Q. **Problem 1:** A multimode step index, core diameter = 80μm, relative index difference = 1.5%, Wavelength = 0.85 μm, core (n) = 1.48 (a) V (b) No. of guided modes

$\boxed{\therefore NA = n_1\sqrt{2\Delta}}$

Sol: $n_1 = 1.48$

$\Delta = 1.5\% = 0.015$

$2a = 80\mu m \Rightarrow a = 40\mu m$

$\lambda = 0.85\mu m$

$\left(NA = 1.48\sqrt{2 \times 0.015} = 1.48\sqrt{0.03} \right)$

As, $V = \dfrac{2\pi a (NA)}{\lambda}$

$= \dfrac{2\pi \times 40}{0.85}(0.2563)$

$\boxed{V = 75.8}$

$\boxed{\text{Total No. of modes}}$: $M \simeq \frac{V^2}{2}$ for Step-index

$M \simeq \left(\frac{\alpha}{\alpha+2}\right)\frac{V^2}{2}$ for Graded index

$(\alpha \neq 0)$

$\alpha - 1 \rightarrow$ Triangle

$\alpha - 2 \rightarrow$ Parabolic ✓

(b) No. of guided modes : $\frac{V^2}{2}$

$$M \gtrsim \frac{(75.8)^2}{2} = 2872.82$$

$$\Rightarrow M = 2873.0$$

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20. $V = 2.405$, $\lambda = 1550\,nm$, Single-Mode Operation

$n_1 = 1.480$, $n_2 = 1.478$

Sol $V = \frac{2\pi a (NA)}{\lambda} \Rightarrow 2.405 = \frac{2\pi (a)\sqrt{1.48^2 - 1.478^2}}{1550 \times 10^{-9}}$

$$\Rightarrow a = \frac{2.405 \times 1550 \times 10^{-9}}{2\pi\sqrt{1.48^2 - 1.478^2}}$$

$$= 7713 \times 10^{-9}$$

$$= 7.713 \times 10^{-6}$$

$$\boxed{\therefore a = 7.7\,\mu m}$$

3Q. $a = 3\,\mu m$, $NA = 0.1$, $\lambda = 800nm$ 2.356

Will this fiber exhibit single-mode operation? (Based on V, as $V \leq 2.405 \rightarrow$ Single mode) $V = ?$

4Q. Graded-index fiber: Core Diameter = $50\,\mu m$ has parabolic refractive index profile ($\alpha = 2$). 174

$N.A = 0.22$, $\lambda = 1310\,nm$, Total no. of guided modes?

Sol: $a = 25\,\mu m$, $NA = 0.22$, $\lambda = 1310nm$, $\alpha = 2$

$$V = \frac{2\pi a}{\lambda}(NA) = \frac{2\pi \times 25 \times 10^{-6}}{1310 \times 10^{-9}} \times 0.22$$

$$\Rightarrow V = 26.379$$

$\therefore$ No. of guided modes $= \left(\frac{\alpha}{\alpha+2}\right)\frac{V^2}{2} = \left(\frac{2}{4}\right)\frac{(26.379)^2}{2}$

$$= \frac{(26.379)^2}{4} = 173.9 \Rightarrow M = 174$$

$$\boxed{\therefore M = 174}$$

3Ans $a = 3\,\mu m$, $NA = 0.1$, $\lambda = 800nm$

$$\therefore V = \frac{2\pi a}{\lambda}(NA) = \frac{2\pi \times 3 \times 10^{-6}}{800 \times 10^{-9}}(0.1) = 2.3562$$

$$\boxed{V = 2.356}$$

As, $V \leq 2.405 \Rightarrow$ Fiber exhibits single-mode operation

• Total Dispersion : $D = D_m + D_{wg} + D_{inter}$

fiber-multimode : $D \simeq D_{inter}$ ↑ (Dominate)

fiber-Singlemode $D \simeq D_m + D_{wg}$ ↑ (Dominate)

(3) → Polarized Mode Dispersion : Due to polarization

• $n_1 \simeq n_2$ → then we will get Linear polarized modes

• Then we get '2' group velocities v_{gy} v_{gx}

• Group delay : $\Delta T = \frac{L}{v_{gx}} - \frac{L}{v_{gy}}$

(for weakly modes) $= L \frac{d\beta_x}{d\omega} - L \frac{d\beta_y}{d\omega}$

Problems :

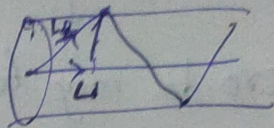
10. A 6 km optical link consists of multimode step-index fiber with a core refractive index of 1.5 and relative refractive index difference of 1%. Estimate (a) the delay difference b/w the slowest and the fastest modes at the fiber output. (b) The max. bit rate that may be obtained without substantial errors.
(c) the rms pulse broadening due to intermodal dispersion link

Ans: given: $n_1 = 1.5$, $\Delta = 0.01$, $L = 6$ km (fiber length)

(c) $\sigma = \frac{L}{2\sqrt{3}c} n_1 \Delta = 86.$

(a) $\Delta T = \frac{L}{c} n_1 \Delta$ Intermodal Dispersion

$= \frac{6\times10^3}{3\times10^8} \times 1.5\times10^{-2}$



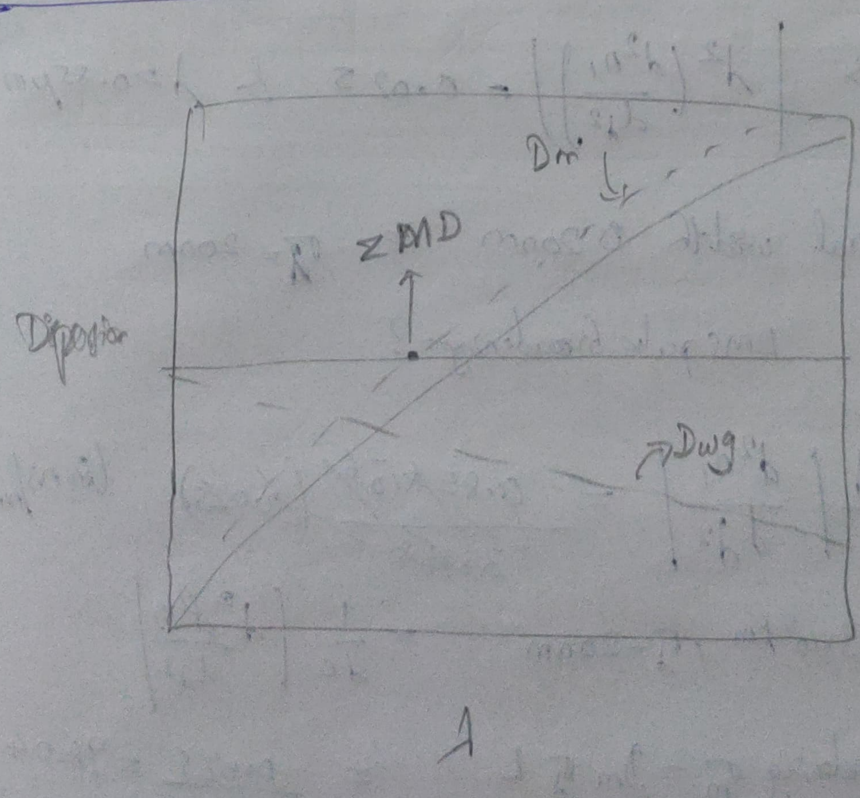
$= 3\times10^{-7} = 300$ n Seconds $\boxed{\therefore \Delta T = 300\, ns}$

(b) $B_{max} = \frac{1}{2\tau}$; Max. Bandwidth

$= \frac{1}{2\times3\times10^{-7}} = \frac{10}{6}\times10^6 = \frac{5}{3}\times10^6$

$= 1.67$ MHz $\boxed{B_{max} = 1.67\, MHz}$

1/2/2023



ZMD - Zero material Dispersion

Problem: $D_m \Rightarrow \left| \lambda^2 \left(\frac{d^2 n_1}{d\lambda^2} \right) \right| = 0.025$ & $\lambda = 0.85\,\mu m$

rms spectral width is 20nm i.e. $\sigma_\lambda = 20nm$

$D_m = ?$ RMS pulse broadening $= ?$

Sol

$$D_m = \frac{\lambda}{c} \left| \frac{d^2 n_1}{d\lambda^2} \right| = \cancel{\frac{0.85 \times 10^{-6} (0.025)}{3 \times 10^{8}}} \quad (\text{in ns/nm-km})$$

$\lambda = 850\,nm$, $C = 3 \times 10^5\,km$, $\sigma_\lambda = 20\,nm$

$$= \frac{1}{\lambda c} \left| \lambda^2 \frac{d^2 n_1}{d\lambda^2} \right|$$

• RMS pulse broadening $\sigma_m = D_m \sigma_\lambda L$

$$= \frac{0.025}{3 \times 10^5 \times 850} = 98.04\ ps\,nm^{-1} km^{-1}$$

- RMS pulse broadening per km : $\frac{\sigma_m}{L} = D_m \sigma_\lambda$ ns/km

- $\frac{\sigma_m}{L} = \sigma_{mat} \sigma_\lambda = 1.96$ ns/km

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Problem: $D_{mat} = 110$ ps/(nm-km) $\qquad \lambda = 860$ nm

$\sigma_\lambda = 40$ nm (spectral bandwidth) ← at an o/p wavelength of 860nm

- rms pulse broadening per km = ?

Sol

$1p = 10^{-10}$
$1n = 10^{-9}$
$1p = 0.1 \times 1n$

$\frac{\sigma_m}{L} = D_m \sigma_\lambda = 110 \times 860$ ps/km

$= 9460$ ns/km
