Phys 532 Assignment 6 Due February 28

1. In a HeNe laser, the gain medium is a low pressure mixture of helium and neon gases. Lasing occurs on a neon atomic transition near $\lambda = 633$ nm. At room temperature (300 K), the transition is Doppler broadened, so the laser can operate in several longitudinal modes simultaneously. Suppose a laser has a cavity of length 30 cm and a total loss per pass of 1%. At the peak of the Doppler profile, the small signal gain per pass is $g_0 = 4\%$. How many modes can be expected to oscillate? You can assume that the homogeneous linewidth is small compared to the mode spacing.

2. A medium with a population inversion can be used to amplify an existing laser beam. Suppose your gain medium is a solution of dye molecules in water, with a concentration 10^{18} cm^{-3}, contained in a cell of length $\ell = 1$ cm. (Water has an index of refraction $n = 1.33$.) The dye molecules are an ideal four-level system, where the $1 \leftrightarrow 2$ transition has a vacuum wavelength $\lambda = 670$ nm, a radiative lifetime $t_s = 20$ ns, a total linewidth of 1 GHz, and a saturation intensity of 10 mW/cm^2. The total decay rate from 1 to 2 is $1/t_s$, and the decay rate from 1 to 0 is $\Gamma_1 = 1 \times 10^{10}$ s^{-1}. You may assume all levels to be equally degenerate.

The dye is optically pumped with uniform illumination by light at 514 nm, for which the absorbtion coefficient is $\alpha_{03} = 1$ cm^{-1}. What intensity of pump light is required to amplify an input beam of intensity 10 μW/cm^2 by a factor of 10? (Note that for large gains, you should use $I_{\text{out}} = I_{\text{in}} e^{\gamma \ell}$.)

822 students only:

3. In the previous problem, what pump intensity is required to achieve 10× amplification if the input intensity is 2 mW/cm^2? Here saturation causes the effective gain to decrease as the beam is amplified. To account for this, you will need to set up and solve a differential equation for the intensity as a function of propagation distance $I(z)$.