
Laser Physics PHGN480

Midterm - take home: due thursday Nov 6 in class.

Ground rules: open book, open notes. No discussion with others
- ask me if you need clarification. You may use *Mathematica*.

■ problem 1

Two level system in saturation.

Consider an atomic system: the population difference is $\Delta N = N_1 - N_2$ and the total atomic density is $N_t = N_1 + N_2$. At $t = 0$, there is an initial value of $\Delta N(0)$, and an incident beam is turned on that has a frequency that is resonant with the energy difference. Calculate the evolution of the population difference $\Delta N(t)$. Express your result in terms of the saturation intensity. Show all your work.

Comments:

- in your rate equations, include spontaneous emission with a rate A .
- you may assume that the two states have the same level of degeneracy ($g_1 = g_2$).

■ problem 2

Consider a molecule that makes a transition between two rotational levels J' and J'' , while at the same time the vibrational level changes from v' to v'' (the electronic level stay the same).

- a) Calculate an expression for the dipole moment for a dipole transition from the $v'=1, J' = 3$ to the $v''=0, J'' = 2$ levels. You may assume the molecule starts and ends in the $J_z = 0$ sublevel for the purposes of this integral. Note that the wavefunction for the molecule is the product of a spherical harmonic with a constant value of R (for the rotational state), and the simple harmonic wavefunction. For the SHO portion of this problem, you may adapt the calculation shown in Griffiths, example 9.1.
- b) The molecular radius is $R = 2.66$ angstroms, the atomic mass is 127 atomic mass units, and the moment of inertia is $I = m R^2 / 2$. The vibrational frequency is 6.43×10^{12} Hz.
 - Calculate the energy difference between these levels in eV and the corresponding wavelength for the transition.
 - Although there can be transitions among other J_z sublevels (all degenerate in energy), with slightly differing dipole moments, let's assume the dipole moment you calculated in part a works for all of them. Calculate the spontaneous emission rate for the transition between the levels in part a.

■ problem 3

Show that a Gaussian beam that goes through a simple imaging system will be

- a) Calculate the ABCD matrix through this system.
- b) Interpret this system geometrically: what happens to a ray of input height h , and ray angle h' ?
- c) Interpret the effect of this system on a Gaussian beam:
 - How is the output waist and beam radius affected? Consider both cases where:

- > the beam is at a waist at the input, and
 - > the beam is not at a waist at the input
- d) if plane mirrors are placed at the object and image distances to form a resonator, what will be the value of the stability parameter?
 - > Will the cavity be stable, marginally stable, or unstable? Based on the stability parameter, make a sketch of an equivalent two-mirror cavity.