FIBRE OPTICS

(CO-4)

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Introduction of Fibre

- An optical fibre cable is containing one or more optical fibres that are used to carry light.
- It is made of glass or plastic or transparent materials, as thin as human hair and transmits signals in the form of light.

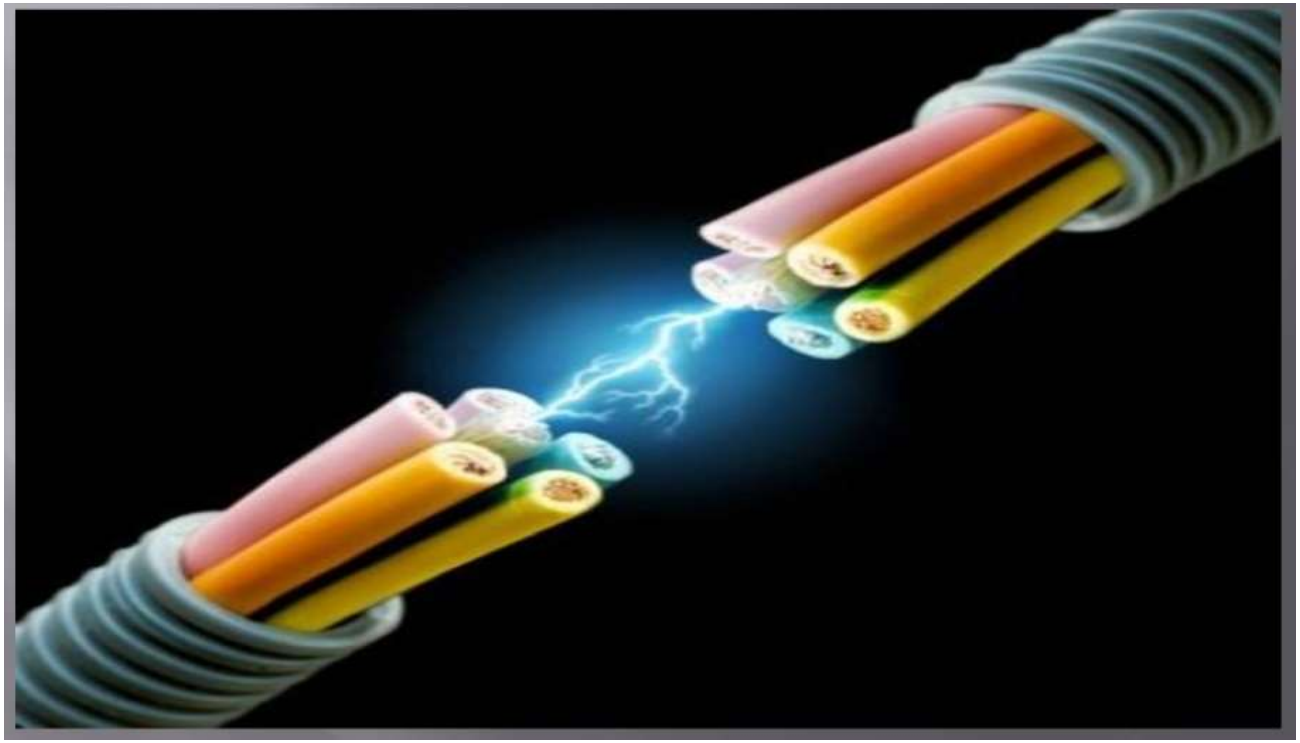


Figure.1*

Contd….

- There are different uses of fibres but mainly used in communication system.
- A light-emitting diode (LED) or laser diode (LD) can be used as a source in communication system.
- Advantages of optical fibre include greater bandwidth than copper wire cable & lower loss in signal. No electrical hazard.

Figure.2*

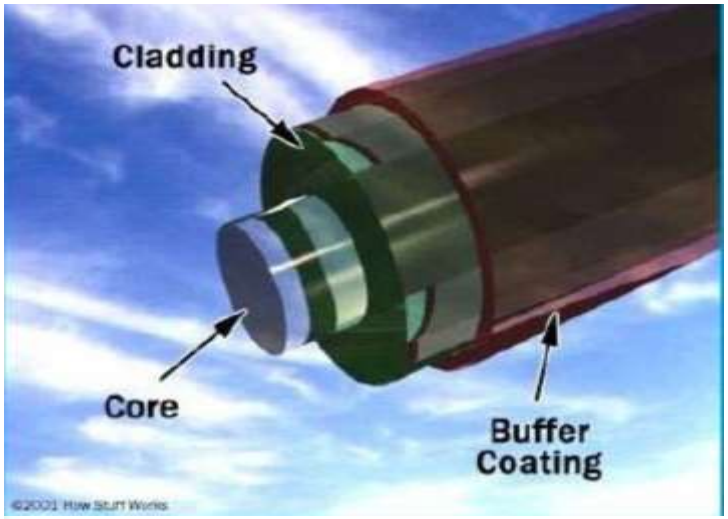
Construction of fibre

Fibre consist mainly three parts;

Core - central region of very thin size made up of optically transparent dielectric medium and carries the light form transmitter to receiver. The core diameter can vary from about 5μm-100 μm. Thin glass center of the fiber where the light travels.

Cladding - Outer optical material surrounding the core having reflecting index lower than core. It helps to keep the light within the core.

Contd.…



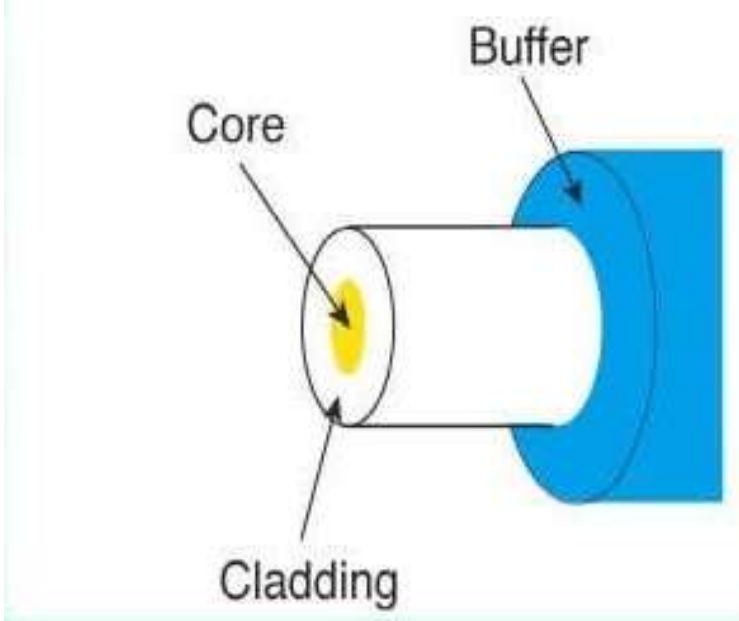


Figure.3*

Buffer Coating/Outer Jacket-

Plastic coating that protects the fiber from damage and moisture. The typical diameter of fiber after coating is 250-300μm The bundles are protected by the cable's outer covering, called a jacket.

- If n_1 & n_2 be the refractive index of core & cladding material then it is necessary that

$$n_1 > n_2$$

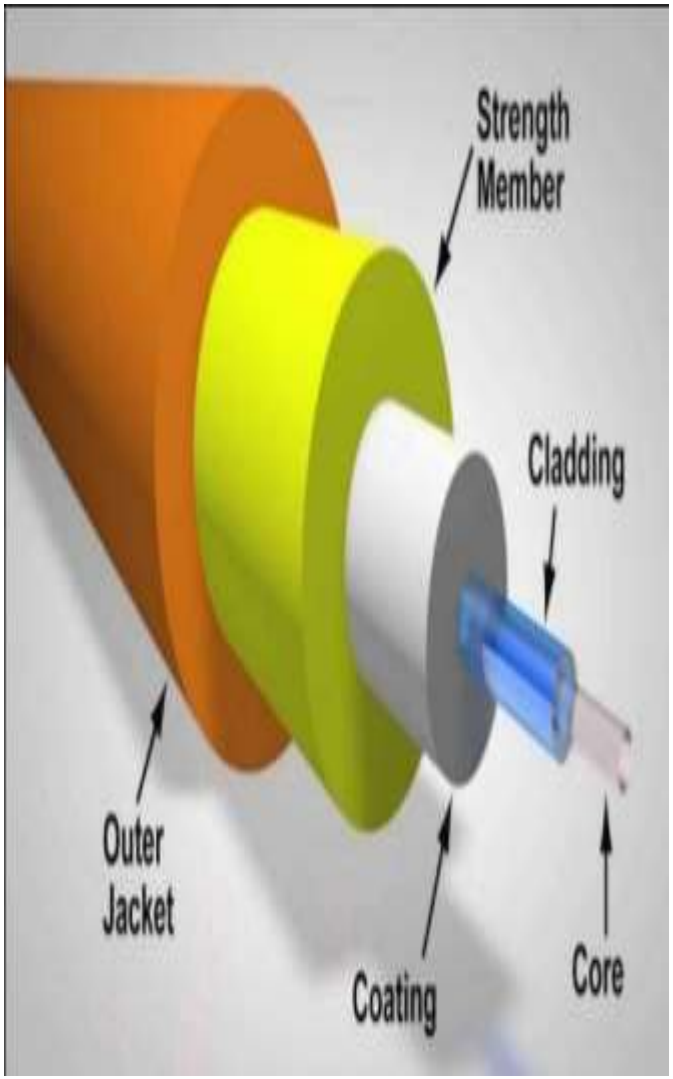


Figure.4*

Working principle of Fiber

- It works on the principle of *Total Internal Reflection*(TIR).
- In the optical fiber the rays undergo repeated total number of reflections until it emerges out of the other end of the fiber, even if fiber is bend. Due to this path of the rays inside fibre is Zig-Zag.

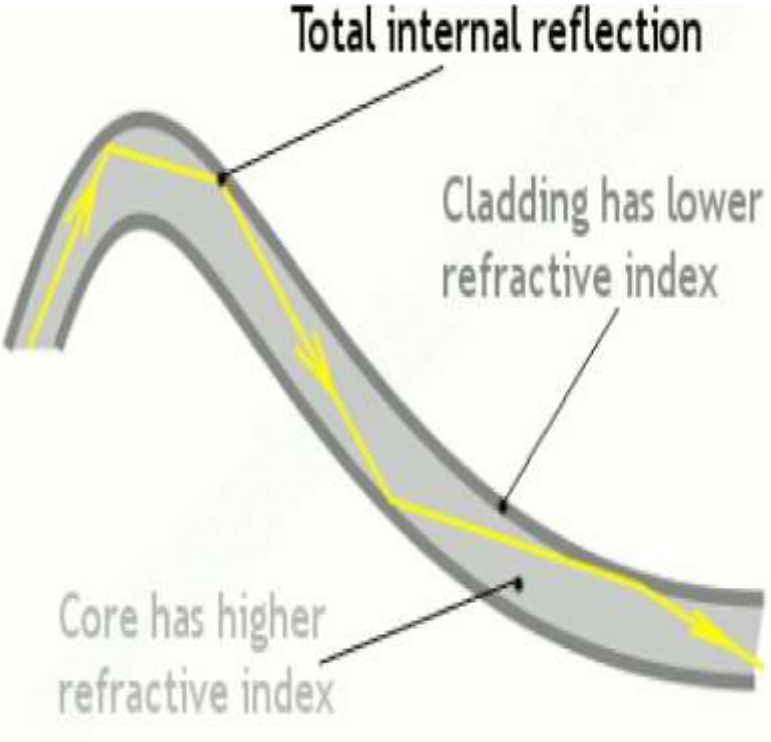


Figure.5*

Contd. ……

- Conditions for TIR:- When an ray of light travels from a denser to a rarer medium such that the angle of incidence is greater than the critical angle, the ray reflects back into the same medium. This phenomenon is known as Total Internal Reflection.
- TIR occurs at core cladding interface.

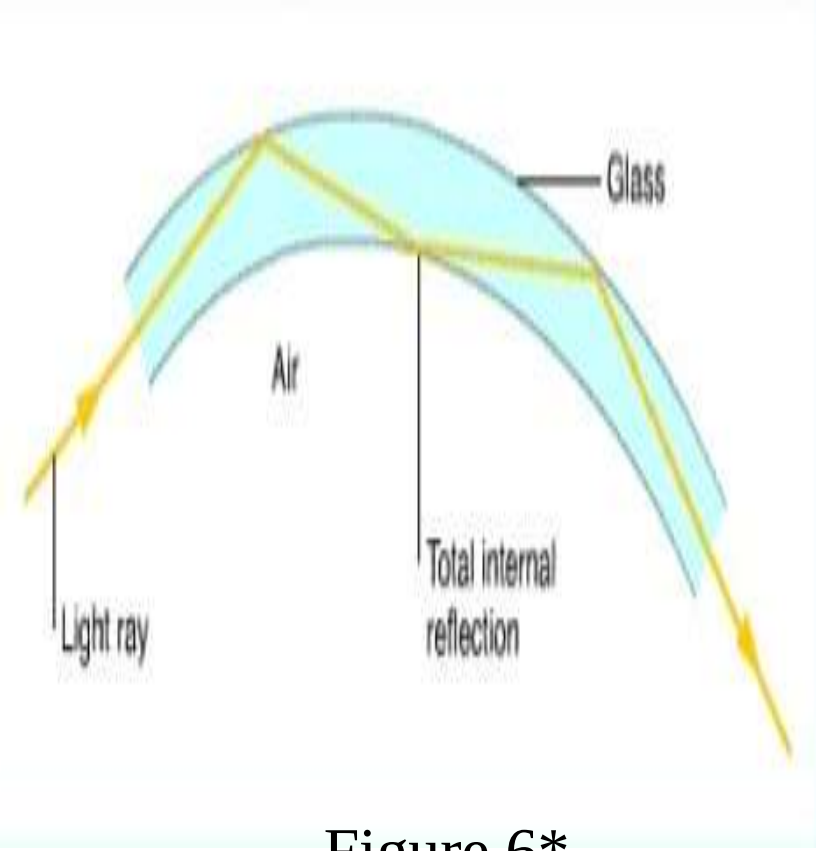


Figure.6*

Light propagation in Fibre

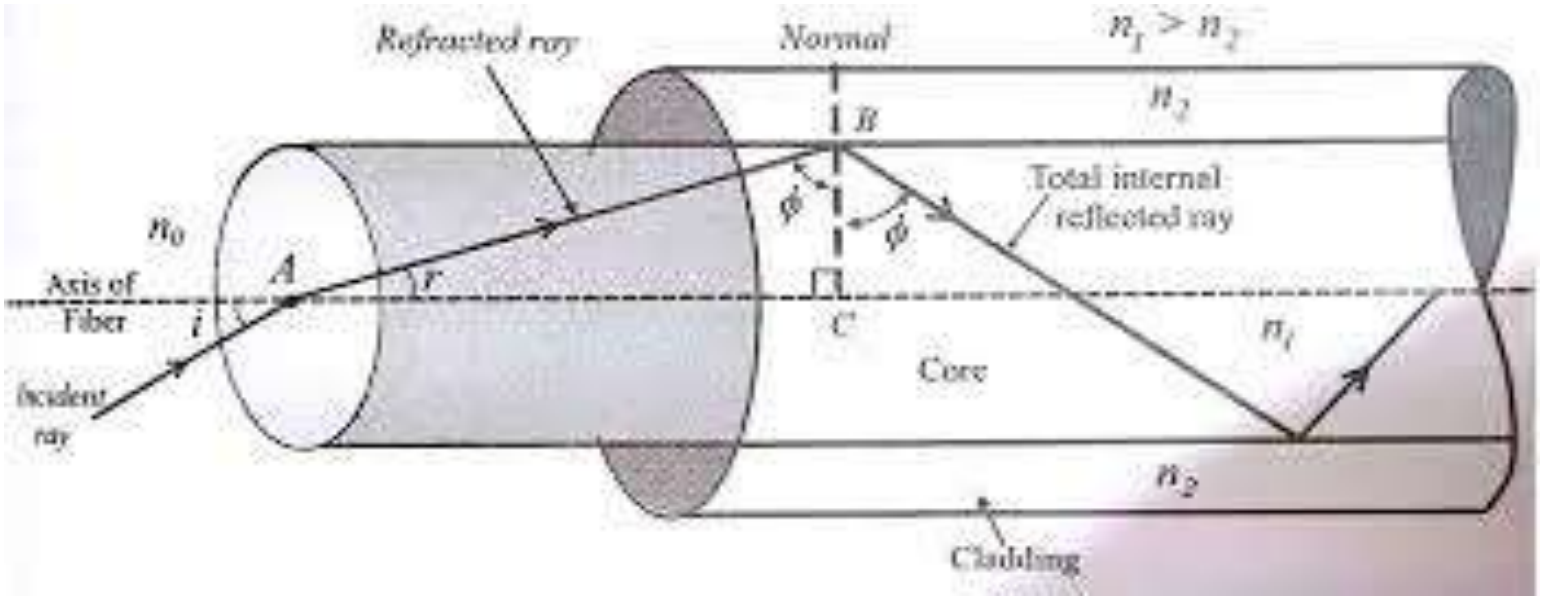


Figure.7*

i=angle of incident, r = angle of refraction

Φ=critical angle, θ_m= max acceptance angle

n_0=launching medium refractive index

n_1=core refractive index

n_2= cladding refractive index

Snell's law at launching face, we get

$$\text{Sin } i / \text{Sin } r = n_1 / n_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

now largest value of i occurs when $\Phi = \Phi_c$ and $r = 90 - \Phi$

Therefore $\text{Sin } i = n_1 / n_0 \text{ Cos } \Phi c$

When $\Phi = \Phi_c$ then $i = \theta_m$, so

$$\text{Sin } \theta_m = n_1 / n_0 \text{ Cos } \Phi c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

But at core cladding interface

$$\text{Sin } \Phi c = n_2 / n_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Therefore $\text{Cos } \Phi c = (n_1^2 - n_2^2)^{1/2} / n_1$ then from equation (2)

$$\text{Sin } \theta_m = = (n_1^2 - n_2^2)^{1/2} / n_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Launching medium is generally air therefore $n_0 = 1$

Therefore

$$\boxed{\text{Sin } \theta_m = = (n_1^2 - n_2^2)^{1/2}}$$

Terms related to optical fibre

- ***Relative Refractive Index Change (Δ):-*** it is defined as the ratio of the difference between refractive indices of the core and cladding to the refractive index of core.

$$\Delta = n_1 - n_2 / n_1$$

Where n_1 & n_2 be the refractive index of core & cladding material.

- ***Numerical Aperture(NA):-*** it is defined as the sin of the acceptance angle & measure of the light gathering capability of the fibre.

$$NA = (n_1^{\,2} - n_2^{\,2})^{1/2} = n_1 (2\,\Delta)^{1/2}$$

- ***Acceptance Angle (θ_m):-*** It may defined as the maximum angle that a light ray can have relative to the axis of the fibre and propagate down the fibre.

$$\theta_m = \sin^{-1}(NA) = \sin^{-1}[(n_1^2 - n_2^2)^{1/2}] = \sin^{-1}[n_1(2\Delta)^{1/2}]$$

- ***Acceptance Cone ($2\theta_m$):-*** The twice of the acceptance angle is known as Acceptance Cone.

$$\text{Acceptance Cone} = 2\theta_m$$

- ***Normalized frequency/ V. No.*** :-It is use to calculate the no. of modes supported by the fibers.

$$\text{V. no.} = 2\pi a/\lambda\ (NA)$$
$$= 2\pi a/\lambda\ [(n_1^2 - n_2^2)^{1/2}]$$
$$= 2\pi a/\lambda\ [n_1(2\Delta)^{1/2}]$$

Where a=core radius, λ=Wavelength

Advantage of Optical Fibre

- Small size and light weight.
- Very low transmission loss.
- High signal security.
- higher bandwidth to utilize.
- Total electrical isolation in the transmission medium.

Disadvantage of Optical Fibre

- System installation is very costly.
- Only point-to-point communication is possible.
- Precise and costly instruments would be required.
- Splicing is time consuming.

Applications of Optical Fibre

Optical fiber have wider range of application in almost all field, some are as follows.

- In telecommunication field.
- Broadband applications.
- In decorations, etc.
- Civil, consumer and industrial application.
- The Endoscope (In medical field).

References:

*Figure 1,2,6** https://www.slideshare.net/RamSinghPatel/ppt-on-optical-fiber

*Figure 3-4** https://www.google.com/search?sxsrf=ALeKk03eEW_m8iAXBZCOVEdNoex-iyfYXA:1585395062158&q=optical+fiber+images&tbm=isch&source=univ&sa=X&ved=2ahUKEwjdr4jsiL3oAhWBUn0KHUhLCFQQ7Al6BAgKEDs&biw=1280&bih=657

*Figure5** https://www.learnpick.in/prime/documents/ppts/details/1513/optical-fibre

Figure 7 A textbook of Engineering Physics by Navneet Gupta & S. K. Tiwari*