PHYS 5130, Homework Set 3, due at 5 pm on Thursday, March 24th.

1. A HeNe laser is 15 cm long ($L = d$ for this case). The absorption coefficient at the main lasing transition is 10^{-13} cm^2. We estimate losses in the entire system to be 10%.

(a). (10 points) What is ΔN, where $\Delta N > N_{\text{threshold}}$ is the population inversion?

(b). (10 points) If the neon gas pressure is 0.3 mbar and the gas temperature is 25°C, what fraction of the total *density* of neon atoms in the laser is ΔN?

2. (15 points) Calculate the gain constant of a hypothetical laser have the following parameters: $N_2 - N_1 = 10^{18}$ cm^{-3}, wavelength = 800 nm, linewidth = 1 nm, spontaneous emission lifetime = 10^{-4} seconds. Remember that you need to use the relation for A_{21} (spontaneous emission rate; in s^{-1}) to B_{21}.

3. Schawlow-Townes Formula:

(a). (10 points) What is the Schawlow-Townes limit to the laser frequency width for a HeNe laser operating at 632.8 nm with an output power of 1 mW and a cavity mode width of 4.7×10^5 Hz?

(b). (10 points) What is the Schawlow-Townes limit to the laser frequency width for a semiconductor laser operating at 850 nm with an output power of 3 mW, cavity length of 300 μm, index of refraction of 3.5, and a front and back facet reflectivity of 0.3?

4. (15 points) Estimate the frequency drift of a laser oscillating at $\lambda = 500$ nm due to thermal expansion of the resonator for a temperature drift of 1°C when the resonator mirrors are mounted on supports made of (a) invar ($\alpha = 1.2\times10^{-6}$ K^{-1}) and (b) fused quartz ($\alpha = 4\times10^{-7}$ K^{-1}).

5. A laser medium has a Doppler-broadened gain profile HWHM of 2 GHz ($= \delta\nu$) and a central wavelength of 633 nm (main lasing transition of a HeNe laser). The homogenous width is 50 MHz ($= \Delta\nu$), and the transition probability A_{ik} is 1×10^8 s^{-1}. Assume that one of the resonator modes ($L = 40$ cm) is exactly at the

center frequency, ν_0, of the gain profile. Resonator losses are 10%. We want to find (1) the threshold inversion for the central mode and (2) at what level of population inversion does oscillation start on the two adjacent longitudinal modes.

(a). (5 points) What is the spacing (in MHz) of the longitudinal modes?
(b). (10 points) Using the gain curve, what is the relation between N_0 and N_1, where N_0 is the population at ν_0 and N_1 is the population of the adjacent mode?
(c). (10 points) Find $\Delta N_{threshold}$ (answer to part 2).
(d). (5 points) Once a mode surpasses $\Delta N_{threshold}$, oscillation begins. Using your answers in (b) and (c), when $\Delta N_1 = N_{threshold}$, what is ΔN_0, where ΔN_i is the population inversion at N_i (answer to part 1 when adjacent modes are in oscillation)?