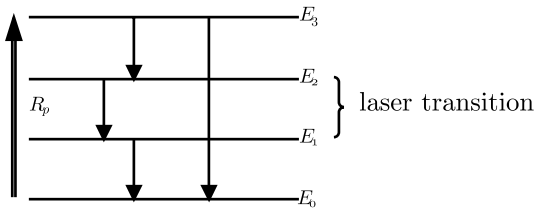
MASSACHUSETTS INSTITUTE of TECHNOLOGY
Department of Electrical Engineering and Computer Science

Problem Set No. 7	*6.637 Optical Signals, Devices and Systems*	Issued Thurs. 3/20/2003
Spring Term, 2003		Due Thurs. 4/3/2003

Reading recommendation: 6.637 Class Notes, Chapter 6; Yariv may be helpful as well.

Problem 7.1

For the ideal four-level system shown below, $E_1 \gg kT$ and the allowed transitions are as shown.



(a) Write down the rate equations for this system in the presence of stimulated coherent radiation for the laser transition shown.

(b) What conditions on the relaxation times would be ideal for optimizing the population inversion?

(c) Using the conditions you chose in (b) and further assuming that $R_P t_{10} \gg \frac{t_{32}}{t_{10}} \gg 1$, derive an expression for the steady-state population inversion in the presence of stimulated coherent radiation for the laser transition shown.

(d) Assume the specified laser transition has a central wavelength of 633nm. Further assume that this atomic system is gaseous and that it is Doppler broadened such that the Doppler broadened line width is $\Delta\nu_D = 1.5 \times 10^9$Hz. Use a computer plotting routine to plot the line shape $g(\nu)$ of this system. Also plot the corresponding $g(\lambda)$ and comment on the difference between the two curves.

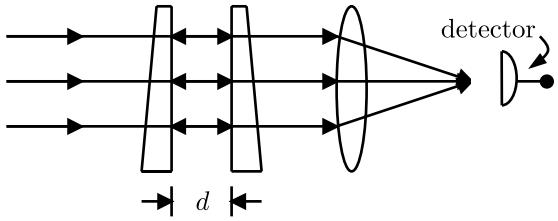
(e) The laser has mirrors with a reflectivity of 98% and the mirrors are 150mm apart. What is the value, m, of the longitudinal mode number for the mode closest to the central wavelength?

(f) Approximately how many longitudinal modes can exist under the gain curve?

(g) What is the line width, $\Delta\nu_m$, of each longitudinal mode?

Problem 7.2

In the scanning Fabry-Perot spectrometer shown below, the gap d between the mirrors is varied, and the intensity of the central spot transmitted through the spectrometer is monitored



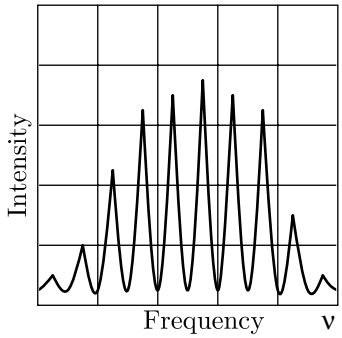
Let λ_m and λ_{m+1} be two adjacent wavelengths for which bright central maxima of order m and $m+1$ respectively occur. The free spectral range of the instrument is defined as the wavelength separation between adjacent maxima; i.e.,

$$\Delta\lambda_{fsr} = \lambda_m - \lambda_{m+1}$$

(a) Derive an expression for the free spectral range. The free spectral range is sometimes more useful when expressed in the frequency domain. Write down the expressions for $\Delta\nu_{fsr}$.

(b) As d is varied, the wavelength of maximum transmittance for a fixed order, m, varies. How much must d be varied to scan through a wavelength range equal to the free spectral range?

(c) These instruments have very high resolving power and are used to measure the fine structure of spectral lines. If you were given the task of designing a scanning Fabry-Perot spectrometer to analyze the structure of the spectrum shown below, how large would you make d, and what reflectivity would you choose for the mirrors? Show clearly your reasoning.



Each frequency division is 100MHz wide and the overall spectral bandwidth is 500MHz