Universität Hamburg
Physics Department

Ultrafast Optical Physics II
SoSe 2019

Problem Set 8

Issued: June 21, 2019. Due: June 28, 2019.

Problem 8.1: Phase matching for sum frequency generation (15 points)

Explain why processes such as sum frequency generation can be efficient only if the phase-matching relation $\Delta k = 0$ is satisfied, whereas no such requirement occurs for the case of self-phase modulation. Please ***elaborate your answer with necessary background theory***.

Problem 8.2: Sum frequency generation and non-linear crystals (35 points)

Two incident waves with frequencies at ω_1 and ω_2 are focused into a BBO crystal to generate light in their sum frequency $\omega_3 = \omega_1 + \omega_2$. General case for phase matching condition is given by:

$$\overrightarrow{k_1} + \overrightarrow{k_2} = \overrightarrow{k_3}$$

where $\overrightarrow{k_1},\ \overrightarrow{k_2}\ and\ \overrightarrow{k_3}$ are the wavevectors of the 3 photons at the frequencies $\omega_1, \omega_2\ and\ \omega_3$ respectively.

a) For a ***collinear type I o-o-e mixing*** configuration in a BBO crystal, derive the specific phase matching conditions.
If one uses incident light at fundamental wavelengths at $\lambda_1 = 808\ nm\ and\ \lambda_2 = 1030\ nm$ (i.e. $\lambda = 2\pi/c$) to generate sum frequency signal with these conditions, what should be the corresponding cut angle θ of the BBO crystal?

b) Investigate whether it is possible to achieve ***type II sum frequency generation*** using the same fundamental wavelengths at $\lambda_1 = 808\ nm\ and\ \lambda_2 = 1030\ nm$ in a BBO crystal.
If it is possible, indicate the mixing configuration and corresponding phase matching angle in the crystal.

Hints: for a uniaxial crystal (i.e. BBO), the refractive index of the extraordinary wave $n(\theta, \omega)$ depends on the angle θ between the direction of the wave and the optic axis of the crystal:

$$\frac{1}{n^2(\theta,\omega)} = \frac{\cos^2\theta}{n_o^2(\omega)} + \frac{\sin^2\theta}{n_e^2(\omega)}$$

where $n_o\ and\ n_e$ are the principal values of the refractive indices for the ordinary and extraordinary beams respectively in the plane normal to the optic axis of the uniaxial crystal. For BBO, Sellmeier Equations for $n_o\ and\ n_e$ are given as (wavelength λ in μm):

$$n_o^2 = 2.7405 + \left[\frac{0.0184}{\lambda^2 - 0.0179}\right] - 0.0155\ \lambda^2$$

$$n_e^2 = 2.3730 + \left[\frac{0.0128}{\lambda^2 - 0.0156}\right] - 0.0044\ \lambda^2$$