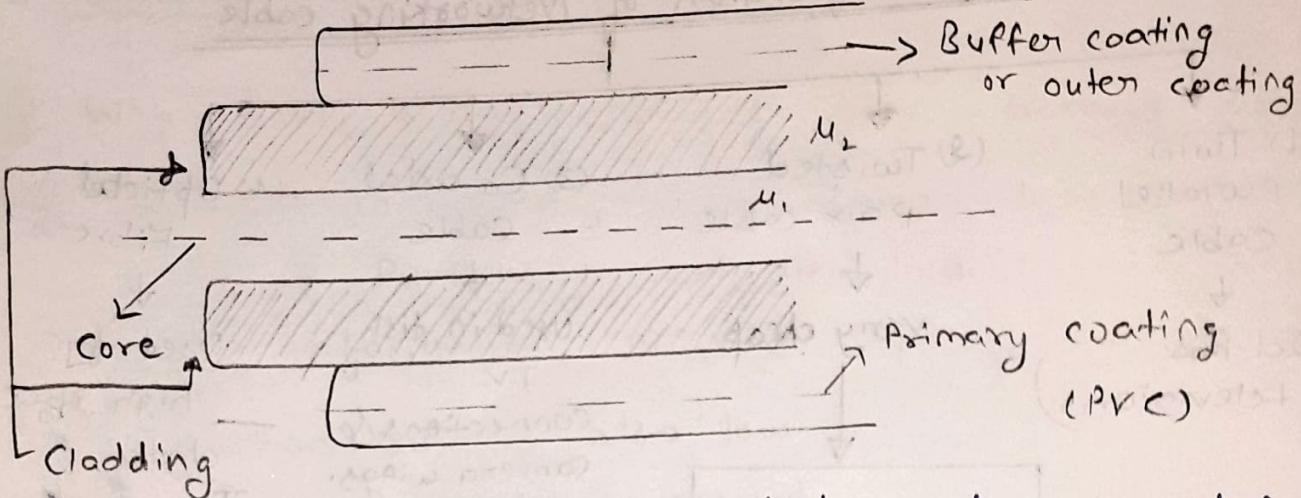


* Unit-3 *

Optical Fibre

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



n_1 is refractive index at core material

n_2 is refractive index at cladding material

[Always $n_1 > n_2$]

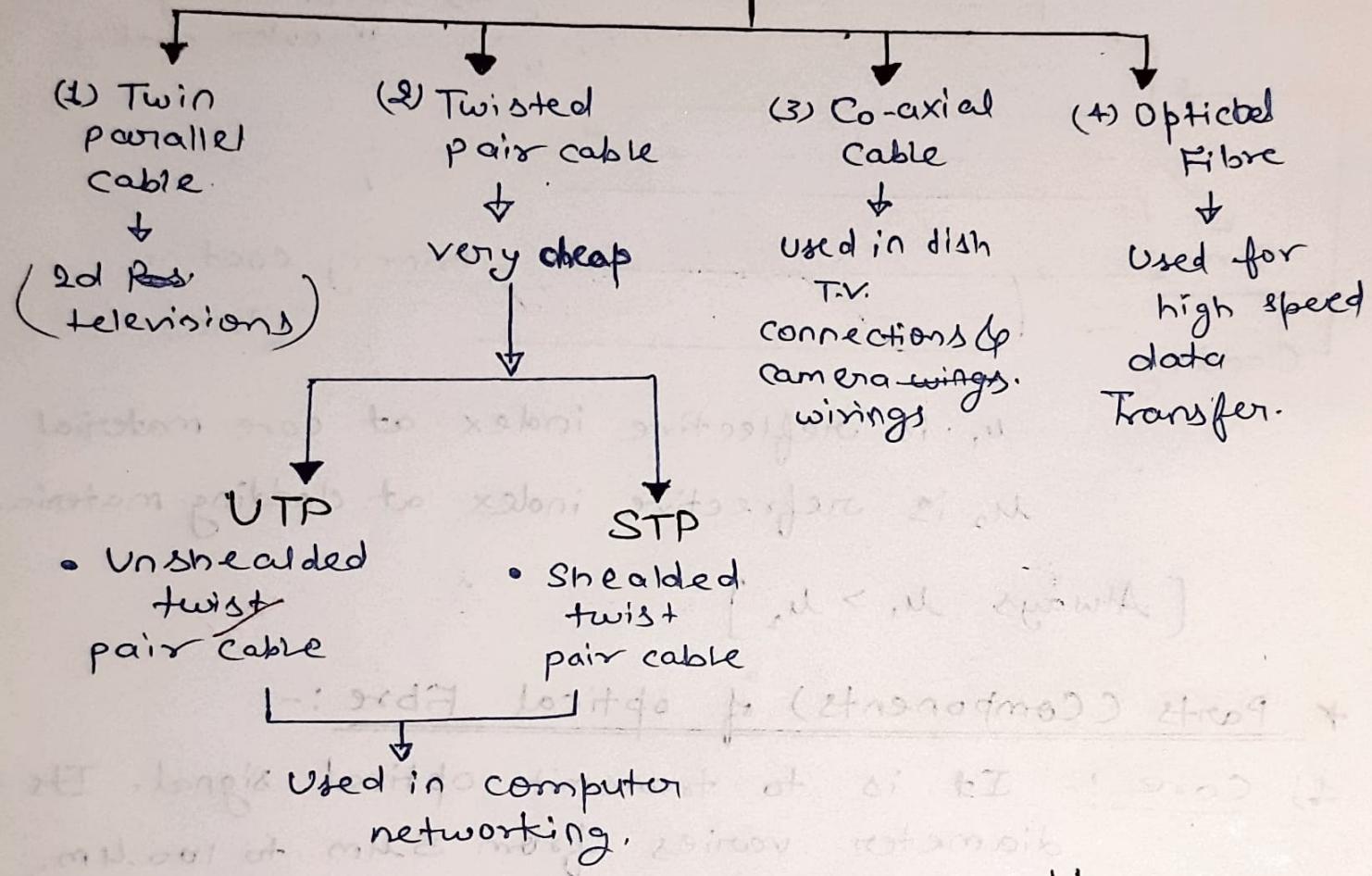
- * Parts (Components) of optical Fibre :-

1) core :- It is to transmit optical signal. Its diameter varies from 5μm to 100μm.

2) Cladding :- The purpose of the cladding is to guide the light with inter core. It's diameter varies from 50μm to 200μm. 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 & grazes (cut). Its diameter varies upto 250 μm.

Classification of Networking cable



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

1. Speed Optical fibre operated at high speed upto Giga bit (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 introduced.

5. Maintenance :- Low maintenance cost.

Q Why now-a-days optical fibre became popular?

Ans (1) Light in weight, small in size, low maintenance 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) Multi mode 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:- Multi mode optical fiber has can propagate 100 of modes. If the lights takes more then one path to propagate down the cable, it is called a multimode fibre. In multimode fibre the diameter of core vary from 20μm to 100μm.

- Sum Important terms used in Optical Fibre -

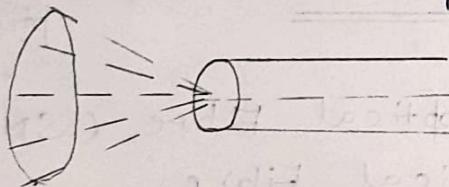
(1) Acceptance Angle (i_o) -

It is the maximum angle of incidence at which incident lights propagate inside the core by TIR.

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

(2) Acceptance Cone -

A cone like structure inside the core which all incident incident lights are collected with an acceptance angle (i_o) 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.

$$N.A. = \sin i_o$$

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

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

Δ = Relative refractive index

* Relative Refractive index (Fractional index change (Δ))

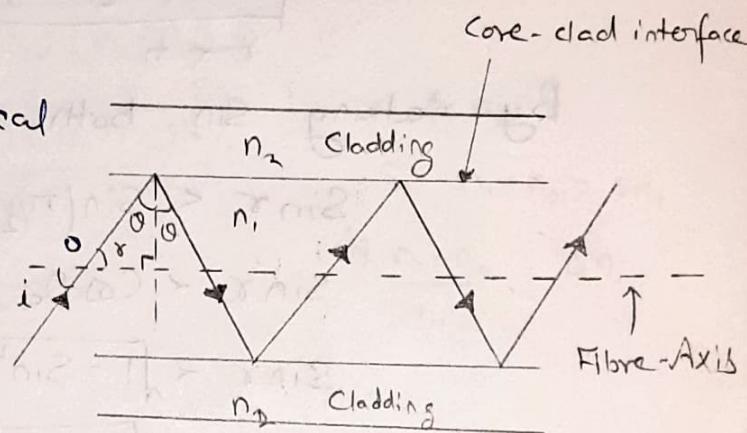
$$\Delta = \frac{n_1 - n_2}{n_1}$$

→ 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'.

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

Condition of critical angle at core-cladding interface-
for TIR

$$\theta > \theta_c$$

(θ_c = Critical Angle)

$$\sin \theta_c = n$$

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

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 ΔOCB

$$\tan r = n$$

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

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

$$\therefore \theta > \theta_c$$

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

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

$\downarrow n$

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

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

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 Aperature (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.

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

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

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

$$n_1 \approx n_2$$

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

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

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

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

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

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

Sol 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 $N.A = 0.5 \quad \therefore N.A = \sqrt{n_1^2 - n_2^2}$

$$n_1 = 1.48 \quad (0.5)^2 = (1.48)^2 - n_2^2$$
$$n_2 = ? \quad n_2^2 = 2.19 - 0.25$$
$$n_2^2 = \sqrt{1.94} \quad n_2 = 1.39$$

$n_2 = 1.39$ [Answer]