m → mass]

3. Wavelength of laser light (semi conductor laser)

$$\lambda = \frac{hc}{E_g}$$

4. $$\frac{N_2}{N_1} = e^{-(E_2-E_1)/kT} = e^{-h\nu/kT} = e^{-hc/\lambda kT}$$

Here, $N_2, N_1 \rightarrow$ population in excited & lower energy level.

$(E_2-E_1) \rightarrow$ energy difference between 2 levels.

$k \rightarrow$ Boltzmann constant.

5. $$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3} = \frac{8\pi h}{\lambda^3} \quad \left[\because \lambda = c/\nu\right]$$

6. ~~Here~~ θ_0 = acceptance angle = $\dfrac{\sin^{-1}\sqrt{n_1^2-n_2^2}}{n_0}$

for air, $n_0 = 1$

Here, n_1 & n_2 are refractive index of core and cladding respectively.

7. $$NA = \sqrt{n_1^2-n_2^2} \quad \text{(or)} \quad n_1\sqrt{2\Delta}$$

$$\Delta = \frac{n_1-n_2}{n_1}$$

Energy of

Problems

1. find the wavelength of emitted photons from a GaAs laser diode, which has a band gap of 1.44eV.

<u>Given,</u> $E_g = 1.44\ eV = 1.44 \times 1.6 \times 10^{-19}\ J$

$$\therefore \lambda = \frac{hc}{E_g} = \frac{6.634 \times 10^{-34} \times 3 \times 10^{8}}{1.44 \times 1.6 \times 10^{-19}}$$

$$= 8626\ \mathring{A}$$

2. A laser source emits light of wavelength 0.621 µm & has an output of 35 mW. Calculate how many photons are emitted per minute by this laser source.

Give, $P_{out} = 35\ mW$; $\lambda = 0.621\ \mu m$

To find, no. of photons emitted per minute. (N)

<u>soln.</u>

$$N = \frac{P}{h\nu} = \frac{P}{(hc/\lambda)} = \frac{P\lambda}{hc}$$

$$N = \frac{35 \times 10^{-3} \times 0.621 \times 10^{-6}}{6.634 \times 10^{-34} \times 3 \times 10^{8}}$$

$$N = \frac{21.735}{19.902} \frac{\times 10^{-9}}{\times 10^{-26}} = 1.092 \times 10^{17}$$

for 1 minute,

$$N = 1.092 \times 10^{17} \times 60 \times 1$$
$$= 65.520 \times 10^{17}$$
(or) $N = 6.552 \times 10^{18}$ photons/minute

3. Prove that laser action is not possible for optical frequencies under thermal equilibrium.
(or) Show that the stimulated emission is not possible for sodium D-line at 300K.

Given, $\lambda = 5000 \mathring{A}$ (sodium D-line)

$T = 300k$

$$\left.\begin{aligned}\frac{R_{sp}}{R_{st}} &= e^{h\nu/kT} - 1 \\ &\text{(or) } e^{hc/\lambda kT} - 1\end{aligned}\right\} = \exp\left[\frac{6.634 \times 10^{-34} \times 3 \times 10^{8}}{5000 \times 1.38 \times 10^{-23} \times 300}\right] - 1$$

$$= e^{96.01} - 1 = 4.9953 \times 10^{41} - 1$$

Ratio of R_{sp} & R_{st} $\Big\}$ $\dfrac{R_{sp}}{R_{st}} \approx 4.9953$

4. A step-index fiber has a numerical aperture of 0.26, a core refractive index of 1.5 & a core diameter of 100 µm calculate,

a. The refractive index of the cladding
b. The acceptance angle i_m
c. The maximum number of modes [the] fiber [can support at] a wavelength of 1 µm that the fiber

a. Refractive index of cladding

$$NA = \sqrt{n_1^2 - n_2^2}$$

$$n_2^2 = 1.5^2 - (0.26)^2$$

$$n_2 = 1.4772$$

b. The acceptance angle,

$$\sin i_m = \frac{NA}{n_0} = \frac{0.26}{1}$$

$$i_m = 15.07^\circ$$

c. The maximum number of modes

$$N = 4.9\left[\frac{d \times NA}{\lambda}\right]^2$$

$$= 4.9\left[\frac{100 \times 10^{-6} \times 0.26}{1 \times 10^{-6}}\right]$$

$$N = 3312.4$$