Phys 551 Homework 5

1. Optical dipole trap

Suppose that you want to build an optical dipole trap for Cs atoms with a potential depth of 1 millikelvin using a 10W Nd:YAG laser operating at 1064 nm. What should be the focal spot w_0 of the beam at the dipole trap? If the beam coming out of the laser is collimated with $w_0 =$ 1 mm, what focal length lens would you use to focus the laser beam?

2. EDM measurements with Tl atoms

A beam of Tl atoms had been used to set the most stringent limit on electron electric dipole moment (EDM). The ground state of Tl atom is $6P_{1/2}$ and with nuclear spin I=1/2 it has two hyperfine states, F = 0 and F = 1. In the measurement the atoms are first optically pumped into F = 1, $m_F = 0$ state. The interaction of the atoms in the apparatus can be described by

$$H = (AE^2)F_z^{\ 2} + (dE)\,F_z + \mu B \cdot F$$

Here dE represents the EDM interaction and AE^2 represents the quadrupole interaction with the electric field and μB represents magnetic interaction. The measurement is performed by first applying a magnetic field B_x for a short time τ to put the atoms in a superposition of $m_F = \pm 1$ states, then allowing the atoms to evolve for a time T with B_x=0 and then applying another pulse of magnetic field B_x for time τ to bring the atoms back to $m_F = 0$ state ($\tau \ll T$). Then the number of atoms in $m_F = 0$ state is counted by measuring florescence when they are excited by a laser. For simplicity assume that all terms except μB_x are small compared with T ($TAE^2/\hbar \ll 1$, $TdE/\hbar \ll 1$, $T\mu B_z/\hbar \ll 1$) and B_y=0.

Using density matrix formalism find the evolution of the atoms. What is the optimal pulse time τ? For this value of τ, plot the number of atoms in $m_F = 0$ state after both pulses as a function of B_z assuming that $d = 0$. What is the optimal value of B_z to measure a small d? How sensitive is the measurement to AE^2? Feel free to explore the problem numerically by assigning some numbers to all parameters before deriving general conclusions.