# Numerical Problems on Lasers

Q.1. Find the ratio of populations of the two states in a He-Ne laser that produces light of wavelength 6328 A° at 27°C.

Solⁿ :- Ratio of population is given as

$$\frac{N_2}{N_1} = e^{-(E_2-E_1)/kT}$$

$$E_2 - E_1 = \frac{12400}{6328} \, eV = 1.96 \, eV.$$

$$\frac{N_2}{N_1} = exp\left[\frac{-1.96}{(8.61 \times 10^{-5} \times 300)}\right] = e^{-75.88}$$

$$= 1.1 \times 10^{-33}.$$

Q.2: The wavelength of emission is 6000 A° and the coefficient of spontaneous emission is $10^6$ /s. Determine the coefficient for the stimulated emission?

Solⁿ: The coefficient of stimulated emission is given by

$$B_{21} = \frac{c^3}{8\pi h \nu^3 \mu^3} A_{21}.$$

Substituting $\nu = \frac{c}{\lambda}$ & $\mu = 1$

$$B_{21} = \frac{\lambda^3}{8\pi h} A_{21}$$

$$= \frac{(6000 \times 10^{-10})^3}{8 \times 3.14 \times 6.63 \times 10^{-34}} \times 10^6$$

$$= 1.3 \times 10^{19} \ m/kg.$$

Q.3: At what temperature are the rates of spontaneous & stimulated emission equal.?
Assume $\lambda = 5000\ A^\circ$.

Sol$^n$: If the rates of spontaneous & stimulated emission equal then, $R_1 = \frac{1}{e^{h\nu/kT} - 1} = 1$

$$e^{h\nu/kT} = 2$$

$$\lambda = 5000\ A^\circ \ ; \ \nu = \frac{c}{\lambda} = 6 \times 10^{14}\ Hz.$$

$$\frac{h\nu}{KT} = \left[\frac{6.63 \times 10^{-34} \times 6 \times 10^{14}}{1.38 \times 10^{-23}}\right] = \frac{28.8 \times 10^3 K}{T}$$

$$e^{h\nu/kT} = e\left[\frac{28.8 \times 10^3}{T}\right] = 2.$$

After solving $\Rightarrow T = \frac{28.8 \times 10^3}{\ln 2}$

$\therefore T = 41.558\ K.$

Q.4: The length of a laser tube is 150 mm and the gain factor of the laser material is 0.0005/cm. If one of the cavity mirrors reflects 100% light that is incident on it, what is required reflectance of the other cavity mirrors.

Ans.:

$$\gamma_{th} = \frac{1}{2L} \ln \frac{1}{r_1 r_2}$$

$$r_2 = \frac{1}{r_1 e^{2\gamma L}} = \frac{1}{1 \times e^{2 \times 15 \times 0.0005}}$$

$$r_2 = 0.985$$

$\therefore$ Reflectance $= 98.5\%$.

Page No.: Date: YOUVA

Q5. A laser source is emitting a laser beam with an average power of 4.5 mW. Find the number of photons emitted per sec. by the laser. The wavelength emitted is 6328 A°.

Sol. $P = 4.5\ mW = 4.5 \times 10^{-3}\ W$

$\lambda = 6328\ A^{\circ} = 6328 \times 10^{-10}\ m.$

Energy of a photon $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{6328 \times 10^{-10}}$

$E = 3.14 \times 10^{-19}\ J.$

Energy emitted /s by the laser light. = 4.5 mW

$\therefore$ No. of photons emitted /s $= \frac{4.5 \times 10^{-3}}{3.14 \times 10^{-19}}$

$= 1.43 \times 10^{16}$.

Q.6: A pulsed laser emits photons of wavelength 780 nm with 20 mW average power / pulse. Calculate the number of photons contained in each pulse if pulse duration is 10 ns.

Ans. $\lambda = 780\ nm$

$P = 20\ mW$

$t = 10\ ns = 10^{-8}\ s$

Energy of photons $E = h\nu$

" " n photons $\Rightarrow E = nh\nu$

Also $P = \frac{E}{t} \Rightarrow E = Pt$.

$nh\nu = Pt \Rightarrow \frac{nhc}{\lambda} = Pt$

$n = \frac{P\lambda t}{hc} = \frac{20 \times 10^{-3} \times 780 \times 10^{-9} \times 10^{-8}}{6.63 \times 10^{-34} \times 3 \times 10^{8}}$

$= 784.31 \times 10^{6}$

$= 7.84 \times 10^{8}$ photons.