5.1.5 Summary to: 5.1 Optics

Know your numbers and relations for visible light!

- Wavelengths: $\lambda \approx$ **400 nm - 800 nm.**

  $\lambda_{mat} = \lambda_0/n$.

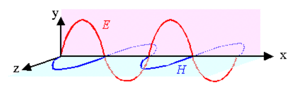
- Frequency: $\nu \approx$ **10^{15} Hz**.
- Index of refraction: $n = \epsilon_r^{1/2} \approx$ **1,5 - 2,5**
- Energy $E \approx$ **1,8 eV - 3,2 eV**.
- Dispersion relation: $c_0 = \nu \lambda_0 = 3 \cdot 10^8$ m/s
  $c_{Mat} = \nu \lambda_0/n(\lambda)$

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

Snellius law:
***n* = sinα/sinβ** with α, β the angle of incidence
or propagation, resp.

Know yout basic equations and terminology

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

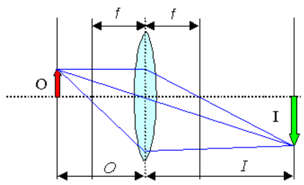


Coherent monochromatic plane wave
E and ***H*** perpendicular and in phase

- **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

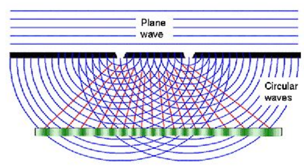
- Focal length ***f*** and
  numerical aperture **NA** of lenses, mirrors.
- Image formation by simple geometric constration
- Various aberrations (spherical. chromatic, astigmatism, coma, ...) limit performance.



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 $\underline{E}$, magnetic field $\underline{H}$ and **Poynting vector** (energy flow vector) $\underline{S} = \underline{E} \times \underline{H}$

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

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

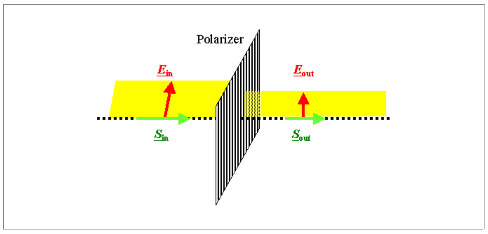
$$[W_{elect;\ magn}] = [\mathrm{Ws\ m^{-3}}]$$

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

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

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



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

Questionaire
Multiple Choice questions to all of 5.1