Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.977 Ultrafast Optics

Spring 2005

Problem Set 5

Issued: March 10, 2005. **Due:** March 17, 2005.

Problem 5.1: Pulse Compression in Fibers

Consider the following pulse compression experiment utilizing two pieces of fiber in series. The first fiber is a highly nonlinear fiber and the second fiber is with large negative dispersion. The fiber parameters are following.

Fiber 1: β_2 = 20 $\mathrm{ps}^2/\mathrm{km}$; γ = 60 $\mathrm{W}^{-1}\mathrm{km}^{-1}$; Length = 2.08 m.
Fiber 2: β_2 = -40 $\mathrm{ps}^2/\mathrm{km}$; γ = 3 $\mathrm{W}^{-1}\mathrm{km}^{-1}$; Length = 1.20 m.

where $\beta_2 = 2D_2$ is GVD parameter and $\gamma = \delta/A_{eff}$ is nonlinear coefficient.

Similar to Problem 4.1, we can use the split-step Fourier method to simulate this process. In order to simulate with real parameters, the following NLSE can be used instead of the normalized NLSE:

$$\frac{\partial A}{\partial z} = (\hat{D} + \hat{N})A \tag{1}$$

where

$$\hat{D} = j\frac{\beta_2}{2}\frac{\partial^2}{\partial T^2} \tag{2}$$

and

$$\hat{N} = -j\gamma|A|^2 \tag{3}$$

In addition, A is normalized such that $|A|^2$ represents the optical power in the fiber, T is the retarded time frame, and z is the distance.

The initial pulse is given as:

$$A(t) = \sqrt{P_0}e^{-\frac{t^2}{2T_0^2}} \tag{4}$$

where P_0 = 400 W and T_0=0.6 ps (this is equivalent to T_{FWHM} = 1 ps for Gaussian pulse).

Using a similar program as in Problem 4.1, simulate this pulse compression process.

(a) Plot the pulse amplitude evolution in time domain for each fiber (the initial pulse is entering Fiber 1 first. The output pulse from Fiber 1 is entering Fiber 2).

(b) Plot the pulse amplitude evolution in frequency domain for each fiber (the initial pulse is entering Fiber 1 first. The output pulse from Fiber 1 is entering Fiber 2).

Suggestion: since the pulse width is in the ps range, it may be easier to normalize all the time units in ps and frequency units to THz.

Problem 5.2: Relaxation Oscillations

We consider a continuously operating Ti:sapphire laser at a wavelength of $\lambda_0 = 0.8\,\mu m$, 100 MHz repetition rate, pumped with 5 W power. The laser threshold is 0.5 W. The upper state lifetime of Ti:sapphire is 2.5 μs and a 10% output coupler is used.

(a) Is the relaxation oscillation in this laser over- or under-damped?

(b) What is the relaxation oscillation frequency and the damping rate of the relaxation oscillations as a function of the pump parameter r?

(c) Plot the root locus of the complex relaxation oscillation frequency as a function of the pump parameter. What is the result for the pumping conditions described above?

(d) How much pump power is required to suppress relaxation oscillations?