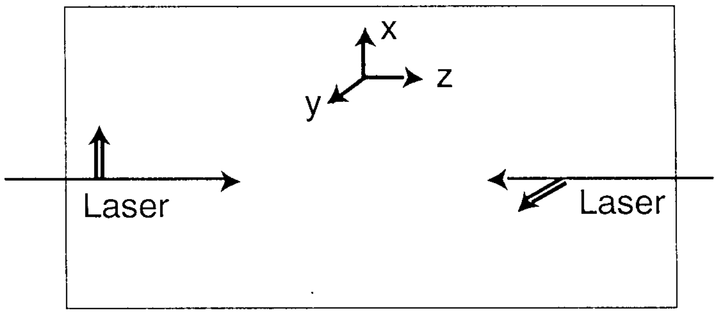
Consider two lasers, each of equal intensity, aimed on a box. The first is aimed in the $+z$ direction and has plane polarization (double line) in the x direction, and the other is aimed in the $-z$ direction and has plane polarization in the y direction. Assume that the lasers both have frequency ω and that the light from each is a plane wave completely uniform in the x, y plane. Thus the total electric field in the box is

$$\vec{E}(x, y, z, t) = (E_x, E_y, E_z) = E_0 \left(\cos(qz - \omega t), \cos(qz + \omega t), 0\right),$$

where E_0 is a constant.



a) What is the probability P_+ that a photon (from the lasers) at point (x, y, z) has angular momentum $+\hbar$ in the $+z$ direction? What is the probability P_- that a photon has angular momentum $-\hbar$ in the $+z$ direction?

Next consider placing a uniform gas of hydrogen atoms in the box. Ignore the motion of the atoms and the spin of the protons, and assume that the electrons remain in their spatial ground state. Assume that the atoms are in a uniform magnetic field B in the z direction, in addition to the laser fields. Call the state in which the electron has spin angular momentum along z equal to $+\hbar/2$ the "up" state, and that in which it is $-\hbar/2$ the "down" state.

b) What are the energies of the up and down states of the atoms in the field in terms of the Bohr magneton, μ_B?

Now assume that the lasers are tuned to a frequency to cause a transition from the down to the up states and vice versa.

c) What must the laser frequency be?

d) At which points in space can the lasers *not* cause a transition from the down to up states, and at which points can they *not* cause a transition from the up to down states?