Problems on Optical fibers

(i) An optical fiber has a core material with refractive index 1.55 and its cladding material has a refractive index of 1.50. The light is launched from air. Calculate its numerical aperture, the acceptance angle and also fractional index change?

Soln: we have R.I of core = 1.55

R.I of cladding = 1.50

N.A = ?

Acceptance angle = ?

fractional index change Δ = ?

we know that Numerical aperture = $NA = \sin\theta_0 = \sqrt{n_1^2 - n_2^2}$

$$NA = \sqrt{(1.55)^2 - (1.50)^2}$$

$$NA = 0.3905$$

Acceptance angle $NA = \sin\theta_0 = 0.3905$

$$\theta_0 = \sin^{-1}(0.3905)$$

$$\theta_0 = 22.98^\circ$$

Fractional index change $\Delta = \frac{n_1 - n_2}{n_1} = \frac{1.55 - 1.50}{1.50} =$

$$\Delta = 0.033$$

2. A glass clad fiber is made with core glass of R.I 1.5 and cladding is doped to give fractional index difference of 0.005. Find (a) the acceptance angle (b) the numerical aperture and (c) the critical internal reflection angle?

Soln: we have R.I of core $n_1 = 1.5$

fractional index change $\Delta = 0.005$

Acceptance angle = ?

NA = ?

Critical angle (internal reflection) = ?

we know $\Delta = \frac{n_1 - n_2}{n_1} = \frac{1.5 - n_2}{1.5} = 0.005$

$n_2 = 1.5 - 0.0075$

$n_2 = 1.4925$

$N.A = \sqrt{n_1^2 - n_2^2} = \sqrt{1.5^2 - (1.4925)^2} = 0.1498$

Acceptance angle = $\sin\theta_0 = 0.1498$

$\theta_0 = \sin^{-1}(0.1498) = 8.616^\circ$

Critical angle of (internal reflection) = $90 - \theta = 81.384^\circ$

(3) Calculate the acceptance angle & critical angle for the for the core-cladding interface when the R.I core is 1.48 and fractional index change is 2%.

Soln: $n_1 = 1.48$ $\Delta = \frac{n_1 - n_2}{n_1} = \frac{1.48 - n_2}{1.48} = \frac{2}{100}$

$n_2 = 1.45$

(4) Acceptance angle $\sin\theta_0 = \sqrt{n_1^2 - n_2^2}$

$$= \sqrt{(1.48)^2 - (1.45)^2}$$

$$= \sqrt{0.0879}$$

$$\sin\theta_0 = 0.2964$$

$$\theta_0 = 17.24^\circ$$

Critical angle $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

$$= \sin^{-1}\left(\frac{1.45}{1.48}\right)$$

$$\theta_c = 78.44^\circ$$

(4) Calculate the V-number for a fiber of core diameter 40 μm and with RI of 1.55 and 1.50 respectively for Core and cladding when wavelength of propagation wave is 1400 nm. Also calculate the no of modes that the fiber can support for propagation. Assume that fiber in air.

Soln: we have R.I of core = 1.55

R.I of cladding = 1.50

wavelength $\lambda = 1400$ nm

Diameter of core = 40 μm ⇒ radius = 20 μm

Thus V number $= \frac{2\pi r}{\lambda}\sqrt{n_1^2 - n_2^2}$

$$= \frac{2 \times 3.14 \times 20 \times 10^{-6}}{1400 \times 10^{-9}}\sqrt{(1.55)^2 - (1.50)^2}$$

$$= 0.035 \times 10^3$$

$$V = 35$$

No of modes $M = \frac{V^2}{2} > \frac{35^2}{2} = \underline{612.5}$

(5) Find the attenuation in an optical fiber of length 500m when a light signal of power 100mW emerges out of the fiber with a power 90mW.

Sol: Given : length $l = 500m = 0.5km$

Light power $P_{in} = 100mW$

$P_{out} = 90mW$

Attenuation $\alpha = ?$

we know that $\alpha = -\frac{10}{L}\log_{10}\left(\frac{P_{out}}{P_{in}}\right)$

$= -\frac{10}{\cancel{500}\ 0.5}\log\left(\frac{90\times10^{-3}}{100\times10^{-3}}\right)$

$= 9.1514\times10^{-4}$ ~~dB/km~~ m

$= \underline{0.9151\ dB/km}$

(6) Calculate the R.I of core & cladding material of an optical fiber if its N.A is 0.22 and R.I diff is 0.012

Sol: Given $NA = 0.22$

R.I diff $\Delta = 0.012$

$n_1 = ?$

$n_2 = ?$

we know that $N.A = n_1\sqrt{2\Delta}$

$0.22 = n_1\sqrt{2\times0.012}$

$n_1 = \frac{0.22}{\sqrt{2\times0.012}} = \frac{0.22}{0.155} = \underline{1.42}$

$$N.A = \sqrt{n_1^2 - n_2^2}$$

$$(0.22)^2 = n_1^2 - n_2^2$$

$$n_2^2 = n_1^2 - (0.22)^2$$

$$= (1.42)^2 - (0.22)^2$$

$$n_2^2 = 1.968$$

$$n_2 = 1.402$$

(7) ~~Find~~ the angle of acceptance of an optical fiber is 30° when kept in air. Find the angle of acceptance when it is kept in a medium of R.I 1.33

Soln: Given angle of acceptance $\theta = 30^\circ$

$n_1 = 1$

$n_2 = 1.33$

$\theta_2 = ?$

we have $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$1 \times \sin 30^\circ = 1.33 \sin\theta_2$

$$\frac{0.5}{1.33} = \sin\theta_2$$

$$\theta_2 = \sin^{-1}\left(\frac{0.5}{1.33}\right)$$

$$\theta_2 = 22.08^\circ$$