Dr. Boris Narozhny, Institut für Theorie der Kondensierten Materie (TKM), narozhny@tkm.uni-karlsruhe.de
Dr. Panagiotis Kotetes, Institut für Theoretische Festkörperphysik (TFP), panagiotis.kotetes@kit.edu

THEORETICAL OPTICS: EXERCISE SHEET 4

Announcement date: 12.05.2013 – Tutorials' date: 16.05.2013 and 17.05.2013

1. Polarization of a transmitted extraordinary wave

Consider the refraction of electromagnetic waves on a surface separating vacuum from an optically uni-axial dielectric depicted below:

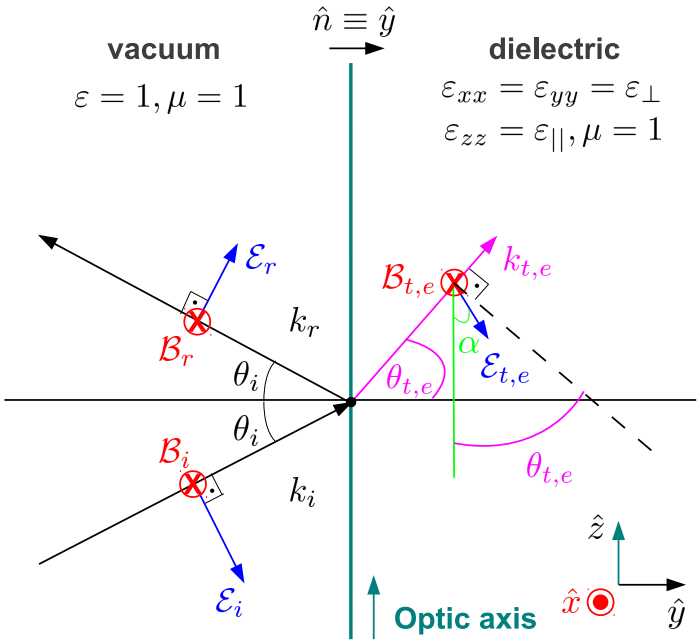

FIG. 1: Refraction of an electromagnetic wave $\boldsymbol{\mathcal{E}}_i$ incident to the surface separating vacuum from an optically uni-axial dielectric. The polarization of the incident electric field, the wave-vectors $\boldsymbol{k}_{i,r,t}$ and the optic axis lie in the yz-plane.

a. Retrieve $k_{t,e}$ and $\theta_{t,e}$ by matching the wave-vectors oriented tangential to the refraction surface. (6 points)

b. Calculate the angle α which defines the polarization of the transmitted electric field of the extraordinary ray. (6 points)

2. Optically uni-axial crystals as polarization converters

Consider an electromagnetic wave normally incident to a surface separating vacuum from an optically uni-axial dielectric, depicted in Fig. (2). The incident electromagnetic wave is generated by two orthogonally polarized Nd:Yag laser beams emitted at 1064 nm.

a. Determine the polarization of the electric field in the dielectric for the ordinary and extraordinary waves. (6 points)

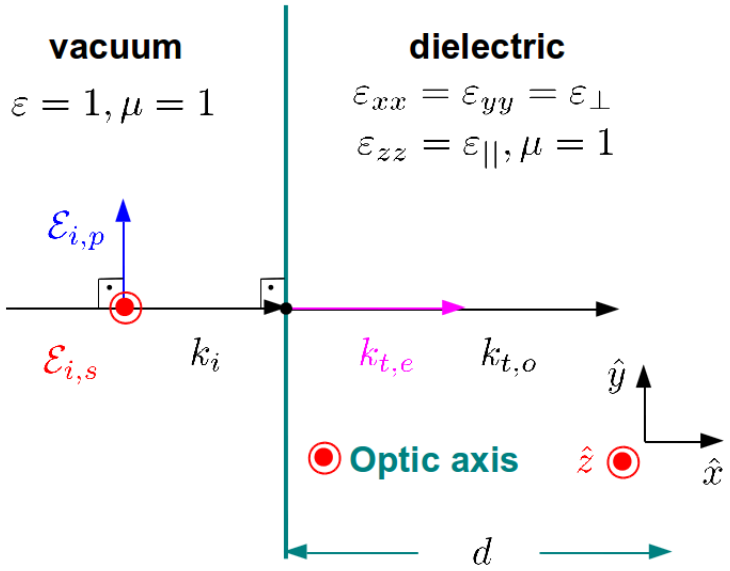

FIG. 2: Refraction of an electromagnetic wave normally incident to the surface separating vacuum from an optically uni-axial dielectric. The incident beam consists of two orthogonal polarizations $\boldsymbol{\mathcal{E}}_{i,p}||\hat{\boldsymbol{y}}$ and $\boldsymbol{\mathcal{E}}_{i,s}||\hat{\boldsymbol{z}}$. The optic axis is parallel to $\boldsymbol{\mathcal{E}}_{i,s}$.

b. Determine the ratio $|\boldsymbol{\mathcal{E}}_{i,s}|/|\boldsymbol{\mathcal{E}}_{i,p}|$ so that $|\boldsymbol{\mathcal{E}}_{t,e}| = |\boldsymbol{\mathcal{E}}_{t,o}|$. (6 points)

c. Assume that the incident wave in the complex representation has the form

$$\boldsymbol{\mathcal{E}}_{i,p}(\boldsymbol{r},t) = \mathcal{E}_{i,p} e^{i(k_i x - \omega t)} \hat{\boldsymbol{y}} \qquad \text{and} \qquad \boldsymbol{\mathcal{E}}_{i,s}(\boldsymbol{r},t) = \mathcal{E}_{i,s} e^{i(k_i x - \omega t + \pi/4)} \hat{\boldsymbol{z}}\,, \tag{1}$$

with a ratio $|\boldsymbol{\mathcal{E}}_{i,s}|/|\boldsymbol{\mathcal{E}}_{i,p}|$ leading to $|\boldsymbol{\mathcal{E}}_{t,e}| = |\boldsymbol{\mathcal{E}}_{t,o}|$. Determine the planes $x = d$ for which the total electromagnetic wave in the dielectric becomes circularly polarized. Consider that $n_o = 1.8$ and $n_e = 2.0$. (6 points)