For optical fiber, the refractive index is 1.48 and 1.46 respectively. Calculate the critical angle.

$n_1 = 1.48$, $n_2 = 1.46$

$\sin(\theta_c) = \frac{n_2}{n_1} = \frac{1.46}{1.48} \rightarrow \theta_c = 79.73$

$\theta_c = 79.73$

$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\sqrt{1-\Delta} = \sin^{-1}\sqrt{2\Delta}$

$\theta_c = 17.4$

→ Step index of a optical cable is.

$\rightarrow \Delta = \frac{n_1^2 - n_2^2}{2n_1^2} = \frac{n_1 - n_2}{n_1}$

For the step index optical fiber, the refractive index of core is 1.48 and the refractive index of cladding is 1.46. Calculate the numerical aperture.

$SI = 1.48 \rightarrow n_1 = 1.48$

$SI = 1.46 \rightarrow n_2 = 1.46$

$\sin(\theta_c) = \frac{n_2}{n_1} \rightarrow \sin(\theta_c) = \frac{\sqrt{n_1^2 - n_2^2}}{\sin(\theta_c)} \rightarrow \sin\theta_c \rightarrow \theta_c = 83.66$

$\rightarrow \theta_c = 90 - \theta_c$

Calculate the numerical aperture of a step index optical fiber.

Find:

(i) Critical angle

(ii) Acceptance angle

(iii) Acceptance cone angle

(iv) Fiber power

$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1.46}{1.48}\right) = 80.6$

$\theta_a = \sin^{-1}\sqrt{n_1^2 - n_2^2} = \sin^{-1}\sqrt{1.48^2 - 1.46^2} = 14.61$

$\theta_a = \frac{\theta_c}{2} = \frac{14.61}{2} = 7.3$

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$P_0 = \frac{\pi}{4} n_1^2 \Delta \frac{c}{n_1} = \frac{\pi}{4} n_1^2 \Delta c = 0.47 \times 10^{-3}$

$P_0 = 0.47 \times 10^{-3}$

$V = \frac{2\pi r}{\lambda} \sqrt{n_1^2 - n_2^2}$ $V < 2.405$ for single mode

$V = \frac{2\pi r}{\lambda} NA = \frac{2\pi r}{\lambda} \sqrt{2\Delta}$ TE01

If model, $V \leq 2.405$ number of mode inside fiber.

For a step index fiber, $n_1 = 1.48$, $\Delta = 0.01$, $r = 4.5\mu m$

Calculate the $\frac{V}{\lambda}$ and λ.

$\therefore M = \frac{V^2}{2}$, $V = \frac{2\pi r}{\lambda} NA$, $V = r NA$

$\therefore V = \frac{2.405(1.48)}{(0.01)^{1/2}} = 66.7$ $\rightarrow M = 2192$

where, the value of normalized frequency in step index fiber, where is $V_c = 2.405$.

Exercise 2.7

Suppose the maximum core diameter for which fiber single mode operation is approximately 10 μm.

Estimate the maximum core diameter which allows single mode operation in approximately 0.5 μm.

A step index fiber has a core diameter of 50 μm and a refractive index of 1.48. The refractive index of the cladding is 1.46. Calculate the normalized frequency and the number of modes when the wavelength of the light is 1.3 μm.

Given: Using Eq. 2.19 the maximum value of normalized frequency is

$$V = \frac{2\pi a}{\lambda} NA = \frac{2\pi a}{\lambda} \sqrt{n_1^2 - n_2^2}$$

The maximum core radius may be obtained from Eq. 2.19 where

$$a_{max} = \frac{\lambda V_{max}}{2\pi \sqrt{n_1^2 - n_2^2}}$$

Hence the maximum core diameter which allows single mode operation is approximately 10 μm.

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Given: Using Eq. 2.19 the normalized frequency is

$$V = \frac{2\pi a}{\lambda} \sqrt{n_1^2 - n_2^2} = \frac{2\pi \times 25 \times 10^{-6}}{1.3 \times 10^{-6}} \sqrt{1.48^2 - 1.46^2} = 30.8$$

Hence the number of modes is approximately

$$M = \frac{V^2}{2} = \frac{(30.8)^2}{2} = 475$$

Step index

$NA = 0.16$

$n_1 = 1.48$

$\Delta = 1.5\%$

$d = 50\ mm$ $\lambda = 0.85\ mm$

$\lambda = 0.1\ mm$

Find V, M_s

(i) $V = \frac{2\pi}{\lambda} a \times NA = \frac{2\pi}{0.85 \times 10^{-6}} \times 25 \times 10^{-6} \times 0.16$

$V = 37.4 \approx 38$ (dimensionless)

(ii) $M_s = \frac{V^2}{2} = \frac{(38)^2}{2} = 722$ modes

Graded index

$d = 50\ mm$ $\Delta = 2\%$

$n_1 = 1.48$

$\lambda = 0.85\ mm$

Find the standard V which allow single mode operation and M_g which exists

(i) V_c for single mode $= 2.405$

(ii) $V_c = \frac{2\pi}{\lambda} a \times n_1 \times (2\Delta)^{1/2}$

$2.405 = \frac{2\pi}{0.85 \times 10^{-6}} \times (1.48) \times (2 \times 0.02)^{1/2}$

$\lambda_c = 1.05\ mm$

A graded index fiber with a parabolic index profile supports the propagation of 75 guided modes. The fiber has a core diameter of 50 μm and a refractive index of 1.48. Assuming the wavelength of the light is 1.3 μm, calculate the numerical aperture of the fiber, the normalized frequency and the maximum core radius for single mode operation.

$M = 75$ $NA = ?$ $d = 50\ \mu m$ $\lambda = 1.3\ \mu m$

$\Delta = 0.01$ $n_1 = 1.48$

$\rightarrow M_g = \frac{\alpha}{\alpha+2} \frac{V^2}{2}$ $\rightarrow V = 7.82 \times \frac{\alpha}{\alpha+2} \times \frac{V^2}{2}$ $\rightarrow V = 154.97$

$\rightarrow V = \frac{2\pi a}{\lambda} NA$

$\rightarrow 154.97 = \frac{2\pi \times 25 \times 10^{-6}}{1.3 \times 10^{-6}} (NA)$ $\rightarrow NA = 0.32$

$\rightarrow \Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \rightarrow n_2 = \sqrt{n_1^2 - 2\Delta n_1^2}$

$\rightarrow n_2 = \sqrt{1.48^2 - 2 \times 0.01 \times 1.48^2}$

$\rightarrow n_2 = 1.46$

$\rightarrow NA = \sqrt{n_1^2 - n_2^2}$ $\rightarrow NA = \sqrt{(1.48)^2 - (1.46)^2}$

$NA = 0.3$

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