LASERS

(h= 6.62 x 10^{-34} J.s ; c= 3 x 10^{8} m/s ; k =1.38 x 10^{-23} J/K)

Review: E_2 ——— **(no. of atoms /m^3 = N_2)**

$\lambda = hc / (E_2 - E_1)$ is the wavelength of emitted spectral line

E_1 ——— **(no. of atoms/m^3= N_1)**

$E_2 - E_1 = \Delta E = h\nu = \frac{hc}{\lambda}$ is the energy of the photon

Boltzmann Ratio or the ratio of atomic populations $\frac{N_2}{N_1} = e^{-\left(\frac{hc}{\lambda kT}\right)} = e^{-\left(\frac{\Delta E}{kT}\right)}$

Ratio of stimulated to spontaneous emissions = $R_{21}/R_{12} = \frac{1}{[e^{hc/\lambda kT}-1]}$

Power (J/s or W) $= \frac{Energy}{time}$ **=(no. of photons emitted per sec) . (energy of each photon) = nhc/λ**

Numerical Problems

1. A photon of wavelength 4000Å is emitted when an atom in an excited state transits to ground state. Calculate the energy and momentum of the photon. What is the ratio of populations of the two states at 300 K?
2. The wavelength of a laser is 6000Å. The number of photons emitted in a minute by the laser is 10^{17}. Calculate the power of the laser. If the input power is 1W, what is the fraction of power converted to output?
3. Two energy levels are separated by 1.75 eV. Calculate the ratio of spontaneous to stimulated emission at 400 K.
4. The ratio of populations of two energy states at 300K is 7.5×10^{-32}. Calculate the temperature at which this ratio becomes equal to 0.5.
5. E_1 ——— 2 eV

   E_2 ——— 0 eV

   (a) Calculate the ratio of populations N_2/ N_1 at a temperature of 400 K.
   (b)At what temperature will this ratio be 0.01?
6. The output power of a continuous wave CO_2 laser is 10 kW at a lasing wavelength of 10.6μm. How many photons are emitted per second?
7. The number of photons emitted per sec by a laser source is 3.2×10^{16}. If output power is 10mw, calculate the wavelength of the light emitted. If the laser beam is focused to a spot of diameter 1mm, calculate the intensity of the spot.
8. The ratio of stimulated emission to spontaneous emission is 10^{-34}. What is the ratio of populations? If the difference in temperature corresponds to a wavelength of 6000Å, calculate the temperature.
9. The ratio of population of two energy levels at 300K is 1.059×10^{-30}. Find the number of photons emitted per sec if the ouput power is 4.5mw.
10. Show that at optical frequencies and at room temperature the ratio of stimulated to spontaneous transitions is << 1.
11. Two energy levels are separated by 1.95 eV. At what temperature will the ratio of populations be 10^{-29}? Calculate the ratio of Einstein coefficient.
12. A laser pulse of duration 1 ms has a power of 10 mW. If the number of photons emitted in a pulse are 10^{10} , calculate the wavelength of emitted photon.
13. A pulsed laser emits photons of wavelength 780nm with 20mw average power/pulse. Calculate the number of photons contained in each pulse if the pulse duration is 10ns.
14. Calculate the ratio of stimulated emission to spontaneous emission at 50°C when the excited state is 1.8eV above the ground state. Also calculate the ratio of Einstein coefficients.
15. Find the number of modes of the standing waves in the resonant cavity of length 1m of He-Ne laser operating at a wavelength of 632.8nm.
16. The energy gap of GaAs is 1.4eV. Find the wavelength of the light emitted by GaAs laser.
17. If rate of spontaneous and stimulated emissions are R_1 and R_2, show that the wavelength of emitted spectral line $\lambda = \frac{hc}{kT\left(ln\left(1+\frac{R_1}{R_2}\right)\right)}$