HW1 PHYS168 lasers Spring 2012 Prepared by N. Eradat
Due date Feb 8, 2012

- Use references (and cite them) to find the numbers and other information needed.
- Make tables and use spreadsheets whenever necessary to reduce tediousness of the calculations.
- You can use MATLAB or other software for solving a problem if needed however you need to print the code as well as the results. Just results won't give you the credit.

- Some of these numbers will be very important on having a sense about the laser field and magnitude of some quantities.
- Don't think of them as something you do for this HW and will forget about them. They will reappear in many situations so it is good to focus on magnitude of the numbers and develop a feel for them.
- Reference Svelto, Verdeyene, and other laser books as needed with some modifications.

EM spectrum and lasers, Energies, wavelengths, and frequencies, photon flux, rate equations (20 points each)

1. (make a table and use an spreadsheet) The part of the EM spectrum of interest in the laser field starts from the sub-millimeter wave region and decreases in wavelength to the x-ray region. This covers the following regions in succession: far infrared, near infrared, visible, UV, vacuum ultraviolet (WV), soft x-ray, x-ray:
   a) From standard textbooks find the wavelength intervals of these regions. Express them in proper units.
   b) What are these wavelength intervals inside the ND:YAG crystal and BK7 glass (find the index of refraction for these material from the reliable references.
   c) Calculate the corresponding frequency intervals in vacuum.
   d) Calculate the corresponding energy intervals in eV and Joules
   e) Find the wavelength intervals corresponding to the different colors of the visible spectrum, and calculate the corresponding frequency intervals. Memorize the approximate numbers for the center of the red, green and blue.
   f) Find the most common wavelengths (and frequency and energy per photon) of the following lasers. What kind of laser are they? HeNe, Nd:YAG, second harmonic of the Nd:YAG, Nd:YVO4, second harmonic of the Nd:YVO4, Argon ion, Ti: sapphire, CO_2.
2. (make a table) Determine the ratio between the thermal equilibrium population of two levels separated by the energy difference *dE* equal to the following. Assume that the two levels have the same degeneracy and that the temperature is 100 K, 300 K (room temperature) and 1000K.
   a) 1E-4 eV, which is a value eV, equivalent to the spacing of rotational levels for many molecules
   b) 5E-2eV which corresponds to molecular vibrational levels
   c) 3 eV, which is of the order of magnitude of electronic excitation of atoms and molecules.
3. For a system in thermal equilibrium
   a) First calculate the temperature at which the spontaneous and stimulated emission rates are equal for a wavelength of 500 nm.
   b) Next find the wavelength at which these rates are equal at a temperature of 4000 K.
4. Calculate the photon flux of a plane monochromatic wave of intensity I=200 W/m^2 with a wavelength of either 500 nm and 100 micrometer. Interpret the results

5) Temporal evolution of the population densities in a three-level system.

Consider the energy level scheme shown in Fig. 1.1. Atoms are raised from level 0 to level 2 at a pump rate R. The lifetime of levels 1 and 2 are τ_1 and τ_2 respectively. Assuming that the ground state 0 is not depleted to any significant extent and neglecting stimulated emission: (i) write the rate equations for the population densities, N_1 and N_2, of level 1 and 2 respectively; (ii) calculate N_1 and N_2 as a function of time; (iii) plot the population densities in the following two cases: (a) $\tau_1 = 2$ μs, $\tau_2 = 1$ μs; (b) $\tau_1 = 1$ μs, $\tau_2 = 2$ μs. Assume that levels 1 and 2 have the same degeneracy.

[Hint: the differential equation for the population of level 1 i.e. $(dN_1/dt)+(N_1/\tau_1) = f(t)$, can be solved multiplying both sides by the factor $\exp(t/\tau_1)$. In this way the left-hand side of the preceding differential equation becomes a perfect differential]

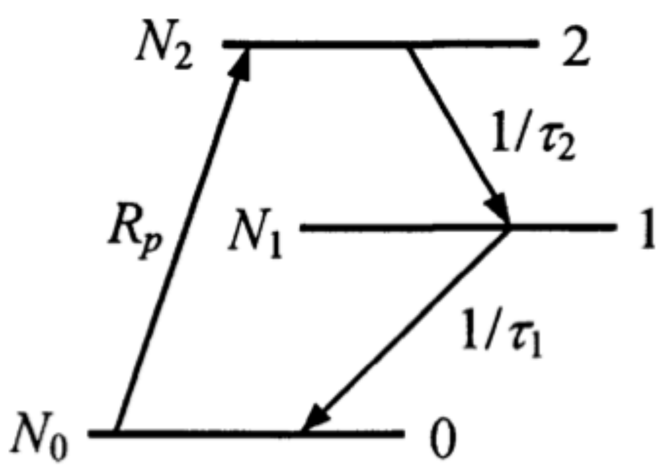

Fig. 1.1 Energy level scheme of the three-level system described in 1.8P