Transmission through Optical Fiber

***Prof.Vidya Mahadik**

Abstract

Optical fiber consists of a bundle of glass threads, just thin like a human hair that carries digital information over long distances. These optical fibers are used extensively for data transmission system because of their greater efficiency and large carrying capacity such as telephone communication, cable television, space vehicles in web browsing, email exchange and medical field also. Based on the principle of Total Internal reflection (TIR) optical fiber transmits information in the form of light pulses. A powerful aspect of an optical communication link is that many different wavelengths can be sent along a fiber simultaneously and the technology of combining a number of wavelengths onto the same fiber is known as wavelength division multiplexing (WDM). This concept is used in conjunction with optical amplifiers in communication links that allow rapid communication between users in countries all over the world. Hence this document includes information regarding how optical fiber transmits data from longer distance through different types of modes.

Introduction

Optical fiber refers to the medium and technology associated with the transmission of information in the form of light pulses using glass or plastic wires. Fiber optic wire carries much more information than conventional copper wires. The transmission of fiber wire requires high speeds and large carrying capacity. The main difference is, fiber optic uses light pulses to transmit information whereas copper wire uses electronic pulses. Light pulses move easily through fiber optic because of the principle of Total Internal reflection (TIR).When this principle is applied to the construction of fiber optic strands digitized data is transmitted in the form of light.

Fiber optics has several advantages over traditional metal:

- **Speed:** Fiber optic Network operates at high speed up into the gigabits.
- **Bandwidth:** Large carrying capacity.
- **Distance:** Signals can be transmitted without need to be refreshed or strengthen.
- **Resistance:** Greater resistance to electromagnetic noise such as radios, motors, etc.
- **Maintenance:** Fiber optic cables cost much less to maintain.

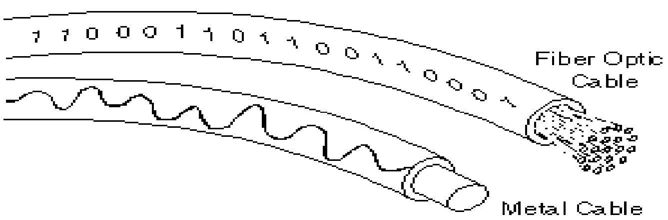


Fig1.1: optical Fiber

Principle of Optical Fiber

Transmission of Optical Fiber depends on the principle of Total Internal reflection (TIR). When light falls on the surface like glass (denser) to air (rarer) medium reflection and refraction takes place. Reflection is the property of light which passes through the same medium whereas Refraction means light changes its path when it enter from one medium to another medium.

Asst. Professor, Humanities and Management Deaprtment, Vidyalankar College of Engineering,Wadala(E), vidyamahadik9@gmail.com,vidya.mahadik@vpt.edu.in,Contact No: 9757142910

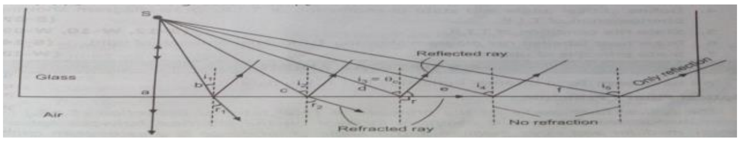


Fig.1.2: Total Internal reflection

As shown in diagram, consider light rays from point source S in glass medium falls on the surface of air medium. For the rays a, b, c … there are both reflection and refraction takes place at the interface for ray d the angle of refraction is 90°.which means that refracted ray runs along with interface. For the ray's e, f when angle of incidence is larger than critical angle i.e. $i > \theta_c$ here is no refraction only reflection takes place i.e. TIR. Critical angle is the angle of incidence at which angle of refraction is 90°.

That is if light travels from high refractive index to low refractive index and angle of incidence is greater than critical angle only reflection takes place is called as TIR.

- **Condition of TIR**
  1. The angle of incidence 'i' > critical angle (θ_c)
  2. $\mu_1 > \mu_2$

Where μ_1 = refractive index of first medium,

And μ_2 = refractive index of Second medium

- **Snell's Law,**

Snell's Law states that, for any two media the ratio of sine angle of incidence to the sine angle of refraction is constant.

By snell's Law:

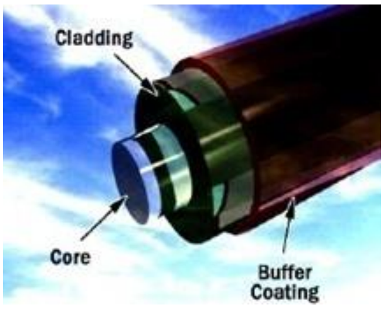
$\sin i / \sin r = \mu_2 / \mu_1$
Put $r=90°$ and $i = \theta_c$
$\therefore \mu_1 = 1.50$ and $\mu_2 = 1$
$\sin \theta_c / \sin 90° = 1.00 / 1.50$
Since $\sin 90° = 1$
So $\sin \theta_c = 0.667$
$\theta_c = \sin^{-1} (0.667)$
$\theta_c = 41.8°$

Thus the internal reflection does not occur when light originates in the medium of lower index of refraction.

Structure of Optical Fiber

Communication optical fiber has core surrounded with cladding which is coated with protective skin or jacket.

Here cladding acts like a reflector and keeps the light wave within the core due to TIR concept. The cladding provides some strength to the core when bunch of optical fibers is packed in one cable; the cladding layer avoids the interface between light rays in the adjacent fibers.



Core:

Core is the innermost layer of Fiber; the light is transmitted within the core

Cladding:

Cladding is the outer layer of Core; the cladding keeps the light waves within the core since the refractive index of cladding is less than refractive index of Core.

Figure 1.3: Structure of optical fiber

Protective Skin:

The protective skin protects the fiber from moisture and provides mechanical strength to the optical fiber. Fiber optic cable is made from either glass or plastic special techniques have been developed and the glass and plastic is melted and pulled such that a fine thread like fiber is formed.

Dimension= length of optical fiber 1 km
Outer diameter 0.1 mm to 15 mm
Core diameter from 5 µm to 600 µm
Cladding diameter from 125 µm to 750 µm
Thickness of protective skin is around 30 µm to 50 µm

To keep light waves within the core cladding must have minimum thickness.

Propagation of Light through Optical Fiber:

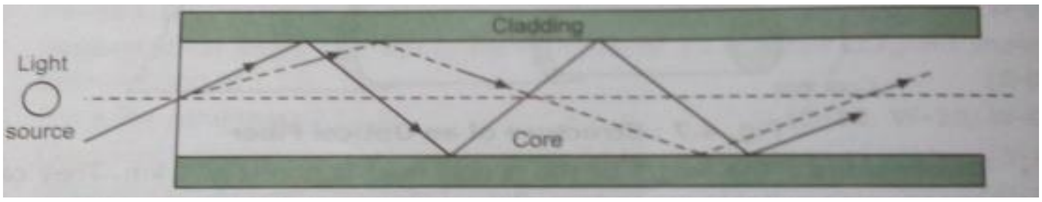


Fig 1.4: Propagation of optical Fiber

As shown in the diagram beam of light wave is focused on the end of cable.The angle of incidence greater than critical angle. Therefore TIR takes place and the light beams are reflected through the fiber cables. The beam bounces back and passes the surface cable and it exists at the other end. Thus light entering into the glass fiber from one end gets reflected within the cable and follows zig zag path and this light emerges out form the other end. This light which travels from one end to the other is called "light is guided "through the fiber. When the light beam reflects from inner surface of core:

Angle of incidence = Angle of reflection

Because of this light rays entering at different angles will take different paths therefore some light paths will be longer and some will be shorter. Hence some light rays exist later and some will exist sooner. Because of this TIR the light beam will continue to propagate through the fiber even though it is bent number of times.

There are two basic types of fiber:

- Multimode optical fiber

- Single Mode optical fiber

Multimode Optical Fiber

Using Multimode fiber numerous modes or light rays are carried simultaneously through the waveguide. Modes result from the fact that light will only propagate in the fiber core at discrete angles within the cone of acceptance. This fiber type has a much larger core diameter, compared to single-mode fiber, allowing for the larger number of modes, and multimode fiber is easier to couple than single-mode optical fiber. Multimode fiber may be categorized as shown in figure

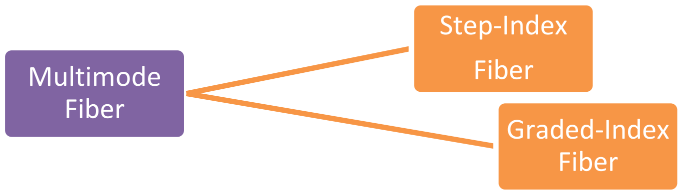


Fig.1.5: Types of Multimode Optical Fiber

1.1 Multimode Step-index Fiber:

Figure 1.6 shows how the principle of total internal reflection applies to multimode step-index fiber. Since the core's refractive index is higher than the cladding's refractive index, then light enters is less than the critical angle. Three diffrent light waves travel down the fiber. One mode travels straight down the center of the core. A second mode travels at a steep angle and bounces back and forth by Total Internal Reflection. The third mode exceeds the critical angle and refracts into the cladding.

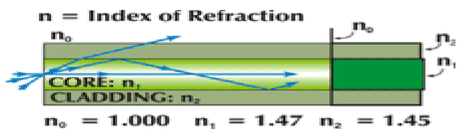


Figure 1.6: Multimode Step-index fiber

Spontaneously, it can be seen that the second mode travels a longer distance than the first mode, causing the two modes to arrive at separate times. This disparity between arrival times of the different light rays is known as dispersion, and result is a muddied signal at the receiving end.

1.2 Multimode Graded-index refers:

This refers to the fact that the refractive index of the core gradually decreases further from the center of the core. The increased refraction in the center of the core slows the speed of ome

This figure shows the principle of multimode graded-index fiber. The core's central refractive index, nA, is greater than that of the outer core's refractive index, nB. The core's refractive index is Parabolic, being higher at the center. As Figure shows, the light rays no longer follow straight lines; they follow a bending path being gradually bent back toward the center by the continuously declining refractive index. This reduces the arrival time difference because all modes light rays, allowing all the light rays to reach the receiving end at approximately the same time, reducing dispersion.

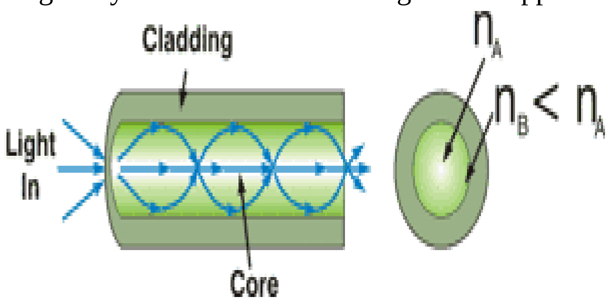


Figure 1.7: Multimode Graded-index Fiber

arrive at about the same time. The modes traveling in a straight line are in a higher refractive index, so they travel slower than the bending modes. These travel further but move faster in the lower refractive index of the outer core region.

1. Single Mode Optical Fiber:

Single-mode fiber allows for a higher capacity to transmit information because it can retain the reliability of each light pulse over longer distances, and it exhibits no dispersion caused by multiple modes. Single-mode fiber also enjoys lower fiber attenuation than multimode fiber. Thus, more information can be transmitted per unit of time. Like multimode fiber, single-mode fiber was generally characterized as step-index fiber meaning the refractive index of the fiber core is a step above that of the cladding rather than graduated as it is in graded-index fiber

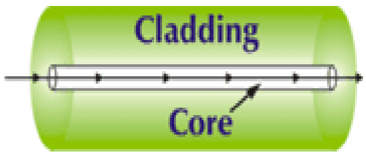


Figure 1.8: Single Mode Optical Fiber

Application of Optical Fiber:

- Telephone transmission method uses fibre-optic cables.
- Optical fibres are well suited for medical use. They can be made in extremely thin, flexible strands for insertion into the blood vessels, lungs, and other hollow parts of the body. Optical fibres are used in a number of instruments that enable doctors to view internal body parts without having to perform surgery.
- Field of military applications and aircrafts ,
- Civil, consumer and industrial applications,
- Field of computers
- To carry TV cable signal
- To Carry Fax and TELEX Signals

Conclusion

As we move towards a more sophisticated and modern future, the uses of fiber optics are going to grow in all computer systems as well as telecommunication networks. There are a number of essential points about fiber optics regarding transmission that have been mentioned throughout this report which gives the brief knowledge about process of transmission of data through different types of optical Fiber.

References

- *Introduction to Optical Electronics by Keneth E Jones*
- *Fiber Optic Communication Technology by Djafer K Mynbaev and Lowell L Scheine*
- *Optical Fiber Communication technology and system overview Jacobs FIBER OPTICS HANDBOOK, 2002 196.29.172.66 Basic elements of an optical fiber communication system include the transmitter, fiber (multimode, single-mode), and the receiver [positive-intrinsic-negative (PIN) diode and avalanche photo detector (APD)*
- *Fiber attributes Dispersion Compensation Strategies in Optical Communication Systems*
  S Raghavan, J Downie, J Hurley on Fiber Optics and 2008 corning-cable-systems.de