Session 3

Exercise 1: Absorption

a) How deep does an electromagnetic wave penetrate into a material with a complex refractive index $n_{Silicon}(633\ nm) = n_r + jn_i = 3.8736 + j0.0157$ until eighty percent of its intensity (irradiance) is absorbed?

b) How much of the intensity is absorbed at a distance of 40 nm?

Hints: Derive the propagation depth for the wanted absorption from the squared harmonic plane wave model of an electric field and the absorption coefficient given in the course material.

Exercise 2: Waves in metals

Give reasons why the visual protector of an astronaut's helmet visor is covered with a metal coating?

Hints: Analyse the reflectance of metals shown in the course material.

Exercise 3: Conservation of energy

Show that the conservation of energy does not hold for amplitudes but for intensities.

Hints: Assume an incident electric field of unit amplitude and declare the situation to be representative for an electromagnetic field as the energy is distributed equally on the electric and magnetic field. Then derive the reflected and transmitted amplitude from the Fresnel coefficients for an interface of your choice and show that the sum does not yield the incident amplitude, i.e. $A_r + A_t \neq A_i = 1$. Second, derive the intensity from the squared amplitudes and show that the reflected and transmitted intensities in Watts per square meter sum up to the incident intensity. The expressions for reflected and transmitted intensity can be taken from the course material.

Exercise 4: Fabry-Perot resonator

a) Derive the reflectance of a Fabry-Perot resonator from the infinite sum of reflected amplitudes.

b) Show that $\mathcal{R} = 1 - \mathcal{T}$, if $\mathcal{A} = 0$.

Hints: Script module 3 pages 30-33.

Exercise 5: Anti reflection coating

An electromagnetic wave penetrates from air $n_{air} = 1 + j0$ into Silicon with a complex refractive index $n_{Si}(633\ nm) = 3.8736 + j0.0157$.

a) What percentage of the intensity is reflected and transmitted?

b) What is the refractive index $n_{ARC}(0°)$ for an anti-reflection coating for vertical incidence?

c) Give the function of the anti-reflection coating refractive index n_{ARC} in terms of the angle of incidence θ , $n_{ARC}(\theta)$.

Hints: Script module 3 pages 40-42.