University of Hamburg, Department of Physics

Nonlinear Optics

Kärtner/Mücke, WiSe 2017/2018

Problem Set 4

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Tunable Radiation in the visible and ultra-violet spectral region

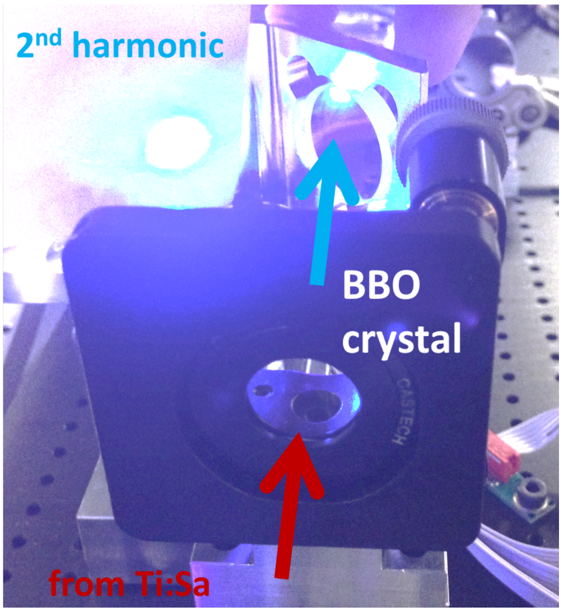

Figure 1: Frequency doubling of a Ti:Sapphire laser beam in a BBO crystal.

Modern solid-state lasers allow for the generation of a vast variety of different wavelengths. For example, the Ti:Sapphire laser covers 700 - 1000 nm of tunable radiation. With modern modelocking techniques, these lasers generate shorter than 30 fs duration pulses with up to 2 W average power at a pulse repetition rate of 100 MHz.The corresponding peak intensities will reach 0.6 MW. These high powers enable the generation of ultrashort pulses in the rage from 350 nm to 500 nm by frequency doubling. Here you should design the frequency doubling stage for an ultrashort laser pulse from a Ti:Sapphire Laser. Ultrashort pulse lasers in the visible and UV are important for photo-biological processes and semiconductor spectroscopy (z.B. GaN) as well as pump source for broadband OPA (optical broadband amplifier) in the visible spectrum that generate even broader spectra ans shorter pulses. In the following we use β-Barium-Borat (BBO) for the frequency doubling process.

1. Which phase matching technique would you implement for frequency doubling? Which waist size will be necessary. What will be the ordinary or extraordinary beam and which crystal orientation would you use? The aim is to phase match the spectrum completely from the long down to the short wavelength part.
2. Compute the phase matching angle for frequency doubling of waves in the range 700-1000 nm. Plot the phase matching angle as a function of wavelength.
3. Choose the crystal orientation in a way that the effective nonlinear optical coefficient d_{eff} is maximum. Plot d_{eff} as a function of wavelength of the doubled light. (Use that d_{11} is much larger than all other coefficients.)
4. Compute an expression for the "walk-off "-angle as a function of wavelength of the doubled light, assuming type I phase matching.
5. Derive an expression for the bandwidth of the frequency doubling. Plot the bandwidth in units [bandwidth*crystal length] as a function of the wavelength of the input light.
6. Frequency double 30 fs,800nm sech function shaped pulses. Derive an expression for the upper limit of the length of the doubler crystal.
   (Hint: for a given pulse duration , there is a minimum possible bandwidth,i.e Fourier limit.)

BBO is a negative uniaxial crystal with refractive indices:

$$n_o^2 = 2.7359 + \frac{0.01878}{\lambda^2 - 0.01822} - 0.01354\lambda^2 \tag{1}$$

$$n_e^2 = 2.3753 + \frac{0.01224}{\lambda^2 - 0.01667} - 0.01516\lambda^2 \tag{2}$$