University of Calgary
Fall semester 2008

PHYS 673: Quantum and Nonlinear Optics

Homework assignment 2

Due October 7, 2008

Problem 2.1. You need to generate second harmonic of continuous-wave laser light at wavelength $\lambda = 1064$ nm in a beta barium borate (BBO) crystal of length $L = 5$ mm cut for optimal phase matching. Use the data from Wikipedia to answer the following questions.

a) At which angle to the optical axis should the beam propagate to achieve phase matching?

b) Which wave (fundamental or second harmonic) is ordinary, which extraordinary?

c) Find the FWHM of the phase matching band (in units of wavelength).

d) Find the acceptance angle.

e) Find the walk-off angle for both waves.

f) The power of the fundamental beam is $P = 100$ mW. Estimate the power of generated second harmonic assuming optimal beam geometry.

Problem 2.2. You need to generate second harmonic of continuous-wave laser light at wavelength $\lambda = 1064$ nm in a periodically poled potassium titanyl phosphate (PPKTP) crystal of length $L = 5$ mm. Light propagates along the x axis and is polarized along the z axis. Find the necessary information about the crystal on the Internet and answer the following questions.

a) What is the poling period required for phase matching?

b) Find the FWHM of the phase matching band.

c) The power of the fundamental beam is $P = 100$ mW. Find the power of generated second harmonic assuming optimal beam geometry.

Problem 2.3. In class we related the temporal and frequency bandwidth σ_τ and σ_ν with the mutual coherence function $\Gamma(\tau)$ and the cross spectral density $W(\nu)$.

a) Show that for a Gaussian $\Gamma(\tau)$ the product $\sigma_\tau \sigma_\nu$ reach the minimum value $1/4\pi$.

b) The electric field of a single-longitudinal mode laser is well described by $E(t) = A\exp[i(\omega_0 t + \phi(t))]$, where ω_0 is the central laser wavelength, A can be taken as a constant real amplitude, and $\phi(t)$ is a random phase describing a random-walk process. Assuming for $\phi(t+\tau) = \phi(t) + \Delta\phi(\tau)$ a Gaussian probability distribution, given by:

$$f(\Delta\phi) = \frac{1}{\sqrt{4\pi|\tau|/\tau_c}}\exp\left[-\frac{\tau_c\Delta\phi^2}{4|\tau|}\right] \tag{1}$$

where τ_c is the time constant associated to the random walk, show that the autocorrelation function $\Gamma(\tau) =< E(t+\tau)E^*(t) >$ of the electric field is given by:

$$\Gamma(\tau) = \exp(i\omega_0\tau)\exp(-|\tau|/\tau_c). \tag{2}$$

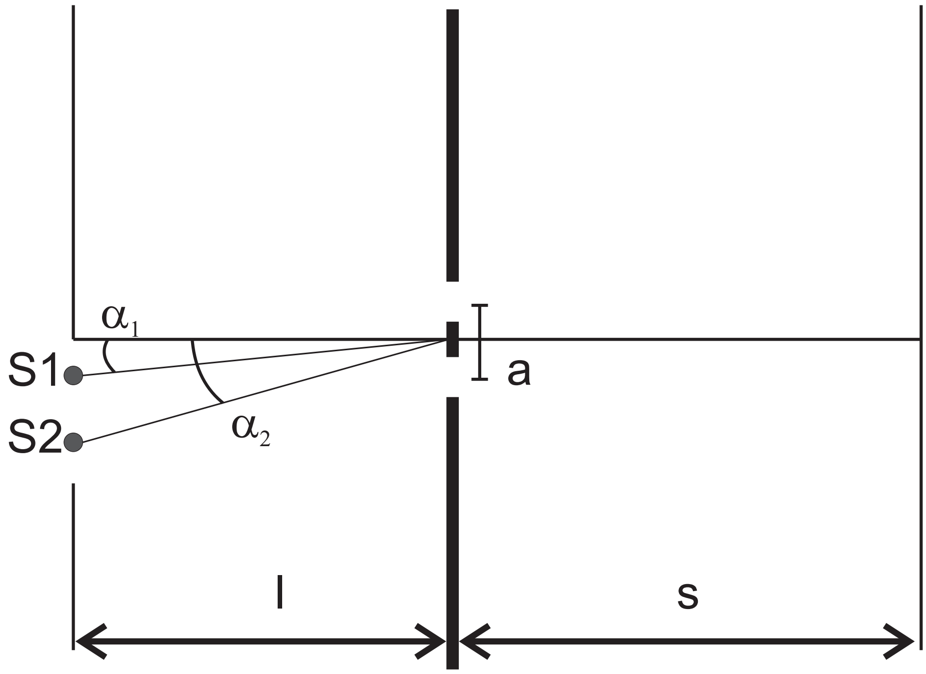
c) Show that the power spectrum $S(\nu) = W(\nu)$ of the laser field is Lorentzian with a FWHM given by $\Delta\nu = 1/\pi\tau_c$.

d) Finally calculate the the product $\sigma_\tau\sigma_\nu$ and show that it is greater than $1/4\pi$.
Hint:

$$\int_0^\infty x^2[1/(1+x^2)]^2 dx = \int_0^\infty [1/(1+x^2)]^2 dx = \pi/4 \tag{3}$$

Problem 2.4. Suppose that we have an incoherent, quasimonochromatic, uniform slit source, such as a discharge lamp with a mask and a filter in front of it. We wish to illuminate a region on an screen 10 m away, such that the absolute value of the complex degree of coherence everywhere within a region 1.0 mm wide is equal or greater to 90% when the wavelength is 500 nm. How wide can the slit be?

Problem 2.5. The Figure shows two incoherent, quasimonochromatic point sources illuminating two pinholes in a mask. Show that the fringes formed on the plane of observation have minimum visibility when $a(\alpha_2 - \alpha_1) = \frac{1}{2}m$ when $m = \pm1, \pm3, \pm5.....$



α_1
S1
S2
α_2
a
l
s