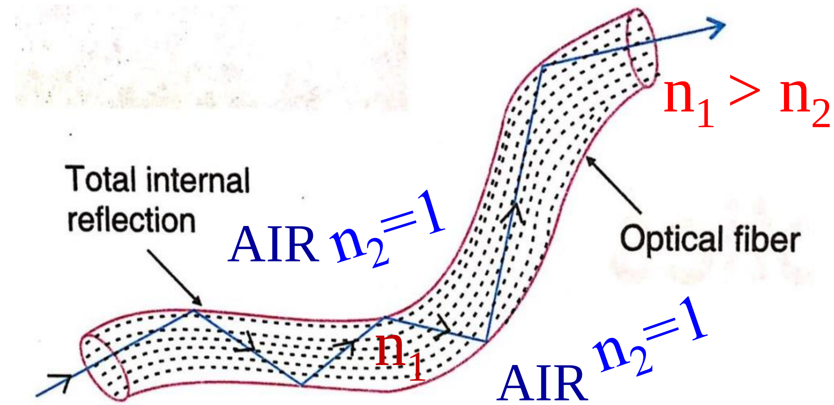
PHY110 UNIT III: Fiber optics

LECTURE 2

Revision

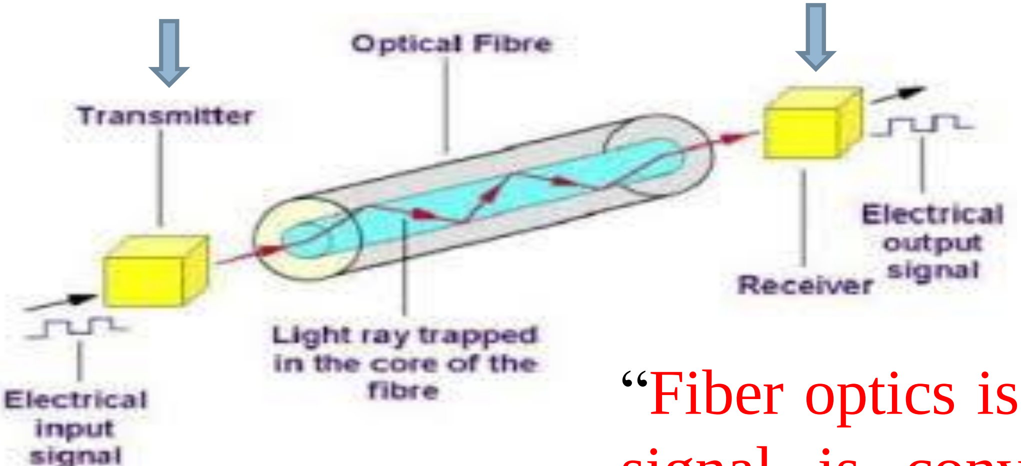
Fiber- Thin strand of **dielectric** material (*transmission of light*)
Wire: The stand of **metal** (*transmission of electricity*)

Laser diode: Forward biased



Laser diode/LED

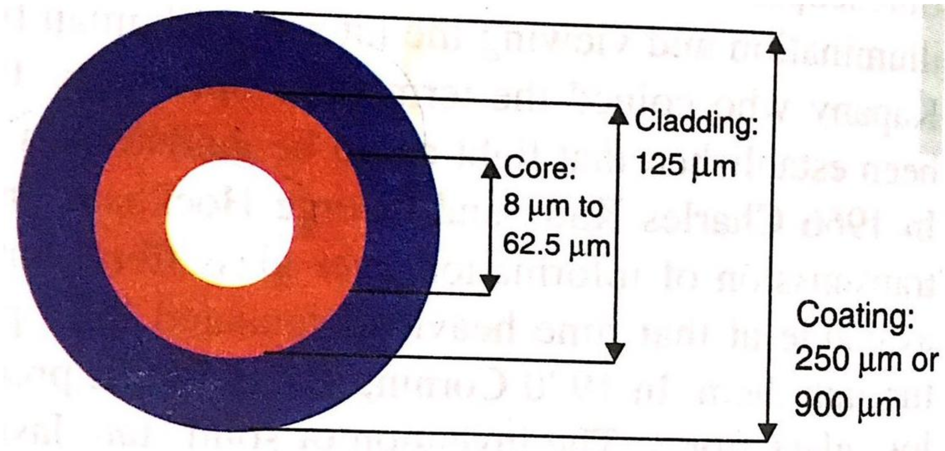
Photo diode

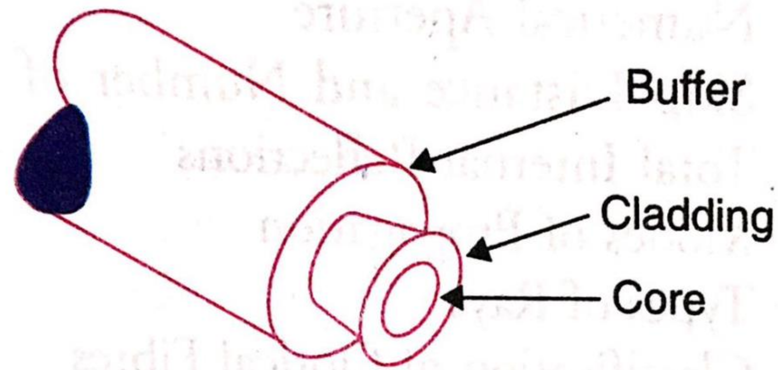


OPTICAL FIBER SYSTEM

"Fiber optics is a technology in which electrical signal is converted to optical signals and transmitted through fibers and reconverted back into electrical signals"

Human hair thickness ~ 100μm



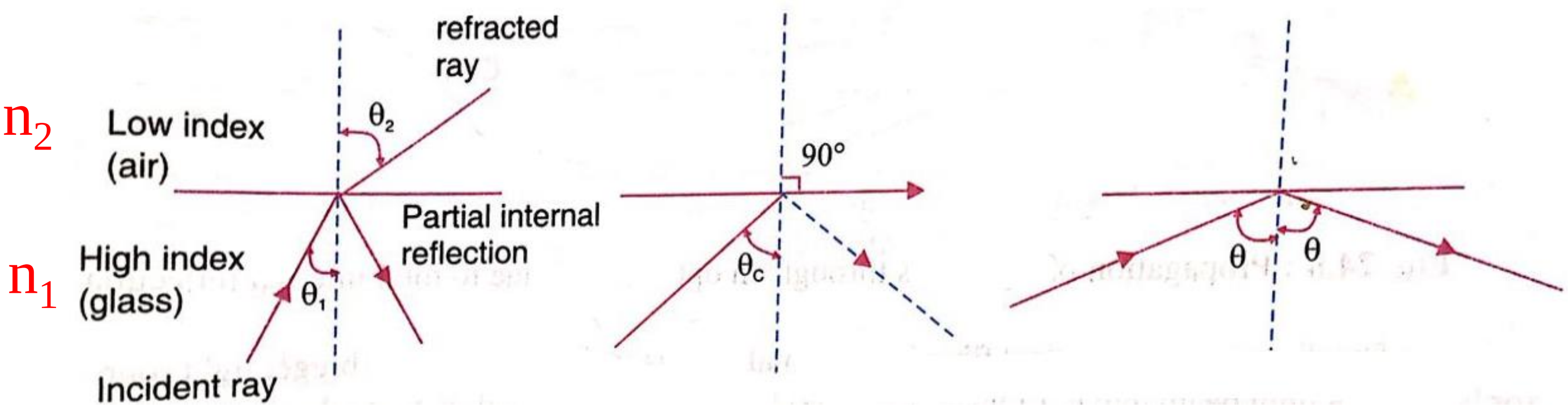


1. Core - *Light guiding region*
2. Cladding- *confine the light to the core*
3. Buffer or Sheath - *protect the fiber from physical and environmental damage*

Additional functions of cladding

- ✓ *To maintain the uniformity along the length of the fiber*
- ✓ *To protect the outer surface of the core*
- ✓ *To reduce the cone of the light*

TOTAL INTERNAL REFLECTION happens when a ray light pass from the denser medium to rarer medium:



TOTAL INTERNAL REFLECTION

Critical angle

$\theta > \theta_c$

Snell's law

$$\sin\theta_2 = \frac{n_1}{n_2}\sin\theta_1$$

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

Principle on which Fiber optic communication rely on is **TOTAL INTERNAL REFLECTION**

Total Internal Reflection

The phenomena in which light is totally reflected back to denser medium at the denser-rarer boundary is known as TOTAL INTERNAL REFLECTION.

$$\sin\theta_2 = \frac{n_1}{n_2}\sin\theta_1 \quad \text{--------------------------------} \quad \text{Eq.1}$$

Critical angle can be obtained from Eq.1

$\theta_1 = \theta_c$; $\theta_2 = 90°$

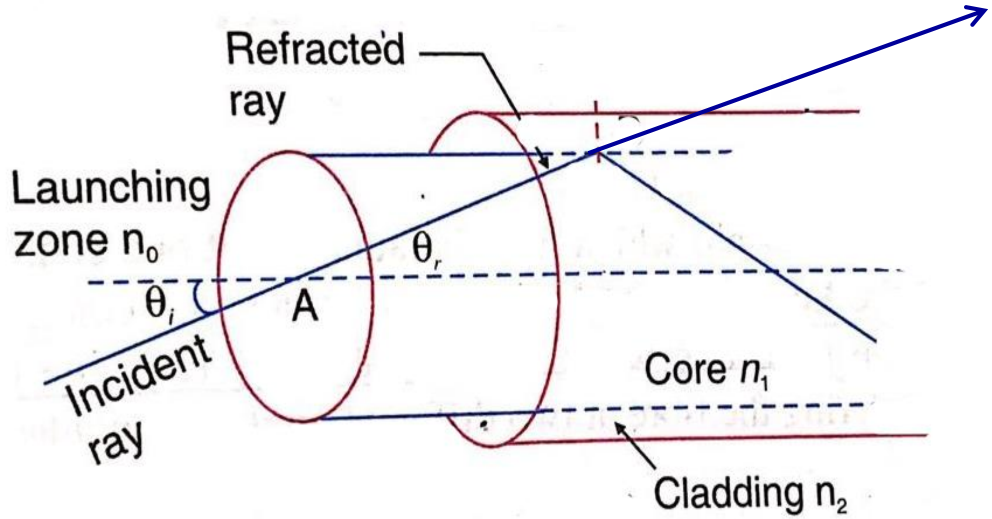
$$\sin\theta_c = \frac{n_2}{n_1} \quad \text{------------------} \quad \text{Eq.1a}$$

Later we use ϕ for θ ☺

If the rarer medium is air $n_2=1$

$$\sin\theta_c = \frac{1}{n_1} \quad \text{or} \quad \theta_c = \sin^{-1}\left(\frac{1}{n_1}\right) \quad \text{------------------} \quad \text{Eq.2}$$

Acceptance Angle



Case 1: Refraction at A

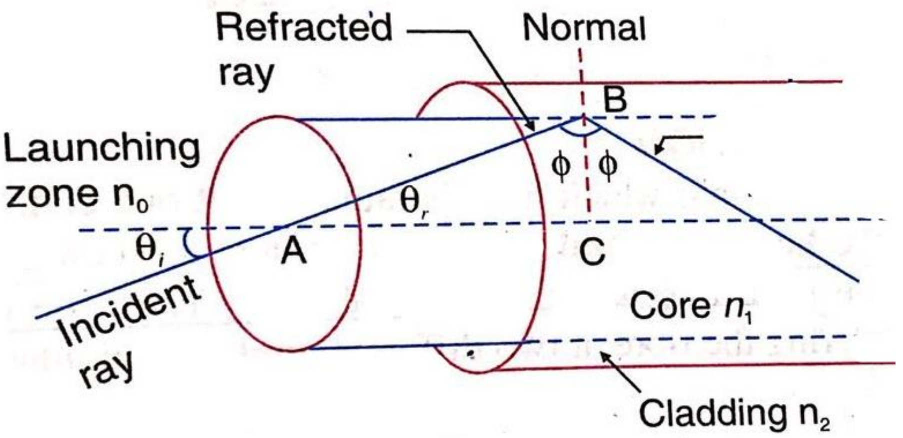
Incident ray from launching medium having the refractive index n_0 → refracted into the core having refractive index n_1 , according to the Snell's law…

$$n_1 \sin\theta_r = n_0 \sin\theta_i \qquad \text{------------------ Eq.3}$$

Acceptance Angle

Case 2: Refracted ray incident on interface at B

Refracted ray in the core (n_1) now incident on the core-cladding interface at an angle (ϕ),



From the triangle ABC

$\theta_r = 90 - \phi$ -------- Eq.4

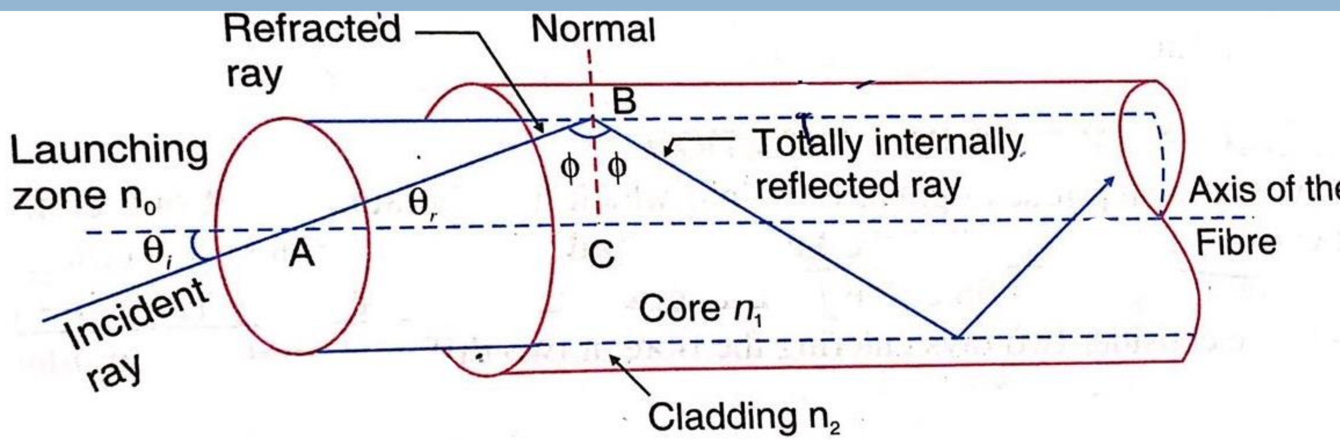
substitute Eq.4 in Eq.3 $n_1 \sin(90 - \phi) = n_0 \sin\theta_i$

$$n_1 \cos\phi = n_0 \sin\theta_i$$

$$\mathrm{Sin}\theta_i = \frac{n_1}{n_0}\cos\phi \quad \text{-------- Eq.5}$$

Acceptance Angle

Case3: Total internal reflection at B



When $\phi=\phi_c$ total internal reflection occurs at B, that set the maximum allowable launching angle, θ_{imax} , equation 5 changes to

$$\text{Sin } \theta_{imax} = \frac{n_1}{n_0} \cos\phi_c \qquad \text{-------- Eq.6}$$

But from Eq.1a

$$\sin \phi_c = \frac{n_2}{n_1} \qquad \text{-------- Eq.7}$$

Acceptance Angle

$\cos^2\phi_c + \sin^2\phi_c = 1$ substitute for $\sin^2\phi_c$ from Eq.7

$$\cos^2\phi_c + \left(\frac{n_2}{n_1}\right)^2 = 1$$

$$\cos^2\phi_c = \frac{n_1^2 - n_2^2}{n_1^2} \quad \text{Or} \quad \cos\phi_c = \frac{\sqrt{n_1^2 - n_2^2}}{n_1} \quad \text{-------- Eq.8}$$

substitute Eq.8 in Eq.6

$$\text{Sin}\ \theta_{imax} = \frac{n_1}{n_0}\frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

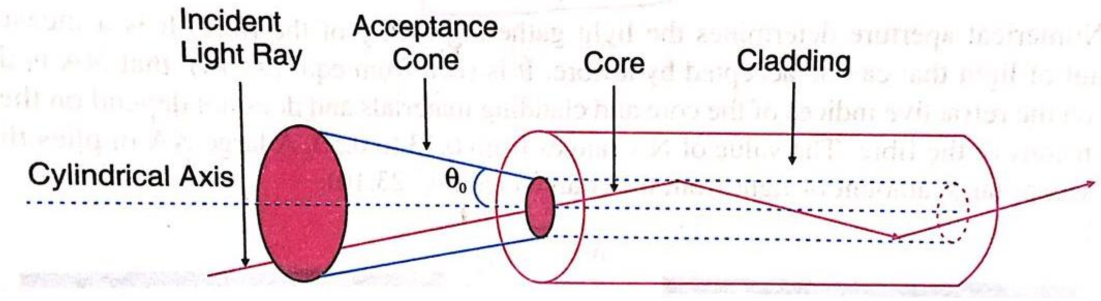
For launching from air $n_0=1$

$$\text{Sin}\ \theta_{imax} = \sqrt{n_1^2 - n_2^2} \qquad \theta_{imax} = \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right) \quad \text{-------- Eq.9}$$

θ_{imax} is the acceptance angle of the fiber. Also called waveguide acceptance angle

Acceptance Cone

We know in 2D, θ_{imax} is the acceptance angle- and is with axis of the fiber



If you consider 3Dimension, instead of angle it is the **cone (solid angle)**, **Light rays within the cone having full 2θ_{imax}** are accepted and hence called **acceptance cone (2θ_{imax}).**

- Larger the θ_{imax} easier to launch light into the fiber
- Incident at an angle more than θ_{imax} refract through the cladding and lost

What is the other name for maximum external incident angle?

a) Optical angle
b) Total internal reflection angle
c) Refraction angle
d) Wave guide acceptance angle

Ans: D

Relative Refractive Index

The fractional difference between the refractive indices of the core and the cladding *is relative refractive index or the fractional refractive index difference*

$$\Delta = \frac{n_1 - n_2}{n_1} \qquad \text{-------- Eq.10}$$

- Δ is always positive because $n_1 > n_2$.
- Typically value of Δ is the order of 0.01
- For effective light transmission through the fiber, $\Delta << 1$.