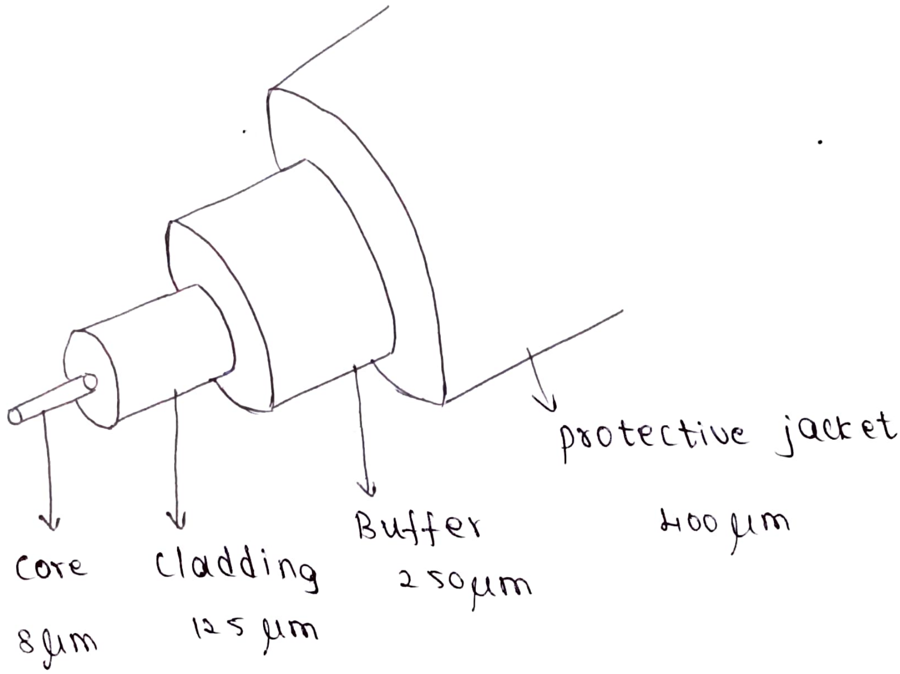
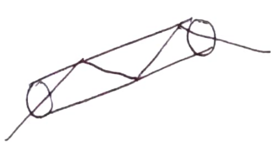
UNIT - 1

⇒ structure of optical fibres:



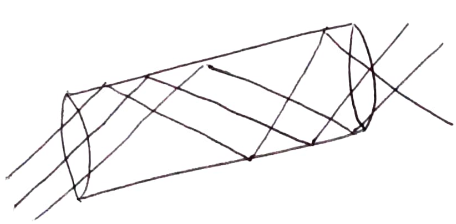
⇒ Modes :

1. single mode:



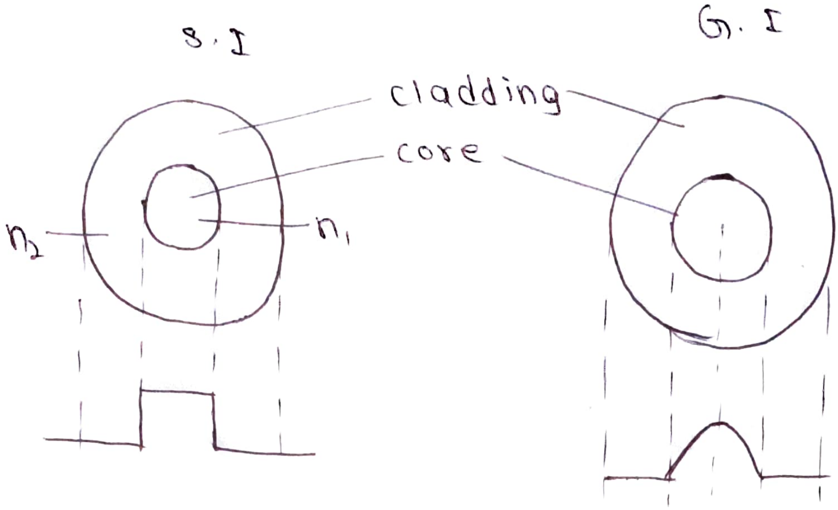
2. Multimode :

different angle of incidence



→ Based on R.I :

1. step Index :
2. Graded index :

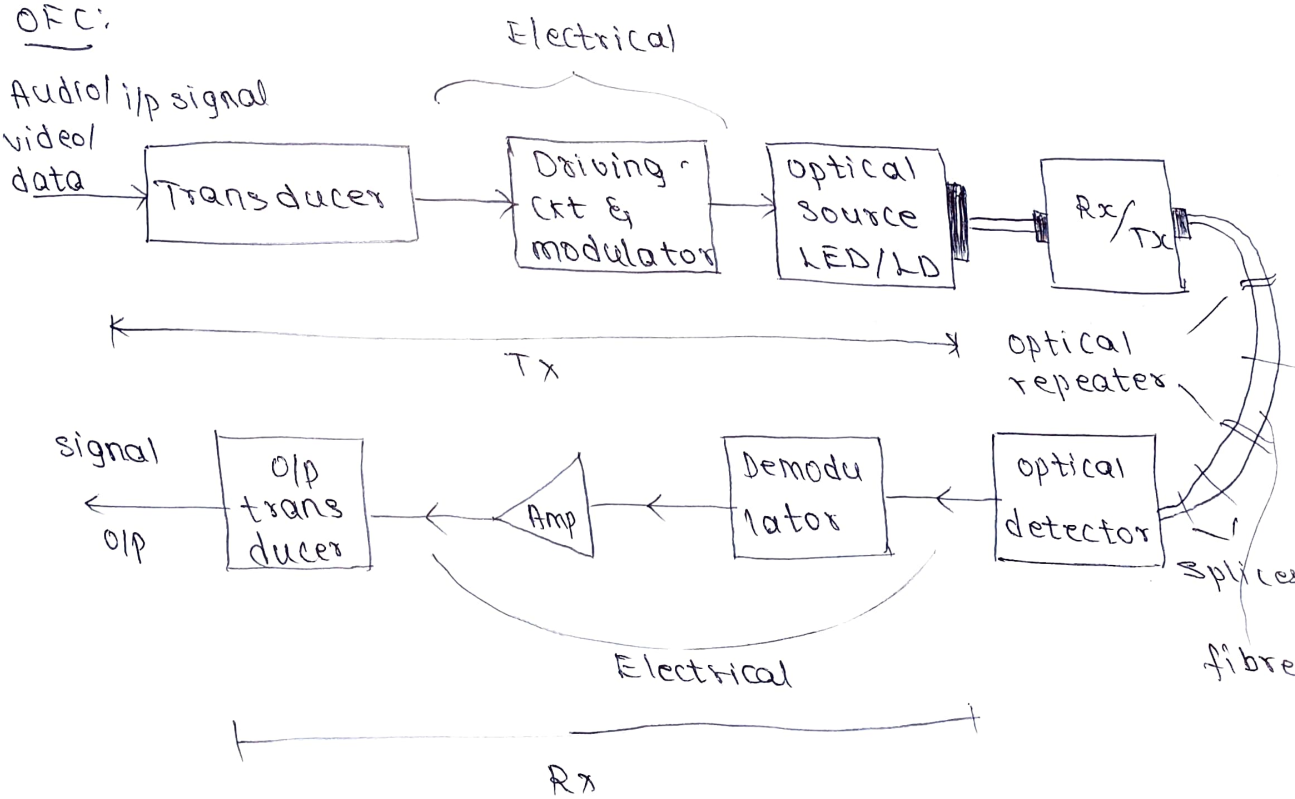


	S.I	G.I
*	$\frac{n_1 - n_2}{n_1}$	$\frac{n_1^2 - n_2^2}{2n_1^2}$
* parameters:	Gbps	Tbps
* pulse spreading:	more	less
* Attenuation:	less (0.3	more (many no of light rays) 0.6 - 1

* R.I is max at the centre.

	Single Mode	Multi model
* No of mode:	single (one)	many
* Core dia:	Smaller	longer (50-200 μm)
* optical sources:	Lasers	LED
*	Intramodel	Intermodel
* Coupling efficiency:	40-50%	50-60%
* N.A:	smaller	Larger
* splicing:	very difficult	easier
* B.W product:	Higher	smaller
* Application:	Long distance comm	Broadband.

OFC:



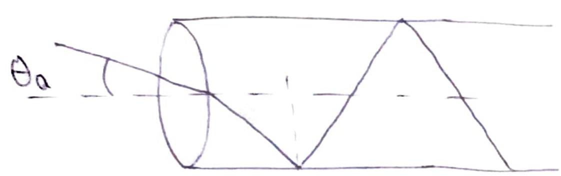
→ Fibre materials:

* Flexible
* high tensile strength
* Temperature resistance
* Low cost
* Transparent

Silica

Plastic fibres < PMMA, PF

15-3-21



θ_a - acceptance angle

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

⟹ Problems:

1. Multimode silica fibre, core RI, $n_1 = 1.48$, cladding R.I $= 1.46$, Calculate the critical angle θ_c, numerical aperatioe NA & Acceptance angle θ_a.

→ $n_2 = 1.46$

$n_1 = 1.48$

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

$\theta_2 = 90°$

$\theta_1 = \theta_c$

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$\theta_c = 80.56°$$ //

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

$$= \sin^{-1}\sqrt{1.48^2 - 1.46^2}$$

$$= \sin^{-1}(0.242)$$

$$\theta_a = 14.03^\circ$$

$$N.A = 0.242$$

Normalised freq variable, $V = \frac{2\pi a}{\lambda}(NA)$

2. A step Index fibre has a normalised freq $V = 26.6$ at 1300nm wavelength, core radius is $25\mu m$. calculate NA, core R.I for given cladding R.I $n_2 = 1.47$.

→

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

$$26.6 = \frac{2\pi \times 25 \times 10^{-6} \times NA}{1300 \times 10^{-9}}$$

$$N.A = \frac{26.6 \times 1300 \times 10^{-9}}{2\pi \times 25 \times 10^{-6}}$$

$$NA = 0.22$$

$$N.A = \sqrt{n_1^2 - n_2^2} = 0.22$$

$$n_1^2 - n_2^2 = 0.04846$$

$$n_1^2 = 0.04846 + 1.47^2$$

$$n_1^2 = 2.209 \quad , n_1 = 1.486$$

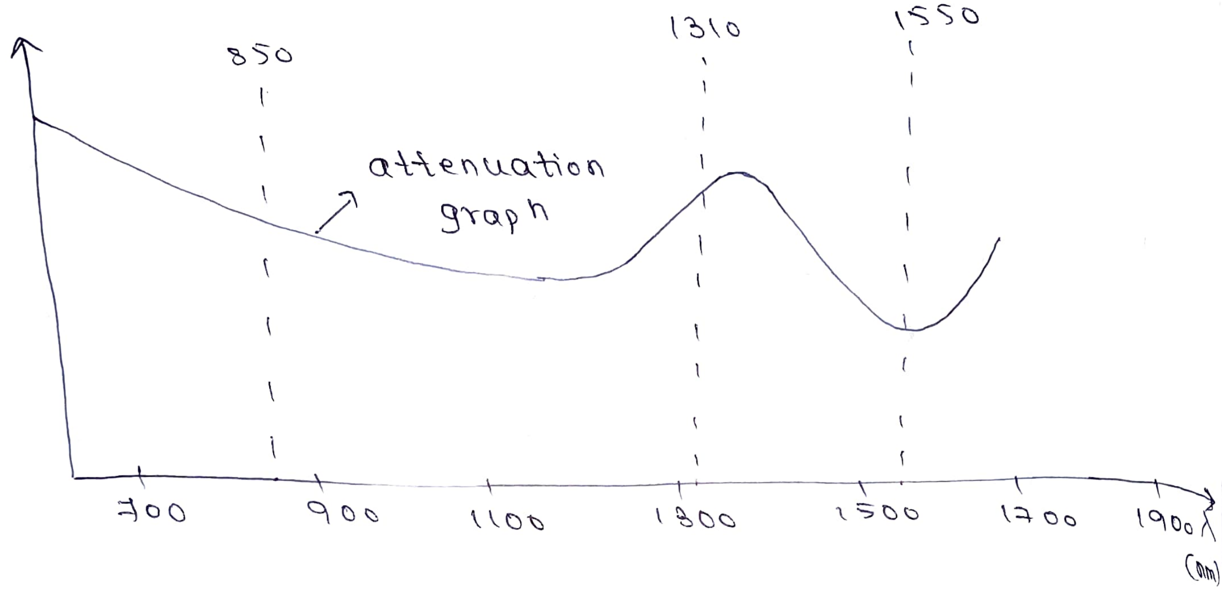
16-3-21

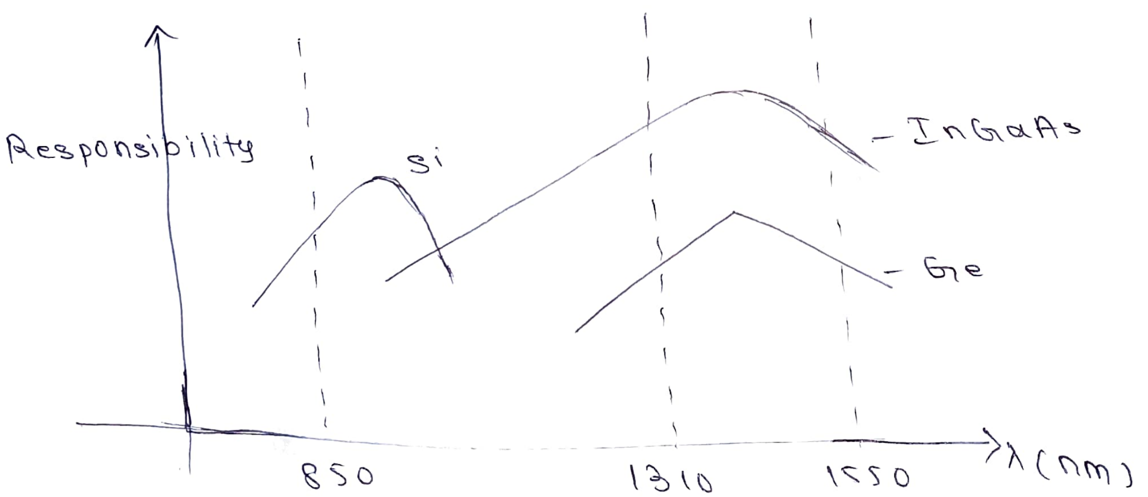
⇒ EM spectrum :

850 nm - short wavelength

1310 nm - O band

1550 nm - Higher wavelength.





→ Relative Index diff $\Delta n = n_1 - n_2$

$$\Delta n_1 = \frac{n_1 - n_2}{n_1}$$

→ $NA = n_1 \sqrt{2\Delta}$

3. A typical relative refractive index diff for an optical fibre designed for long distance transmission, is 1%. estimate the NA and the solid acceptance angle in air for the fibre when the core index is 1.46. Also calculate the critical angle at the core cladding interface within the fibre.

→ For small angles $\Sigma = \pi\theta_a^2 = \pi\sin^2\theta_a$.
solid acceptance angle

* $\Delta = 1\% = 0.01$

* $NA = n_1\sqrt{2\Delta}$

$= 1.46\sqrt{2\times 0.01}$

$N.A = 0.206.$ $\quad 0.206^2 = 1.46^2 - n_2^2$

* $n_2 = 1.445$

* $\sin\theta_c = \dfrac{n_2}{n_1}$

$\theta_c = 81.77°$

* $\theta_a = \sin^{-1}\sqrt{n_1^2 - n_2^2}$

$= \sin^{-1}(0.206)$

$= 11.91°$.

17-3-21

4. A multimode step index fibre with a core dia 80μm & R.I.D of 1.5% is operating at a wavelength of 0.85μm If the core R.I is 1.48 Estimate the normalised freq for the fibre & the no. of guided modes.

→ $\lambda = 0.85\mu m$ $\quad \Delta = 1.5\%$

$n_1 = 1.48$

* $$\Delta = \frac{n_1 - n_2}{n_1}$$

$$0.015 = \frac{1.48 - n_2}{1.48}$$

$$n_2 = 1.45$$

* $N.A = n_1\sqrt{2\Delta} = 1.48\sqrt{2 \times 0.015}$

$$= 0.256$$

* $$V = \frac{2\pi a}{\lambda}(NA)$$

$$= \frac{2 \times \pi \times 40\mu \times 0.256}{.85 \times \mu}$$

$V = 75.69$ normalised freq variable

* No. of modes, $\frac{V^2}{2} = 2864.48$

$\boxed{\text{Single mode } V = 2.405}$

~~5. A multimode step index fibre~~
~~Find the number of modes~~

5. Calculate the core diameter if the fibre is replaced with single mode fibre.

→ $$V = \frac{2\pi a}{\lambda}(NA)$$

$$V = 2.405$$

$$2.405 = \frac{2\pi a (0.256)}{0.85\mu}$$

$$a = 1.27\mu m$$

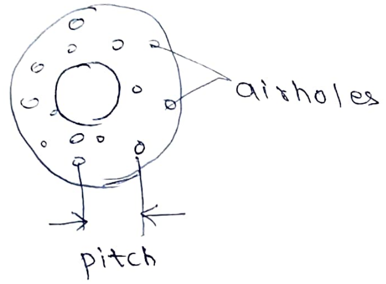
core diameter $= 2a = 2.54 \times 10^{-6}$ m

* Number of modes (single mode) $= \frac{V^2}{4}$

⇒ Photonic crystal fibre :

* also calles as faber Holey fibers.

→ R.I depends on the dia of the air holes



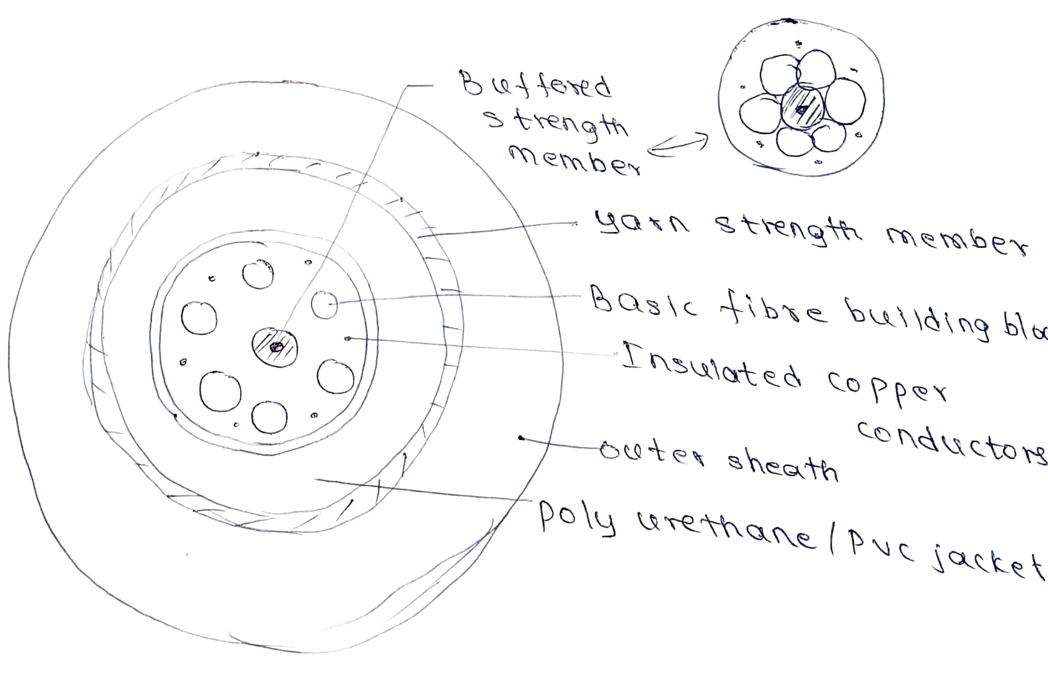
→ small R.I diff b/w core & cladding (air = 1 , silica = 1.45)

Adv:

→ Highly effective to darkening effect.

→ It supports single mode

⇒ Fibre optic cables:

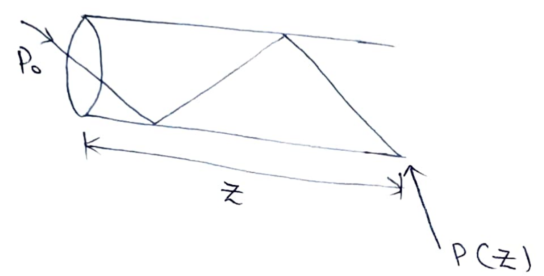


18-3-21

UNIT - 2

SIGNAL DEGRADATION IN FIBRES

→ Attenuation:



$$P(z) = P(0)\, e^{-\alpha_p \cdot z}$$

$$\alpha_p = \frac{1}{z} \ln\left(\frac{P(0)}{P(z)}\right)$$

→ Absorption Loss:

* by atomic effects in glass composition.
* dissipation of optical power
* Extrinsic absorption & intrinsic absorption.

→ Scattering loss:

22-3-21

* $$\alpha_{uv} = \frac{154.2x}{46.6x + 60} 10^{-2} \exp\left(\frac{4.63}{\lambda}\right)$$

23-3-21

→ Scattering loss:

$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4} (n^2 - 1)^2 K_B T_f \beta_T \text{ Nepers.}$$

1. Mean optical power launched into a 8 km length of optical fibre is 12 μW & o/p power is 3 μW a) Find overall signal attenuation in dB & Nepers

b) For 10 km optical lane, using same fibre compare attenuation loss if there are ~~pairs~~ splices located at 1 km intervals each having attn loss of 1dB.

→ a) * $P(z) = P(0)\, e^{-\alpha_p \cdot z}$

$$\alpha_p = \frac{1}{z} \ln\left(\frac{P(0)}{P(z)}\right)$$

$$= \frac{1}{8\times10^{3}} \ln\left(\frac{12\times10^{-6}}{3\times10^{-6}}\right)$$

$$= +1.73\times10^{-4} \text{ Nepers.}$$

* $$\alpha_p = \frac{10}{z} \log\left(\frac{P(0)}{P(z)}\right)$$

$$= \frac{10}{8} \times \log\left(\frac{12\times10^{-6}}{3\times10^{-6}}\right)$$

$$= 0.75 \text{ dB/km.}$$

b) loss per km, $\alpha_p = 0.75$ dB/km

10 km $\alpha_p = 7.5$ dB/km.

For 10 km = 9 splicing

$\alpha_{Total} = \alpha_p + \alpha_p$ (splicing)

$= 7.5 + 9 \times 1$

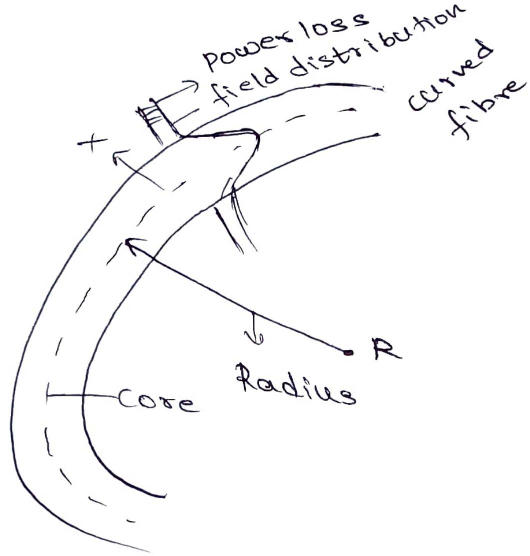
$\alpha_{Total} = 16.5$ dB

25-3-21

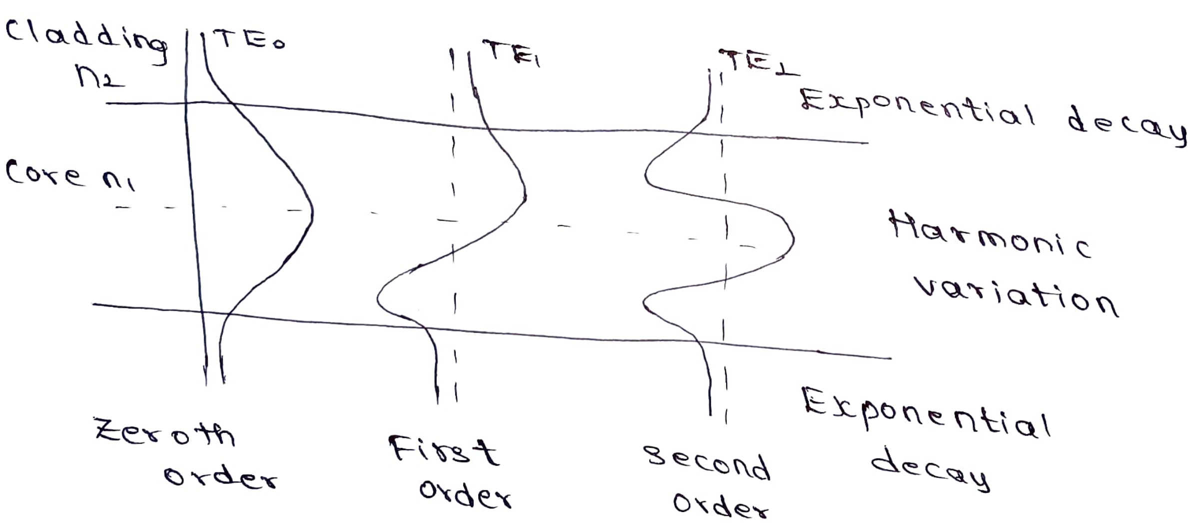
⇒ Bending Loss:

1. Macroscopic B.L
2. Microscopic B.L

1.



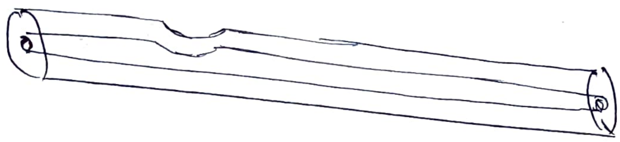
→ Radius decreases, loss increases



$$N_{eff} = N_\infty \left\{ 1 - \frac{d+2}{2d\Delta} \left[\frac{2a}{R} + \left(\frac{3}{2n_2 k R} \right)^{2/3} \right] \right\}$$

$$N_\infty = \frac{d}{d+2} (n_1 k a)^2 \Delta$$

2. Microscopic B.L



→ also called as packaging loss

$$F(\alpha m) = \left[1 + \pi \Delta^2 \left(b/a\right)^4 \underbrace{\frac{E_f}{E_j}}_{\text{young's modulus}}\right]^2$$

b - outer radius

⇒ Core and cladding Loss:

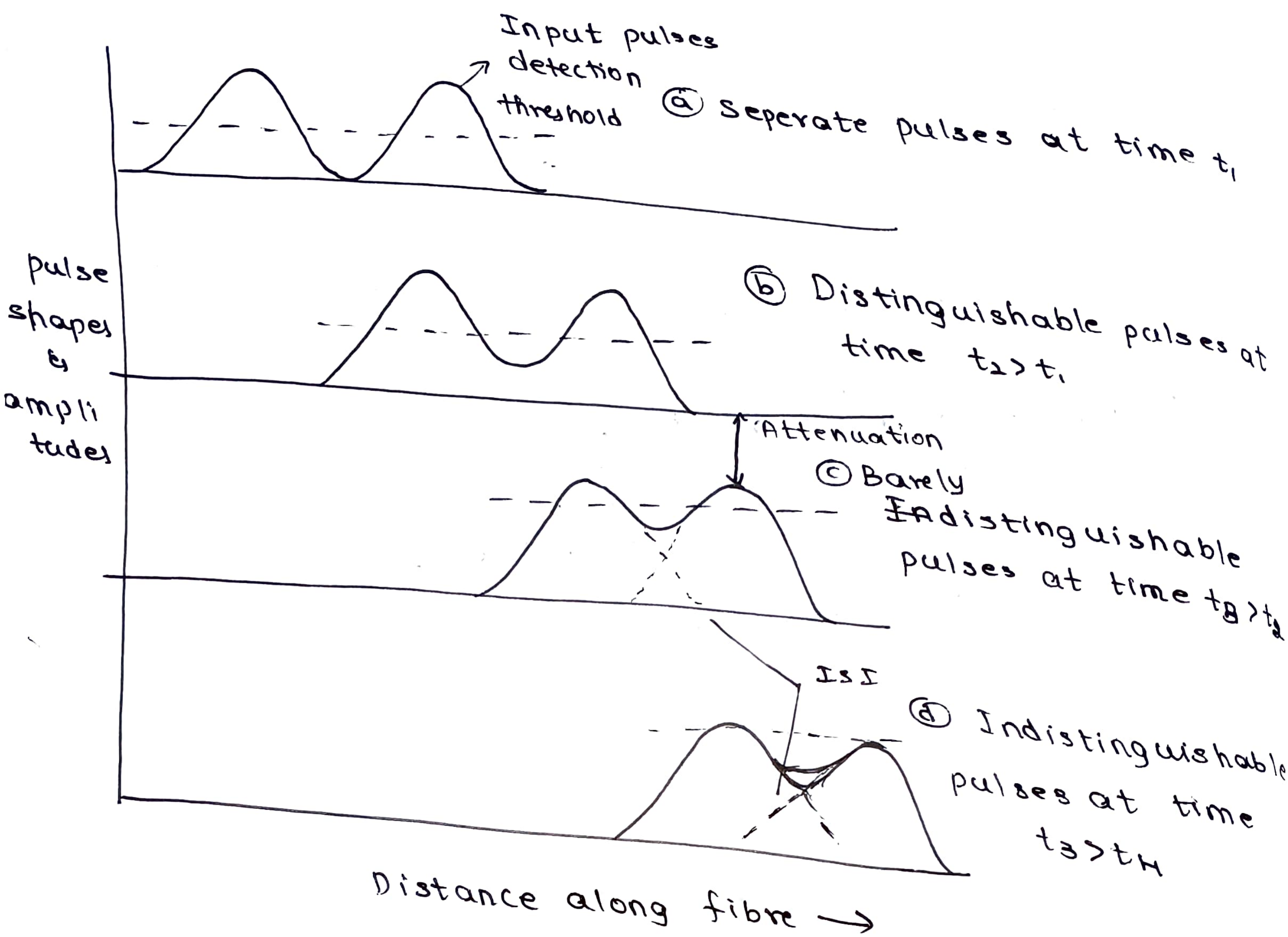
$$\alpha_{vm} = \frac{\alpha_1 P_{core}}{P} + \frac{\alpha_2 P_{clad}}{P}$$

$$\alpha_{vm} = \alpha_1 + (\alpha_2 - \alpha_1) \frac{P_{clad}}{P}$$

$$\alpha(r) = \alpha_1 + (\alpha_2 - \alpha_1) \frac{n^2(0) - n^2(r)}{n^2(0) - n_2^2}$$

31-3-21

⟹ Dispersion:



1. Calculate radius of curvature R at which the no. of modes decreases by 50% in a graded index fibre. $\alpha = 2$, $n_2 = 1.5$, $\delta = 0.01$, $a = 25\,\mu m$ & wavelength of the guided light is $1.3\,\mu m$

→

$$N_\infty = \frac{\alpha}{\alpha+2}(n_1 k a)^2 \Delta$$

$$\cancel{N_{eff} = N_\infty \left\{ 1 - \frac{4}{4 \times 0.01} \right.}$$

$$N_{eff} = N_\infty \left\{ 1 - \frac{d+2}{2d\Delta} \left[\frac{2a}{R} + \left(\frac{3}{2n_2 k R} \right)^{2/3} \right] \right\}$$

$$\frac{N_\infty}{2} = N_\infty \left\{ 1 - \frac{4}{4 \times 0.01} \left[\frac{2 \times 25 \times 10^{-6}}{R} + \left(\frac{3}{2 \times 1.5 \times 4.83 \times 10^{6} \times R} \right)^{2/3} \right] \right\}$$

$$\frac{1}{2} = 1 - 100 \left[\frac{50 \times 10^{-6}}{R} + \frac{3.499 \times 10^{-5}}{R^{2/3}} \right]$$

$$\frac{1}{2} = 1 - 100 \left[\frac{50 \times 10^{-6} \times R^{2/3} + 3.499 \times 10^{-5} R}{R^{5/3}} \right]$$

$$R^{5/3} = 2R^{5/3} - 0.01 R^{2/3} + 6.998 \times 10^{-3} R$$

$$= 2 - 0.01 R^{-1} + 6.998 \times 10^{-3} R^{-2/3}$$

$$R = 1.03 \text{ cm}$$

7-4-21

12-4-21

⇒ Dispersion:

i) material

ii) w.g } Intramodal

iii) polarisation-mode

→ Group vel $v_g = \frac{d\omega}{d\beta}$

→ Group delay, $\tau_g = \frac{l}{v_g} = l\frac{d\beta}{d\omega}$

⇒ I/p o/p signals