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WS 2022/2023

Series 11

Fundamentals of Modern Optics

to be returned on **26.01.2023**, at the beginning of the lecture

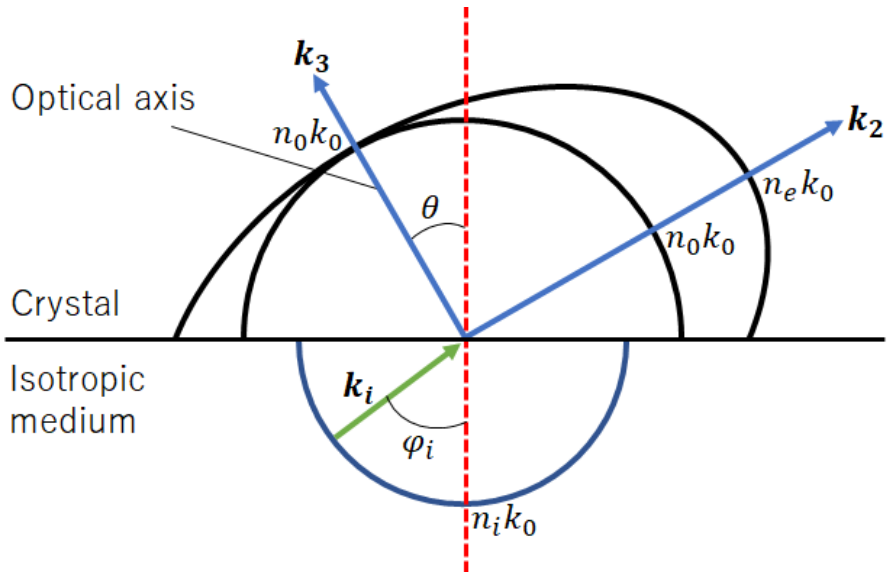
Task 1: Ewald construction (2+2+2 points)

Consider the interface between an isotropic medium (refractive index n_i) and a uniaxial crystal (ordinary and extraordinary refractive indices n_o and n_e, respectively) as shown in the figure below. A plane wave is incident on the crystal at an angle φ_i to the surface normal. The optical axis of the crystal ($\mathbf{k_3}$) and the surface normal form an angle θ.

a) Draw in the figure the wave vectors of the refracted ordinary wave $\mathbf{k_o}$ and the refracted extraordinary wave $\mathbf{k_e}$ for unpolarized incident light.

b) Draw the corresponding Poynting vectors $\mathbf{S}_\mathrm{o}$ and $\mathbf{S}_\mathrm{e}$. Are they parallel to their respective wave vectors? Are they parallel to each other? If not, what are the consequences?

c) Draw the electric displacement fields $\mathbf{D}_\mathrm{o}$ and $\mathbf{D}_\mathrm{e}$.



Task 2: Birefringence in anisotropic media (2+2+3+2* points)

One of the most fascinating phenomena related to the light propagation in anisotropic media is birefringence when the ordinary and extraordinary waves can become spatially separated upon propagation in the crystal. The reason for this effect is the fact that the beam propagation direction (i.e. the direction of Poynting vector) and the direction of wavevector (i.e. the direction of normal to the wavefront) are in general different.

Consider that we have a transparent, uniaxial crystal with the ordinary refractive index n_o and the extraordinary index n_e, the optical axis of the crystal is oriented along **c**. The angle between the optical axis and wavevector **k** is α.

a) Derive and explain why the angle between Poynting vector **S** and wavevector **k** is equal to the angle between electric flux density vector **D** and electric field vector **E**.

b) What is the angle between Poynting vector $\mathbf{S}_\mathrm{o}$ and wavevector $\mathbf{k}_\mathrm{o}$ for the ordinary wave? Sketch $\mathbf{S}_\mathrm{o}$, $\mathbf{k}_\mathrm{o}$ and the field vectors $\mathbf{E}_\mathrm{o}$, $\mathbf{D}_\mathrm{o}$.

c) What is the angle between the Poynting vector $\mathbf{S}_\mathrm{e}$ and the wavevector $\mathbf{k}_\mathrm{e}$ for the extraordinary wave. Sketch $\mathbf{S}_\mathrm{e}$, $\mathbf{k}_\mathrm{e}$ and the field vectors $\mathbf{E}_\mathrm{e}$, $\mathbf{D}_\mathrm{e}$.

d*) Find the expression for α that gives the maximum angle between the Poynting vector $\mathbf{S}_\mathrm{e}$ and wavevector $\mathbf{k}_\mathrm{e}$ for the extraordinary wave. Calculate the value of it for $n_\mathrm{o} = 2.4$, $n_\mathrm{e} = 2.7$.