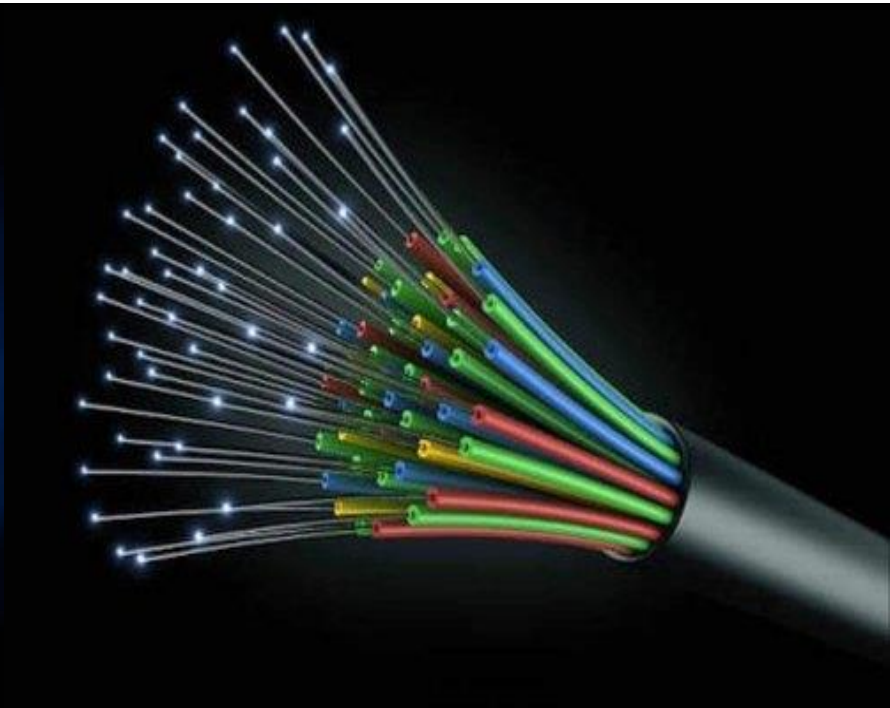
UNIT-IV

Laser Holography and Optical Fibre

Lecture-5: Optical Fibre



Content of Lecture

- INTRODUCTION TO OPTICAL FIBRES
- ADVANTAGES OF OPTICAL FIBERS.
- FUNDAMENTALS OF OPTICAL FIBRES
- PROPAGATION OF LIGHT THROUGH OPTICAL FIBRE

OPTICAL FIBRE

- Communication is defined as the transfer of information from one point to another.

- Main constraints in the communication are transmission fidelity, data rate, distortions, and distance between relay stations.

- In order to meet out the demands of telecommunication companies worldwide, optical fibers are used as a dominant transmission system.

- This optical communication system consists of hair-thin glass fibers that guide light signals with minimum losses over long distances.

OPTICAL FIBRE

- An optical fiber is a cylindrical waveguide system consisting of three regions. The centre is a the core, the middle region is a cladding and the outer region is a protective sheath.

- Fibers fabricated with recently developed technology are characterized by extremely low losses (less than 0.2 dB/km) as a consequence of which, the distance between two successive repeaters could be as large as 250 km.

- Due to the low cost and better response, optical fibers are replacing the traditional copper cables.

WHY WE USE OPTICAL FIBERS?

There are many advantages of optical fibers over conducting wires. The main advantages are:

(1) Cheaper

- Silicon (Si) is the main component in the manufacturing of optical fibers.
- It is one of the most abundant materials on earth.
- Due to this the overall cost of optical fiber is lower than that of an equivalent cable used in communication.

WHY WE USE OPTICAL FIBERS?

(2) Small size, light weight, flexible, and strong:

- The size of optical fiber is very small. It is of the order of few hundred microns.
- Its weight is very less.
- Optical fibers are flexible. They can be molded at any place with the help of suitable connectors and splices.
- An optical fiber has an outer jacket, which protects it from any outer damage and hence, makes it strong.

WHY WE USE OPTICAL FIBERS?

(3) Not hazardous:

- In optical fiber cables there is no chance of sparking and short circuit.
- This removes the risk of high damage.

(4) No crosstalk:

- There is no chance of crosstalk in the optical fiber communication because the information propagating through the optical fiber is trapped within the fiber and cannot leak out.

(5) Immune to RFI and EMI:

- The information is carried by photons in the optical fiber communication.
- Due to this signals propagating through fibers suffer less loss and are immune to electromagnetic interference and radio frequency interference.

WHY WE USE OPTICAL FIBERS?

(6) High information-carrying capacity:

- A light source, acting as a carrier wave is capable of carrying far more information than radio waves and microwaves.
- It has been observed that the light signals used instead of electric signals in the process of communication can transmit 45 million pulses per second

(7) Low loss:

- Optical fibers are characterized by extremely low losses (less than 0.2 dB/km) as a consequence of which, the distance between two successive repeaters can be as large as 250 km.

(8) Higher data-rate transmission:

- Optical fiber communication permits the transmission of data over longer distances and at higher data rates than other forms of wired and wireless communications.

FUNDAMENTALS OF OPTICAL FIBERS

- **What is an optical fiber?**

➢ Optical fibers are dielectric waveguides which are fabricated from glass or plastic and are operated on optical frequencies.

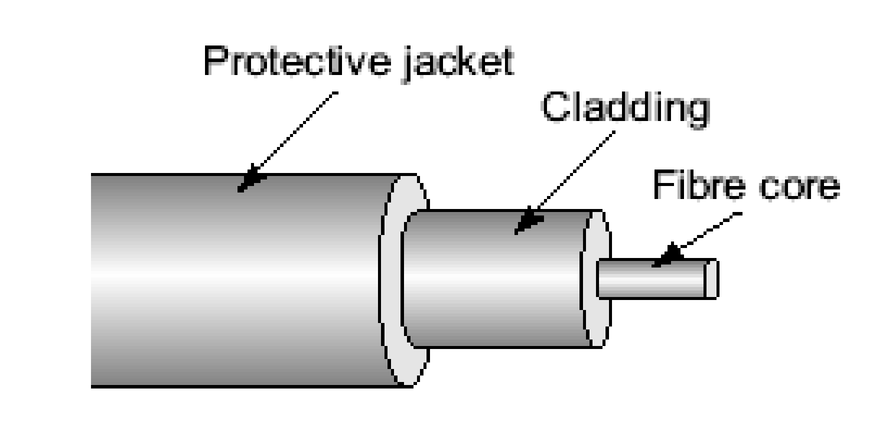
- **Structure of an optical fiber:**

➢ Optical fibers are normally of cylindrical form. It has three principal sections:

(i) Core

(ii) Cladding

(iii)Jacket



FUNDAMENTALS OF OPTICAL FIBERS

- **(i) Core**
- It is the innermost region of the fiber which has specific property of conducting an
- optical beam.
- Core is usually made of glass or plastic.
- It is covered with another layer of glass or plastic having slightly different chemical
- composition known as cladding.

- **(ii) Cladding**
- It is the region just above the core region of the optical fiber.
- It has lower refractive index than the core region.
- The optical fiber may have an abrupt boundary between the core and the cladding or there may be a gradual change in the material between the two.

FUNDAMENTALS OF OPTICAL FIBERS

- **(iii) Jacket**
- The outermost section of the optical fiber is known as jacket.
- It is made up of plastic or special kind of polymer and other materials usually opaque in nature.
- It protects the core from abrasion, interaction with environment, moisture, absorption, crushing, and other adversities of the terrestrial atmosphere and thus, enhances its tensile strength.

PROPAGATION OF LIGHT THROUGH OPTICAL FIBER:

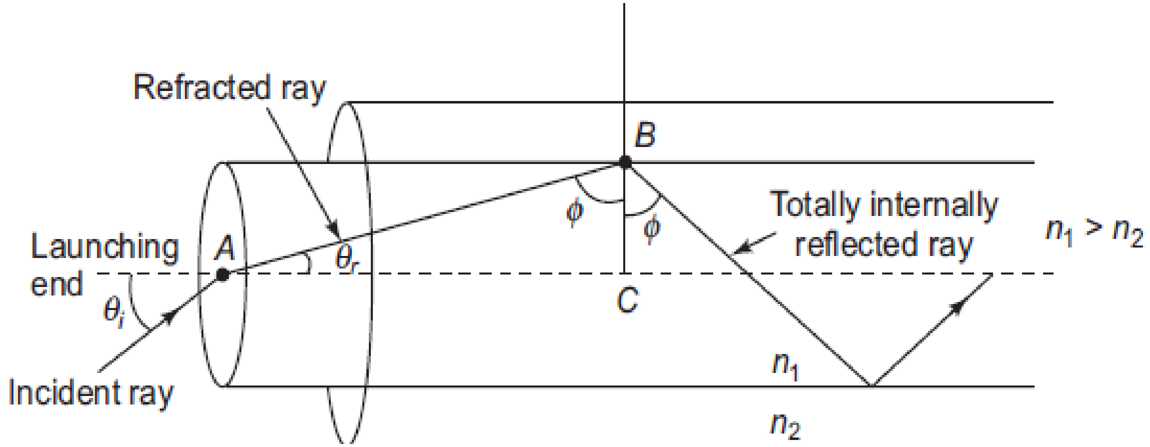
- In the optical fiber, the arrangement of core and cladding regions is done in such a way that the core acts like a continuous layer of two parallel mirrors.

- The message which has to be sent through fiber is first encoded into a light wave and then fed into the fiber where it is propagated as a result of multiple internal reflections.

- The end at which the light enters the fiber is known as the launching end.

PROPAGATION OF LIGHT THROUGH OPTICAL FIBER

- $\mathbf{n_1}$ = the refractive index of the core and
- $\mathbf{n_2}$ = the refractive index of cladding ($n_2 < n_1$).
- $\mathbf{n_0}$ = refractive index of outside medium from where the light is launched
- $\boldsymbol{\theta_i}$ be the angle made by light with the axis of fiber at launching end and
- $\boldsymbol{\theta_r}$ be the angle made by the refracted ray with the axis
- $\boldsymbol{\Phi}$ be the angle at which refracted ray strikes the core–cladding interface
- If Φ > critical angle (θ_c), then the ray undergoes total internal reflection at the interface. As long as the angle $\Phi > \theta_c$ the light remains within the fiber.



PROPAGATION OF LIGHT THROUGH OPTICAL FIBER

- Applying Snell's law at the launching face of the fiber, we get
- $$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_1}{n_0} \qquad (1)$$
-
- Now, the largest value of $\boldsymbol{\theta_i}$ will be at $\Phi = \theta_c$
- From the right-angled triangle ABC, we have
- $\sin\theta_r = \sin(90° - \Phi) = \cos\Phi$
- From Eq. (1), we know that
- $$\sin\theta_i = \frac{n_1}{n_0}\sin\theta_r$$
- By putting the value of $\sin\theta_r$, we get

PROPAGATION OF LIGHT THROUGH OPTICAL

- By putting the value of sin θ_r , we get
- $$\sin\theta_i = \frac{n_1}{n_0}\cos\phi$$
- When $\Phi = \theta_c$, $\theta_i = \theta_{max}$
- Now,
- $$\sin\theta_{max} = \frac{n_1}{n_0}\cos\theta_c \qquad (2)$$
- Using Snell's law at point B or cladding boundary,

$$n_1\sin\theta_c = n_2\sin 90$$

- or, $\sin\theta_c = \frac{n_2}{n_1}$ (because for total internal reflection, reflection angle will be 90°)

PROPAGATION OF LIGHT THROUGH OPTICAL

So, $$\cos\theta_c = \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

$$\sin\theta_{max} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

For the conditions when $\sqrt{n_1^2 - n_2^2} \leq n_0$, for all values of angle of incidence, total internal reflection will occur. For special condition, when $n_0 = 1$, the maximum value of angle of incidence (θ_i) for the ray to be guided is given by

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

$$\theta_m = \sin^{-1}\left[\sqrt{n_1^2 - n_2^2}\right]$$

In the above expression, θ_m is known as the acceptance angle of the fibre. Acceptance angle is defined as the maximum angle which incident light makes with the axis of fibre at which the ray is propagated (guided) through the fibre.

The light rays contained within the cone having a full angle $2\theta_m$ are accepted and transmitted along the fibre. This cone is known as acceptance cone.

Assignment Based on this Lecture

- Give an introductory remark to optical fibres
- What are the advantages of optical fibers over traditional Cable?
- Discuss the fundamentals of optical fibres.
- Explain the propagation of light through optical fibre.
- Define Acceptance angle and Acceptance cone.