Fibre Optics

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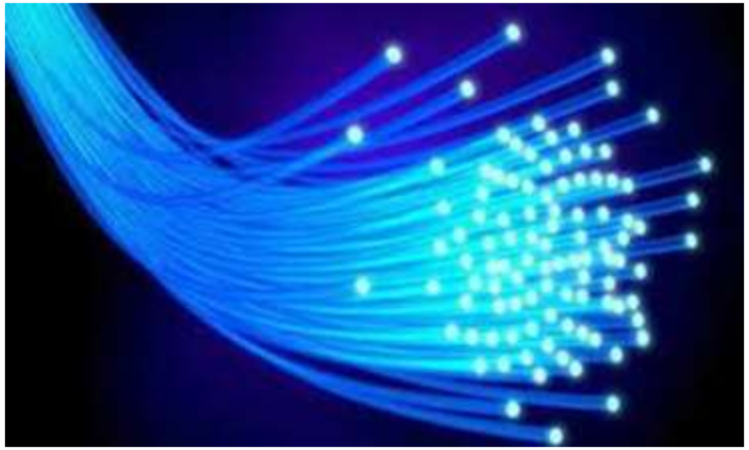
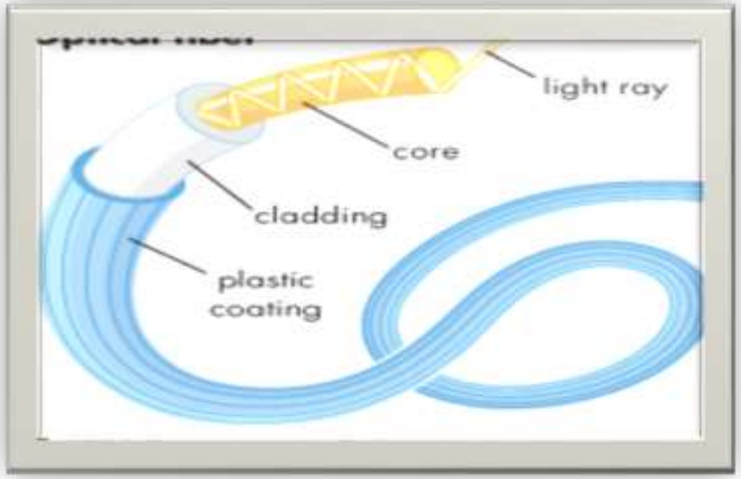
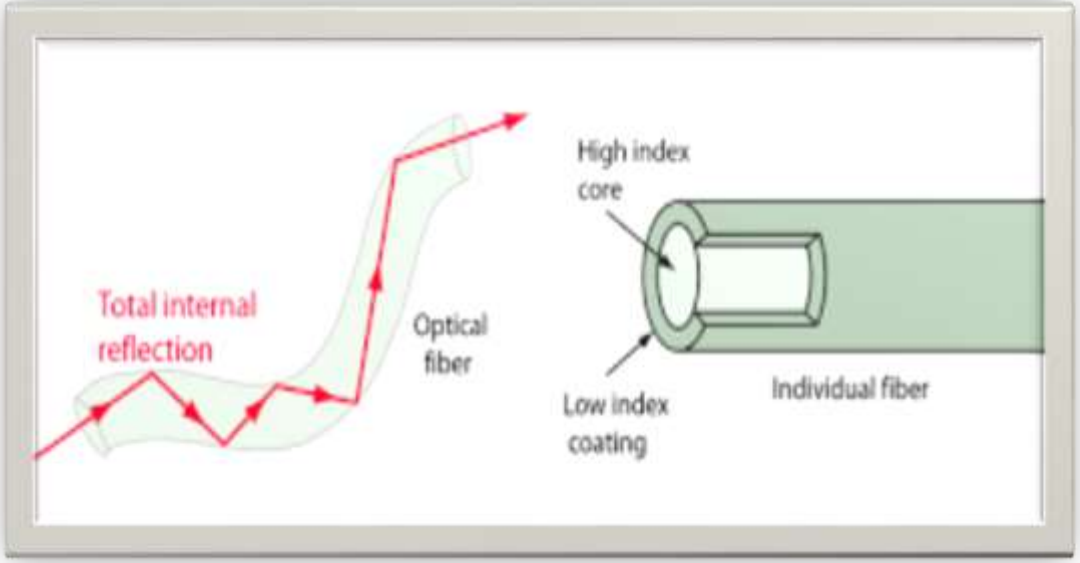
Fibre optics is the technology used to transmit information as pulses of light through strands of fibre made of glass or plastic over long distances.





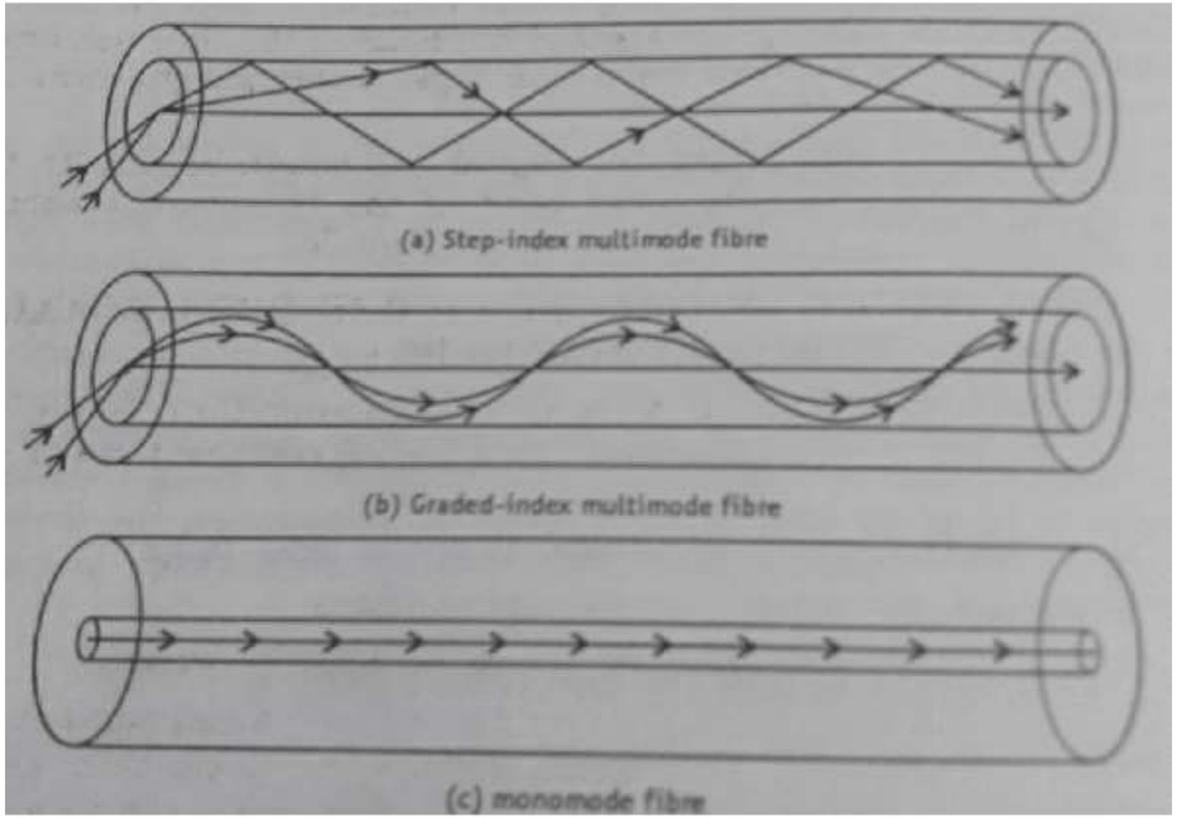
Within the fibre the light travels following laws of total internal reflection.



Basically there are three types of fibre:

i) Step index multimode fibre
ii) Graded index multimode fibre
iii) Monomode fibre

Multimode step index fibre is oldest of the three types. It is less expensive and can be easily infused with light . But it is not suitable for long distance communication due to its intermodal dispersion.



(a) Step-index multimode fibre

(b) Graded-index multimode fibre

(c) monomode fibre

In graded index fibre intermodal dispersion problem is not so serious.

In mono mode optical fibre the ray travels parallel to the axis of the tube and problem of intermodal dispersion is practically eliminated.

Application of fibre optics:

There are number of advantages of fibre optic cables over copper cables, such as higher bandwidth and transmission speeds.

Fibre optics is commonly used in telecommunication services such as internet, television and telephones etc.

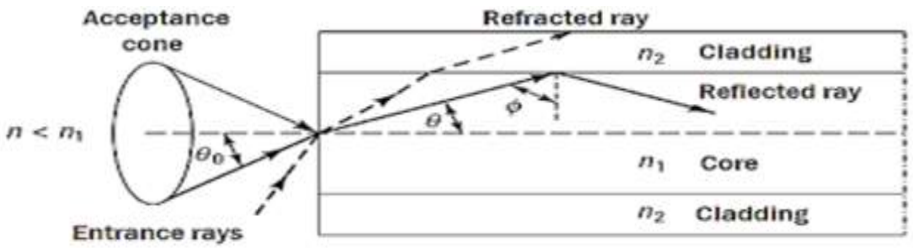
It is used as sensors and coupler.

Acceptance angle and numerical aperture of optical fibre:

Acceptance angle is the maximum angle with the axis of the Optical Fibre at which the light can enter into the optical fibre in order to be propagated through the fibre by total internal reflection.

$\boldsymbol{\theta_0}$ ***is acceptance angle***

From the fig ϕ= 90 °-$\boldsymbol{\theta}$ When $\boldsymbol{\theta_0}$increases,$\boldsymbol{\theta}$ *also increases and* as result ϕ *decreases*. There is a maximum value of $\boldsymbol{\theta_0}$ for which the ray suffer total internal reflection at the core cladding interface is called as acceptance angle



From Snell's law we have

$$n\ \sin\theta_0 = n_1 sin\theta$$
$$= n_1 \sin(90\text{-}\emptyset)$$
$$= n_1 \cos\emptyset$$

When θ_0=θ_A , $\emptyset = \theta_c$ therefore

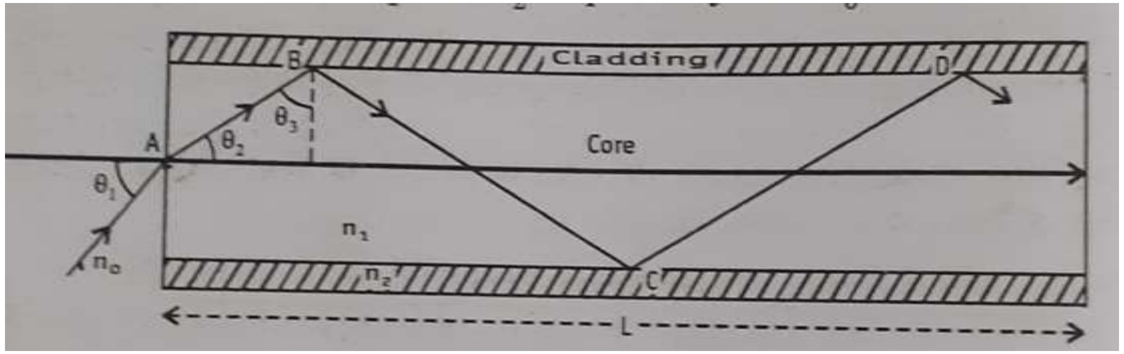
$$n\ \sin\theta_A = n_1\ \cos\emptyset \quad \text{-------(1)}$$

Since $\sin\emptyset = \frac{n_2}{n_1}$ we can write from eqn. (1)

$$n\ \sin\theta_A = n_1\sqrt{(1\text{-}\ \sin^2\emptyset)} = n_1\sqrt{(1 - \frac{n_2^2}{n_1^2}\ )}$$
$$= \sqrt{(n_1^2 - n_2^2\ )}$$
$$= \text{NA(numerical aperture)}$$

The Numerical Aperture (NA) of a fibre is defined as the sine of the largest angle an incident ray can have for total internal reflectance in the core. A higher core index, with respect to the cladding, means larger NA.

Intermodal dispersion in a step index fibre:



n_1- r.i of core

n_o -r.i of surrounding medium

n_2- r.i of cladding

If t be the length of the fibre , the minimum time of travel

$$t_{min} = \frac{axial\ length\ of\ the\ fibre}{Velocity\ of\ light\ in\ the\ fibre}$$

$$t\,min \;= \frac{L}{c/n_1} = \frac{Ln_1}{c} \qquad ---\;-(1)$$

If the ray traversed *l* distance inside the fibre then from the fig. we get $\cos\theta_2 = \frac{L}{l}$

$$\therefore\; l = \frac{L}{\cos\theta_2}$$

The path will be longest when $\theta_3 = \theta_c$

In this case $\theta_2 = 90^\circ - \theta c$

$$\cos\theta_2 = \sin\theta c \quad \text{here } \sin\theta c = \frac{n_2}{n_1}$$

Therefore $t_{max} = \frac{l}{c/n_1} = \frac{L}{\cos\theta_2} \cdot \frac{n_1}{c} = \frac{L}{\sin\theta c}\,\frac{n_1}{c}$

$$tmax = \frac{Ln_1^{\,2}}{cn_2} \qquad \text{----------------- ------(2)}$$

Thus maximum time interval between these two rays at the output is $\Delta t = t_{max} - t_{min} = \frac{Ln_1{}^2}{cn_2} - \frac{Ln_1}{c}$

$$= \frac{Ln_1}{c}\left[\frac{n_1}{n_2} - 1\right] \text{-------------------(3)}$$

If the light travels with a velocity c/n_1 in the core medium then in time Δt it will spread in a space by a distance

$$\Delta L = \frac{c}{n_1}\Delta t = L\left[\frac{n_1}{n_2} - 1\right]$$

Due to this difference in path length the digitally coded signal will be distorted. To make the transmission signal readable time interval between two signal must be large,so it limits the rate of signal transmission.

Thank You