Deposition of Thin Film Coatings from a Gas Aggregation Cluster Source (Talk)*, Department seminar, Prague, Czech Republic, 19.-19.03.2013
- F. Faupel, T. Koschine, K. Rätzke, S. Rautenberg, C. Ohrt, *Free volume in polymer-solid interfaces and polymer nanocomposites (Talk)*, Messungen am Positron Probe Microanalyzer am National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan, 22.-26.04.2013
- F. Faupel, K. Rätzke, *Free Volume in Polymer Thin Films and Nanocomposites (Invited Talk)*, Kolloquium in der Physikalischen Chemie der Universität Hamburg, Hamburg, Germany, 14.-14.05.2013
- F. Faupel, *Neue Werkstoffe durch Nanotechnologie (Invited Talk)*, Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Kiel, Germany, 27.-27.05.2013
- M. Elbahri, F. Faupel, *Functional nanocomposites: tailoring of functional properties (Talk)*, 5. Schwerpunkttreffen SPP 1369 bei Dechema, Frankfurt / Main, Germany, 14.-14.06.2013
- N. Oshima, G. Schneider, F. Faupel, K. Rätzke, S. Rautenberg, T. Koschine, C. Ohrt, *Free Volume at polymer-solid interfaces (Poster)*, 5. Jahrestreffen des DFG-Schwerpunktes 1369:, Frankfurt / Main, Germany, 14.-14.06.2013
- L. Ravelli, W. Egger, F. Faupel, T. Koschine, S. Rautenberg, C. Ohrt, K. Rätzke, *Free volume at polymer-solid interfaces and in nanocomposites (Talk)*, 5. Schwerpunkttreffen SPP 1369 bei Dechema, Frankfurt / Main, Germany, 14.-14.06.2013
- A. Meyer, K. Rätzke, S. W. Basuki, A. Bartsch, F. Faupel, *Dynamic arrest in multicomponent glass forming alloys (Invited Talk)*, 7th International Discussion Meeting on Relaxations in Complex Systems, Barcelona, Spain, 21.-26.07.2013
- F. Faupel, *Functional nanocomposites prepared by vapour phase deposition (Invited Talk)*, Particles 2013, Dayton / Ohio, USA, 03.-06.08.2013
- F. Faupel, *Functional nanocomposites prepared by vapour phase deposition (Invited Talk)*, 5. International Symposium on Plasma Nanoscience (iPlasmaNano-IV), Asilomar Beach, Californien, USA, 26.-29.08.2013
- T. Strunskus, *Nanocomposites for Functional Applications (Invited Talk)*, International Conference School, Palanga, Lithuania, 27.-31.08.2013
- T. Strunskus, *Near-Edge-X-Ray Absorption Fine Structure Spectroscopy (NEXAFS) for Materials and Surface Analysis (Invited Talk)*, International Conference School, Palanga, Lithuania, 27.-31.08.2013
- F. Faupel, H. Biederman, V. Zaporozhchenko †, A. M. Ahadi, T. Peter, O. Polonsky, T. Strunskus, *Preparation of nanoparticles and nanocomposites through high efficiency cluster generation in the gas phase by reactive pulsed DC sputtering (Talk)*, European Congress and Exhibition on Advanced Materials and Processes (EUROMAT 2013), Seville, Spain, 08.-13.09.2013
- F. Faupel, R. Knöchel, E. Quandt, H. Lewitz, K. Meurisch, J. Teliban, R. Jahns, A. Piorra, A. Kulkarni, T. Strunskus, *PVDF-TrFE polymer based thin film composites with very high magnetoelectric coefficient (Talk)*, European Congress and Exhibition on Advanced Materials and Processes (EUROMAT 2013), Seville, Spain, 08.-13.09.2013

- S. Rautenberg, C. Ohrt, *Depth profiling of Free Volume at polymer-solid contacts (Poster)*, 13th International Workshop on Slow Positron Beam Techniques and Applications (SLOPOS13), Munich, Germany, 15.-20.09.2013
- L. Ravelli, B. Löwe, W. Egger, F. Faupel, K. Rätzke, T. Koschine, *Improvements of PLEPS for Positron Lifetime Spectroscopy in Polymers (Poster)*, 13th International Workshop on Slow Positron Beam Techniques and Applications (SLOPOS13), Munich, Germany, 15.-20.09.2013
- F. Faupel, K. Rätzke, *Free volume in thin films and at polymer-solid interfaces (Invited Talk)*, 13th International Workshop on Slow Positron Beam Techniques and Applications (SLOPOS13), Munich, Germany, 15.-20.09.2013
- F. Faupel, *Polymer/metal nanocomposites prepared by vacuum based processes (Invited Plenary Talk)*, 6th International Workshop on Polymer/Metal Nanocomposites, Toulouse, France, 16.-18.09.2013
- F. Faupel, T. Strunskus, A. M. Ahadi, T. Peter, O. Polonsky, *Highly efficient transition metal nanoparticle generation in the gas phase by pulsed DC (Talk)*, 6th International Workshop on Polymer/Metal Nanocomposites, Toulouse, France, 16.-18.09.2013
- T. Hrkac, M. Ghorri, T. Peter, J. Xiong, N. Alissawi, T. Strunskus, *Fine tuning the silver release properties of polymetric or ceramic silver nanocomposite coatings using thin barriers (Talk)*, 6th International Workshop on Polymer/Metal Nanocomposites, Toulouse, France, 16.-18.09.2013
- F. Faupel, M. Elbahri, T. Strunskus, S. W. Basuki, V. Schneider, *Optically switchable conductance of polymer nanocomposites based on photochromic molecules (Poster)*, 7th International Symposium on Photochromism 2013 (ISOP 2013), Berlin, Germany, 23.-26.09.2013
- M. Elbahri, T. Strunskus, C. Pakula, M. Keshavarz Hedayati, S. W. Basuki, V. Schneider, F. Faupel, *Photoswitchable polymer nanocomposites (Invited Talk)*, 7th International Symposium on Photochromism 2013 (ISOP 2013), Berlin, Germany, 25.-25.09.2013
- F. Faupel, R. Knöchel, E. Quandt, T. Strunskus, I. Barg, L. Kahle, H. Lewitz, J. Zabel, K. Meurisch, J. Teliban, R. Jahns, A. Piorra, A. Kulkarni, *P(VDF-TrFE) polymer based thin film composites with very high magnetoelectric coefficient (Talk)*, Euro Intelligent Materials, Kiel, Germany, 25.-27.09.2013
- N. Oshima, G. Schneider, F. Faupel, K. Rätzke, S. Rautenberg, T. Koschine, C. Ohrt, *Free Volume distribution at polymer solid contacts (Poster)*, International Conference on Polymer Interphases in Research and Technology (SPP 1369), Frankfurt / Main, Germany, 30.09.-02.10.2013
- L. Ravelli, W. Egger, F. Faupel, T. Koschine, S. Rautenberg, C. Ohrt, K. Rätzke, *Free volume at polymer-solid interfaces and in nanocomposites (Talk)*, International Conference on Polymer Interphases in Research and Technology (SPP 1369), Frankfurt / Main, Germany, 30.09.-02.10.2013
- O. Polonsky, *Deposition and characterization of metal nanoparticles prepared by gas aggregation source (Poster)*, GISAXS Workshop (DESY), Hamburg, Germany, 07.-09.10.2013
- F. Faupel, *Functional Nanocomposites - Preparation and Physical Properties (Invited Talk)*, Allgemeines Physikalisches Kolloquium am Institut für Materialphysik, Münster, Germany, 31.-31.10.2013
- F. Faupel, *Neue Werkstoffe aus der Nano-Technologie (Invited Talk)*, Schleswig-Holsteinische Universitäts-Gesellschaft (SHUG), Hohenwestedt, Germany, 05.-05.11.2013
- F. Faupel, T. Strunskus, A. Hinz, A. M. Ahadi, O. Polonsky, *Metal and metal oxide nanoparticles deposited by gas aggregation method: preparation and basic properties (Talk)*, Seminar, Prague, Czech Republic, 17.-19.11.2013



## Further Activities and Events

### Selected Honorary Activities of Prof. Faupel:

Coordinator of the *North German Initiative Nanomaterials (NINA)*,

Principle Editor of the *Journal of Materials Research*, edited by the *Materials Research Society (MRS)*,

Editor of the *encyclopaedia RÖMPP online*, *Thieme Chemistry*,

Member of the Advisory Board of *Diffusion and Defect Data*,

Member of the Editorial Board of the Journal "Solid State Phenomena"

Member of the DGM Scientific Advisory Board, *German Material Research Society*,

Member of the Minerva-Weizmann Committee of the Max-Planck Society,

Member of the Programme Committee of the conference "Euro Intelligent Materials 2013" (DGM), Kiel 2013,

Member of the Programme Committee of the DFG SPP 1369 Priority Programme "Polymer-Solid Interfaces, Thin Films, and Interphases - from Molecular View to Continuum",

Member of the managing committee of the SFB855 "Magnetolectric Composites - Future Biomagnetic Interfaces",

Member of the *Societas Christiana Albertina*,

Member of the management board of the "Friends of the Faculty of Engineering",

Member of the Programme Committee of the International Conference Polymer Interphases in Research and Technology, Frankfurt (2013),

Member of the International Advisory Committee for the International Conference on Soft Materials (ICSM 2014),

Member of the International Advisory Committee for the International Conference on Nanostructuring by Ion Beams & Innovative Methods (ICNIB 2013),

In addition to the activities listed above, Prof. Faupel was involved in many evaluations for the German Science Foundation (DFG), scientific journals, and other Institutions

# Nanochemistry and Nanoengineering

Fabrication of nanomaterials, nanocomposites and bio-nanocomposites for energy and environmental applications are the main research area in our group. Through bridging the gaps between several disciplines - chemistry, physics, bio- and materials science, we took an important step toward the consolidation of nano-science and nanotechnology. The research encompasses design, synthesis, bio-functionalization, patterning, and self-assembly for applications in plasmonics, photonics, electronics, sensing and separation. Using wet chemistry, electrospinning, physical vapour deposition and bio-mineralization, we aim to create a smart and advanced material with diverse multifunctional properties for innovative technological purposes. For more details please see our website (<http://www.tf.uni-kiel.de/matwis/nanochem/research.html>).

## Results

### 1. Nanofabrication @ the Leidenfrost condition

The main goal of the nanofabrication at the Leidenfrost condition, is to understand some of the basic principles of the Leidenfrost phenomenon. In parallel, we are aiming to employ this process in development of novel synthetic routes and nanofabrication strategies for construction of functional materials.

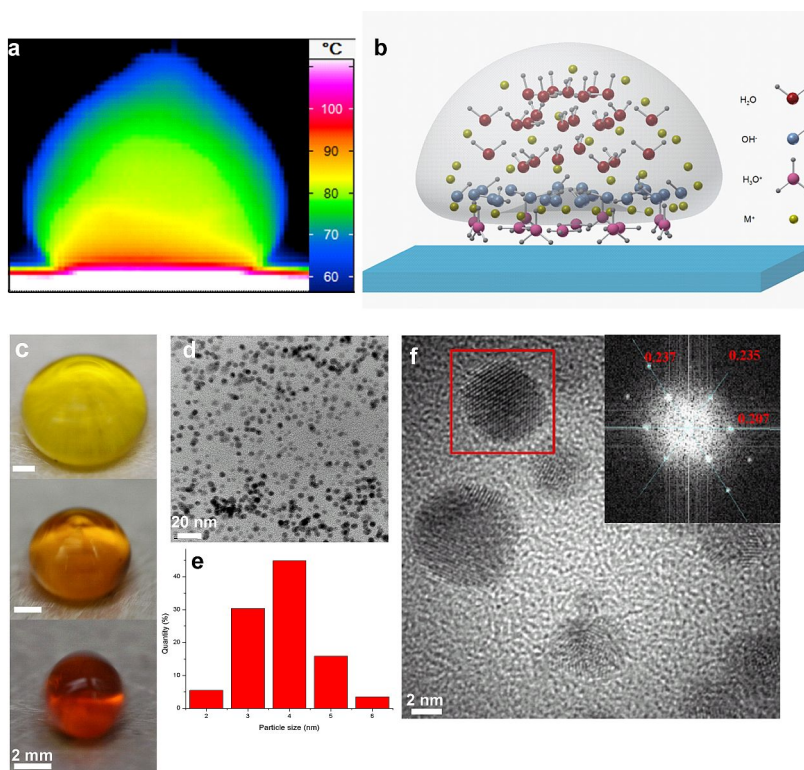


Fig. 1: **a**: IR-Temperature measurement shows the temperature gradient inside a levitated droplet, **b**: 3D sketch of the postulated mechanism for green nanochemistry with a Leidenfrost drop, **c**: Gold salts were converted to gold nanoparticles without additional reducing agent, **d**: Bright-field TEM image recorded on the Au nanoparticles, **e**: Particle size distribution, **f**: High-resolution TEM micrograph with inserted fast Fourier transformation pattern calculated from the red marked region.

Everyone is familiar with the experience of sprinkling water onto a hot frying pan. The water drop vaporizes and appears to levitate upon its own vapour; this is the Leidenfrost effect in action. In our previous work we introduced the



Leidenfrost as a new tool of green nanochemistry. In the current study, the scientific origin of the Leidenfrost phenomenon is explored by showing for the first time the electrostatic, temperature gradient, and overheating nature of the drop under Leidenfrost conditions (see Figure 1a). The mechanism of our green nanochemistry based on a Leidenfrost drop is illustrated schematically in Figure 1b. There, the fast evaporation at the interface of the hot surface and the drop generates an overheated zone, which along with the self-ionization of water at the liquid-vaporvapour interface gives rise to a local boost of metal ( $M^+$ ) and hydroxyl ( $OH^-$ ) ion concentrations. The increase in hydroxyl ion concentration is attributed to loss of the hydronium ions ( $H_3O^+$ ) upon evaporation; hence the basic condition is satisfied. In Figures 1(c-f) and 2, some examples of gold nanostructures (in different morphologies) which that are successfully fabricated by Leidenfrost drop isare shown.

The presented wet-chemical nanofabrication method presented could be a promising technique for production and development of nanostructures for many applications.

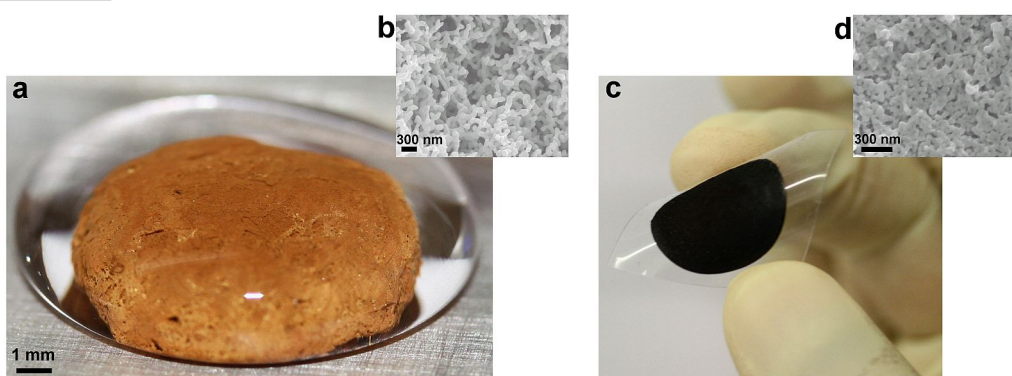


Fig. 2: **a**: Photograph of a nanoporous gold sphere produced in the Leidenfrost drop, **b**: SEM image of the brown nanoporous gold, **c**: A flexible polymeric substrate coated with the black nanoporous gold, **d**: SEM image of the black nanoporous gold.

## 2. Plasmonic metamaterial

Plasmonic metamaterials are artificial materials typically composed of noble metals in which the features of photonics and electronics are linked by coupling photons to conduction electrons of metal (known as a surface plasmon). These rationally designed structures have spurred interest noticeably since they demonstrate some fascinating properties which that are unattainable with naturally occurring materials. Complete absorption of light is one of the recent exotic properties of plasmonic metamaterials which that has broadened its application area considerably. However, up to date all of the applied methods (perforated metallic films, grating structured systems, and conventional metamaterials) are costly and suffer from a lack of flexibility. In 2011, we introduced a plasmonic perfect absorber based on gold nanocomposite which that operates in the visible frequency range. In tThis year, we took one step forward and shifted the realm of our absorber to higher frequency, i.e. UV. By replacing the base mirror by kitchen aluminum foil, we further showed that such an approach has immense potential for being deposited on any substrate (Figure 3a). In that sense, we proposed a new application of plasmonic metamaterial to be used as UV protection film. The cheaper production method that we used for fabrication potentially could potentially pave the way of plasmonic metamaterial for many applications of plasmonic metamaterial, such as UV sensors, and protective films in solar cells amongst others.

Moreover, by depositing a dye molecules composite atop on top of optically thick metal film, we demonstrated a photodriven perfect absorber wherein the absorption band and intensity can be tuned by illumination (Figure 3b). This work was presented in the *7th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics* in Bordeaux by Mehdi Keshavarz Hedayati. The poster was selected by the steering committee as the best student poster by the steering committee (Figure 3c). MoreoverFurthermore, because of his efforts in this field (Figure 3d), in December 2013

our PhD student, Mehdi Keshavarz Hedayati was received the Khwarizmi Youth Award (2nd rank in Innovation) in the 15th Khwarizmi Youth Festival organized by the Iranian Research Organization for Science and Technology in December 2013 because of his efforts in this field (Figure 3d). As a new trend in the field of plasmonics, we have begunstart to consolidate combine biological molecules and plasmonic metamaterial in order to develop some new designs and functionality. Generally, colors in living organisms are mainly due to the specific shape and distribution of nano-structures in their outer skin (surface) and these colors may change by alteration of environmental conditions. For instance, the cuticle of the dock beetle changes its color depending on the hydration state owing to the conformational change of the protein and its interaction with the pigment. We adopted this principle to bridge the gap between "Bio-Filtration and Plasmonics". We are currently working on the aforementioned interface in order to make our structure smart i.e. photoswitchable. Since this study is rather new, no detailed description can be given here and but further information will be demonstrated presented in the Almanach 2014.

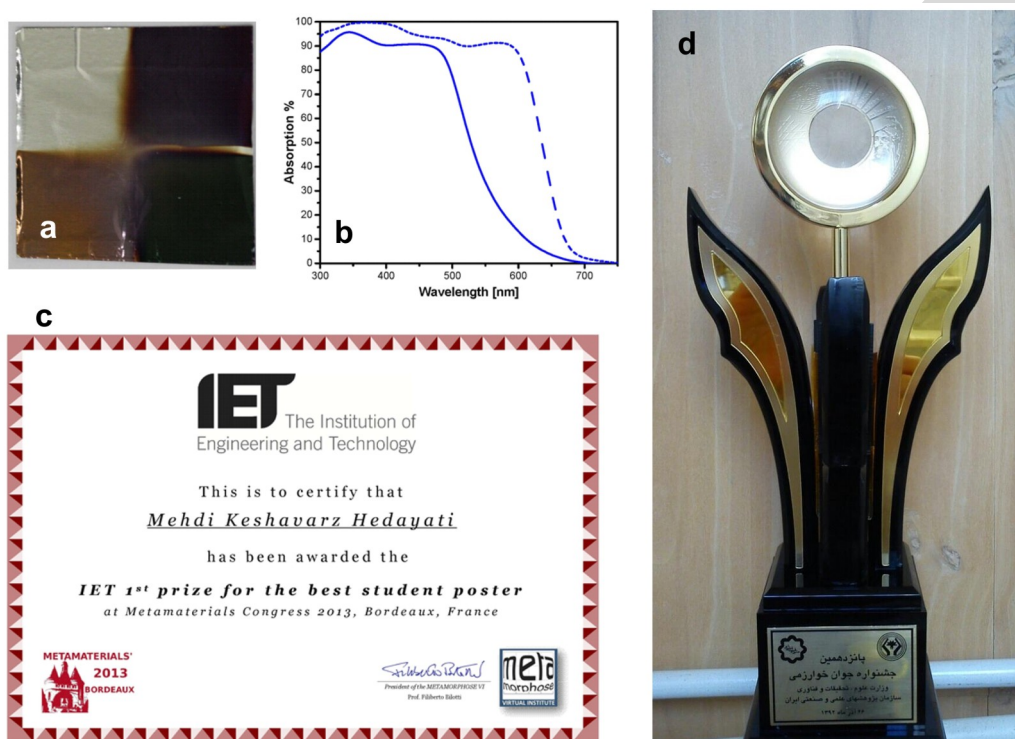


Fig. 3: a: True photograph of 50 nm gold nanocomposite with (13%), (20%) and (30%) filling factor on aluminum foil resulting in different color. The white are (top left) is the bare aluminum foil. b: Absorption spectra of PS-SPO composite (solid line) as deposited and upon UV irradiation (dashed line) deposited on 100 nm gold. c: Certificate of the prize received by M. K. Hedayati for his poster in at the 7th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics (Bordeaux, France). d: The Youth Khwarizmi Award Statuette given to Mehdi Keshavarz Hedayati in at 15th Khwarizmi Youth Festival organized by the Iranian Research Organization for Science and Technology in December 2013.

## Personnel

Head of the group: Prof. Dr. -Ing. M. Elbahri; Secretary: N. Gühlke (50%), Dipl.-Chem. S. Kastaun (50%)  
 Technical Staff: Dipl. -Ing. (FH) R. Kloth (on leave), Techn. C. Ochmann (DFG, BMBI), Dipl.-Ing. (FH) S. Rehders, Dipl.-Inf. P. Sommer

# Scientific Staff:

M.Sc. M. Abdelaziz Plasmonic materials	01.10.-31.12.2013	Fellowship CAU
M. Sc. R. Abdelaziz Nanofabrication	01.01.-31.12.2013	SFB 677, DFG
M.Sc. D. Disci Nanofabrication for Bio.	01.01.-31.12.2013	DFG, SFB 677
Prof. Dr. H. El-Khozondar	01.07.-31.08.2013	Fellowship DAAD
Dr. S.S. Homaeigohar Nanofibres for Filtration	01.01.-31.12.2013	HZG, DAAD, HGF
M.Sc. M. Keshavarz Hedayati Plasmonic materials	01.01.-31.12.2013	SFB 677, DFG, CAU
Dr. R. Khalil	15.10.-31.12.2013	Fellowship DAAD
M.Sc. J. Worley Bionanotechnology	01.01.-30.06.2013	HGF
M.Sc. A.U. Zillohu Photonic nanomaterials	01.01.-31.12.2013	HZG, DAAD, HGF

## Lectures, Seminars, and Laboratory Course Offers

### Winter 2012/2013

Nanochemistry for Nanoengineering, 2 hrs Lecture/Week,  
M. Elbahri

Nanochemistry for Nanoengineering - Seminar, 1 hrs Seminar/Week,  
M. Elbahri

Werkstoffe - Polymere, 2 hrs Lecture/Week,  
M. Elbahri

Polymer based Smart and Multifunctional Devices, 2 hrs Lecture/Week,  
M. Elbahri

Polymer based Smart and Multifunctional Devices - Seminar, 1 hrs Seminar/Week,  
M. Elbahri

Nanochemistry and Nanoengineering, 2 hrs Seminar/Week,  
M. Elbahri

### Summer 2013

Werkstoffe - Polymere, 2 hrs Lecture/Week,  
M. Elbahri

Einführung in die Makromolekulare Chemie, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
M. Elbahri



Nanochemistry and Nanoengineering, 2 hrs Seminar/Week,  
M. Elbahri

*Winter 2013/2014*

Nanochemistry for Nanoengineering, 2 hrs Lecture/Week,  
M. Elbahri

Nanochemistry for Nanoengineering - Seminar, 1 hrs Seminar/Week,  
M. Elbahri

Werkstoffe - Polymere, 2 hrs Lecture/Week,  
M. Elbahri

Nanochemistry and Nanoengineering, 2 hrs Seminar/Week,  
M. Elbahri

### **Third-Party Funds**

GKSS, *Einrichtung einer gemeinsamen Helmholtz-Hochschul-Nachwuchsgruppe*, 01.03.2009-28.02.2015 (2.100.000 Euro)

DFG, *Nanosynthesis and Nanopatterning based on "Drop-on-a-hot-Plate"*, 01.08.2009-31.08.2013 (280.370 Euro)

DFG SFB 677, *Function by Switching: Photoswitchable Metal-Polymer Nanocomposites*, 01.07.2011-30.06.2015 (228.470 Euro)

DFG SFB 677, *Function by Switching: Multifunctional Photoswitchable Polymer Fibers*, 01.07.2011-30.06.2015 (261.720 Euro)

DAAD, *2. Verlängerung Stipendium zur Promotion für Ahnaf Usman Zillohu*, 01.04.2012-31.03.2013 (12.168 Euro)

DAAD, *3. Verlängerung Stipendium zur Promotion für Ahnaf Usman Zillohu*, 01.04.-30.09.2013 (6.084 Euro)

DAAD, *Stipendium zum Forschungsaufenthalt für El-Khozondar*, 15.03.-15.06.2013 (6.575 Euro)

CAU, *Promotionsstipendium für Moheb Abdelaziz Mahmoud Abdelaziz*, 01.10.2013-30.09.2014 (13.200 Euro)

DAAD, *Forschungsaufenthalt für Frau Dr. Rania Mohammed Ahmed Khalil*, 01.11.-31.12.2013 (6.575 Euro)

### **Further Cooperation, Consulting, and Technology Transfer**

Prof. Dr. F. Faupel, Institute for Material Science, several topics with hybrid organic/inorganic materials

Prof. Dr. R. Adelung, Institute for Material Science, several topics nanostructures, biomaterials i.e. submitted DFG joint project for conductive polymer nanowires

Prof. Dr. Dieter Adam, Institut für Immunologie, Christian-Albrechts-Universität Kiel

Prof. Dr. L. Kienle, Institute for Material Science, Transmission electron microscopy

Prof. Dr. V. Abetz, Helmholtz Zentrum Geesthacht, Zentrum für Material- und Küstenforschung GmbH, Blockcopolymers

Prof. Dr. Eich, TU Hamburg, Photonic crystal

Prof. Dr. Martin Müller, Helmholtz Zentrum Geesthacht, Zentrum für Material- und Küstenforschung GmbH

Prof. Dr. sc.hum. Rainer Podschun, Institut für Infektionsmedizin, Christian-Albrechts-Universität Kiel

Prof. Dr. Carsten Rockstuhl, Photonik, Uni Jena

Priv.-Doz. Dr. C. Röhl, Institut für Toxikologie und Pharmakologie für Naturwissenschaftler, Christian-Albrechts-Universität

Prof. Dr. Selhuber-Unkel, Biocompatible Nanomaterials, Faculty of Engineering

Prof. Dr. rer. nat. S. N. Gorb, Spezielle Zoologie, Christian-Albrechts-Universität Kiel

Dr. Thomas Emmeler, Helmholtz Zentrum Geesthacht, Zentrum für Material- und Küstenforschung GmbH

Dr. Wolfgang Reinert, Fraunhofer ISIT

Prof. Dr. Peter Müller-Buschbaum, Institute of Physics, TU München

Prof. Dr. Stefan Linden, Institute of Physics, Bonn University

Prof. Dr. Horst-Günter Rubahn, NanoSYD, Mads Clausen Institute, Denmark

Prof. Dr. Andrei Lavrinenko, Department of Photonics, TU Denmark

Prof. Dr. Abhijit Biswas, Electrical Engineering, Notre Dame, USA

Prof. Dr. Alexander Govorov, Physics Department, Ohio University, USA

## Diploma, Bachelor's and Master's Theses

L. Michalewicz, *Ermittlung der durchschnittlichen Razyklatmenge der im Fahrzeug verwendeten Kunststoffe, Reifen und Gläser*, 07.10.2013

S. Röder, *Methodenentwicklung zur quantitativen Messung der Schlagzähigkeit von Hochleistungsklebebandern*, 14.10.2013

B. Gothe, *Tunable, photoswitchable polymer systems: Film vs. Fibres*, 04.11.2013

F. Schütt, *From Bioshell to Functional Bioplasmonic*, 07.11.2013

## Publications

Published in 2013

R. Abdelaziz, D. Disci-Zayed, J.-H. Pöhls, M. Keshavarz Hedayati, A.U. Zillohu, B. Erkartal, V.K. Chakravadhanula, V. Duppel, L. Kienle, M. Elbahri, *Green Chemistry and Nanofabrication in a levitated Leidenfrost drop*, Nature Communications, **4**, Article number: 2400, (2013)

S. Homaeigohar, T. Dai, M. Elbahri, *Biofunctionalized nanofibrous membranes as super separators of protein and enzyme from water*, Journal of Colloid and Interface Science, **406**, 86 - 93 (2013)

Y.K. Mishra, R. Adelung, G. Kumar, M. Elbahri, S. Mohapatra, R. Singhal, A. Tripathi, D.K. Avasthi, *Formation of Self-organized Silver Nanocup-Type Structures and Their Plasmonic Absorption*, Plasmonics, **8** (2), 811 - 815 (2013)

S. Homaeigohar, D. Disci-Zayed, T. Dai, M. Elbahri, *Biofunctionalized nanofibrous membranes mimicking carnivorous plants*, Bioinspired, Biomimetic and Nanobiomaterials, **2**, 186 - 193 (2013)

## Patent Applications

M. Elbahri, V. Zaporozhchenko /dag, T. Strunskus, F. Faupel, M. Keshavarz Hedayati, V.S.K. Chakravadhanula, *Omni-directional Transparent Conducting Metal based Plasmonic Metamaterials*, German Patent and Trade Mark Office (GTPO), 27.02.2013, PCT/DE2007/001176

M. Elbahri, M. Keshavarz Hedayati, F. Faupel, T. Strunskus, V. Zaporozhchenko /dag, *Absorberschicht für den VIS- und/oder NIR-Spektralbereich*, German Patent and Trade Mark Office (GTPO), 01.08.2013, DE 10 2011113571B4

M. Elbahri, K. Hirmas, F. Faupel, R. Adelung, *Ordered Pattern by a controllable Dewetting around a defect*, United States of America Patent and Trademark Offi, 01.10.2013, US 12/741 905

## Presentations

- M. Elbahri, F. Faupel, M. Keshavarz Hedayati, *Photoswitchable perfect absorber at visible frequency (Talk)*, 4th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 13), Sharjah, United Arab Emirates, 18.-22.03.2013
- M. Elbahri, F. Faupel, T. Strunskus, M. Keshavarz Hedayati, *Design, fabrication and characterization of a new transparent conductor based on plasmonic nanocomposite (Poster)*, 4th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 13), Sharjah, United Arab Emirates, 18.-22.03.2013
- M. Elbahri, *Plasmonic nanoparticles as dielectric tuner, sub-wavelength light confiner and heat generator. (Invited Talk)*, 4th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 13), Sharjah, United Arab Emirates, 18.-22.03.2013
- M. Elbahri, M. Javaherirahim, M. Keshavarz Hedayati, *Photoswitchable perfect absorber at visible frequency (Talk)*, 4th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 13), Sharjah, United Arab Emirates, 18.-22.03.2013
- M. Elbahri, F. Faupel, T. Strunskus, M. Javaherirahim, M. Keshavarz Hedayati, *Design fabrication and charcterization of a new transparent conductor based on plasmonic nanocomposite (Talk)*, 4th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 13), Sharjah, United Arab Emirates, 18.-22.03.2013
- M. Keshavarz Hedayati, *Photoswitchable Transparent Conductor (Talk)*, SFB 677 internes Meeting, Kiel, Germany, 18.-18.06.2013
- M. Elbahri, F. Faupel, T. Strunskus, A.U. Zillohu, M. Keshavarz Hedayati, *Optical analysis of photoswitchable perfect absorber (Talk)*, SFB 677 internes Meeting, Schleswig, Germany, 15.-15.08.2013
- M. Elbahri, M. Keshavarz Hedayati, *Perfect Plasmonic Absorber for Visible Frequency (Poster)*, Metamaterials 2013: The 7th International Congress on Advanced Electrimagnetic Materials in Microwaves and Optics, Bordeaux, France, 16.-19.09.2013
- R. Abdelaziz, D. Disci, S.S. Homaeigohar, M. Elbahri, *Plasmonic Bionanocomposites (Talk)*, 6th International Workshop on Polymer/Metal Nanocomposites, Toulouse, France, 16.-18.09.2013
- M. Elbahri, T. Strunskus, B. Gothe, A.U. Zillohu, *Electrospun Nanofibrous Affinity Membranes: A Modern Cleaning Method (Poster)*, International Symposium on Photochronism 2013, Berlin, Germany, 23.-26.09.2013

## Further Activities and Events

Our article entitled "Green chemistry and nanofabrication in a levitated Leidenfrost drop" that was published in **Nature Communication** (R. Abdelaziz et al., *Nature Communication* 2013, 10.1038/ncomms3400) drew considerable press attention:

Press release: NPG press office (<http://www.natureasia.com/en/research/highlight/8877>)

Press release: New scientist (<http://www.newscientist.com/article/dn24481-skittering-water-droplets-spin-tiny-sponges-of-gold.html#.UwtOwbRFY7Z>)

Press release: Physics.org (<http://phys.org/news/2013-10-nanoparticles-fabricated-leidenfrost-video.html>)

Press release: Chemical and Engineering News (C & EN) ([http://cen.acs.org/articles/91/i44/Water-Catalyzed-Nanofabrication-Strikes-Gold.html?utm\\_source=feedburner&utm\\_medium=feed&utm\\_campaign=Feed%3A+materials\\_scene+%28Chemical+%26+Engineering+News%3A+Materials+SCENE%29](http://cen.acs.org/articles/91/i44/Water-Catalyzed-Nanofabrication-Strikes-Gold.html?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+materials_scene+%28Chemical+%26+Engineering+News%3A+Materials+SCENE%29))

Press release: Spiegel Online (<http://www.spiegel.de/wissenschaft/technik/leidenfrost-effekt-mini-reaktoren-tanzen-auf-der-herdplatte-a-931039.html>)

Press release: University of Kiel (<http://www.uni-kiel.de/pressemeldungen/?pmid=2013-353-gruene-chemie>)

Press release: Guardian (<http://www.theguardian.com/science/small-world/2013/nov/21/nanotech-roundup-chemistry-gadgets-energy>)

Press release: MRS Bulletin (News & Analysis) (<http://journals.cambridge.org/action/displayFulltext?type=6&fid=9147089&jid=MRS&volumeId=39&issueId=01&aid=9147088&bodyId=&membershipNumber=&societyETOCSession=&fulltextType=XX&fileId=S0883769413003199>)

Press release: Chemistry World (<http://www.rsc.org/chemistryworld/2013/10/nanoparticle-synthesis-leidenfrost-drop-levitating>)

# Nanoscale Magnetic Materials - Magnetic Domains

The main focus of research in the department of “Nanoscale Magnetic Materials - Magnetic Domains” is on magnetic heterostructures with tailored magnetic properties. Nanostructuring and layering by various methods is used to modify the magnetic microstructure enabling us to design artificial magnetic materials and specifically, to control the magnetic domains, as well as optimizing magnetic structures for various types of applications. The effective magnetic properties are influenced by the use of different magnetic interaction effects. Magnetic properties are analyzed by probing the magnetic response laterally on time-scales from DC down to the picosecond range. Therefore, a main task within the department is the methodical advancement of magnetic domain investigation tools with high lateral and temporal resolution.

In general, the scientific focus of the research group is on micro- and nanostructured magnetic thin films. The magnetization behaviour of structured and layered magnetic thin films is illuminated from a fundamental point of view as well as from the perspective of application-related scientific questions. We are investigating new fundamental concepts based on magnetic domain engineering for the property design of nanostructured magnetic layer systems. A central goal is to improve existing magnetic material systems with respect to their functionality. On the other side, the methodological emphasis of the department is on the optimization, development, and application of optical and microscopic techniques for the investigation of magnetic and ferroelectric domain behaviour with high spatial and temporal resolution. Time-resolved polarization microscopy and magneto-optical microscopy is intended to be developed with picosecond temporal resolution. The development of these methods is essential for achieving the intended research goals.

## Results

### DUAL PATH MULTI-COMPONENT MAGNETO-OPTICAL IMAGING

The imaging of magnetic domains in magnetic materials is essential in order to obtain an understanding of the underlying mechanisms of magnetization reversal and the related processes in micro- or nanoscale magnetic devices. This promotes further development in domain imaging techniques. For this purpose, magneto-optical microscopy has not only the advantage to deliver a signal proportional to the magnetization (Kerr effect,  $\sim M$ ), but also allows for imaging modes that provide magneto-optical contrast being quadratic to the magnetization components (Voigt effect,  $\sim M^2$ ). However, the process of obtaining magnetic vector information by magneto-optics was until now restricted to static magnetization patterns. Also, the extraction of complementary images by other means, like Voigt effect microscopy combined with multi-axis Kerr microscopy, was not possible until now. The combination of images obtained under different imaging conditions is, however, highly advantageous for the understanding of complicated domain patterns. Based on a dual path imaging scheme, we were able to perform complementary real-time imaging with different sensitivity directions. The technique is used for the investigation of complex magnetization reversal processes in magnetic single and multi-layer film structures with in-plane and out-of-plane anisotropy. Domain images with different magnetic information are recorded simultaneously. By that means for instance, the spatial variation of the magnetization vector is extracted in real-time, and the transverse and longitudinal magnetization components (and hysteresis loops) are measured simultaneously. Additional applications include the adaption to methods that rely on the combination of multiple magneto-optical imaging conditions in order to identify the magnetization directions even in complex domain patterns.

An instructive example of the imaging method applied to a cubic anisotropy Fe layer is displayed in Fig. 1. Multiple images from the same domain pattern are displayed, allowing for unequivocal identification of all characteristics of the magnetization structure. Longitudinal effect images are shown: with orthogonal magneto-optical sensitivity, transversal sensitivity, with a sensitivity in-between the longitudinal sensitivity axes, and a Voigt effect image proving antiparallel orientation of magnetization in the domains with the same magneto-optical contrast. The derived vector magnetization distribution is also shown. With the addition of real-time multiple component imaging to full field magneto-optical Kerr microscopy the technique will be of even greater importance for the investigation of fundamental and applied aspects of magnetization domain processes in magnetic materials. Magneto-optical imaging is taken to the next level.

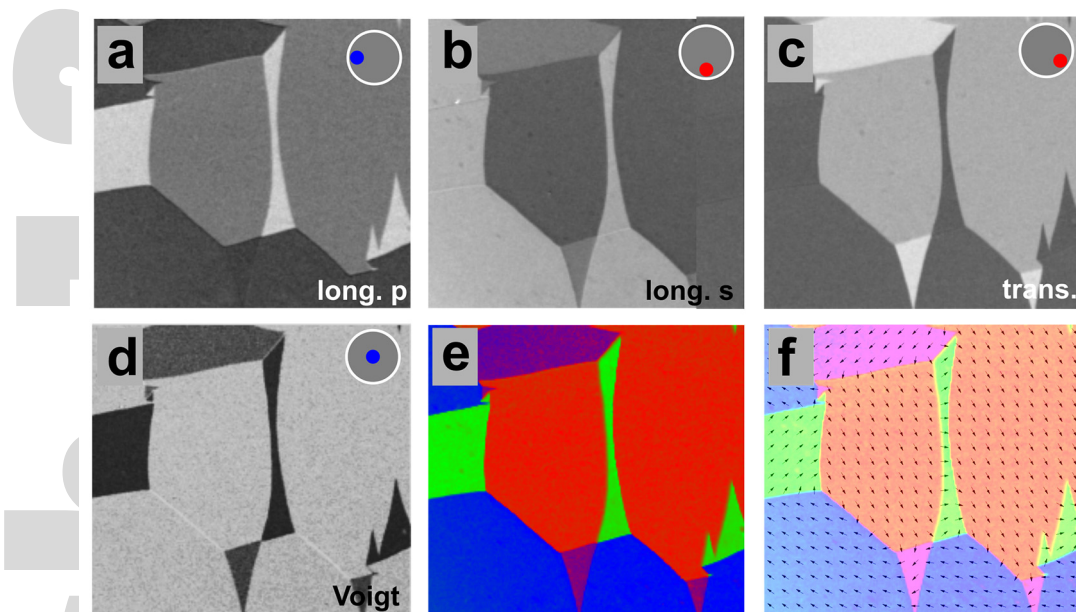


Fig. 1: (a, b) Longitudinal effect images with orthogonal magneto-optical sensitivity, (c) transversal sensitivity, and (d) corresponding Voigt effect image. The derived vector magnetization distribution is shown in (e) and (f) (together with D. Bürgler, Forschungszentrum Jülich).

## MAGNETIC DOMAIN EFFECTS IN MAGNETO-ELECTRIC COMPOSITE MATERIALS

High sensitivity magneto-electric (ME) sensors are promising candidates for magnetic field sensing. Through careful material selection and optimization, especially two phase ME-composites, which consist of a magnetostrictive and a piezoelectric layer in contact, can enable ultra-low sensitivity. From magneto-resistive sensor applications it is well known that the exhibited noise in the sensors is strongly degraded by closure domain and domain wall activity, which also holds true for ME-sensors. Yet, due to the patterned devices used and to the use of unavoidably magnetostrictive material, local variations of effective magnetic anisotropy and complicated domain structures occur. Magnetic domain activities in magneto-electric sensors are therefore an important factor that limits the low field sensitivity of the sensor. Using spatially resolved characterization methods, we obtained an understanding of the magnetic rearrangement processes in the magnetic phase of ME thin films. From this, concepts for the control of the magnetic domain behaviour are developed with the objective of achieving the largest effective susceptibility.

An example of the remagnetization behaviour of a magnetic phase is shown in Fig. 2. Increasing the magnetic field from negative magnetic saturation, narrow ripple-like domains are nucleated in the centre of the sample. Stress relaxation effects at the edges of the tensile stressed, magnetostrictive layer lead to a local change of magnetic anisotropy aligned perpendicular to the intrinsic film anisotropy. Unexpectedly, a big portion of the reversal process does not take place through rotation of magnetization, but complicated closure domains propagate into the sample with changing field. These closure domains are modulated perpendicular to the net magnetization's direction and are composed of narrow spike domains of tilted magnetization direction that are separated by asymmetric Néel walls. The magnetization reversal found is not only performed through the rotation of the magnetization, but is rather dictated by domain wall motion inside the material. As the magnetic field is increased, additional spike domains nucleate from the edge region, move into the material, and thereby gradually refine the domain width. Overall, complicated magnetic domain processes are found even in soft magnetic ME sensor composites. Whereas in the regions of magnetization rotation the ME response corresponds well with the behaviour predicted from the magnetization loop, the formation and growth of complicated closure domain structures with reduced net magnetization alters the ME response.



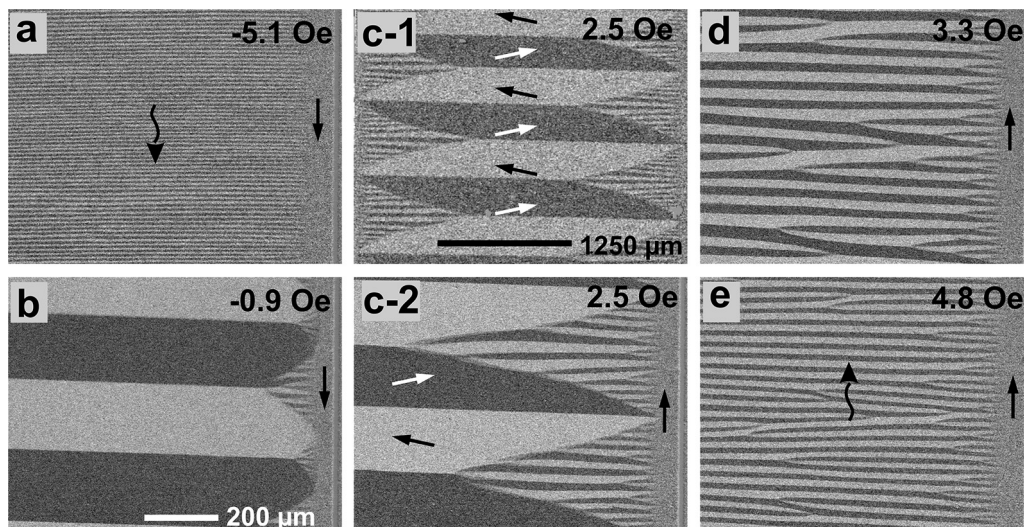


Fig. 2: Domain formation during magnetization reversal in the magnetic phase of a ME sensor structure (together with A. Piorra and E. Quandt).

## HYBRID MAGNETIC MATERIALS - TUNING OF MAGNETORESISTANCE RESPONSE

Artificial magnetic domain configurations can be created by light ion irradiation on thin magnetic films. By this, magnetic properties, such as magnetic anisotropy, exchange coupling, and interlayer exchange coupling, are tailored on a length scale comparable to the magnetic characteristic correlation length. Imprinting domains and domain walls in this fashion combined with a reduction of structure size leads to the creation of magnetic hybrid materials that show novel effective magnetic properties. As an example, results from exchange coupled ferromagnetic/antiferromagnetic NiFe/IrMn thin films, tailored by Helium ion irradiation in the presence of a magnetic field, are shown in Fig. 3. The large area thin films are irradiated stripe-like in order to imprint magnetization patterns, enabling a local magnetization alignment. Magnetic structures with zigzag oriented exchange bias directions across adjacent stripes are created. Patterning in such a way is used to alter the magnetization curve and to obtain a unique angular sensitivity behaviour of anisotropic magneto-resistance (AMR). The predicted anisotropic magneto-resistive behaviour is in good agreement with the resulting experimental data. Domain images obtained by MOKE microscopy reveal that the magnetic zigzag structure is sustained through magnetic charge effects at the imprinted domain walls.

The patterned area is only sensitive along a single magnetic field axis and stabilized in a quasi-single domain structure which permits its application as a magnetic field sensing device with a unique sensitivity function. Demonstrated on full films, such arrangements can be modified in various ways and incorporated in different kinds of AMR sensor structures. Fine tuning of the field response is possible by taking into account the domain wall behaviour at the interfaces. The application of the general scheme of locally adjusting the magneto-resistance sensitivity function to other magneto-resistive effects is straightforward.

## PYROMAGNETIC BASED THERMAL MICROIMAGING WITH MAGNETO-OPTICAL INDICATOR FILMS

Using magneto-optical indicator films we were able to develop a thermal microimaging approach for the visualization of lateral temperature distributions with high lateral and temporal resolution. The method is based on the pyromagnetic effect as probed by magneto-optical Faraday effect imaging. It involves a magneto-optical indicator film (MOIF), which is placed in contact with the sample of interest in the same way as for the imaging of magnetic stray fields generated from magnetic materials or current carrying devices. Based on the alteration of saturation magnetization with temperature, through the concurrently occurring change of the magneto-optical Faraday rotation, we were able to probe minimal temperature changes with lateral resolution. The MOIF is thereby exploited as a transducer of a local variation of temperature into

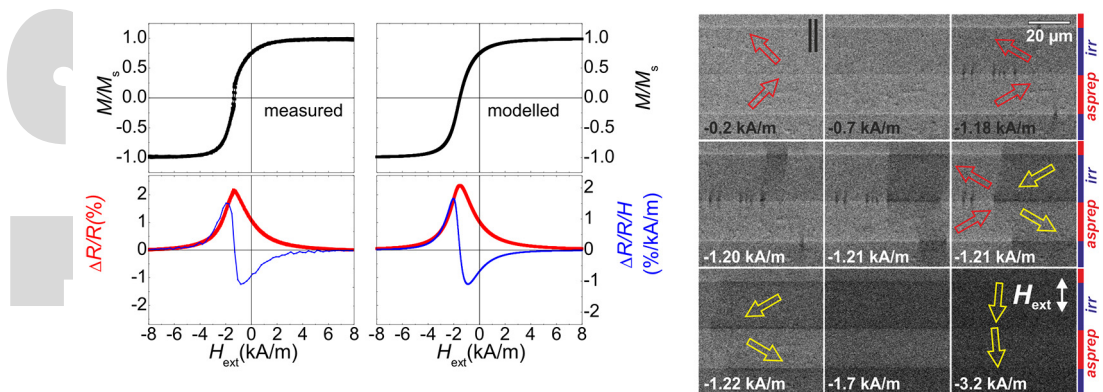


Fig. 3: Measured and modelled magnetization curves, magneto-resistance response and sensitivity curves for a folded exchange biased sensor structure together with corresponding magneto-optical images.

a variation of magneto-optical contrast. Relying on optics, the imaging scheme is able to work up to high temporal resolution, only being limited by thermal conductions. We were able to demonstrate lateral and time-resolved imaging of temperature changes in devices, occurring below one millisecond. Temperature resolution of about 0.01 K is achieved. The method opens new paths for the characterization of lateral temperature changes in electronic devices, including failure analysis, as well as for the investigation of phase transitions in materials.

## MAGNETIC HIGH-FREQUENCY PROPERTIES - DOMAIN CONFIGURATIONS AND OBSERVATION OF MAGNETIZATION DYNAMICS OF STRUCTURED FERROMAGNETIC LAYERS

The knowledge of fast magnetization reversal processes in magnetic elements is a key parameter for many new technologies and applications such as microinductors and magnetic recording heads. In general, the dynamic behaviour of the structures is related to the precessional frequency and damping parameter of the materials. However, due to local demagnetization fields, the exhibited magnetic domain, and domain wall structure, the effective dynamic response is altered in a complicated way. In order to obtain a clear picture of these dynamic effects the switching mechanisms of magnetic domains and domain wall configurations in magnetically structured thin films are investigated by using laterally resolved techniques with high temporal resolution. Jitter-free time-resolved stroboscopic Kerr microscopy with picosecond resolution is applied to analyze the local dynamic magnetic domain response of patterned magnetic thin films. The magnetic state is excited with radio-frequency magnetic fields of different frequencies up to several GHz and the corresponding local dynamic magnetic response is imaged directly, allowing for separation of domain and domain wall induced effects. As an example, the investigated magneto-dynamic behaviour of a patterned soft magnetic amorphous ferromagnetic layer is shown here. An example set of dynamic images for different frequencies of field excitation is displayed. In order to extract in-plane and out-of-plane magnetization response from one individual longitudinal sensitivity time-resolved measurement, the change of symmetry of the magnetic response is analyzed for two equivalent but inverted domain structures imaged at the same time.

## SEPARATION OF INTERFACIAL AND VOLUME CONTRIBUTIONS TO EXCHANGE BIAS IN NiO-PERMALLOY THIN FILMS

In a fundamental study using measurement techniques working down into the picosecond range, we were able to identify the existence of different contributions to exchange bias in NiO based exchange bias structures using independent measurement and field cooling schemes. By adjusting the field cooling procedure, the amplitude and the sign of exchange bias can be controlled and tuned across various temperatures. We could demonstrate a reversal of the initial exchange bias direction, even well below the Néel or blocking temperature of the antiferromagnetic layer. Regions of the antiferromagnet freeze in separately with decreasing temperature leading to separate contributions to exchange anisotropy. The field



cooling procedure is then remembered by the multilayered structure. The results prove that a particular fraction of exchange anisotropy, already existing at a given temperature, is unaffected when approaching lower temperatures. Together with strong non-linear alteration of exchange bias at lower temperatures, and especially in comparison with dynamic measurements at room temperature, thereby we prove undoubtedly that the exchange bias at low temperatures is not a result of antiferromagnetic bulk or grain contributions, but is dominated by interfacial effects. The absolute amount of alteration of exchange anisotropy with temperature is constant, a sign that it depends only on the alignment of ferromagnetic layer magnetization during temperature changes. The data clearly points to an interfacial spin-glass layer being the dominating contribution to exchange bias in NiO layer at low temperatures. At the same time, even for the low anisotropy NiO film, the well-known Mauri-model of exchange bias is refuted to account for the extracted data.

## **Personnel**

Head of the group: Prof. Dr. J. McCord; Secretary: E. Riemer, G. Schroeder

Technical Staff: Dipl.-Ing. (FH) T. Metzger

Scientific Staff:

Dr. M. Kustov	01.01.-30.06.2013	DFG
SPP 1239 - Domain Structures and Dynamics in Ferromagnetic Shape Memory Materials		
M.Sc. B. Mozooni	01.01.-31.12.2013	DFG
Einstellbarkeit und schaltbare Hochfrequenzeigenschaften		
Dipl.-Phys. J. Trützschler	01.01.-31.12.2013	DFG
Hybride Magnetische Materialien		
M.Sc. N. O. Urs	01.01.-31.12.2013	DFG
SFB 855, Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft, Teilprojekt B05		
Dr. T. von Hofe	01.01.-28.02.2013	DFG
SFB 855, Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft, Teilprojekt B05		

## **Lectures, Seminars, and Laboratory Course Offers**

*Winter 2012/2013*

Magnetic Domains, 2 hrs Seminar/Week,

J. McCord

Werkstoffe - Keramiken, 2 hrs Lecture/Week,

J. McCord

Advanced Materials A - Metals, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

J. McCord

Magnetism and Magnetic Materials, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

J. McCord

Nanoskalige magnetische Werkstoffe - magnetische Domänen, 2 hrs Seminar/Week,

J. McCord

*Summer 2013*

Magnetische Materialien, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

J. McCord

Advanced Materials B - Ceramics, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

J. McCord

Nanoskalige magnetische Werkstoffe - magnetische Domänen, 2 hrs Seminar/Week,

J. McCord

Advanced Lab Course (MOKE) for Master's Students, 3 hrs Lab/Week,

J. McCord (+ J. Trützscher)

*Winter 2013/2014*

Werkstoffe - Keramiken, 2 hrs Lecture/Week,

J. McCord

Advanced Materials A - Metals, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

J. McCord

Magnetic Materials: Physics and Applications, 2 (+ 1) hrs Lecture (+ Exercises)/Week,

J. McCord

Nanoskalige Magnetische Werkstoffe, 2 hrs Seminar/Week,

J. McCord

### Third-Party Funds

DFG, *Heisenberg-Professur*, 01.07.2011-30.06.2014 (189.000 EUR)

DFG, *Einstellbare und schaltbare Hochfrequenzeigenschaften - Domänenkonfiguration und Beobachtung von Magnetisierungsdynamik*, 01.10.2011-30.09.2014 (311.231 EUR)

DFG, *Hybride Magnetische Materialien - mikroskopische Modifikationen, makroskopische Wirkungen*, 15.02.2012-14.06.2014 (184.870 EUR)

DFG, *SPP 1239 - Änderung von Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder*, 01.11.2011-30.06.2013 (163.500 EUR)

DFG, *SFB 855 - Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen d. Zukunft, Teilprojekt B05*, 01.04.2012-31.12.2013 (207.100 EUR)

DAAD, *PROCOPE*, 01.01.2011-31.12.2013 (5.910 EUR)

Industrie, *Fehleranalyse an magnetischen Dünnschichtköpfen*, 01.04.-30.08.2013 (11.000 EUR)

### Further Cooperation, Consulting, and Technology Transfer

Dr. Andreas Berger, CICnanoGUNE, San Sebastian, Spain

Dr. Daniel Bürgler, Forschungszentrum Jülich - Peter Grünberg Institute

Dr. Peter Fischer, Lawrence Berkeley National Laboratory, Berkeley, USA

Prof. Jürgen Fassbender, Helmholtz-Zentrum Dresden-Rossendorf

Prof. Rostislav Grechishkin, Tver State University, Russia

Dr. Jörg Grenzer, Helmholtz-Zentrum Dresden-Rossendorf

Prof. Oliver Gutfleisch, Technische Universität Darmstadt

Prof. Lorenz Kienle, CAU Kiel

Prof. Reinhard Knöchel, CAU Kiel

Prof. Hermann Kohlstedt, CAU Kiel

Prof. Stephane Mangin, Institute Jean Lamour, Nancy, France

Prof. Olaf Magnussen, CAU Kiel

Dr. Roland Mattheis, IPHT Jena

Prof. Andrzej Maziewski, University of Bialystok, Poland

Dr. Guido Meier, University Hamburg

Dr. Ingolf Mönch, IFW Dresden

Dr. Bridget Murphy, CAU Kiel

Prof. Eckhard Quandt, CAU Kiel

Dr. Rudolf Schäfer, IFW Dresden

Dr. Heidemarie Schmidt, TU Chemnitz

Prof. L. Schultz, IFW Dresden

Prof. Hongbin Hu, Arizona State University, Glendale, USA

## **Diploma, Bachelor's and Master's Theses**

M. Kern, *FeSiB as active layer for a fluxgate sensor*, 14.01.2013

K. Sentosun, *Magneto-resistive characterization of hybrid magnetic films*, 28.04.2013

S. Avula Venkata, *Electrical switching of magnetic anisotropy in artificial multiferroics*, 19.12.2013

## **Dissertations / Postdoctoral Lecture Qualifications**

C. Hengst, *Magnetisierungsdynamik weichmagnetischer Dünnschichten mit modifizierter magnetischer Struktur (Dresden)*, 18.12.2013

## **Publications**

Published in 2013

T. von Hofe, N. O. Urs, B. Mozooni, T. Jansen, Ch. Kirchhof, D. E. Bürgler, E. Quandt, J. McCord, *Dual wavelength magneto-optical imaging of magnetic thin films*, Applied Physics Letters, **103**, 142410 (2013)

S. B. Hrkac, M. Abes, C. T. Koops, C. Krywka, M. Müller, S. Kaps, R. Adelung, J. McCord, E. Lage, E. Quandt, O. M. Magnussen, B. M. Murphy, *Local magnetization and strain in single magnetoelectric microrod composites*, Applied Physics Letters, **103**, 123111 (2013)

J. McCord, S. Mangin, *Separation of low- and high-temperature contributions to the exchange bias in  $Ni_{81}Fe_{19}$ -NiO thin films*, Physical Review, **B 88**, 014416 (2013)

J. McCord, B. Erkartal, T. von Hofe, L. Kienle, E. Quandt, O. Roshchupkina, J. Grenzer, *Revisiting magnetic stripe domains-anisotropy gradient and stripe asymmetry*, Journal of Applied Physics, **113**, 073903 (2013)

## **Presentations**

J. McCord, S. Mangin, *Contributions of freezing interfacial spin structure to exchange bias in NiO-Permalloy thin films*, 2013 Joint Magnetism and Magnetic Materials-Intermag Conference, Chicago, USA, 14.-18.01.2013

- C. Patschurreck, K. Lenz, M. O. Liedke, M. Lutz, T. Strache, I. Mönch, R. Schäfer, L. Schultz, J. McCord, *Magnetization dynamics of buckling domain structures in patterned thin films*, 2013 Joint Magnetism and Magnetic Materials-Intermag Conference, Chicago, USA, 14.-18.01.2013
- N. O. Urs, Ch. Kirchhof, D. Meyners, R. Jahns, E. Quandt, R. Knöchel, J. McCord, *Domain formation in laminated FeCoBSi films for ME sensor applications*, DPG Tagung 2013, Regensburg, Germany, 10.-15.03.2013
- K. Sentosun, J. Trützschler, M. Langer, I. Mönch, R. Mattheis, T. von Hofe, J. Fassbender, J. McCord, *Magneto-resistive characterization of hybrid magnetic films*, DPG Tagung 2013, Regensburg, Germany, 10.-15.03.2013
- M. Kustov, N. Mamkina, R. Grechinskii, J. McCord, *Laterally resolved thermal imaging using magneto-optical indicator films*, DPG Tagung 2013, Regensburg, Germany, 10.-15.03.2013
- J. McCord, T. von Hofe, *Real-time magneto-optical vector magnetization imaging of magnetic thin films*, International Symposium on Metallic Multilayers 2013, Kyoto, Japan, 19.-23.05.2013
- C. Fowley, K. Bernert, Y. Aleksandrov, H. Gan, V. Sluka, E. Kowalska, W. Feng, J. Lindner, J. Fassbender, J. McCord, S. Mangin, A. Deac, *Switching phase diagrams of MgO-based magnetic tunnel junctions*, International Symposium on Metallic Multilayers 2013, Kyoto, Japan, 19.-23.05.2013
- J. McCord, *Activities in Materials Science in Kiel (invited)*, Joint Symposium between Chungnam National University and Kiel University, Chungnam National University (CNU), Daejeon, South Korea, 28.-29.05.2013
- J. McCord, *Microwave Properties of Ferromagnetic Thin Films —Layering and Magnetic Domain Effects (invited)*, Progress In Electromagnetics Research Symposium PIERS 2013, Stockholm, Sweden, 12.-15.08.2013
- J. McCord, M. Kustov, B. Mozooni, N. O. Urs, *Advanced magneto-optic imaging of magnetic domains and beyond (invited)*, Donostia International Conference on Nanoscaled Magnetism and Application DICMA, San Sebastian, Spain, 09.-13.09.2013
- C. Patschurreck, M. Wolf, J. McCord, R. Schäfer, I. Mönch, L. Schultz, *Magnetic domain resonance in closure domain structures*, European Congress and Exhibition on Advanced Materials and Processes EUROMAT 2013, Seville, Spain, 08.-13.09.2013
- J. McCord, *Latest advances in magneto-optical domain imaging applications (invited)*, Fifth Seeheim Conference on Magnetism SCM 2013, Frankfurt/Main, Germany, 29.09.-03.10.2013
- Ch. Kirchhof, R. Jahns, N. O. Urs, D. Meyners, J. McCord, R. Knöchel, E. Quandt, *Magneto-electric sensors with reduced Barkhausen noise for frequency-conversion*, Intelligent Materials, Kiel, Germany, 25.-27.09.2013
- E. L. Jakubisova, S. Visnovsky, A. Wawro, L. Baczewski, P. Mazalski, A. Maziewski, M. Liedke, J. McCord, J. Fassbender, *Effect of Ga irradiation in MBE grown Pt/Co/Pt thin films studied by magneto-optic spectroscopy*, 58th Annual Magnetism and Magnetic Materials (MMM) Conference, Denver, USA, 04.-08.11.2013

## Further Activities and Events

Somyanshu Aurora, DAAD Working Internship in Science and Engineering (guest from 15.05.2013 - 30.07.2013)

Member of the Programme Committee of the 8th International Symposium on Metallic Multilayers (MML), Kyoto, Japan

Chair at the 2013 Joint Magnetism and Magnetic Materials - INTERMAG Conference, Chicago, USA

Chair at the 8th International Symposium on Metallic Multilayers (MML), Kyoto, Japan

Appointed to IEEE Senior Membership level

Juror bei Jugend forscht, Landesausscheid

## Synthesis and Real Structures

The significance of Transmission Electron Microscopy in Kiel arises in the context of numerous project applications not only in the group of "Synthesis and Real Structure", which is responsible for the efficiency of the TEM Centre, but also for almost all groups at the Institute for Materials Science. After the decommissioning of the old Philips CM30 the work overload at the FEI Tecnai F30 STwin illustrates the necessity for the acquisition of a new microscope. The application for the new TEM was made in 2011. Financial support was contributed in equal shares by the state Schleswig-Holstein and the Deutsche Forschungsgemeinschaft (DFG). After the inspection of eligible microscopes, the selected version of the JEOL JEM-2100 (Fig. 1a) fits the requirements slightly better than the offers of competing providers. Finally the microscope was installed starting in August of 2013.

The microscope is scheduled for multi-user purpose. Standard TEM techniques like diffraction contrast imaging as well as Selected Area Electron Diffraction (SAED) are provided by the microscope. Additionally, the microscope is equipped with a bright field detector as well as a dark field detector for performing Scanning TEM (STEM). An EDX (energy dispersive X-ray spectroscopy) detector enables the determination of the chemical composition at the nanoscale. Also the possibility for 3D imaging by tomography is given by the availability of a special sample holder and the recording, reconstruction, and visualization software provided by JEOL.

Not only users from the groups of the institute benefit by independently working with the microscope but also from the summer term 2014 the lab courses concerning TEM should take place using this microscope.

### Results

#### a) Synthesis and analysis of spiral-shaped structures in the system Au-Ga<sub>2</sub>Te<sub>3</sub>

The simple and reproducible synthesis of complex nanostructures remains a challenge in today's nanoscience. In this regard the pseudobinary section Au-Ga<sub>2</sub>Te<sub>3</sub> is relevant. A formation of microspirals can be observed, as first discovered in 2010 (Fig. 1b). However, a reproduction of the initial results including the identification of the decisive growth parameters remained unclear. Recently we started trials for a controlled reproduction and initiated a fundamental analysis of the microspiral morphology and real structures. In a first systematic series of high temperature syntheses the influence of composition, temperature, and time has been investigated. In a first stage stoichiometric Ga<sub>2</sub>Te<sub>3</sub> was synthesized from the elements. Subsequently a compact ingot of the material was wrapped with Au-foil and finally heating experiments were performed. These studies exhibited that besides unexpected high heating temperatures (> 1000 °C) for about one day the presence of silicon dioxide as growth catalyst is required for the desired formation of microspirals. Adding finely crushed quartz particles acting as catalysts spiral-shaped structures were preferentially grown close to the ingots' surfaces (Fig. 1c). For the growth process itself a modified VLS-mechanism is proposed. Thus, from a Ga<sub>2</sub>Te<sub>3</sub> substrate microstructures with gold droplets on their tips start to grow while adsorbing tellurium, which is partially present in its vapour phase. In the ideal case an Au-Ga<sub>2</sub>Te<sub>3</sub> spiral grows until the gold droplet is depleted and completely incorporated into the spiral. Investigations of the structure, morphology, and composition were carried out on different length scales with a combined approach of XRD, TEM, and SEM. For the latter, Figure 1d shows an arrangement of smaller crystallites to a major helical structure. Such super-morphology represents a new crystalline ultrastructure composed of self-organized microcrystals. The mapping of the chemical composition by EDX (Fig. 1e-g) proves the ternary composition of the spirals but a variable concentration of gold. Moreover gold droplets on top of spiral structures have been observed supporting the presence of a VLS-type crystal growth. TEM investigations confirmed a sphalerite-structure of the crystallites forming the helices. The gold appears to be randomly dispersed onto the cation sites of the sphalerite-type structure.

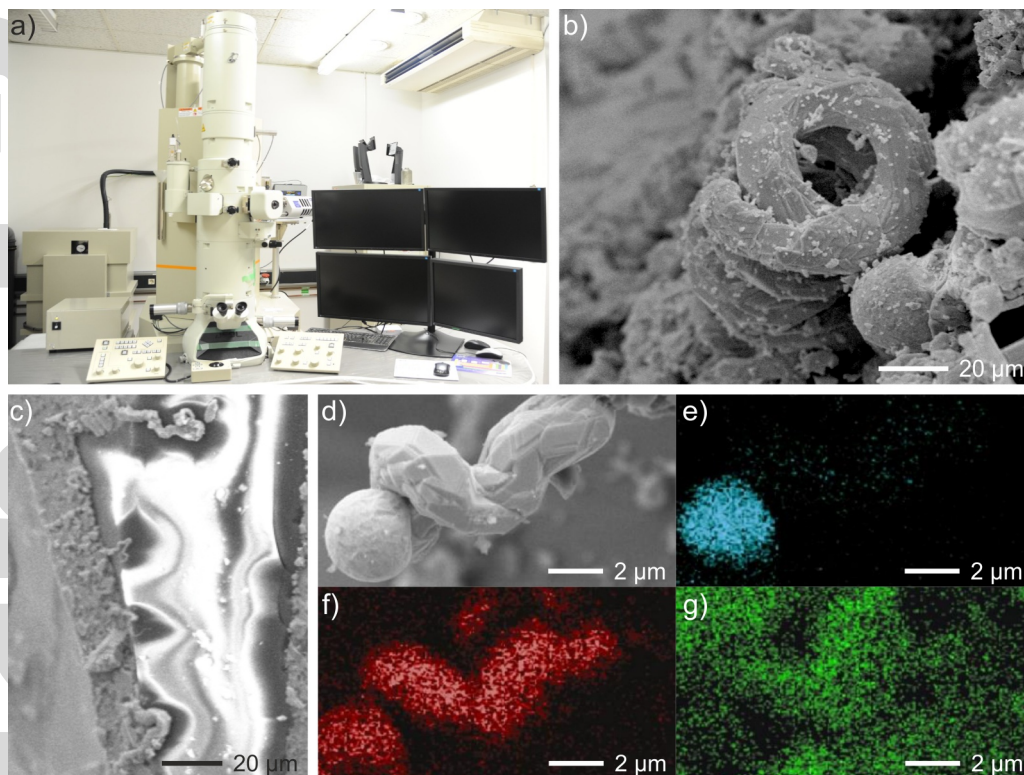


Fig. 1: (a) The newly installed TEM Jeol JEM-2100 at the TEM centre of the Institute for Material Science; (b) SEM image of a microspiral observed in 2010; (c) spiral-shaped structures grown near  $\text{SiO}_2$  particle surface; (d) reproduced helical structure as an arrangement of smaller crystallites and Au-droplet at the top; EDX maps of helical structure illustrating Au (E), Ga (f), Te (g) content.

## b) Amorphous FeCoSiB for exchange bias coupled and decoupled magnetoelectric multilayer systems: Real structure and magnetic properties (in cooperation with: Prof. Quandt, CAU Kiel)

The collaborative research centre (SFB 855) aims to develop strain-mediated piezoelectric-magnetostrictive nanocomposites for the purpose of utilizing the resulting magnetoelectric (ME) effect for the sensing of biomagnetic signals. Particularly, in the field of non-invasive medical imaging such as magneto-encephalography or -cardiography, ME based sensors appear to be a promising alternative to the established technologies.

For the magnetostrictive component multilayer materials were developed that were composed by repetitive layer sequences set up by Ta/Cu/ $\text{Mn}_{70}\text{Ir}_{30}$  and a ferromagnetic layer  $\text{Fe}_{50}\text{Co}_{50}$  or  $\text{Fe}_{70.2}\text{Co}_{7.8}\text{Si}_{12}\text{B}_{10}$  (FeCoSiB). A combined approach of high resolution (HR)TEM and Selected Area Electron Diffraction (SAED) studies confirmed an epitaxial growth between the seed bilayer (Ta, Cu) and the antiferromagnetic  $\text{Mn}_{70}\text{Ir}_{30}$  layer on the (111) planes. As consequence of the direct interface between the antiferromagnetic and the ferromagnetic layers, a pronounced exchange bias coupling is obtained. For the multilayers investigated using  $\text{Fe}_{50}\text{Co}_{50}$ , the ferromagnetic layers exhibited a textured growth along the [111] direction. This texture characteristic showed coarsening from the multilayer-substrate interface to the surface of the specimen. By depositing the multilayer on a piezoelectric AlN thin film, additional roughness effects were induced into the multilayer. Electron tomography was applied to investigate the roughness propagation and evolution within the multilayer, as demonstrated in Figure 2a.

For multilayers using amorphous FeCoSiB as ferromagnetic layer ex situ and in situ (Fig. 2b - 2g) annealing processes were carried out in order to study the structural variations within a field annealing procedure. In the as-deposited condition crystalline and textured filaments were detected in the ferromagnetic layers by using SAED (cf. Figure 2b). Further HRTEM



investigations showed also the presence of a thin crystalline  $\text{Fe}_{50}\text{Co}_{50}$  layer at the antiferromagnetic interface. Preparing another multilayer with separated antiferromagnetic and ferromagnetic layers exhibited entirely amorphous  $\text{FeCoSiB}$  (Fig. 2e) and emphasized the role of  $\text{Mn}_{70}\text{Ir}_{30}$  as the promoting factor for the crystallization within the  $\text{FeCoSiB}$ . Annealing processes were performed for selected temperature stages: up to 250 °C all investigated multilayers were structurally unaltered and preserved the as-deposited condition. A deliberate increase to 350 °C exhibited a different crystallization process for the thin films examined, depending on the presence of crystal nuclei within the  $\text{FeCoSiB}$ , cf. Figure 2c and 2f. Despite the presence of crystalline filaments, a decrease in the permeability recorded along the magnetic hard axis was not detected after the complete temperature treatment. Thus, the necessary soft magnetic properties, which play a decisive role for the biomagnetic sensing, are preserved.

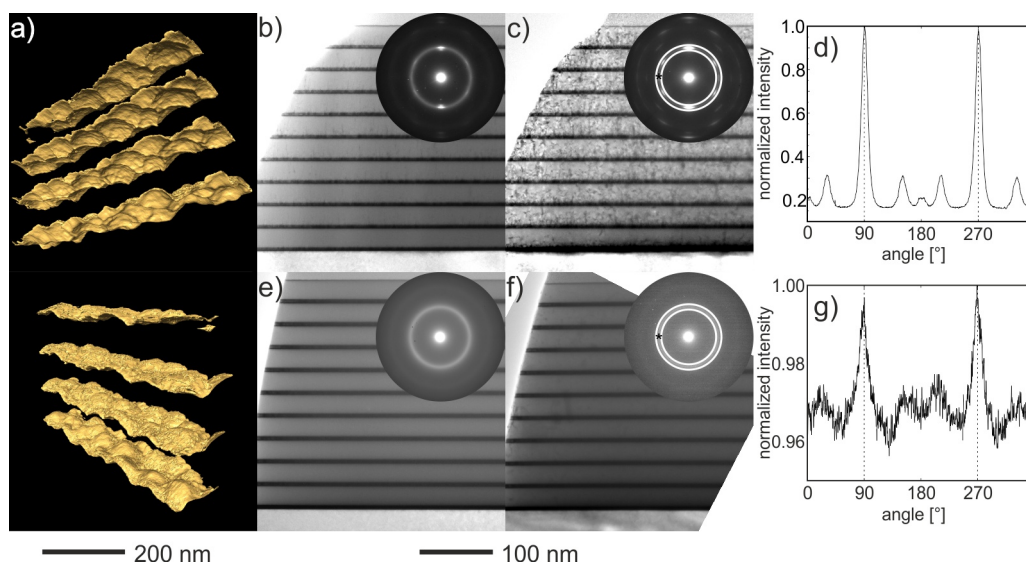


Fig. 2: a) Electron tomography for the three dimensional reconstruction of consecutive Ta layers of an exchange bias coupled multilayer system for two distinct perspectives. b - g) In situ annealing experiments for two different multilayer systems: b - d) Ta/Cu/Mn<sub>70</sub>Ir<sub>30</sub>/FeCoSiB, e - g) Ta/Cu/Mn<sub>70</sub>Ir<sub>30</sub>/Ta/FeCoSiB. b, e) Microstructure after deposition with SAED patterns as inset. c, f) Microstructure after in situ annealing (350 °C, SAED as inset). The white circles and the asterisks within the SAED pattern mark the respective areas and the starting points for the radial integration of the intensities within the SAED pattern of c) and f)

### c) In situ TEM studies of a novel type of amorphous molybdenum disulphide: controlled in situ crystallization via thermal and electron irradiation routes (in cooperation with: Prof. W. Bensch, CAU Kiel)

Molybdenum disulphide ( $\text{MoS}_2$ ) has gained significant interest due to its remarkable functional capabilities in various research fields of inorganic chemistry, including catalysis in hydrodesulphurisation and hydrogen evolution, or as electrode material for Lithium ion batteries. Increased efforts were carried out to deliberately control the crystallinity and grain size by optimizing the synthesis of  $\text{MoS}_2$ . Moreover,  $\text{MoS}_2$  can be prepared as a single-sheet material resembling the fascinating physical and chemical properties of graphene. Due to the presence of an intrinsic band gap for  $\text{MoS}_2$ , the single sheet material appears to be even more relevant for nanoelectronic devices compared to graphene.

In the present study, crystallization phenomena were investigated in situ for a novel type of amorphous  $\text{MoS}_2$  (referred to as sample PX) using methods of Transmission Electron Microscopy (TEM). For the pristine state, a combined approach of high resolution (HR)TEM/FFT confirmed a complete amorphous structure of the investigated sample, as depicted by the HRTEM micrograph and the corresponding FFT in Fig. 3a and 3d.

Irradiating the sample with a 300 kV electron beam, the characteristic (002) single slabs of crystalline  $\text{MoS}_2$  (space group:  $P6_3/mmc$ ) were formed, as demonstrated in the HRTEM micrographs in Fig. 3b and 3e. The length and stacking

numbers of these slabs increased with extended exposure times (cf. the result of long-term irradiation experiments of Fig. 3c and 3f). By closer inspection of the FFTs of Fig. 3e and 3f the formation of (011) (013) (-120) lattice planes was also observable under irradiation.

The time resolved series of HRTEM micrographs demonstrates that the stacking number of the (002) slabs was constant for all cases examined, indicating a controlled development of a uniform grain size of MoS<sub>2</sub>. In other words, a desired stacking height and grain size of crystalline MoS<sub>2</sub> can be achieved conveniently from this amorphous MoS<sub>2</sub> precursor by only adjusting the exposure time within an irradiation experiment. Furthermore, applying a heating stage and a lower dose of electrons in TEM also revealed an increase of crystallinity of the pristine MoS<sub>2</sub> as prepared. Annealing experiments up to 500 °C clearly show time-dependent crystallization phenomena with the increasing growth of (002) slabs. Additionally, ex situ measurements of XRD and Raman spectroscopy (Fig. 3g - h) performed on PX samples that were annealed at different temperatures (450 °C, 900 °C) further supported the in situ TEM observation. Thus, the temperature of annealing procedure to the MoS<sub>2</sub> as prepared can be used as another parameter to realize controlled crystallization.

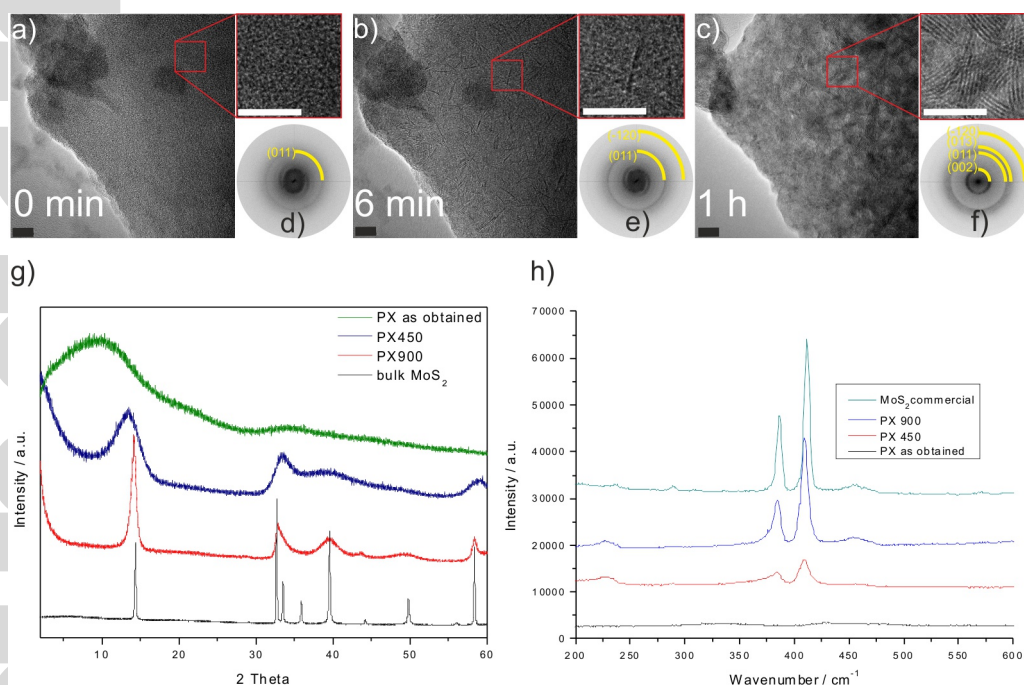


Fig. 3: Time resolved series of HRTEM micrographs of a region of the MoS<sub>2</sub> as prepared showing the evolution of (002) slabs under irradiation with an electron beam voltage of 300 kV for (a) 0 min, (b) 6 min, (c) 1 h, and the corresponding Fast Fourier Transformation (FFT) patterns (d), (e) and (f). Insets show enlarged views of the development of MoS<sub>2</sub> slabs in the same position of the bulk material. Scale bar is 10 nm. (g) Comparison of wide-angle X-ray diffractograms of commercially obtained bulk MoS<sub>2</sub>, as obtained PX and heat treated PX at 450 °C (PX450) and 900 °C (PX900). (h) Raman spectra of PX, PX450, PX900 and commercial MoS<sub>2</sub>. Enhanced E<sub>1</sub>2g and A<sub>1</sub>g peaks indicate that the heating process causes increased crystallisation.

#### d) Sb<sub>2</sub>Te<sub>3</sub>-Bi<sub>2</sub>Te<sub>3</sub> multilayers for thermoelectric application (in cooperation with: Fraunhofer IPM (Freiburg) and Prof. W. Bensch, CAU Kiel)

In 2001 Venkatasubramanian reported that single-crystalline Sb<sub>2</sub>Te<sub>3</sub>-Bi<sub>2</sub>Te<sub>3</sub> multilayers show excellent thermoelectric properties by reducing the thermal lattice conductivity due to phonon scattering. Our project *'Break and Beyond'* within the SPP 1386 is focused on the systematic reproduction of these results and the design of comparable nanostructured multilayered materials. The aim is to give a detailed analysis of engineering key-parameters (e.g. thermal stability, structural integrity, thermoelectric figure of merit etc.) of new and already reported materials which might be applied within



thermoelectric power generators. According to earlier observations the enhancement of thermal stability, i.e. the stability of the multilayers against interdiffusion represents a major task. Granular structures of nanoalloyed films were proven to show preferred interdiffusion at the grain boundaries. To overcome such shortcoming Molecular Beam Epitaxy (MBE) was used to produce entirely single-crystalline  $\text{Bi}_2\text{Te}_3$  (1 nm) -  $\text{Sb}_2\text{Te}_3$  (5 nm) epitaxial superlattices on a  $\text{BaF}_2$  substrate. By atomic-number dependent imaging the growth of the desired layer sequence and epitaxial orientation could be confirmed. This finding indicates a major breakthrough for thermoelectric research since it demonstrates the first reproduction of a superlattice-based single-crystalline structure on a wide range since 2001. However, on the micron scale some grain boundaries were observed still. At these positions, the multilayers tend to bow and partly also to vanish by interdiffusion. Electron microscopy investigations showed that the bowing is based on a stair-like structure made of short  $\text{Bi}_2\text{Te}_3$  stripes. Surprisingly, the crystallographic structure remains unaffected, thus indicating a coherent intergrowth of the  $\text{Bi}_2\text{Te}_3$  stripes and the  $\text{Sb}_2\text{Te}_3$  matrix. Ex situ heating experiments (XRD and TEM) indicate that the single-crystalline sample is thermally stable up to a temperature of 250 °C. A fading of the superlattice starts at 250 °C. In situ TEM heating experiments are applied to determine the diffusion mechanism. First results indicate that the stair like structure tends to diffuse faster compared to areas showing the perfect superlattice. Further experiments are needed to verify the presumption of enhanced diffusivity of the stair-like structures, and transport measurements affiliated with ex-situ heating procedure should follow.

## Personnel

Head of the group: Prof. Dr. Lorenz Kienle; Secretary: Katrin Brandenburg (50%)  
 Technical Staff: Christin Szillus

Scientific Staff:

M.Sc. Torben Dankwort	01.03.-31.12.2013	DFG
SPP 1386 Nanostrukturierte Thermoelektrika: Theorie, Modellsysteme und kontrollierte Synthese, TP Nanostructure, thermoelectric properties and transport theory of V2VI3 and V2VI3/IV-VI superlattices		
M.Sc. Mao Deng	01.01.-31.12.2013	DFG
Synthese und Realstruktur-Eigenschaftsbeziehungen von katalytisch aktiven Nanoteilchen auf der Basis von Übergangsmetallsulfiden		
M.Sc. R. Burak Erkartal	01.01.-31.10.2013	DFG und andere Drittmittel
SPP 1239 Änderung von Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder, TP Characterization of the micro- and nanostructure of magnetic shape memory materials by Transmission Electron Microscopy		
Dipl.-Phys. Viktor Hrkac	01.01.-31.12.2013	DFG
SFB 855 Magnetoelektrische Verbundwerkstoffe - biomagnetische Schnittstellen der Zukunft, TP Z1 Hochauflösende Transmissionselektronenmikroskopie und magnetoelektrische Materialcharakterisierung		
Dr. Dietrich Häußler	01.01.-31.12.2013	CAU
Disordered chalcogenides, advanced microscopy with aberration correction		
Dr. Ulrich Schürmann	01.01.-31.12.2013	CAU
TEM-Zentrum		

## Lectures, Seminars, and Laboratory Course Offers

*Winter 2012/2013*

Thermodynamics and Kinetics I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
 L. Kienle

Solid State Chemistry, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Kienle (+ U. Schürmann)

Solid State Chemistry, 1 hrs Seminar/Week,  
U. Schürmann

Chemistry and Physics of Biomaterials, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Kienle (+ R. Adelung, C. Selhuber-Unkel)

Electron Microscopy, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
L. Kienle

Allgemeine Chemie, 1 hrs Exercise/Week,  
L. Kienle

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,  
L. Kienle

### Summer 2013

Thermodynamics and Kinetics 2, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Kienle

Mikro- und Nanocharakterisierung von Festkörpern mittels TEM, 2 hrs Lecture/Week,  
L. Kienle (+ U. Schürmann)

Materialanalytik 1, 2 hrs Lecture/Week,  
L. Kienle

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,  
L. Kienle

### Winter 2013/2014

Thermodynamics and Kinetics I, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Kienle

Solid State Chemistry and Crystallography, 2 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Kienle (+ U. Schürmann)

Solid State Chemistry and Crystallography, 1 hrs Seminar/Week,  
U. Schürmann

Electron Microscopy, 3 (+ 2) hrs Lecture (+ Exercises)/Week,  
L. Kienle

Materialwissenschaft 3, 3 (+ 1) hrs Lecture (+ Exercises)/Week,  
L. Kienle

Seminar Synthese und Realstruktur, 2 hrs Seminar/Week,  
L. Kienle

### Third-Party Funds

DFG (SPP 1239), *Characterization of the micro- and nanostructure of magnetic shape memory materials by Transmission Electron Microscopy* (im Rahmen des SPP 1239: *Änderung der Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder*), 15.07.2010-31.07.2013 (144.000 EUR)

- DFG (SPP 1239), *Programmpauschale zu: Characterization of the micro- and nanostructure of magnetic shape memory materials by Transmission Electron Microscopy (im Rahmen des SPP 1239: Änderung der Mikrostruktur und Form fester Werkstoffe durch äußere Magnetfelder)*, 15.07.2010-31.07.2013 (28.800 EUR)
- DFG, *SFB 855, TP Z1 Hochauflösende Transmissionselektronenmikroskopie und magnetoelektrische Materialcharakterisierung*, 01.01.2010-31.12.2013 (784.000 EUR)
- DFG, *Synthese und Realstruktur-Eigenschaftsbeziehungen von katalytisch aktiven Nanoteilchen auf der Basis von Übergangsmetallsulfiden*, 16.04.2012-15.04.2015 (144.501 EUR)
- DFG, *Programmpauschale zu: Synthese und Realstruktur-Eigenschaftsbeziehungen von katalytisch aktiven Nanoteilchen auf der Basis von Übergangsmetallsulfiden*, 16.04.2012-15.04.2015 (28.900 EUR)
- DFG, *Investitionsmittel zur Beschaffung eines Großgerätes: Transmissionselektronenmikroskop*, 25.06.2012-24.06.2013 (382.509 EUR)
- Land Schleswig-Holstein, *Investitionsmittel zur Beschaffung eines Großgerätes: Transmissionselektronenmikroskop*, 25.06.2012-24.06.2013 (382.509 EUR)
- DFG (SPP 1386), *Synthesis, theoretical investigation and properties of nanocomposite thermoelectric materials*, 01.10.2013-30.09.2016 (12.000 EUR)
- DFG (SPP 1386), *Programmpauschale zu: Synthesis, theoretical investigation and properties of nanocomposite thermoelectric materials*, 01.10.2013-30.09.2016 (4.800 EUR)
- DFG, *SPP 1386 Nanostrukturierte Thermoelektrika: Theorie, Modellsysteme und kontrollierte Synthese. Nanostructure, thermoelectric properties and transport theory of V<sub>2</sub>VI<sub>3</sub> and V<sub>2</sub>VI<sub>3</sub> IV-VI based superlattices*, 01.03.2013-29.02.2016 (148.800 EUR)
- DFG, *Programmpauschale zu: SPP 1386 Nanostrukturierte Thermoelektrika: Theorie, Modellsysteme und kontrollierte Synthese. Nanostructure, thermoelectric properties and transport theory of V<sub>2</sub>VI<sub>3</sub> and V<sub>2</sub>VI<sub>3</sub> IV-VI based superlattices*, 01.03.2013-29.02.2016 (29.800)
- DFG, *Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen*, 17.09.2013-16.09.2015 (127.825 EUR)
- DFG, *Programmpauschale zu: Elektrochemische und mikrostrukturelle Untersuchung der Prozesse in Anoden für Hochkapazitäts-Lithium-Ionen-Batterien basierend auf Si-Mikrodrahtanordnungen*, 17.09.2013-16.09.2015 (25.600 EUR)

## Diploma, Bachelor's and Master's Theses

- Grit Köppel, *TEM-Untersuchungen an funktionellen Titanoxid-Dünnschichten*, 26.09.2013
- Matthias Frank, *Untersuchung der Defektstruktur an dotiertem Germaniumtellurid zur thermoelektrischen Anwendung*, 26.09.2013
- René Millies, *Synthese und Charakterisierung von Silber-Gallium-Tellurid*, 21.10.2013
- Nico A. Gaida, *Identification and implementation of a viscoelastic material model for a fast-curing CFK*, 20.11.2013
- Gero Neubüser, *Synthese und Analyse von Spiralstrukturen im System Au-Ga<sub>2</sub>Te<sub>3</sub>*, 03.12.2013

## Dissertations / Postdoctoral Lecture Qualifications

- R. Burak Erkartal, *Characterization of Shape Memory Alloys via Transmission Electron Microscopy*, 11.12.2013

## Publications

Published in 2013

- S. Kauffmann-Weiss, B. Erkartal, L. Schultz, L. Kienle, S. Fähler, *Influence of kinetics on the phase formation in epitaxial Fe-Pd films*, *Scr. Mater.*, **68(6)**, 412 - 415 (2013)

- J. McCord, B. Erkartal, T. v. Hofe, L. Kienle, E. Quandt, O. Roshchupkina, J. Grenzer, *Revisiting magnetic stripe domains - anisotropy gradient and stripe asymmetry*, J. Appl. Phys., **113(7)**, 073903 (2013)
- R. Fernandes, M. Hüls, M.-J. Nadeau, P.M. Grootes, C.D. Garbe-Schönberg, H. Hollund, A. Lotnyk, L. Kienle, *Assessing screening criteria for the radiocarbon dating of bone mineral*, Nucl. Instrum. Methods Phys. Res. B, **294**, 226 - 232 (2013)
- J. Djamil, S.A. Segler, A. Dabrowski, W. Bensch, A. Lotnyk, U. Schürmann, L. Kienle, S. Hansen, T. Beweries, *The influence of carbon content on the structure and properties of MoS<sub>x</sub>C<sub>y</sub> photocatalysts for light-driven hydrogen generation*, Dalton Transactions, **23**, 1287 - 1292 (2013)
- N. Alissawi, V. Zaporozhchenko, T. Strunskus, I. Kocabas, V.S.K. Chakravadhanula, L. Kienle, D. Garbe-Schönberg, F. Faupel, *Effect of gold alloying on stability of silver nanoparticles and control of silver ion release from vapour-deposited Ag-Au/polytetrafluoroethylene nanocomposites*, Gold Bull., **46**, 3 - 11 (2013)
- S. Permien, H. Hain, S. Scheuermann, V. Mangold, V. Mereacre, A.K. Powell, S. Indris, U. Schürmann, L. Kienle, V. Duppel, S. Harma, W. Bensch, *Electrochemical insertion of Li into nanocrystalline MnFe<sub>2</sub>O<sub>4</sub>: a study of the reaction mechanism*, RSC Adv., **3(45)**, 23001 - 23014 (2013)
- M. Winkler, X. Liu, U. Schürmann, J.D. König, L. Kienle, W. Bensch, H. Böttner, *Theoretical and experimental advances in Bi<sub>2</sub>Te<sub>3</sub>/Sb<sub>2</sub>Te<sub>3</sub>-based and related superlattice systems*, MRS Proceedings, 1490 (2013)
- V. Hrkac, L. Kienle, S. Kaps, A. Lotnyk, Y.K. Mishra, U. Schürmann, V. Duppel, B.V. Lotsch, R. Adelung, *Superposition twinning supported by texture in ZnO nanospikes*, J. Appl. Crystallogr., **46**, 396 - 403 (2013)
- P. Hartmann, T. Brezesinski, J. Sann, A. Lotnyk, J.P. Eufinger, L. Kienle, J. Janek, *Defect Chemistry of Oxide Nanomaterials with High Surface Area: Ordered Mesoporous Thin Films of the Oxygen Storage Catalyst CeO<sub>2</sub>-ZrO<sub>2</sub>*, ACS Nano, **7(4)**, 2999 - 3013 (2013)
- J. Eiblmeier, M. Kellermeier, M. Deng, L. Kienle, J.M.G. Ruiz, W. Kunz, *Bottom-Up Self-Assembly of Amorphous Core-Shell-Shell Nanoparticles and Biomimetic Crystal Forms in Inorganic Silica-Carbonate Systems*, Chem. Mater., **25(9)**, 1842 - 1851 (2013)
- R. Abdelaziz, D. Disci-Zayed, M.K. Hedayati, J.H. Pöhls, A.U. Zillohu, B. Erkartal, V.S.K. Chakravadhanula, V. Duppel, L. Kienle, M. Elbahri, *Green chemistry and nanofabrication in a levitated Leidenfrost drop*, Nat. Commun., **4**, 2400 (2013)
- S. Bhowmick, D. Stauffer, H. Guo, S. Kaps, Y.K. Mishra, V. Hrkac, O. Warren, R. Adelung, A. Minor, L. Kienle, *In Situ Electromechanical Study of ZnO Nanowires*, Microscopy and Microanalysis, **19(2)**, 434 - 435 (2013)
- U. Schürmann, V. Duppel, T. Nilges, S. Britvin, V.A. Kovalenker, L. Kienle, *From Chalcogenides to Polychalcogenidehalides - First Identification in Mineral Samples*, Zeitschrift für anorganische und allgemeine Chemie, **639(15)**, 2761 - 2766 (2013)
- T. Peter, S. Rehders, U. Schürmann, T. Strunskus, V. Zaporozhchenko, F. Faupel, *High rate deposition system for metal-cluster/SiO<sub>x</sub>C<sub>y</sub>H<sub>z</sub>-polymer nanocomposite thin films*, Journal of Nanoparticle Research, **15(6)**, 1 - 8 (2013)
- J. Djamil, S.A. Segler, A. Dabrowski, W. Bensch, A. Lotnyk, U. Schürmann, L. Kienle, S. Hansen, T. Beweries, *The influence of carbon content on the structure and properties of MoS<sub>x</sub>C<sub>y</sub> photocatalysts for light-driven hydrogen generation*, Dalton Transactions, **42(4)**, 1287 - 1292 (2013)

## Presentations

- L. Kienle, *Transmission Electron Microscopy on Functional Materials*, Invited lecture at Max Planck Institut für Festkörperforschung, AG Nanochemistry, Stuttgart, Germany, 18.07.2014
- U. Schürmann, V. Hrkac, S. Marauska, B. Gojdka, A. Petraru, V. Duppel, V.S.K. Chakravadhanula, C. Kübel, B. Wagner, H. Kohlstedt, F. Faupel, L. Kienle, *TEM observations on different length scales for characterization of AlN texture and columnar growth (poster)*, Microscopy Conference 2013, Regensburg, Germany, 25.-30.08.2013
- M. Deng, V. Hrkac, K. Gerwien, B. Hesseler, F. Beiroth, V. Duppel, W. Bensch, L. Kienle, *Observation of the transformation behaviour of CdSe-Cr<sub>2</sub>Se<sub>3</sub> nanoparticle composites by in-situ TEM techniques (poster)*, Microscopy

Conference 2013, Regensburg, Germany, 25.-30.08.2013

T. Dankwort, M. Winkler, X. Liu, V. Duppel, U. Schürmann, J.D. König, H. Böttner, L. Kienle, W. Bensch, *Nanostructured tellurides for thermoelectric applications: GeTe doped with Bi and Se*, Microscopy Conference 2013, Regensburg, Germany, 25.-30.08.2013

L. Kienle, *Application of Transmission Electron Microscopy in Material Science*, Invited lecture at

“Fortbildungsveranstaltung der Fachgruppe Festkörperchemie und Materialforschung”, Berlin, Germany, 16.09.2013

L. Kienle, *Transmission Electron Microscopy on Functional Materials*, Plenary speaker at INTERM 2013 International Multidisciplinary Microscopy Congress, Antalya, Turkey, 10.-13.10.2013



## Further Activities and Events

Prof. Dr. L. Kienle is the executive director of the Institute for Materials Science, a board member of the KNMF user committee, and is the author of the Römpp encyclopaedia.



# CMA Centre for Materialanalytics

Executive board: Prof. Dr. F. Faupel, Prof. Dr. H. Föll, Prof. Dr. B. Wagner, Prof. Dr. E. Quandt, Prof. Dr. J. McCord, Prof. Dr. R. Adelung, Prof. Dr. C. Selhuber-Unkel, Prof. Dr. L. Kienle.

Within the Institute for Materials Science the various groups and chairs possess advanced equipment for preparation and analysis, including electron microscopy and photoelectron spectroscopy among others, in the recently established Nanolab.

The main tasks of the CMA include, but are not restricted to:

- support of scientific cooperation, service and consulting for industry and research institutes,
- materials characterization, e.g. structure and properties of thin films, surface topography and spectroscopy, materials testing, in particular testing of mechanical properties,
- allocation of modern equipment and scientific knowledge with respect to materials testing and analysis of modern materials for internal and external users,
- extension of the available experimental methods by resource sharing with other institutions within suitable cooperations,
- support of students (bachelor's, master's and PhD) within their respective theses,
- support during study courses by various lectures and experimental courses in modern analytical methods, materials testing and investigations with transmission electron microscopy,
- support of students during job-seeking through various contacts to (local) industry and research institutes.

## Personnel

Head of the group: Dr. O. Riemenschneider; Secretary: M. Wallisch (75 percent)

Technical Staff: Dipl.-Ing. K. Rath (85 percent)

Scientific Staff:

Dipl.-Min. M. Schwitzke	01.01.-31.12.2013	(50%)
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## Third-Party Funds

contract work, *maintenance and expansion of equipment*, 01.01.-31.12.2013 (9.436,55 EUR)

## Further Cooperation, Consulting, and Technology Transfer

Cooperation with Industry:

1. Danfoss Silicon Power GmbH, Flensburg,
2. Howaldtswerke-Deutsche Werft GmbH, Kiel,
3. Agrosolution GmbH & Co. KG, Linz, Oesterreich,
4. Fa. Element22, Kiel,

5. ThyssenKrupp Marine Systems, Kiel,

Cooperation with Institutes:

1. Institut fuer Schadenverhuetung und Schadenforschung der oeffentlichen Versicherer e. V., Kiel,

Industrial and Academic cooperation includes:

- inquiries and consulting regarding damage analysis, material selection and surface treatment,
- general consulting,
- single and serial analysis of damage analysis of material characteristics, of compounding techniques and material application,
- material analysis on the micro and macro scale.



## Deanship



The Dean's office is the administrative centre of the Faculty of Engineering and therefore responsible for managing the total budget including current costs, investments, and personnel costs. For the two institutes of the faculty that are located in Kiel-Gaarden, the Dean's office is also responsible for the computer operating services, the building services, and the mechanical workshop. The Dean's office is directed by Dr. Frank Paul the head of the administration of the faculty.

To fulfil all these tasks there are 18 persons in the Dean's office. In 2013 the deanship was led by Prof. Dr. Wilhelm Hasselbring and Prof. Dr.-Ing. Eckhard Quandt as well as Prof. Dr.-Ing. Ludger Klinkenbusch as the Vice deans.



Fig. 1: During the "Sommerfest" Prof. Dr. Frank Kempken, Vicepresident of the University, Prof. Dr. Wilhelm Hasselbring, Dean, Dr. Philipp Murmann, president of the "Friends of the Faculty"

Worth mentioning are the successful negotiations with our newly appointed professors. As new professors of the faculty, Prof. Dr. Marco Liserre began his work in the autumn of 2013, replacing Prof. Dr.-Ing. Friedrich Wilhelm Fuchs who retired in the spring 2013. Also in autumn of 2013 Dr. Michael Höft became professor replacing Prof. Dr.-Ing. Reinhard Knöchel who retired in autumn 2013. As a new professor at the Faculty of Engineering Dr. Isabella Peters started at the *German National Library of Economics* in the autumn 2013.

Besides the impressive scientific work of the different groups that is reflected in this Almanac, the raising of a respectable amount of third party funding has to be mentioned. Two professors were awarded by a ERC-Grant. Prof. Christine Selhuber-Unkel got a Starting Grant (1.5 Mio eur) and Prof. Marco Liserre a Consolidator Grant (2.0 Mio eur). Thus three of four ERC-Grants in Schleswig-Holstein were devoted to members of the Faculty of Engineering.

To attract more female students, once more again the nationwide Girls' Day was organized by Dr. Ina Pfannschmidt, the equal opportunities officer of the faculty, on 24th April 2013. Different groups from our three institutes for Electrical Engineering and Information Technology, for Material Science and for Computer Science showed the girls some first impressions to the study programmes and work at the faculty. Nearly 100 girls from all parts of Schleswig-Holstein took the chance to visit the different projects.

Finally, the skilful organization by the Dean's office, of the contest "Jugend forscht - Schüler experimentieren" in Schleswig-Holstein should be noted. After participating in the regional contest about 50 young participants were guests of the Faculty of Engineering in April 2013. A remarkable number of young people who participated the contests of "Jugend forscht" begin later their university studies in fields which are covered by "Jugend forscht" (e.g. biology, chemistry, computer science, engineering, geo science, mathematics or physics) and passed it very successfully.



Fig. 2: Participants interviewed by university and schools experts

## Personnel

Head of the group: Dr. F. Paul (Managing Director);

Staff:

S. Anders 01.01.-31.12.2013

Head Administrator for Staff and Budget Department

U. Bruse 01.01.-31.12.2013

Division Manager of Building Services

M. Burmeister 01.01.-31.12.2013

Division Manager of the Mechanical Workshop

R. Doose 01.01.-31.12.2013

Caretaker

M. Firnau 01.01.-31.12.2013

Division Manager of Computer Service Department

M. Hacker 01.01.-31.12.2013

Secretary of Budget Department

S. Keller 01.01.-31.12.2013

Trainee

M. Kulling	01.01.-31.12.2013
Employee of the Mechanical Workshop	
C. Martin	01.01.-31.12.2013
Administrator Deans Office	
S. Moeller	01.01.-31.12.2013
Secretary of Staff Department	
B. Neumann	01.01.-31.12.2013
Vice Devison Manager of the Mechanical Workshop	
C. Neue	01.01.-31.12.2013
Administrator Computer Service Department	
K. Prehn	01.08.-31.12.2013
Trainee	
M. Quedens	01.01.-31.12.2013
Electrician	
T. Wengler	01.01.-31.12.2013 (50%)
Aministrator Deans Office	
E. Wetendorf	01.01.-31.12.2013
Trainee	

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## Service Centre

The Service Centre at the Faculty of Engineering was launched in Spring 2009. It is a joint corporation of the Institute of Electrical and Information Engineering and the Institute for Materials Science. The Service Centre is managed by assistants from the two institutes who are subordinated to the managing directors of the institutes. In addition, the examination offices of the two institutes, with three employees and a secretariat with two employees, belong to the Centre. The task of the Service Centre is to organize centrally (as far as it is possible) all issues related to studies, teaching and laboratory courses as well as examinations for the study programmes of both institutes.

The following tasks belong to the above-named fields:

Studies:

- accreditation and re-accreditation of study courses,
- design and development of study and examination regulations,
- capacity calculation,
- public relations, e.g. information days and hosted programmes at schools,
- advertisement for the different study courses,
- collecting and evaluating applications for the study courses in Materials Science,
- mentoring and supervising students, not only in topics related to study courses but also for foreign students with respect to daily life in Germany.

Teaching and laboratory courses:

- coordination of schedules for all study courses of the two institutes,
- coordination of rooms for all lectures of the two institutes,
- coordination of UnivIS entries,
- organization and administration of the joint basic laboratory courses,
- holding lectures, exercises, lab courses, and tutorials (see below).

Lab support:

- centralized purchasing of gas.

Examination offices:

- administration of student matters,
- administration of examination matters,
- preparation of transcripts.

The Service Centre, together with the Centre of Material Analysis, is located in building G on the East Shore Campus of the Faculty of Engineering.

Head of the group: Dr. Oliver Riemenschneider, Dr.-Ing. Kirstin Scholz; Secretary: Margit Marter (25 percent, since 01.09.2013), Maren Wallisch (75 percent)  
Technical Staff: Dipl.-Ing. (FH) Kay Rath (85 percent)

Staff:

Vera Nilsson (Examination Office)	01.01.-31.12.2013	(50%)
Christiane Otte-Hüls (Examination Office)	01.01.-31.12.2013	(50%)
Lars Struwe (Examination Office)	01.01.-31.12.2013	

Scientific Staff:

Dipl.-Min. Marlies Schwitzke	01.01.-31.12.2013	(50%)
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Lectures, Seminars, and Laboratory Course Offers

Winter 2012/2013

Tutorial for Junior Students, 1 hrs Seminar/Week,  
O. Riemenschneider

Tutorial for Senior Students, 1 hrs Seminar/Week,  
O. Riemenschneider

Basic Lab Course, 3 hrs Practical/Week,  
O. Riemenschneider (+ Emmanuel Ossei-Wusu, A. Kulkarni, E. Lage, S. Kaps, A. Piorra)

Einführung in die Materialwissenschaft I, 2 hrs Lecture/Week,  
O. Riemenschneider (+ K. Rätzke)

Tutorial für Bachelorstudierende Junior, 1 hrs Seminar/Week,  
O. Riemenschneider

Tutorial für Bachelorstudierende Senior, 1 hrs Seminar/Week,  
O. Riemenschneider

Grundpraktikum für Ingenieure I, Montags-, Dienstags-, Mittwochskurs, 3 hrs Practical/Week,  
K. Scholz (+ O. Riemenschneider, L. Wienbrandt)

Materialanalytik 2 Praktikum, 4 hrs Practical/Week,  
O. Riemenschneider (+ M. Schwitzke)

Grundlagen der Elektrotechnik, 3 hrs Lecture/Week,  
K. Scholz

Summer 2013

Grundpraktikum für Ingenieure II, Montags-, Dienstags-, Mittwochskurs, 3 hrs Practical/Week,  
O. Riemenschneider (+ L. Wienbrandt, K. Scholz)

Advanced Lab Course, 3 hrs Practical/Week,  
O. Riemenschneider (+ Scientific Staff of the Inst. f. Materials Science)

Tutorial for Junior Students, 1 hrs Seminar/Week,  
O. Riemenschneider

Tutorial for Senior Students, 1 hrs Seminar/Week,  
O. Riemenschneider

Übungen Physikalische Chemie 1 für Materialwissenschaftler, 1 hrs Exercise/Week,  
O. Riemenschneider

Tutorial für Bachelorstudierende Junior, 1 hrs Seminar/Week,  
O. Riemenschneider

Tutorial für Bachelorstudierende Senior, 1 hrs Seminar/Week,  
O. Riemenschneider

Übungen zur Chemie für Materialwissenschaftler, 1 hrs Exercise/Week,  
O. Riemenschneider

## Winter 2013/2014

Tutorial for Junior Students, 1 hrs Seminar/Week,  
O. Riemenschneider

Tutorial for Senior Students, 1 hrs Seminar/Week,  
O. Riemenschneider

Basic Lab Course, 3 hrs Practical/Week,  
O. Riemenschneider (+ E. Ossei-Wusu, A. Kulkarni, E. Lage, S. Kaps, M. Schwitzke, A. Piorra)

Allgemeine Chemie I, Übungen, 1 hrs Exercise/Week,  
O. Riemenschneider

Tutorial für Bachelorstudierende Junior, 1 hrs Seminar/Week,  
O. Riemenschneider

Tutorial für Bachelorstudierende Senior, 1 hrs Seminar/Week,  
O. Riemenschneider

Grundpraktikum für Ingenieure I, Montags-, Dienstags-, Mittwochsкурс, 3 hrs Practical/Week,  
K. Scholz (+ O. Riemenschneider, L. Wienbrandt)

Materialanalytik 2 Praktikum, 4 hrs Practical/Week,  
O. Riemenschneider (+ M. Schwitzke)

Grundlagen der Elektrotechnik, 3 hrs Lecture/Week,  
K. Scholz

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## Friends of the Faculty of Engineering

Friends of the Faculty of Engineering

### Executive Council:

Dr. Philipp Murmann (President),

Dr. Jörn Biel (Vice-president),

Prof. Dr. Helmut Föll (till 11.12.2013), Prof. Dr. Jeffrey McCord (beginning from 11.12.2013)(Vice-president),

Prof. Dr. Dr. Marcus Porembski (Treasurer),

Dr. Frank Paul (Secretary),

Prof. Dr.-Ing. Reinhard Knöchel (till 11.12.2013) Prof. Dr. Wilhelm Hasselbring (beginning from 11.12.2013) (Assessor)

Prof. Dr. Franz Faupel (till 11.12.2013), Prof. Dr. Christine Selhuber-Unkel (beginning from 11.12.2013) (Assessor),

Prof. Dr. Reinhard von Hanxleden (Assessor),

Herbert Jacobs (Assessor).

Auditors: Prof. Dr. Michael Hanus, Prof. Dr.-Ing. Gerhard Schmidt.



*“Zweck des Vereins ist die Förderung von Wissenschaft und Forschung, Studium und Lehre durch Unterstützung der Technischen Fakultät.*

*Der Verein pflegt die Beziehungen zwischen der Technischen Fakultät einerseits, der Wirtschaft und ihren Organisationen, den Studierenden, den Absolventen sowie ehemaligen Fakultätsangehörigen andererseits.*

*Er bietet dazu ein Forum für den Gedankenaustausch zwischen den Wissenschaftsdisziplinen Technik, Naturwissenschaft, Geistes-, Sozial- und Gesellschaftswissenschaften sowie der Fakultät und der Wirtschaft.*

*Mitglieder des Vereins sind Unternehmen, Institutionen und Personen, die die Technische Fakultät in ihren Zielen und ihrem Wirken unterstützen und begleiten.”*

*“The purpose of the Friends of the Faculty is the encouragement of science and research, study, and teaching, by supporting the Faculty of Engineering.*

*The Friends of the Faculty support the faculty with its finances and institutions on the one hand, and with the students, graduates, and alumni on the other.*

*The Friends of the Faculty present a forum for the exchange of ideas between the different disciplines of technology, science, philosophy, social science, and the economy.*

*Members are companies, institutions, and persons who support and encourage the faculty with its aims and its tasks.”*

During 2013 the Friends of the Faculty were active concerning the basic ideas above. Many different projects were supported and prizes awarded for the best diploma, bachelor's, master's and doctoral theses. These prizes should help the young scientists to make successful careers within the economy as well as in the scientific community.

Further activities covered the financial support of a visit by young students to the most important industrial fair in Germany if not Europe, the “Hanover fair”, of organizing the ‘Girls’ day’, and many other activities of the faculty's students. Also events like the “Sommerfest” and the “Winterfest” were made possible by the help of the Friends of the Faculty.

A very important task was the financing of the important competition "Jugend forscht - Schüler experimentieren". Using good contacts to different companies, donations were collected to help the faculty organize this important contest of young scientists. The intention is to cover the costs of the contest for the following years and to get more talented young students for the engineering and computer science study courses. In the recent past many former participants finished their study courses at Kiel University successfully.

The current number of members leaves room to welcome new recruits. Although some have left the Friends of the Faculty the overall number of members could be increased slightly.



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