MODULE – III

LASERS & FIBER OPTICS

NUMERICAL PROBLEMS

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1. Find the relative population of the two states in a ruby laser that produces a light beam of wavelength 6943 Å at 300 K.

Solution: The population ratio is given by

$$\frac{N_2}{N_1} = \exp - (E_2 - E_1)/KT$$

$$E_2 - E_1 = h\upsilon = \frac{hc}{\lambda} \text{ joule}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{6943 \times 10^{-10}} = 2.85 \times 10^{-19}\,J$$

$$\therefore \frac{N_2}{N_1} = \exp\left[\frac{-2.85 \times 10^{-19}}{1.38 \times 10^{-23} \times 300}\right] = \exp(-69.3) = 8 \times 10^{-31}$$

2. **For a He-Ne laser at 1 m and 2 m distances from the laser the output beam spot diameters are 4 mm and 6 mm respectively. Calculate the divergence.**

Solution:

a_1 and a_2 are the laser beam diameters

d_1 and d_2 are the distances

$$\text{Divergence}, \theta = \frac{a_2 - a_1}{2(d_2 - d_1)}$$

$$= \frac{(6 - 4) \times 10^{-3}}{2(2-1)}$$

$$= 10^{-3}\ \text{radian} = 1\ \text{mrad}$$

3. A He-Ne laser emits light at a wavelength of 632.8 nm and has an output power of 2.3 mW. How many photons are emitted in each minute by this laser when operating ?

Solution:

Given data: The wavelength of the laser beam, λ = 632.8 nm = 6328×10^{-10} m

The output power, P = 2.3 mW

$$\text{The frequency of the photon emitted by the laser beam, } \nu = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{6328 \times 10^{-10}} = 4.74 \times 10^{14} \text{ Hz}$$

$$\text{The energy of a photon, } h\upsilon = 6.626 \times 10^{-34} \times 4.74 \times 10^{14} = 3.14 \times 10^{-19} \text{ J}$$

$$\text{Energy emitted by the laser} = 2.3 \text{ mW} = 2.3 \times 10^{-3} \text{ J s}^{-1} = 2.3 \times 10^{-3} \times 60 \text{ J min}^{-1}$$

$$\text{The number of photons emitted} = \frac{\text{Output power in laser beam}}{\text{Energy of each photon emitted by the laser}}$$

$$= \frac{2.3 \times 10^{-3} \times 60}{3.14 \times 10^{-19}} = 4.3949 \times 10^{17} \text{ photons min}^{-1}$$

4. Solve the wavelength of emitted radiation from GaAs which has a band gap of 1.44eV.

Solution: Energy gap of a semiconductor, $E_g = h\nu$

Where h is Planck's constant=6.63×10^{-34}J.S

$$E_g = h\nu \quad \frac{hC}{\lambda} \quad \text{or } \lambda = \frac{hC}{Eg}$$

$$E_g = 1.44 \text{ eV} = 1.44 \times 1.6\times10^{-19}\text{J}$$

$$E_g = \frac{hC}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.44\times1.6\times10^{-19}} = 8633\times10^{-10}\text{m} = 8633\text{Å}$$

5. A semi conductor laser diode laser has a wavelength of 1.55 μm. Estimate its energy gap in eV.

Solution. Energy gap of a semiconductor,

Energy of emitted photon, $E_g = h\nu = \frac{hC}{\lambda}$

where c = velocity of light $= 3\times10^{8}$ m/s

Wavelength, $\lambda = 1.55\ \mu m = 1.55\times10^{-6}$ m

Energy gap, $E_g = ?$

$$E_g = \frac{hC}{\lambda} = \frac{(6.63\times10^{-34}\times3\times10^{8})}{1.55\times10^{-6}} J$$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{1.55\times10^{-6}\times1.6\times10^{-19}}\, eV = 0.8\ eV$$


Thank you

6. A step index fiber has a numerical aperture of 0.16 and core refractive index of 1.45. Estimate the acceptance angle of the fiber and refractive index of the cladding.

Solution:

Given: Numerical Aperture, NA = 0.16,

Refractive index of core, $n_1 = 1.45$

We have to find, Acceptance angle, $i_{max} = ?$

Refractive index of cladding, $n_2 = ?$

Formula, Acceptance angle, $i_{max} = \sin^{-1}(NA) = \sin^{-1}(0.16) = 9.206^{o}$

$$n_2 = \sqrt{n_1^2 - NA^2} = \sqrt{1.45^2 - 0.16^2} = \sqrt{2.1025 - 0.0256} = 1.44$$

7. The refractive indices of core and cladding materials of a step index fiber are 1.48 and 1.45 respectively. Simulate i) Numerical aperture ii) Acceptance angle.

Solution:

Given: Refractive index of core=1.48

Refractive index of the cladding=1.45

We have to find, Numerical Aperture, NA = ?

and Acceptance angle, i_{max} = ?

Numerical aperture, $NA = \sqrt{n_1^2 - n_2^2} = \sqrt{1.48^2 - 1.45^2} = 0.2965$

Acceptance angle, $i_{max} = \sin^{-1}(NA) = \sin^{-1}(0.2965) = 17^o\ 15'$

8. An optical fiber has a numerical aperture of 0.2 and a cladding refractive index of 1.59. Find the acceptance angle for the fiber in water which has a refractive index of 1.33.

Solution:

Given: Numerical Aperture, NA = 0.2,

Refractive index of cladding, $n_2 = 1.59$,

Refractive index of water, $n_o = 1.33$

We have to find acceptance angle, i_{max} = ?

Numerical aperture, $NA = \sqrt{n_1^2 - n_2^2} = 0.2$

In water,

$$NA = \sin i_{max} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0} = \frac{0.2}{1.33} = 0.1504$$

$$i_{max} = 8.65^o$$

9. Calculate the fractional index change for a given optical fiber if the refractive indices of the core and the cladding are 1.563 and 1.498 respectively.

Solution:

Given: Refractive index of core, $n_1 = 1.563$

Refractive index of cladding, $n_2 = 1.498$

We have to find, fractional index change, Δ= ?

Formula,

$$\Delta = \frac{n_1 - n_2}{n_1} = \frac{1.563 - 1.498}{1.563} = 0.0416$$

10. When the mean optical power launched into an 8 Km length of fiber is 120 μW. The mean optical power at the fiber output is 3 μW. Find the overall signal attenuation and signal attenuation per Km.

Solution:

A. Overall Signal attenuation or loss in decibels through the fiber is given by,

Signal attenuation $(\alpha_{db}L)=10\log_{10}Pi/Po = 10\log_{10}(120\times10^{-6}/3\times10^{-6}) = 10\log_{10}40 = 16.0dB$

B. The signal attenuation per Km for the fibers is given by,

$\alpha_{db}L=16.0dB$

As $L=8km$

$\therefore \alpha_{db}=16.0/8$

$\alpha_{db}=2.0dB/km$


Thank you