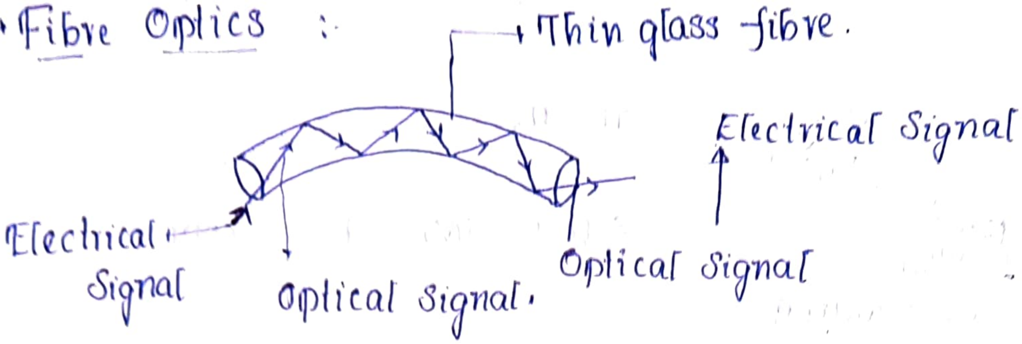
Unit-3. Optical Fibre.

i. Transmision of information.

ii. used in medical purposes.

iii. Sensors.

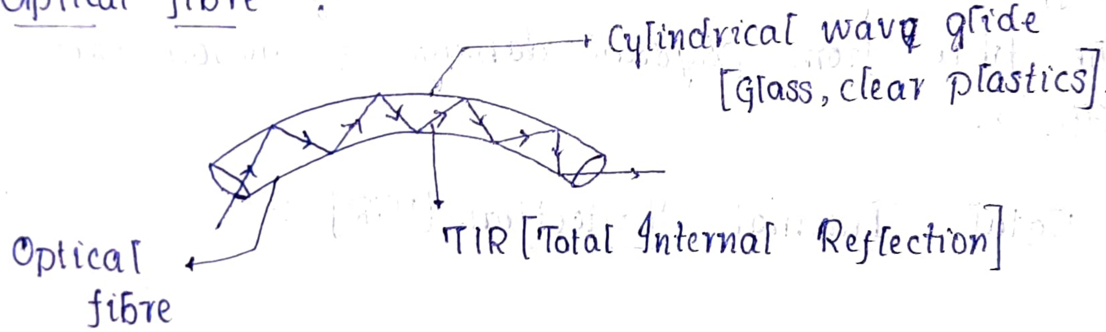
→ **Fibre Optics** :-



→ Fibre optics is a technology in which Signals are converted from Electrical into Optical Signals.

→ Transmitted through a thin glass fibre & reconverted into electrical Signals.

→ **Optical fibre** :-

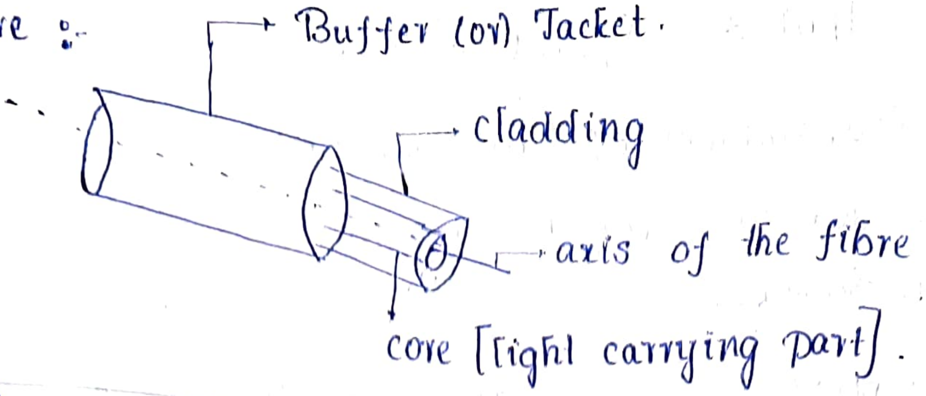


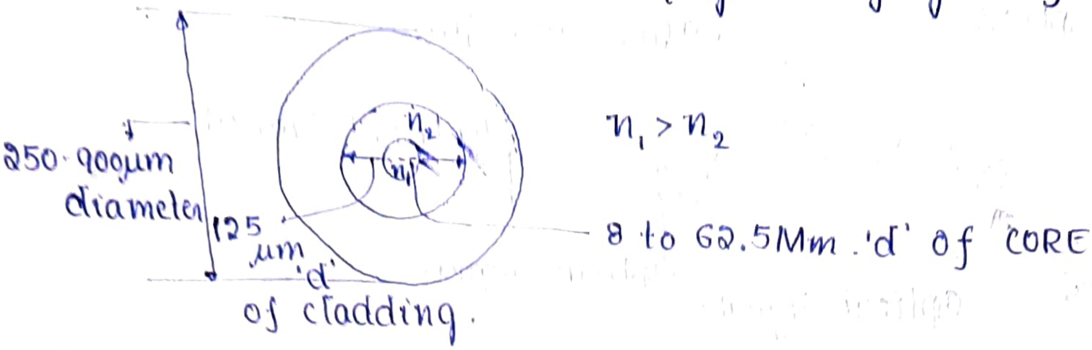
- An Optical fibre is a cylindrical wave guide made of transperant di-electrics. [Glass, clear plastics].

→ Light waves can be guided along the length of the fibre by TIR.

- The Propagation of light from one end to another end of the optical fibre is based on TIR.

Structure :-





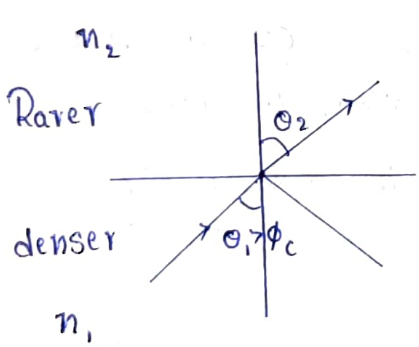
→ cladding → for TIR.

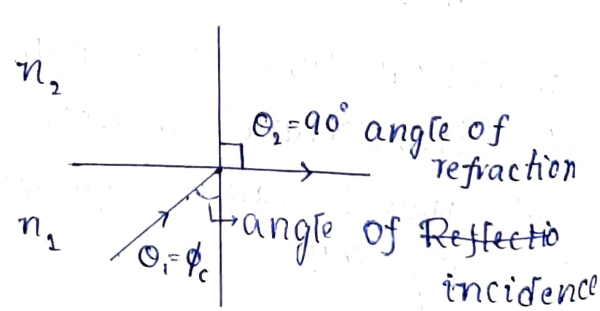
→ CORE is the inner light carrying member.

→ cladding is the middle layer which serves to ~~combin~~ confine the light to CORE.

→ Buffer coating surrounds the cladding, which protects the fibre from physical damage & Environmental effects.

⇒ Total Internal Reflection [TIR] :-



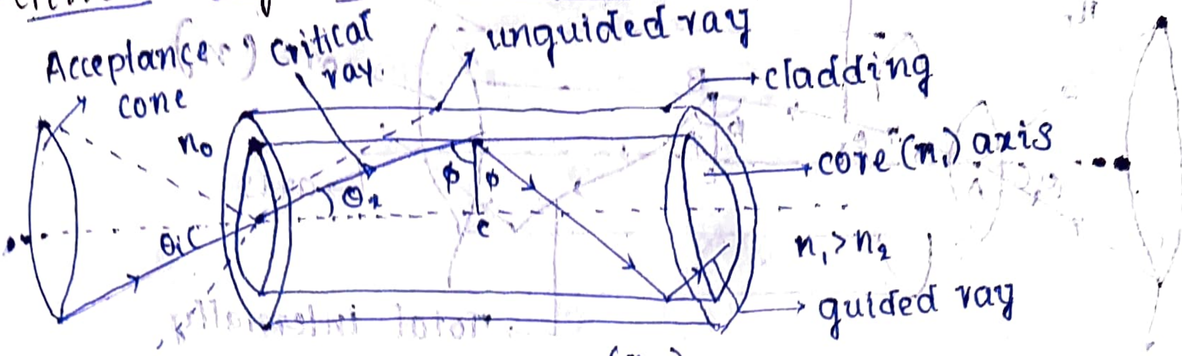


By Snell's law :-

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

Critical angle : Angle of incidence for which angle of refraction is 90°.

- Critical angle of propagation (θ_c) :



$\theta_c = \cos^{-1}\left(\frac{n_2}{n_1}\right)$.

$[\theta_r = \theta_c]$

- Assume that, angle of incidence at core cladding interface is the critical angle. $\phi = \phi_c$.

$$\boxed{\phi_c = \sin^{-1}\left[\frac{n_2}{n_1}\right]} \longrightarrow (1)$$

Let, $\phi = \phi_c$, $\theta_r = \theta_c$

In ΔABC,

$$\phi_c + \theta_c = 90$$

$$\theta_c = 90 - \phi_c$$

$$\cos\theta_c = \cos(90 - \phi_c)$$

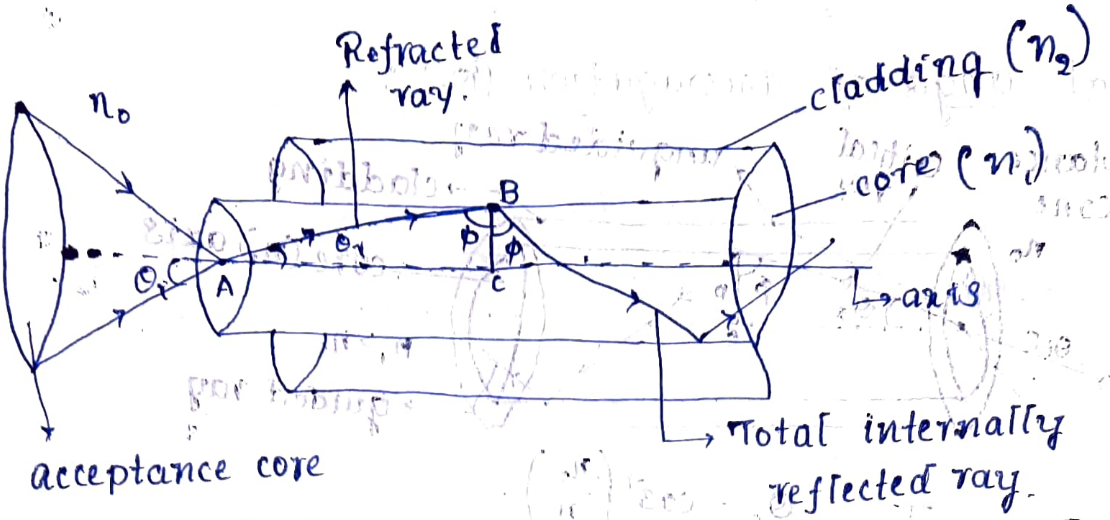
$$\cos\theta_c = \sin\phi_c = \frac{n_2}{n_1} \quad \text{from (1)}$$

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

- For a ray to propagate inside the optical fibre. This $\theta_r \leq \theta_c$.

- Critical angle of propagation is defined as the angle b/w the axis of fibre & critical ray.

→ Acceptance angle (θ_0) :-



$$[\theta_i]_{max} = \theta_0$$

θ_0 = acceptance angle.

$$\boxed{\theta_0 = \sin^{-1}\sqrt{n_1^2 - n_2^2}}$$

Snell's law at A,

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_1}{n_0}$$

n_0 → refractive index of surroundings

$$\sin\theta_i = \frac{n_1}{n_0}\sin\theta_r \longrightarrow ①$$

In ΔABC,

$$\theta_r + \phi = 90$$

$$\theta_r = (90 - \phi).$$

$$\sin\theta_r = \sin(90-\phi) = \cos\phi$$

from ①

$$\sin\theta_i = \frac{n_1}{n_0}\cos\phi.$$

when, $\phi = \phi_c$. $\theta_i = [\theta_i]_{max}$

$$\sin[\theta_i]_{max} = \frac{n_1}{n_0}\cos\phi_c$$

$$= \frac{n_1}{n_0}\sqrt{1 - \sin^2\phi_c}$$

$$\sin(\theta_i)_{max} = \frac{n_1}{n_0}\cos\phi_c$$

$$= \frac{n_1}{n_0}\sqrt{1-\sin^2\phi_c} \Rightarrow \sin(\theta_i)_{max} = \frac{n_1}{n_0}\sqrt{1-\frac{n_2^2}{n_1^2}}$$

$$\sin(\theta)_{max} = \frac{\sqrt{n_1^2-n_2^2}}{n_0} \Rightarrow \text{if } n_0 = 1 \text{ (air)}$$

$$\Rightarrow \boxed{\sin(\theta_0) = \sqrt{n_1^2-n_2^2}}$$

- Here, θ_0 is known as acceptance angle.
  It is the max. angle that array of light can have relative to the axis of fibre & propagate down the fibre.
- The light rays contained within the cone, having a full angle $(2\theta_0)$ are accepted & transmitted along the fibre.
- This cone is known as acceptance cone.
- ~~It's~~ fractional refractive index change :- (Δ)

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

$n_1 \rightarrow$ core refractive index

$n_2 \rightarrow$ cladding refractive index.

$\Delta << 1$ $\Rightarrow [\Delta \approx 0.01]$

- Numerical Appertuve [NA] :- $\boxed{NA = \sin(\theta_0)} = \sqrt{n_1^2-n_2^2}$

  - It is defined as the Sign of Sine function of acceptance angle (θ_0)] Numerical appertuve.

- NA is defined as the light gathering ability of the acceptance cone.

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

→ Relation b/w NA & Δ :-

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

Proof :- $\Delta = \dfrac{n_1 - n_2}{n_1} \longrightarrow (1)$

$NA = \sqrt{n_1^2 - n_2^2} \longrightarrow (2)$

$= \sqrt{(n_1 - n_2)(n_1 + n_2)}$

$= \sqrt{\dfrac{(n_1+n_2)}{2} \cdot \dfrac{n_1 - n_2}{n_1} \times n_1 \cdot 2}$

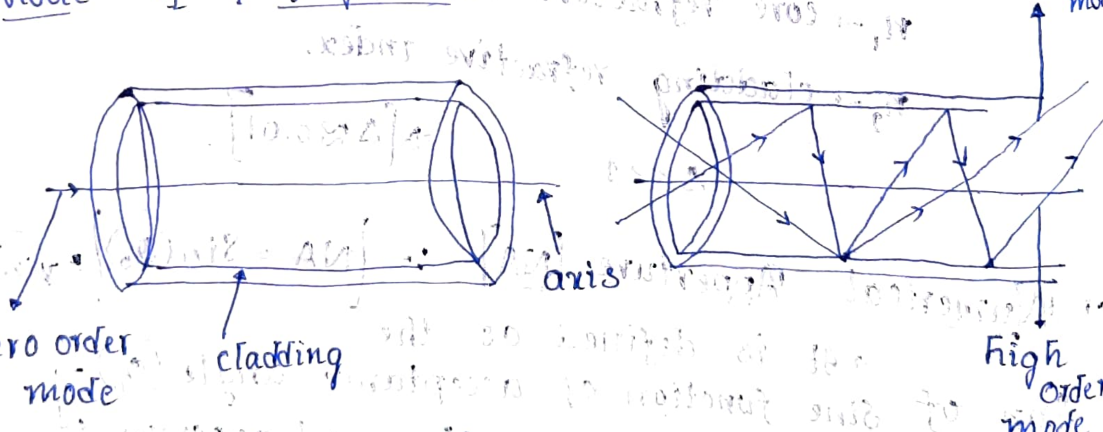
$[n_1 \approx n_2]$. $= \sqrt{(n_1+n_2)(\Delta)\, n_1 \cdot 2} = \sqrt{n_1 \cdot \Delta 2 n_1}$

$N.A = \sqrt{n_1 \cdot \Delta 2 n_1}$

$\because \dfrac{n_1 + n_2}{2} = n_1, \quad \dfrac{n_1 - n_2}{n_1} = \Delta.$

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

→ Mode of propagation :-



→ Light ray path along which the waves are in phase, inside the fibre are known as modes.

Zero Order mode travel along the axis of the fibre.

The mode that propagates at an angles close to critical angle ϕ_c are higher Order mode.

$[\simeq \phi_c]$.

The mode that propagate with angles larger than critical angle ϕ_c are lower order mode.

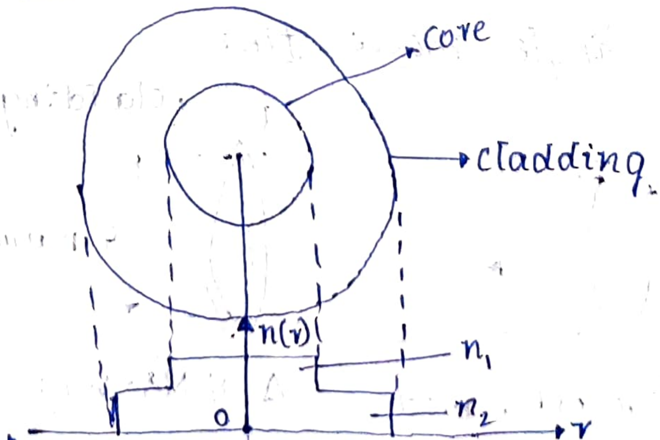
$[> \phi_c]$

Lower order mode takes less time to reach other end as compared to higher order mode.

→ <u>Classification of Optical fibre</u> :-

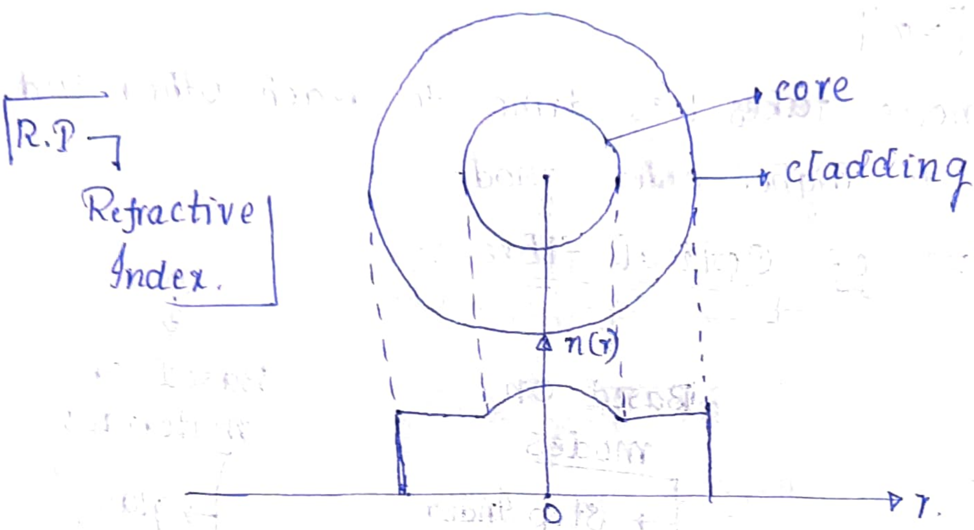
- Based on R.I profile
  - Step Index fibre (S.I fibre)
  - Graded Index fibre (GRIN) fibre
- Based on modes
  - Step Index Single mode fibre
  - Step Index multimode fibre
  - Graded Index multimode fibre
- Based on materials
  - glass/glass
  - plastic/plastic
  - plastic clad Silica

→ <u>Step Index fibre</u> :-



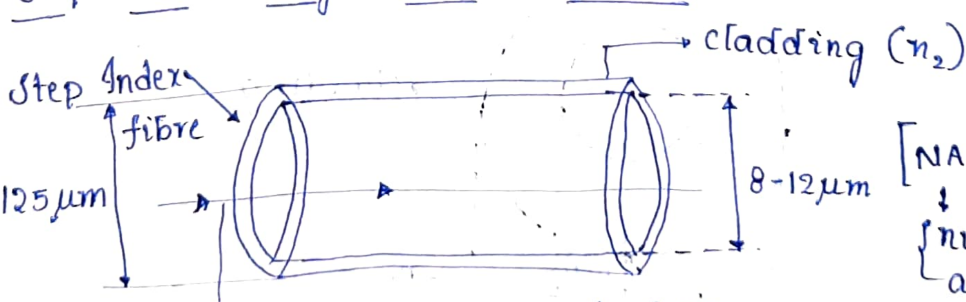
- In step index fibre refractive index is constant throughout the core.
- There is Sudden drop in refractive index at core cladding interface.
- Refractive index is constant throughout the cladding.

- <u>Graded Index fibre</u> :-



- In graded index fibre the refractive index is maximum at the center of the core.
- It decreases slowly when we move away from center to core cladding Interface. And, matches with the refractive index of the cladding at the interface.
- R.I is constant throughout the cladding.

- <u>Step Index Single mode fibre</u> :-

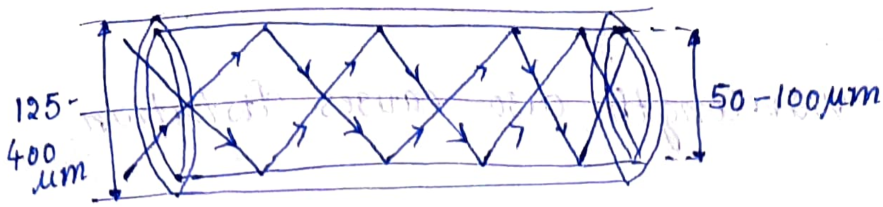


$\left[NA = \sqrt{n_1^2 - n_2^2}\right]$

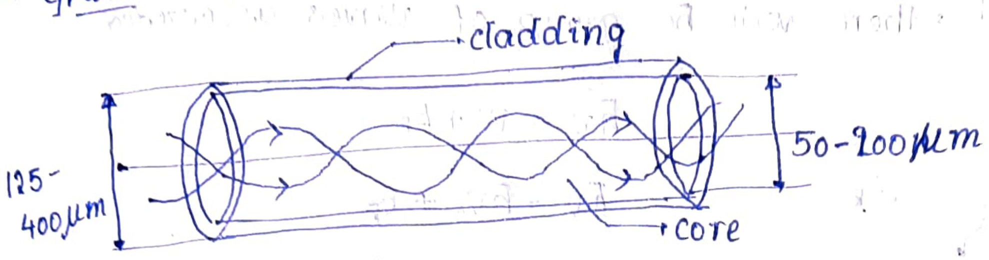
{numerical apperture}

Δ & NA → very Small

→ Step Index multimode fibre :-



→ Graded Index multimode :-



V-number :-

$$V = \frac{\pi d}{\lambda_0} \sqrt{n_1^2 - n_2^2}$$

$\boxed{V < 2.404}$ for Single mode

Normal Sized frequency = V.

Max. number of modes Supported by SI fibre

$$N_m = \frac{V^2}{2}$$

In case of GRIN fibre

$$N_m = \frac{V^2}{4}$$

→ Attenuation :- Loss of amplitude / ~~Signals~~.

→ Distortion :- Loss of Shape of Signals.

→ In attenuation due to micro & macro bending due to strain the R.I changes & T.I.R will be affected.

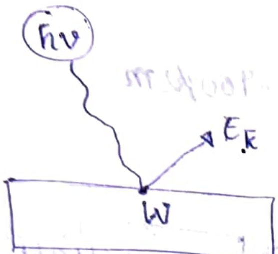
→ Passing of diff. ordered signals doesn't reach in same time.

→ change in wavelength also causes distortion.

Unit - 4 Quantum Mechanics.

De-Broglie concept : Matter waves.

↳ there will be group of waves associated



Photons.

$$h\nu = W + E_K$$

$$h\nu = h\nu_0 + E_K.$$

$$E_K = \frac{1}{2}mv_{max}^2.$$

$$\boxed{\frac{1}{2}mv_{max}^2 = h(\nu - \nu_0)}$$

h - plancks const.

ν_0 - threshold frequency.

W - work func.

E_K - kinetic energy

→ Black Body radiation.

→ P.E.E

→ Crompton Effect.

De-Broglie's wavelength → m ○ → v $p = mv$

$$\lambda = \frac{h}{p} \rightarrow \text{particle nature.}$$