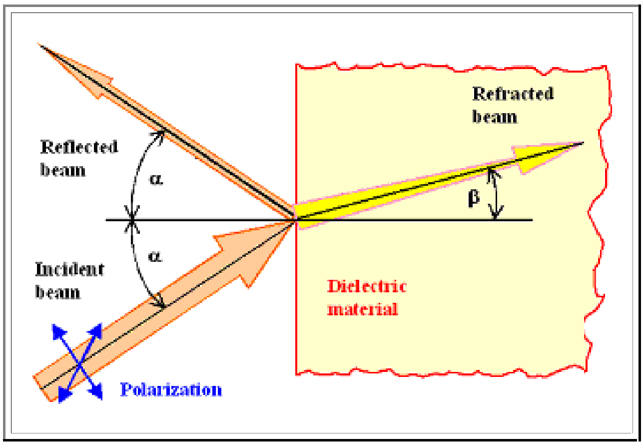
5.2.8 Summary to: Optics and Materials

The task:
Calculate and understand intensities, angles, phases, polarization and attenuation (damping) of the various light beams shown from the materials properties

- Still assuming a perfectly flat surface

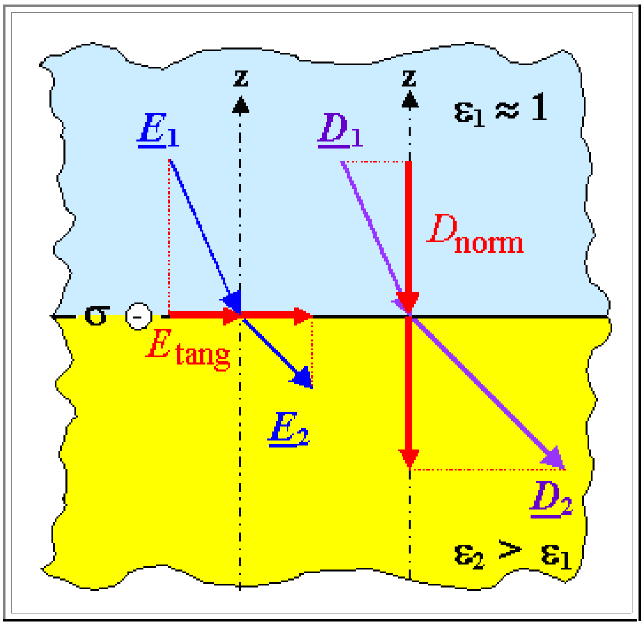


First step: Decompose impinging light into two waves with polarization in he interface plane (**TE** case) or at right angles (**TM** case)

- Energy conservation yields for the intensities:

$$I_{tr}(z = 0) \;=\; I_{in} - I_{re}$$

Boundary conditions as shown in the figure involve the "dielectric constant ε and thus the so far only relevant material property.



- Considering energy (proportional to E^2) and momentum (proportional to k^2") conservation for the TE and TM case separately yields the **Fresnel equations** that provide the answers to the questions above
- A wealth of insights and relations follow, e.g. or field strength E or intensities I:

$$\frac{E_{ref}}{E_{in}} = -\,\frac{n-1}{n+1}$$

$$\frac{I_{ref}}{I_{in}} = \left(\frac{n-1}{n+1}\right)^2$$

- one consequence as example for the power of these equations: $n = 2$ means that almost **10 %** of the intensity will be reflected, implying that for optical instruments you *must* provide some "anti-reflection" coating.

Using the complex (and frequency dependent "dielectric constant $\epsilon(\omega) = \epsilon' + i\epsilon''$ yields the **complex index of refraction**

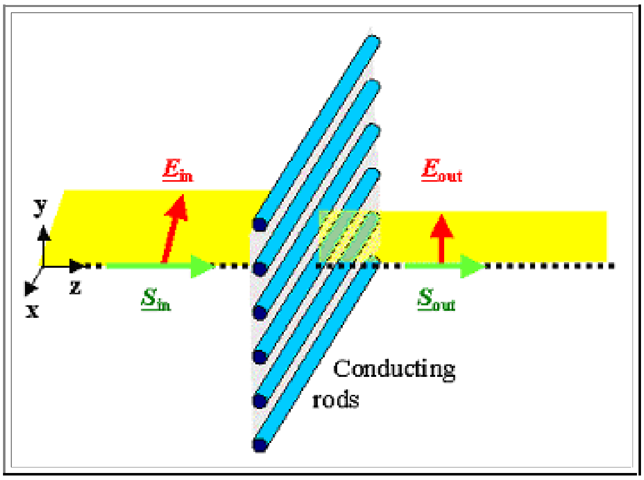
$$n^*(\omega) \;=\; n + i\,\kappa$$

$$n^2 = \frac{1}{2}\left(\left(\epsilon'^2 + \epsilon''^2\right)^{1/2} + \epsilon'\right)$$

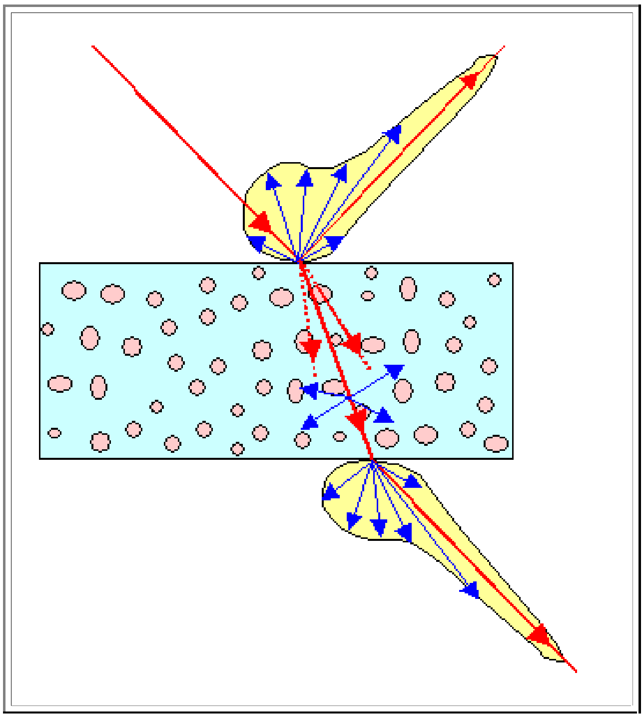
$$\kappa^2 = \frac{1}{2}\left(\left(\epsilon'^2 + \epsilon''^2\right)^{1/2} - \epsilon'\right)$$

- The imaginary part κ describes the attenuation (damping) of the transmitted wave in the material.

- **Polarization and Material**2. How to polarize a light beam
  - **1. Geometry**. Use Fresnel equations to produce a polarzed beam under specific angles ("Brewsater angle")
  - **1. Polarization foils** = alined conducting rods (of possibly molecular size) "short-circuiting" the electrical field in on direction.
  - **3. "Tensor" materials** with optical anisotropy
- Theory can an get rather involved; products can be extremely simple and cheap (e.g. circular polarizer in 3-D movie glasses)



- **Not so perfect materials** and properties like specular and diffuse Reflection, transparency, Translucency, Opacity.
  - Light is scattered at small things in all directions and the scattering of light is the major topic encountered if we look at not-so-perfect materials
  - The picture illustrates:
    Specular and diffuse reflection at the surface.
    Scattering of the transmitted light (running in different directions) at defects or imperfections contained in the material (fat droplets in milk, air bubbles in glass, ...).
    Specular and diffuse reflection at the internal surface the light is coming out off. This is described by a (different) polar diagram characterizing this surface.
- Scatter mechanism depend on the size l_{sca} of the scatterer" relative to the wavelength:
  $l_{sca} << \lambda$: The extreme case would be scattering at single atoms or molecules. Proper **nanoparticles** also belong into this group. This kind of scattering is called **Rayleigh scattering**
  $l_{sca} >> \lambda$: No problem, we covered that already. Just look at any part of the sample by itself.
  $l_{mat} \approx \lambda$: Now we have a problem. What will happen in this case is difficult to deal with and no general rules apply. This kind of scattering is called **Mie scattering**



- **Generating Light**
  Two basic cases:
  - Light from **hot bodies**. Planck radiation law applies. Efficiency tends to be low
- Light from **"cold" bodies** or luminescence
  - There are many types of cold light production. Of utmost importance is electroluminescence or, to use another word for essentially the same thing, radiant electron - hole recombination in semiconductors.
    In yet other words: It's the LED, the **light emitting diode.**.

Luminescence:	**General name for "cold" light production**
Fluorescence:	**Light production shortly after energy input. Short life time of excited level (< µs)**
Phosphorescence:	**Light production long after energy input. Long life time of excited level (> ms)**

Specialities

- Forget it. The list names some, there are many more.

That's where serious "optics and material" starts. This would need another full lecture course

- **Fresnel Lens**
- **Optical Activity**
- **Faraday effect**
- **Kerr Effect**
- **Pockels Effect**