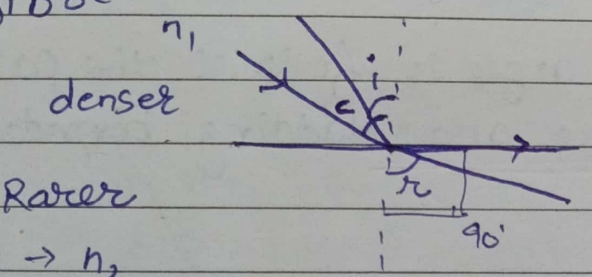
Ch-2 Optical fiber

- Optical fiber : flexible, transparent fiber made by glass or plastic. Very conduits as thin as human hair used for transfortation of optical energy along the length of the fiber and the technology by which the optical energy is transported from one end to another end is specially designed medium is called optical fibre.



① denser to rarer
② $i > C$

refractive index → n_2

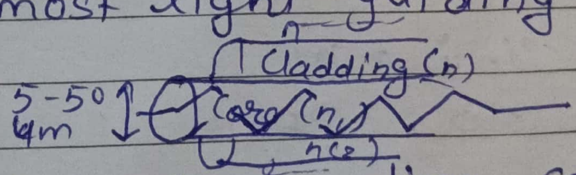
- Snell's rule :

$$\frac{\sin C}{\sin 90^\circ} = \frac{n_2}{n_1}$$

$$\boxed{C = \sin^{-1}\left(\frac{n_2}{n_1}\right)}$$

Basic Structure.

1) Core - the inner most light guiding



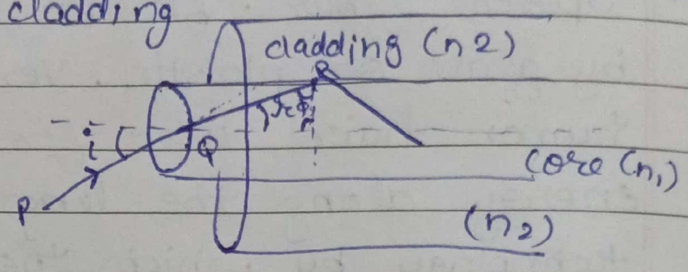
125 μm 2) Cladding - the region surrounding core
3) Sheath/Buffer/Coating - the outside protector
250 μm which protect cable from moisture, contamination and abration.

4)

Exceptance angle and Numerical Aperture

$n_1 > n_2 > n_0$

Consider an optical fibre having core of refractive index n_1 & cladding of index n_2
let a signal PQ enters into the core region at an angle i from the launching medium (n_0).



light bents at an angle r follows the path QR and strike the core and cladding boundary at angle ϕ.

- Apply Snell's law at boundary of launching medium and core

$$\frac{\sin i}{\sin r} = \frac{n_1}{n_0} \quad \text{--- (1)}$$

$r \rightarrow (90 - \phi)$ in eq (1)

$$\frac{\sin i}{\sin(90-\phi)} = \frac{n_1}{n_0}$$

$$\frac{\sin i}{\cos\phi} = \frac{n_1}{n_0}$$

$$\sin i = \frac{n_1}{n_0} \cos\phi \quad \text{--- (2)}$$

If we increase angle i from outside, $\angle\phi$ starts decreasing inside. When i becomes max value $\angle\phi$ become equal to c.

$i \uparrow \ \phi \downarrow$

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

when $i = max$

$\phi = C$ ... → put in eq ②

$$\sin i_{max} = \frac{n_1}{n_0} \cos C \quad \text{... ③}$$

Snell's law

$$\frac{\sin C}{\sin 90°} = \frac{n_2}{n_1} \Big\} \text{ at core - cladding}$$

$$\sin C = \frac{n_2}{n_1} \quad — (*)$$

$$\cos C = \sqrt{1 - \sin^2 C}$$

$$\cancel{\sin^2 C = 1 - \cos^2 C}$$

$$\cancel{\sin C = \sqrt{1 - \cos^2 C}} \quad \rightarrow \text{put in } (*)$$

$$\cos C \rightarrow \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

$$\sin i_{max} = \frac{\cancel{n_1}}{n_0} \frac{\sqrt{n_1^2 - n_2^2}}{\cancel{n_1}}$$

θ_a $\boxed{i_{max} = \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right)}$ $n_0 \rightarrow 1$ for air

Acceptance angle - the max. angle at which a signal is launched inside a cable so that it propagate ~~inside the~~ along the length of the fiber.

\# Light gathering ~~of~~ ability of a fiber is called Numerical Aperture.

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

\# Fractional Index difference

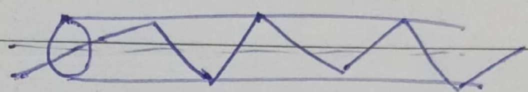
$$\boxed{\Delta = \frac{n_1 - n_2}{n_1}}$$

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

Types of fibre

- Material
  - Glass/ glass-glass fibre
  - PCS (Plastic cladded Silica)
  - All plastic
- Mode
- Index profile

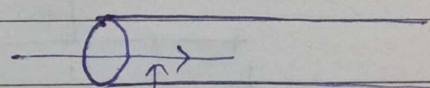
Carrier
Recombination and Generation :-



Mode- the possible no of paths allowed for an optical signal inside the cable is known as mode

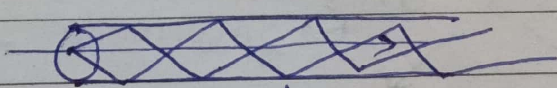
ⓐ SMF (single mode fibre)

5-10 μm {



axial mode

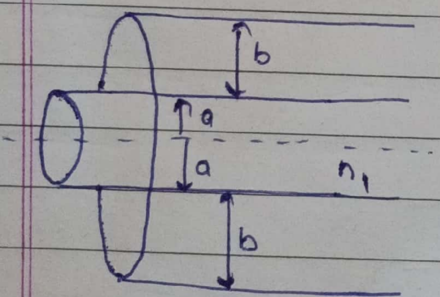
ⓑ Multi mode fibre

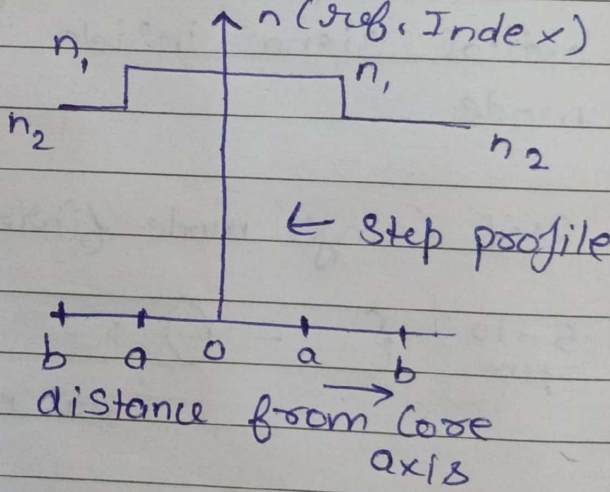


	SMF	MMF
①	Support only one mode	① Support large no. of paths /modes
②	Core diameter is very small 5 to 10 μm.	② 50 to 100 μm.
③	NA is low (Numerical Aperature)	③ NA is high.

(4) Difficult to launch optical signal inside the cable	(4) Easy to launch cheaper
(5) Expensive	(5) Not so expensive
(6) Sophisticated source like laser is used to launch optical fibre.	(6) LED's & laser can be used
(7) Attenuation and dispersion loss are less	(7) Attenuation & dispersion loss are hi[gh]
(8) No dispersion or less	(8) High dispersion

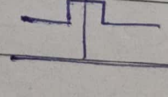
Index profile





The graph b/w refractive index and distance from core axis

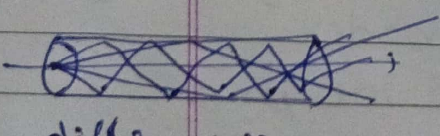
→ Single mode



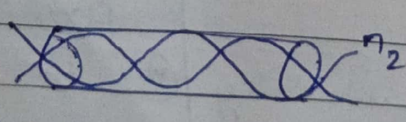
SI
Step index

GRIN
gradded Index

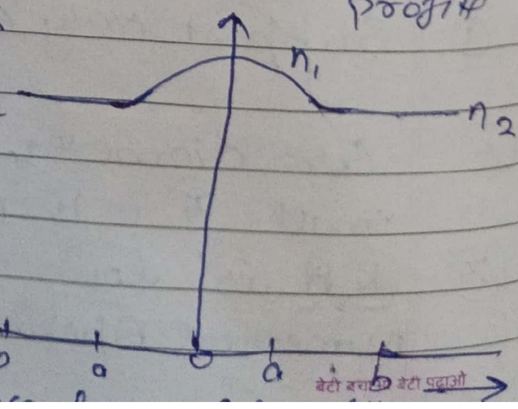
parabolic profile



different time comes out



comes out at same time



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SI	GRIN
① Core is having uniform refractive index	Core is having variable refractive index max at the centre & starts reducing gradually
② Both single and multimode signals	② Multimode signal
③ SI fibres will have sudden bending of light at core cladding surface	③ ~~Multimode~~ GRIN fibre are continuous bending of light resulting in periodic focusing of different rays.

Types of losses

Attenuation loss — Dispersion loss

V-number / Normalized frequency

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

$$= \frac{2\pi a}{\lambda} \times \sqrt{n_1^2 - n_2^2} = \frac{2\pi a}{\lambda} \times n_1 \sqrt{2\Delta}$$

$V < 2.405$
SMF

$V > 2.405$
MMF

(no. of modes) $N_m = \frac{V^2}{2}$ (Step Index)

$N_m \cong \frac{V^2}{4}$ (GRIN)

Q A step index optical having core diameter 50 mm. If its numerical aperature is 0.146 of wavelength

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500 nm . Determe normalize frequency of the fibre as well as no. of modes.

$d = 50\ mm$
$\lambda = 500\ nm \rightarrow 500 \times 10^{-9}$
$NA = 0.146$

Types of losses in fibre

Attenuation loss (decrease in power, intensity, strength of an optical signal dB/km)

$$\boxed{\alpha = \frac{10}{L} \log_{10} \frac{P_{in}}{P_{out}}}$$

$\alpha \rightarrow$ attenuation coefficient
$L \rightarrow$ length of fibre (km)

Dispersion loss (distortion or change in the shape of signal due to time log)
ns/km
nano second

Attenuation loss

- Intrinsic (internal)
  - Absorption (due to impurities like OH^- ions because of moisture)
  - Rayleigh Scattering (scattering of light due to local variations in density because of amorphous glass)
- Extrinsic (external)
  - Microbending (small scale bending) (occur during manufacture)
  - Macrobending (large scale bending) occur during installation

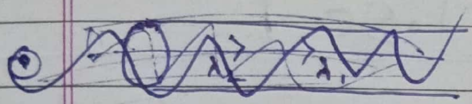
Dispersion loss

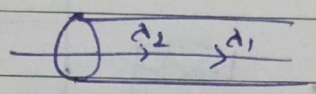
Intermodal
(b/w different modes)

Intramodal
(within one mode)

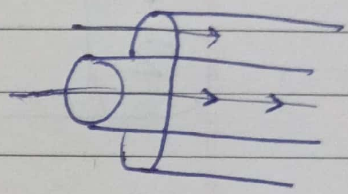
material dispersion

waveguide dispersion





(glass fibre offers different refractive index to different wavelength)



• Holonium