PHYS2202 Nonlinear Optics

Problem Set 7

Due at 17:00 Wednesday, May 27, 2020

1. (20 points) **Nonlinear crystal orientation and length**
   Suppose that you have a pulsed Ti:sapphire laser system producing 100 fs pulses at 800 nm wavelength and you would like to generate terahertz pulses at ∼20 THz (15 μm wavelength). As a first step, you will convert the Ti:sapphire output to signal and idler beams in the infrared (frequencies ω_s and ω_i), which you will then mix in an appropriate nonlinear crystal (e.g., GaSe) to generate the terahertz radiation by difference frequency mixing $\omega_s - \omega_i = \omega_{\mathrm{THz}}$.

   You need to purchase a β-BBO (BBO=BaB_2O_4, barium borate, symmetry group: $3m$) crystal to convert the 800 nm light to the infrared. Suppose that your laser source produces pulses of 800 nm light in a TEM_{00} spatial mode with an energy of 20 μJ.

   Explain which type of phase matching (Type I or II) you should use to realize the most efficient conversion of the 800 nm light, and then explain the orientation, length, and cross section of the BBO crystal.

The following are some relevant parameters for BBO:

1. Wavelength dispersion of the refractive indices:

$$\begin{aligned} n_o^2 &= 2.7405 + \frac{0.0184}{\lambda^2 - 0.0179} - 0.0155\lambda^2 \\ n_E^2 &= 2.3730 + \frac{0.0128}{\lambda^2 - 0.0156} - 0.0044\lambda^2, \end{aligned} \tag{1}$$

   where λ is in μm.

2. Effective nonlinearity[1]:

$$\begin{aligned} d_{\mathrm{ooe}} &= d_{31}\sin\theta - d_{22}\cos\theta\sin 3\phi \\ d_{\mathrm{eoe}} &= d_{\mathrm{oee}} = d_{22}\cos^2\theta\cos 3\phi \\ d_{22} &= \pm(2.22 \pm 0.09)\ \mathrm{pm/V} \\ d_{31} &= \pm(0.16 \pm 0.08)\ \mathrm{pm/V} \end{aligned} \tag{2}$$

3. Angular acceptance at 800 nm ∼0.8 mrad cm.

4. Damage threshold for 1 ps pulses at 1064 nm ∼50 GW/cm^2. Suppose that the damage threshold for 100 fs, 800 nm pulses is the same.