Problem Set 9
Nonlinear Optics (NLO)

Due: July 11, 2017, 09:45 AM

1) Second-harmonic generation in a Beta Barium Borate (BBO) crystal

In this tutorial, second harmonic generation (SHG) using femtosecond laser pulses will be discussed. A mathematical program (for example MATLAB or Mathematica) is required for evaluation and visualization of the equations. For KIT students, MATLAB can be downloaded for free. The SCC provides a guide for the installation that can be accessed here: https://www.scc.kit.edu/downloads/sca/Matlab-Aktivierung-Studierende-v1.1.pdf. The guide is available in German only, but it has instructive pictures.

A titanium sapphire (Ti:Sa) laser creates 30 fs pulses with an average power of 2 W at a repetition rate of 100 MHz. Although the average power seems to be deceptively low, the peak power level that is reached by this laser amounts to 0.6 MW. The wavelength can be tuned in the range between 700 nm and 1000 nm. The laser is focussed on a birefringent crystal for an efficient generation of SHG pulses that have various applications in chemistry, semiconductor physics, and life sciences.

Beta Barium Borate (BBO), β-BaB_2O_4, is a uniaxial crystal that is often used for frequency doubling applications. For wavelengths λ emitted by the Ti:Sa laser, the ordinary refractive index n_o as well as the extraordinary refractive index n_e of BBO are given by the following empirical equations (for λ expressed in µm, valid in the range from 0.22 µm to 1.06 µm):

$$n_o^2(\lambda) = 2.7359 + \frac{0.01878}{\lambda^2 - 0.01822} - 0.01354\lambda^2$$
$$n_e^2(\lambda) = 2.3753 + \frac{0.01224}{\lambda^2 - 0.01667} - 0.01516\lambda^2. \quad (1)$$

1. Plot n_o and n_e as functions of wavelength in the range between 0.3 µm and 1 µm, and comment whether BBO is a positive or a negative uniaxial crystal.
2. What is the phase matching condition required for an efficient SHG? Is SHG in the given wavelength range possible without using critical phase matching or thermal tuning?
3. Assuming critical phase matching of type-1, is SHG possible in the whole wavelength range? Calculate and plot the phase matching angle for type-1 phase matching for all accessible wavelengths.
4. Plot the wavelength dependence of the walk-off angle between the *k*-vector and the Poynting vector of the SHG wave.

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