Fundamentals of Optical Sciences

WS 2017/2018 **3. Exercise sheet** **01.11.2017**

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Deliver your answers on 08.11.2017; discussed in the exercise on 13.11.2017.

Problem 1: Polarization

a) Consider a plane wave

$$\mathbf{E}(x) = \hat{e}E_0 exp(-ikx + i\omega t) \tag{1}$$

where $\hat{e}$ describes the polarization of the wave. What are the possible states of polarization for the wave? Elements to control the polarization state are optical wave plates. (i) How does such a waveplate work? (ii) Describe the general transformation of the linear polarization of a plane wave after passing through a quarter wave plate!

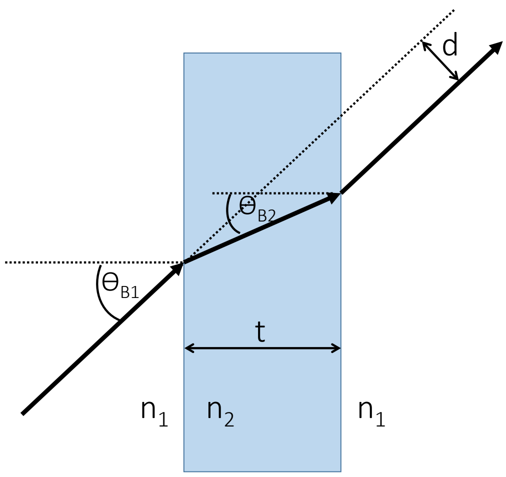
b) An elegant formalism to describe the modification of the polarization of light beams by optical devices is the "Jones calculus". In this formalism, the polarization state is represented by a two-dimensional vector (Jones vector) and the modification of the state is described by 2x2 matrices (Jones matrices). Consider a beam of linearly polarized light passing subsequently through two ideal linear polarizers. A polarizer is an optical filter that passes light with a component along its transmission axis. The angle between the polarizers is 30°. The Jones matrix of a linear polarizer with an angle of α with respect to the x axis is

$$M_{\mathrm{LP}}^{(\mathrm{J})} = \begin{pmatrix} \cos^2\alpha & \sin\alpha\cos\alpha \\ \sin\alpha\cos\alpha & \sin^2\alpha \end{pmatrix}.$$

The angle between the light polarization and the transmission axis of the first polarizer is 15°. Calculate the Jones vector after passing both polarizers.

Problem 2: Refraction

Consider a planar plate made from an isotropic dielectric medium placed in a surrounding medium with a smaller refractive index. A light beam passes this plate, hitting the plate under the Brewster angle Θ_{B1} (see figure).
How large is the beam offset d after a transmission through a standard microscopy slide with n_1=1, n_2=1.5 and a thickness of t=170 μm when entering under the Brewster angle?



Problem 3: Filter

One way of making a cheap but good polarizer (except for wavefront distortion) is to use a stack of microscope slides. Assuming an index of refraction $n = 1.52$ and that the slides are all oriented at Brewster‘s angle with respect to a randomly polarized laser beam, how many slides does it take to attenuate one polarization by a factor of 10^{-4} in intensity compared to the other? Keep in mind that both sides of each slide are at Brewsters angle. Ignore multiple reflections in your calculation.

Problem 4: ABCD method for Gaussian beam

A Gaussian beam of waist spot size w_0 is passed through a solid plate of transparent material of thickness d and refractive index n impinging normal to the plate's surface. The plate is mounted in air ($n_{air} \approx 1$) and is placed just in front of the beam waist. Using the ABCD law of Gaussian beam propagation where the beam (i) enters the plate, (ii) propagates inside the plate, and (iii) leaves the plate. Is the cone half angle changed after the plate with respect to free beam propagation without a plate? What are the wave front radii in both situations (with and without plate)?