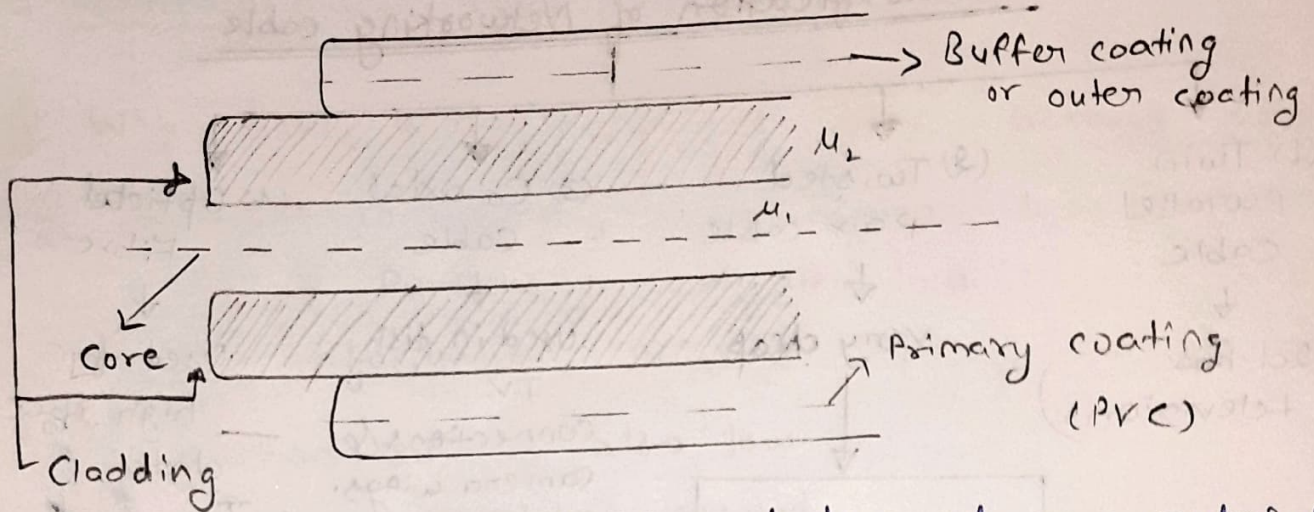


* Unit-3 *

Optical Fibre

- * Optical fibre is a cylindrical waveguide made of glass or polymer which allows the light to propagate by "TIR".



μ_1 is refractive index at core material
 μ_2 is refractive index at cladding material

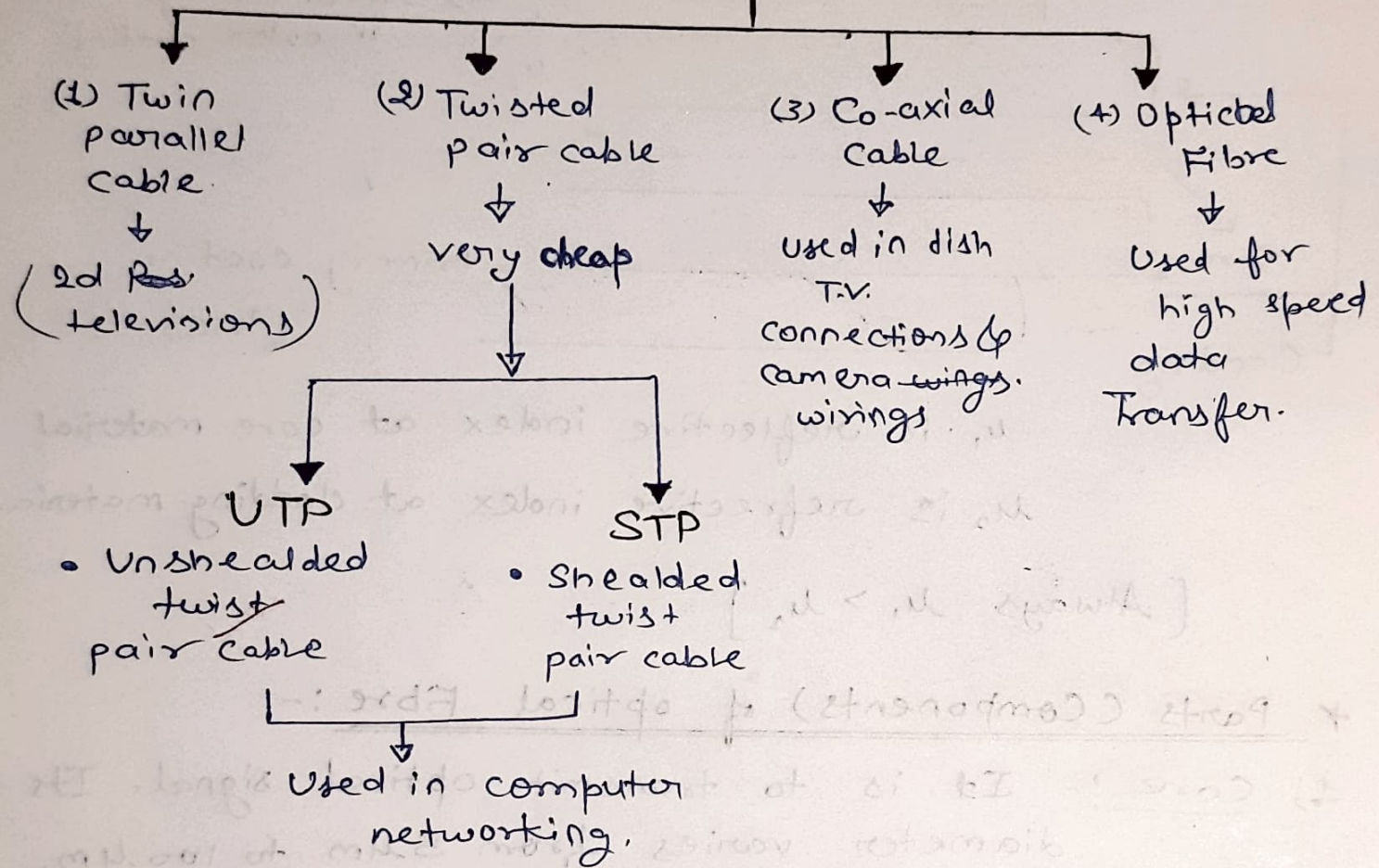
[Always $\mu_1 > \mu_2$]

* Parts (Components) of optical Fibre :-

- 1) Core :- It is to transmit optical signal. Its diameter varies from $5\mu\text{m}$ to $100\mu\text{m}$.
- 2) Cladding :- The purpose of the cladding is to guide the light within core. Its diameter varies from $50\mu\text{m}$ to $200\mu\text{m}$. It is made normally silica glass.

3) Primary coating:- It is made of generally plastic material to protect the core cladding surface from the environmental conditions like temperature, humidity & graze (cut). Its diameter varies upto 250 μ m.

Classification of Networking cable



* Advantages of the Fibre optics cable over to copper wire.

1. Speed Optical fibre operated at high speed upto Giga bite (GB)

2. Band width Large information carrying capacity.

3. Distance :- Signals can be transmitted further without needing to be refreshed.

4. Resistance :- It has greater resistance due to electromagnetic noise reduced.

5. Maintainance :- Low maintainance cost.

Q Why now a days optical fibre became popular?

Ans (1) Light in weight, small in size, low maintainance cost & Purchasing cost also low.

(2) Higher information carrying capacity.

(3) Installation cost is also low.

(4) No electric connection needed.

(5) No Hazards of shock or short-circuit.

(6) Can be safely used in explosive environment.

(7) No effect at temperature.

• Types of Optical Fibre :- (According to mode of optical signal propagation)

(1) Single mode optical Fibre (SMF)

(2) Multimode optical Fibre (MMF)

(1) Single mode optical Fibre :-

A single mode fibre has a very small core diameter and support only one mode of propagation.

iii) Multimode optical Fibre:-

Multimode optical fiber can propagate 100 of modes. If the light takes more than one path to propagate down the cable, it is called a multimode fibre. In multimode fibre the diameter of core varies from 20 μm to 100 μm .

• Some Important terms used in Optical Fibre -

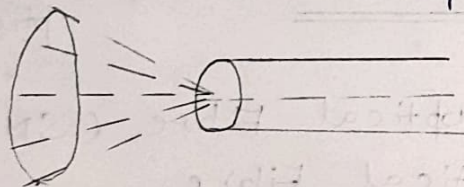
(1) Acceptance Angle (i_0) -

It is the maximum angle of incidence at which incident light propagates inside the core by TIR.

$$i_0 = \sin^{-1} \sqrt{n_1^2 - n_2^2}$$

(2) Acceptance Cone -

A cone-like structure inside the core which all incident lights are collected with an acceptance angle (i_0) and propagate by TIR.



(3) Numerical Aperture (NA) -

It is a light collecting property of an optical fibre which is measured as acceptance angle and based on refractive index of core & cladding.

$$N.A. = \sin i_0$$

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

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

Δ = Relative refractive index

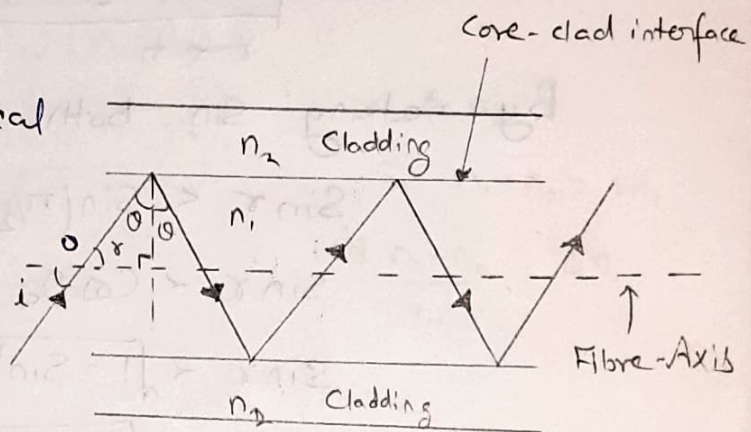
* Relative Refractive index (Fractional index change Δ)

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

→ It is the ratio of difference between refractive index of core and cladding to the refractive index of core.

* Derivation For Acceptance Angle & Numerical Aperture:-

Let us consider an optical fibre having core n_1 of refractive index (n_1) cladding with refractive index (n_2) is placed in a medium refractive index of (n_0).



Light is launched from other medium (n_0) making an angle i with fibre axis.

→ By applying Snell's law at point 'O'.

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

Condition of critical angle at core-cladding interface for TIR
(θ_c = Critical Angle)

$$\theta > \theta_c$$

$$\sin \theta_c = n$$

$$\theta_c = \sin^{-1}(n)$$

for this time

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) \quad \text{--- (ii)}$$

by eq (i) (For TIR $\theta > \theta_c$)
from $\triangle OCB$

$$\text{then } \angle r = \gamma$$

$$\gamma + \theta = \pi/2$$

$$\theta = \pi/2 - \gamma$$

$$\therefore \theta > \theta_c$$

$$(\pi/2 - \gamma) > \theta_c$$

$$\boxed{\gamma < (\pi/2 - \theta_c)}$$

$$\gamma \leftarrow n_1$$

By taking sin both side

$$\sin \gamma < \sin(\pi/2 - \theta_c)$$

$$\sin \gamma < \cos \theta_c$$

$$\sin \gamma < \sqrt{1 - \sin^2 \theta_c}$$

$$\sin \gamma < \sqrt{1 - \left(\frac{n_2}{n_1}\right)^2} \quad \left(\because \sin \theta_c = \frac{n_2}{n_1}\right)$$

By multiplying n_1 both sides

$$n_1 \sin \gamma < \sqrt{n_1^2 - n_2^2}$$

by eq (ii)

$$n_0 \sin i < \sqrt{n_1^2 - n_2^2}$$

$$\boxed{i < \sin^{-1} \left(\frac{\sqrt{n_1^2 - n_2^2}}{n_0} \right)}$$

for Air $n_0 = 1 \Rightarrow i \rightarrow i_{\max}$

$$\boxed{i_{\max} < \sin^{-1} \sqrt{n_1^2 - n_2^2}}$$

i_{\max} = max value
of Acceptance
angle.

For numerical aperture (NA)

$$NA = n_0 \sin(i_{\max}) = \sqrt{n_1^2 - n_2^2}$$

→ NA measure light gathering Power of an optical fibre.

→ N.A is a dimensionless quantity.

→ For N.A maximum value is preferred.

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

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

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

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

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

here $\Delta = \frac{n_1 - n_2}{n_1}$ Refractive index change

$$n_1 \approx n_2$$

$$\text{So } n_1 + n_2 = 2n_1$$

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

Q Calculate the acceptance angle for an optical fibre whose core refractive index is 1.48 and cladding R.I is 1.39.

Soln Given that

$$i = ?$$

$$n_1 = 1.48$$

$$n_2 = 1.39$$

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

$$i_{\max} < \sin^{-1} \sqrt{(2.19) - (1.93)}$$

$$i_{\max} < \sin^{-1} (0.50)$$

$$\boxed{i_{\max} < 30^\circ} \text{ Answer}$$

Q2 Numerical Aperture of a fibre is 0.5 and core RI is 1.48. Find the cladding RI and Acceptance angle.

Soln

$$N.A = 0.5$$

$$n_1 = 1.48$$

$$n_2 = ?$$

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

$$(0.5)^2 = (1.48)^2 - n_2^2$$

$$n_2^2 = 2.19 - 0.25$$

$$n_2^2 = 1.94$$

$$n_2 = 1.39 \quad \text{Answer}$$