UNIT – II WAVES AND OPTICS

TOPIC – IX PROBLEMS DISCUSSION

1. **Calculate the wavelength of radiation emitted by an LED made up of a semiconducting material with band gap energy 2.8ev.**

   Given data:

   $E_g = 2.8ev$

   $= 2.8 \times 1.602 \times 10^{-19}$ J

   $E_g = 4.4856 \times 10^{-19}$J

   Solution:

   We know $E_g = h\gamma$

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

   $$= \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{4.4856 \times 10^{-19}}$$

   $$\lambda = 4430.8 \, A^{\circ}$$

2. **For a semiconductor laser the band gap is 0.8ev. what is the wavelength of light emitted from it.**

   Given data:

   $E_g = 0.8eV = 0.8 \times 1.6 \; 10^{-19}$ joules.

   Solution:

   $E_g = h\gamma$

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

   $$= \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{0.8 \times 1.6 \times 10^{-19}}$$

   $$= 1.5527 \times 10^{-6} \text{ m}$$

   The wavelength of light emitted = 1.5527 μm

3. **Calculate the numerical aperture of an optical fiber whose core and cladding are made of materials of refractive index 1.6 and 1.5 respectively.**

   Given data:

   Refractive index of core $n_1 = 1.6$

   Refractive index of cladding $n_2 = 1.5$

   Solution:

   Numerical aperture of an optical fiber is given by

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

$$NA = \sqrt{(1.6)^2 - (1.5)^2}$$

$$= \sqrt{2.25 - 2.25}$$

$$= 0.55677$$

Numerical aperture of an optical fiber = 0.55677

4. **Calculate the numerical aperture and the acceptance angle of an optical fiber the following data.**

Given data:

Refractive index of core $n_1 = 1.55$

Refractive index of cladding $n_2 = 1.5$

Solution:

Numerical aperture

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

$$NA = \sqrt{(1.55)^2 - (1.5)^2}$$

$$= \sqrt{0.1525}$$

NA = 0.3905 (no unit)

Acceptance angle

$\sin i_m = NA$

$$i_m = \sin^{-1}(NA)$$

$$= \sin^{-1}(0.3905)$$

Acceptance angle = 22°59'

5. **Calculate the numerical aperature, acceptance angle, and the critical angle of a fiber having core refractive index =1.50 and the cladding refractive index = 1.45.**

Given data:

Refractive index of core $n_1 = 1.50$

Refractive index of cladding $n_2 = 1.45$

Solution

Numerical aperture

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

$$NA = \sqrt{(1.5)^2 - (1.45)^2}$$

NA = 0.38405 (no unit)

Acceptance angle

$$\sin i_m = NA$$

$$i_m = \sin^{-1}(NA) = \sin^{-1}(0.3905)$$

Acceptance angle = 22°35'

Critical Angle

$$\text{Critical Angle } \phi_c = \sin^{-1}\left(\frac{n_1}{n_2}\right)$$

$$\phi_c = \sin^{-1}\left(\frac{1.45}{1.5}\right)$$

$$= 75.1648$$

$$\phi_c = 75°9'$$

6. **Calculate refractive indices of core and cladding materials of an optical fiber if its numerical aperture is 0.22 and refractive index differences are 0.012.**

Given data

$\Delta = 0.012$

NA = 0.22

Solution

Numerical aperture $NA = n_1\sqrt{2\Delta}$

$$n_1 = \frac{NA}{2\Delta}$$

$$= \frac{0.22}{\sqrt{2 \text{ x } 0.012}}$$

$$= \frac{0.22}{\sqrt{0.024}}$$

$n_1 = 1.42$

We know, $n_2 = n_1 (1-\Delta)$

$$= 1.42(1.0.012)$$

$$= 1.42(0.988)$$

$n_2 = 1.40$

7. **A signal of 100mW is injected into a fibre. The outcoming signal from the other end is 40mW. Find the loss in dB?**

Given data:

Power input (P_{in}) = 100mW = 100 x 10^{-3}W

Power output (P_{out}) = 40 mW = 40 x 10^{-3} W

Solution:

$$\text{Power loss } (P_L) = 10\log\frac{P_{out}}{P_{in}}$$

$$= 10\log\frac{40\times10^{-3}}{100\times10^{-3}}$$

$$P_L = 10 \log (0.4)$$

$$\mathbf{P_L = -3.979\ dB}$$

8. What is the ratio of the stimulated emission to spontaneous emission at temperature of 280 $^\circ$C for sodium D-line?

Given data:

Temperature (T) = 280 $^\circ$C = 553K

Solution:

$$\frac{\text{Stimulated emission}}{\text{Spontaneous emission}} = \frac{R_{21}(ST)}{R_{21}(SP)} = \frac{1}{e^{\frac{hc}{KT\lambda}}-1}$$

$$= \frac{1}{e^{\frac{(6.63\times10^{-34}\times3\times10^{8})}{(1.38\times10^{-23}\times553\times5.890\times10^{-7})}}-1}$$

$$= 6.264 \times 10^{-20}$$

∴ **The ratio between stimulated emission & spontaneous emission = 6.264 x 10^{-20}**