5.1.5 Summary to: 5.1 Optics

- Know your numbers and relations for visible light!
  - Wavelengths: $\lambda \approx$ **400 nm - 800 nm.**

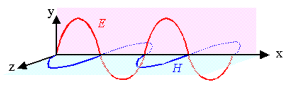
    $\lambda_{mat} = \lambda_0 / n$.
  - Frequency: $\nu \approx 10^{15}$ **Hz**.
  - Index of refraction: $n = \epsilon_r^{1/2} \approx$ **1,5 - 2,5**
  - Energy $E \approx$ **1,8 eV - 3,2 eV**.
  - Dispersion relation: $c_0 = \nu\,\lambda_0 = 3 \cdot 10^8$ **m/s**
    $c_{Mat} = \nu\,\lambda_0 / n(\lambda)$

For the *propagation* of light:
use the *wave model*
For the *generation* and disappearance (= *absorption*) of light:
use the *photon model*

Snellius law:
$n = \sin\alpha / \sin\beta$ with α, β the angle of incidence
or propagation, resp.

- Know yout basic equations and terminology

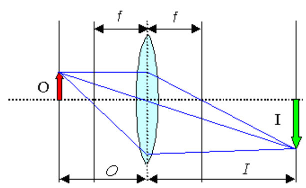
$$\begin{matrix} \underline{E}(\underline{r},t) \\ \underline{H}(\underline{r},t) \end{matrix} = \begin{matrix} \underline{E}_0 \\ \underline{H}_0 \end{matrix} \cdot \exp\{i(\underline{k}\,\underline{r} - \omega t)\}$$



Coherent monochromatic plane wave
$\underline{E}$ and $\underline{H}$ perpendicular and in phase

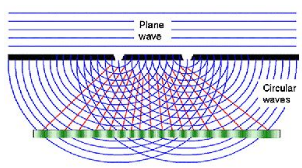
  - **Reflection** always with "angle in" = "angle out".
  - **Refraction** is the sudden "***bending***" or "flexing" of light beams at the interface
  - **Diffraction** is the continous "***bending***" of light beams around corners; interference effects.

- **Geometric optics**
  Key paramters
  - Focal length f and
    numerical aperture **NA** of lenses, mirrors.
  - Image formation by simple geometric constration
  - Various aberrations (spherical. chromatic, astigmatism, coma, ...) limit performance.



- **Wave optics**
  Huygens principle: and interference
  - Ultimate limit to resolution

$$d_{min} \approx \frac{\lambda}{2NA}$$



- Know your basic types of waves:
  - (Running, coherent, monochromatic) *plane wave*.
  - *Standing waves* = superposition of plane waves.
  - Incoherent, multichromatic *real* waves

- Relation s between electrical field ***E***, magnetic field ***H*** and **Poynting vector** (energy flow vector) ***S* = *E* × *H***

$$\langle S \rangle = \frac{E_0 H_0}{2} = \frac{E_0^2}{Z_W}$$

This equation links *energy flow* (easy in photon picture) to *field strength* in wave picture.

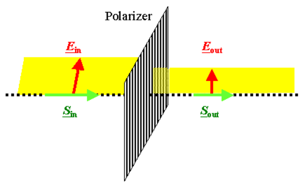
- Z_W **= wave impedance** of the medium.
  Z_W(vacuum) = 376,7 Ω

$$W_{elect} = \frac{\epsilon_0 \cdot E^2}{2} \qquad W_{mag} = \frac{\mu_0 \cdot H^2}{2}$$

$$[W_{elect;\ magn}] = [\mathrm{Ws\ m^{-3}}]$$

$$E_0 = \left(\frac{\mu_r \mu_0}{\epsilon_r \epsilon_0}\right)^{1/2} \cdot H_0 = Z_W \cdot H_0$$

- **Polarization** = key to "advanced" optics.
  Simple case: **linear polarization**.
  - Plane of polarization contains ***E***-vector and ***S*** (***k***) vector.
  - Any (coherent) wave is polarized but *net polarization* of many waves with random polarization is zero!
  - Light *intensity* ($\propto$ ***E***^{2}) between polarizers at angle α scales with **(cos**α**)**^{2}.



- General case: *elliptical* polarization; important are the two extremes: *linear* and **circular** polarization.
  - For circular polarizaiton the ***E***-vector rotates on a circle while moving "forward". This results from a superposition of two plane waves with ***E***-vectors ar right angles and a *phase difference* of π**/2**.
  - Technically important (3-dim Cinema; Lab optics)

Questionnaire
Multiple Choice questions to all of 5.1