Optical Fiber the Backbone of Telecommunication

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Introduction:

About 100 years ago, Alexander Graham Bell transmitted a telephone signal over distances of several hundred meters using visible light beams. He called this "photophone". This amazing discovery marked the first demonstration of the basic principle of optical communications as it is practiced today. However, by today's standards, this system proved impractical mainly due to the lack of a reliable intense light source and a dependable, low-loss transmission medium.

The first proposal to employ clad optical fiber glass as a telecommunication transmission medium appeared in 1966. At this time, a typical fiber loss was above 1000dB/km and many experiments were done to improve the loss. Today, fibers operate at a wavelength less than 1.5μm with loss less than 1dB/km. Low losses have been achieved by reducing impurity absorption due to transition metal ions such as iron, chromium, cobalt, and copper. [1]

As far as we are concerned, the invention of fiber-optic technology is a revolutionary departure from the traditional copper wires of twisted-pair cable or coaxial cable. Today, coppers wires are still used because they're cost effective and reliable interconnect in parallel machines. However, as machines become more powerful, wire density becomes critical, thus making optical fiber an alternatives source.

The usage of optical fiber in the telecommunications industry has grown a few decades ago. Today, many industries particularly telecommunications industry chooses optical fiber over copper wire because of its ability to transmit large amount of information at a time. Besides that, optical fiber could provide more advantages in this industry and this will be discussed further in this paper.

The first section of this paper will discussed about the principle and mechanism of optical fiber telecommunications, and the second section will discuss about the applications and advantages of optical fiber in telecommunications before ending with a conclusion.

Principle and Mechanism of Optical Fiber:

The principles and mechanism of optical fiber in telecommunications could be very complicated if there no basic understanding of optical fiber. Therefore, in this section, we will simplify the discussion by answering the following questions.

- Firstly, what is optical fiber?
- And secondly, how does a fiber optic communication system work?

So, what is optical fiber? As far as we are concern, optical fiber cable use smooth, hair-thin strands of glass or plastic to transmit data as a pulse of light and the cable is about the diameter of a human hair. [2] A fiber optic cable is made up of three main sections. They are the core, cladding, and buffer. This is show in Figure 1. The core is at the middle of the cable and it is made up of silica. It functions as the light transmitting section of the fiber and act as a boundary layer for the cable. Next is the cladding. The cladding is made up of pure silica and it act like a guide for the light waves to travel down the cable. This component is very important because light moves in waves and will shoot out of the core if this component is not present. This cladding will eventually reflect back into the core. As for buffer, it is at the middle of these three layers. It is made up of acrylic polymer. This buffer layer protects cladding and core against ultraviolet light and gives the cable rigidity.

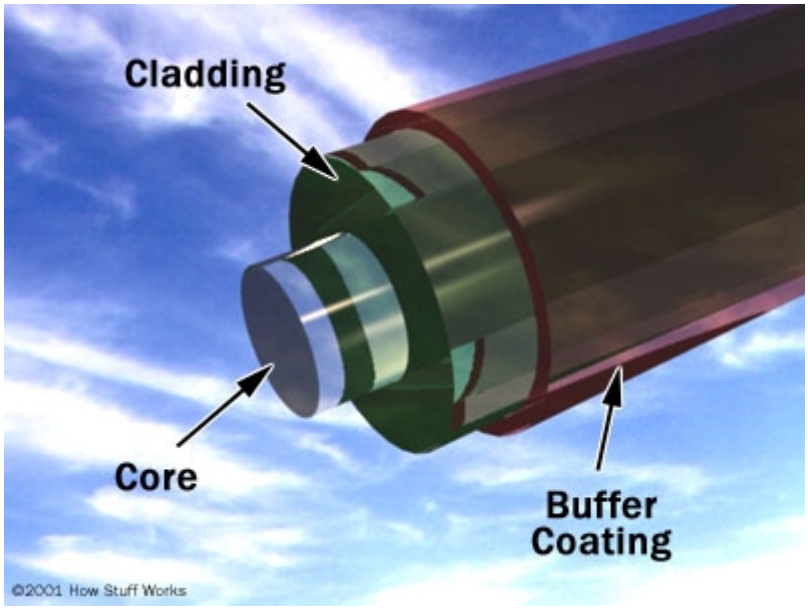

Figure 1: Three main sections of fiber optic cable.

The type of optical fibers cable in telecommunications network can be divided into two classes based on their modal properties. They are single-mode fiber and multimode fiber. Single-mode fiber has a smaller core than multimode fiber. It only allows one signal to transmit at a time. As for multimode fiber, it has a much larger core than single-mode fiber, allowing hundred of signals to pass through the fiber simultaneously. From what we have just discussed, it may seem that multimode fibers carry more information than single-mode fibers, but in reality, single-mode can keep every light pulse over a longer distance because its transmission of dispersion or degradation is very small, allowing it to have a higher bandwidth.[3]. With the high bandwidth, the single-mode fiber is an ideal source of transmission medium for any applications and multimode only applies in the transmission distances within two miles.

The two classes can be further divided into multimode index, multimode graded index, and single-mode step index. Step and graded index refers to the variation of the index of refraction with radial distance from the fiber axis. Ultimately, these fibers consist of a

core surrounded by a cladding. Step index fiber is an optical fiber with a uniform refractive index core, where else in the graded-index fibers, the gradual decrease in the index of refraction with the distance will cause the light rays to bend back toward the axis as they propagate. These different types of fiber are displayed in Figure 2 [4]

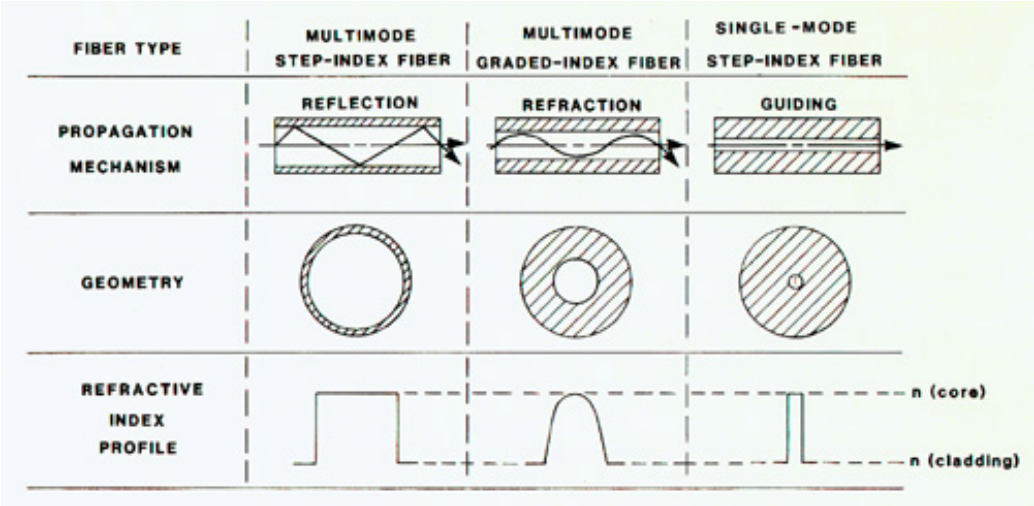

Figure 2: Types of fiber

Next, how does a simple optical fiber communication system work? In order for the communication system to function, the transmission system would need three basic elements. They are the optical fiber transmitter, the optical fiber cable, and the optical fiber receiver. In the optical fiber transmitter, a signal is sent to the system and when it reaches the system it is sent into a converter which changes the electrical signal to light pulse. The common used of optical transmitters are the light emitting diode (LED) and the laser diode (LD) and either one of these could be used in the transmitter and they usually operate at the wavelength of in between 850- 1300nm. Next, the transmitter will drive a current on light sources, which act like a waveguides, into the optical fiber cable. This cable is usually made out of more than one glass fiber, and it provides a layer of protection within the optical fiber. Finally, the detector receives the optical signal and

converts it back to an electrical signal. This receiver could be either avalanche-type photodiode or Pin-type photodiode. This process is summarized in Figure 3.

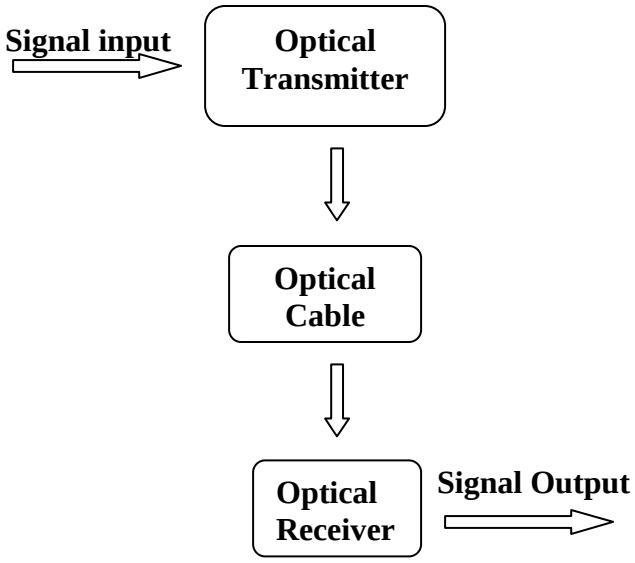

Figure 3: Flow diagram of optical fiber communication system.

Based on the above discussion, actually, the telecommunications system work based on total internal reflection principle. Total reflection principle could be explained in a simpler form by using the following example. For instance, you have a long hollow tube and you want to shin the flashlight beam for some reason. In this case, you will definitely see lights travel in a straight light. However, what if the tube is bended to a zigzag shape? You might want to line the tube with mirrors and angle the beam so that it bounces at the zigzag path. This is what exactly happens in the optical fiber. In the physics point of view, for any transparent material, optical measurement is the most important refractive index (n). The index refraction n of a medium is the ratio between the speed of light c in vacuum and the speed if light in that medium:

$$n = c/v \qquad [5]$$

Since, the speed of light in any material is slower than in vacuum, therefore, the refractive index in the vacuum always greater than the optical material. From the total reflection example, even though light travel in straight line through optical fiber, still light is bent when the surface is not straight. This is because refractive index changes as it moves from one medium to another. Therefore, an increase in the angle of incidence above the critical angle would result in total internal reflection. Figure 4 show the total internal reflection phenomena in an optical fiber.

This is show in Snell Law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad [6]$$

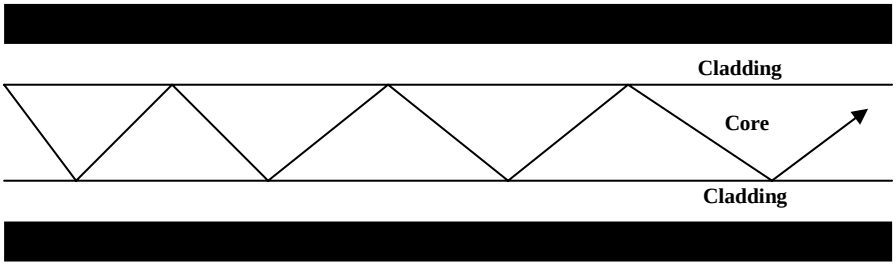

Figure 4: Total internal reflection in optical fiber

The basic concept of light transmission in optical fiber telecommunication system is explained once again. When light travel in an optical fiber through the core (tube), it always bounced from the cladding (mirror wall), and since cladding does not absorb any lights from the core, therefore, the light wave can travel great distance. [7]

After explaining about the principle and mechanism of optical fiber telecommunication, let's move our discussion to the applications of this amazing creation.

Application and Advantages of Optical Fiber:

The transformation of copper wire to fiber optic in the telecommunications industry has open up the new era of technology. Since then, optical fibers are used in various applications. Presently, it is relevant to say that telecommunications industry is the dominant user for the optical fiber technology because the demand is high. Why is the demand high? The main reason is speed. People like high speed because they can get their things done quickly. Through optical fiber, information can transfer at much greater speeds due to the fact that information is transmitted through coded flashes and lights (which travel at approximately the speed of light $c = 3.0 \times 10^{8} ms^{-1}$) are deciphered at the receiving end.

Optical fibers have extremely high bandwidth. High bandwidth means they have greater capacity to carry more information at a faster rate, and this is the ideal that the telecommunications industries are striving towards. Presently, optical fiber can carry about 300 television channels and 45,000 phone conversations at single instance in time. The digital protocol is based upon a 160-bit frame structure and line coding exploiting scrambling techniques. The protocol is described in detail in the EVLA Memorandum #33- "Digital Transmission System Signaling Protocol" Version 2, November 2001. [8]

This advantage has forced telecommunications industries particularly the communications and entertainment industries to change the old cable system to optical fiber. Over the past few decades, communications and entertainment industries have spent millions of dollars to outpace each other in the pursuit of supremacy. For instance,

AT&T has recently poured in 300 million in total investments to upgrade its global network. With this service, people would get unbelievable information at their fingertips. Home entertainment and communication for examples are greatly affected by optical fiber. Movies, which used to only show at a specific time, can now be “piped” into our homes at our own desired time. Presently, cable television companies such as AT&T have been channeling hundreds of movies through the new fiber optic hook ups to our homes.

Telephone, email, fax, and videoconferencing have become lifelines, to connect one individual with another across the globe. These service providers changing their medium of connection from copper wires to optical fiber cable in order to have a safer and more secure communication. This is very useful for people who want to transfer sensitive data. Information can only be transmitted when there are magnetic radiations. Since no magnetic fields radiated around optical fiber, therefore, it is impossible to tap the signal transmission unless one cuts into the fiber. If this is done, safety protocols will go into play and ensure that the data is not leaked. Since optical fiber is made of non-metallic compounds, therefore, it is physically safer and if it breaks, there would be any danger or direct electric shock.

Besides safer and secure communications, the telephone; which previously was limited to sound only can now link with video images and speaker. As for videoconferencing, it would allow faster and clearer transmission of image and information, which replicates traditional face to face. Through optical fiber, a clear visual image of people involved in the conference and data charts shown would provide a better understanding for both parties when dealing with an important agreement.

Optical fiber also allows students to access information and communicate with each other at a faster rate.T1 to T3 connections for example are among the fastest modes of transmitting data currently. These modes of transmission require the extensive use of optical fiber.

Optical fiber cable work better under harsh environments in comparison with its metallic counterparts. It is not fragile or brittle, not heavy or bulky, less prone to electrical interference, more resistant to corrosion, and has a life expectancy of up to thirty years. [9]

Also, optical fiber can withstand higher temperatures than copper wires. This means that even when the outside jacket surrounding the optical fiber has melted, an optical fiber system can still perform well. For example, when outdoor cables in certain computer networks are hit by lightning, it could cause wire and cable destruction in the network. Many computer companies are aware of this problem and they have tried to remedy the problem but to no avail. The only solution is to install optical fiber. Optical fiber is used because it can be made non-conductive by removing metal in the design. For many indoor applications, these cables are cheap and economical. But for many out door applications, it might be expensive. Still, based on the advantages of optical fiber, it should be an open option when the cost is met.

Apart from telecommunications, optical fibers also apply in the medical field. Through this field, medical equipments such as fiberscope and endoscope play a significant role in diagnosing illness. Step-index fibers and graded-index imaging are used to visualize the internal organ and tissue. According to Epstein, “The fabrication techniques of optical fibers for imaging and illumination are considered in juxtaposition to their current

applications in communications with emphasis on the different technologies involved". [10]. Therefore, there's a connection on using optical fiber between the telecommunication and medical field.

Optical fiber needs less optical repeaters than copper wire needs signal regenerator. For example, copper needs a regenerator for every three miles, but fiber cables only need a repeater for an entire sixty miles. From here, it shows that fiber cables are more cost effective.

Nothing is perfect in this world. Although optical fibers give tremendous advantages, still, there are some disadvantages exist. Cost is the main concern in the optical fiber system. Optical fiber is expensive and could be difficult to install and modify. In order to join fiber optics, one needs to be trained to use the sophisticated equipment. To install optical cables, and to ensure the light beam remains continuous the connection needs to be very precise to avoid any losses. Therefore, if something happens in the connecting cables, for example, if the line breaks, this could be very serious and could generate a big loss.

Optical fiber transmissions characteristics are not always efficient. This is because fiber optics introduces loss of light and smearing of modulation imposed on the light signals to represent information. These could delay attenuation limit distance, distortion, and thus limit the information rates to carry over a long distance.

Besides the above disadvantages, optical fiber has limited physical arc of cable. If one bends it too much, it will break. Also, the physical vibration of optical fiber will show up as a signal noise and this could be very disturbing.

Despite these disadvantages, the pros outweigh the cons tremendously and thus prove a very viable option.

Conclusion:

As a conclusion, fiber optic technology is a revolutionary technological departure from the traditional copper wires twisted-pair cable or coaxial cable. As we more forward in the Information Technology age, the responsibility of moving extreme amounts of data must fall on the shoulders of this new technology. There is no doubt as to the vast opportunities that fiber optic technology can give and it should be continuously researched and expanded to cater for future demands.

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