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Optical Data Transmission

The physics part of data transmission through optical fiber

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1 Introduction

The reason why I choose this title question for this last part of physics assignment is that I am a networking major student and it always fascinates me how data transmission through optical fiber takes place. Modern physics has played a tremendous role in our civilization and I believe it will continue bringing much more exciting development in our everyday life.

To begin with, I would like to divide this assignment into four parts. The first is a short introduction about the history of fiber optics while the next part deals with what fiber optics is its basic structure, advantages as well as disadvantages. The third part briefs about the physics about fiber optics and the last part details about mechanism of attenuation.

2 History of fiber optics

It was first demonstrated by Daniel Colladon and Jacques Babinet in Paris in the early 1940s. About 12 years later in London, a demonstration about it public lectures by John Tyndall was found which also included about the property of total internal reflection in an introductory book about the nature of light in 1870. Practical application like close internal illuminati during dentistry of this invention was seen in the 20th century. In the 1920s, Clarence Hansell and John Logie Baird demonstrated independently image transmission through tubes. This priniciple was first used for internal medical examination by Heinrich Lamm in the following decade. Harold Hopkins and Narinder Singh Kapany at Imperial College in London achieved low-loss light transmission through a 75 cm long bundle which combined several thousand fibers. Their article ‘’A flexible fiberscope, using static scanning’’ was published in the journal nature in 1954. In 1880 Alexander Graham Bell and Sumner Tainter invented the Photophone at the Volta Laboratory in Washington, D.C., to transmit voice signals over an optical beam. The emerging field of photonic crystals led to the development in 1991 of photonic-crystal fiber which guides light by diffraction from a periodic structure, rather than by total internal reflection. The first photonic crystal fibers became commercially available in 2000. Photonic crystal fibers can carry higher power than conventional fibers and their wavelength-dependent properties can be manipulated to improve performance. Today, a variety of industries including the medical, military, telecommunication, industrial, data storage, networking, and broadcast industries are able to apply and use fiber optic technology in a variety of applications.

3 What is fiber optics?

Fiber optics is the use of glass or plastic threads to transmit data. It is made of bundle of glass threads which can transmit messages modulated onto light waves. This popular technology is especially used for local-area networks and is also replacing traditional telephone lines.

The basic structure of optical fiber are composed of three parts; the core, the cladding, and the coating or buffer. The core is a cylindrical rod of dielectric material (conducts no electricity), and it is the light transmission area of the fiber. The core varies its dimension; either the fiber is single or multi-mode. When the core is larger more amount of light is going to be transmitted through fiber.

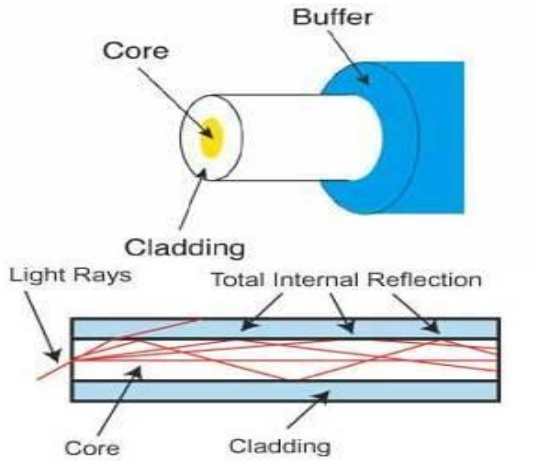

Figure 1. Optical fiber structure

The core is generally made of either glass or plastic. The core is surrounded by a layer of material called the cladding. Even though light will propagate along the fiber core without the layer of cladding material, the function of the cladding is to provide a lower refractive index at the core interface in order to cause reflection within the core so that light waves are transmitted through the fiber. Like the core, the cladding layer doesn't conduct electricity and generally is made of glass or plastic. The main functions of the cladding are:-

- To reduce loss of light from the core into the surrounding air.
- To reduce scattering loss at the surface of the core.
- To protect the fiber from absorbing surface contaminants
- To add mechanical strength.

The most outer layer of optical fiber is called the coating or buffer. It is made of plastic. This layer's major function includes protecting the optical fiber from physical damage and to preserve fiber strength.

The advantages of Fiber optics over traditional metal communications are:-

- They carry more data as they have a greater bandwidth than metal cables..
- They are less susceptible than metal cables to interference.
- They are lighter and thinner than metal cables.
- Data transmission is digital not analogical.

The disadvantage of this technology is that its installation is expensive and also the fact that it is more fragile than wire and hard to splice.

4 The physics behind fiber optics

While I was searching to get the answer for my assignment, I came out to know much practical application of Physics involved in data transmission. The first step to determine in what form the data is. If we consider optical fiber, data in the form of electrical signals from digital circuits (high/low voltages) is converted into discrete optical signals, which is light with the use of LED or solid-state lasers. The step is reversed at the receiver end; light signals are translated back into electrical form through the use of photodiodes or phototransistors for introduction into the inputs of gate circuits.
The transmission digital information in optical form can be done in different form like open air, simply by aiming a laser at a photodetector at a remote distance, by doing so there are many obstacle or interference like temperature variation, dust, smoke, fog and rain.

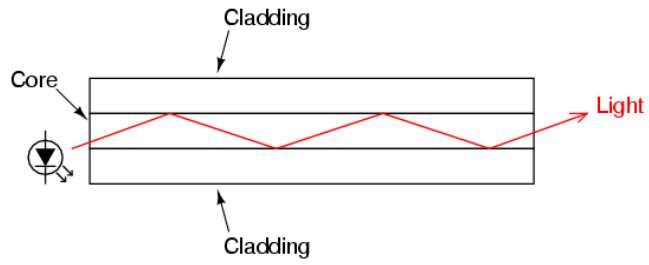

Figure 2. Layers of optical fiber

An optical fiber is made of two layers of ultra-pure glass, each layer made of glass with a slightly different refractive index, or capacity to "bend" light. With one type of glass

concentrically layered around a central glass core, light introduced into the central core cannot escape outside the fiber, but is confined to travel within the core:

These layers of glass are very thin which gives the fiber considerable flexibility. The outer cover is 125 microns in diameter. The fiber is given a thin plastic coating, placed inside of a plastic tube, wrapped with Kevlar fibers for tensile and an outer covering of plastic which is very much alike to electrical wire insulation to protect it from physical damage. These optical fibers are wrapped together within the same sheath to make a single cable. Optical fibers excel the data-handling performance of copper wire in almost every regard. They are resistant against electromagnetic interference and have very high bandwidths.

They also have some disadvantages like microbending whereby the fiber is curved around too small of a radius, causing light to escape the inner core, through the cladding. Microbending as well lead to reduced signal strength as a result of lost light and also comprises a security weakness as a result of a light sensor deliberately kept on the outside of a sharp bend which could intercept digital data transmitted over the fiber.

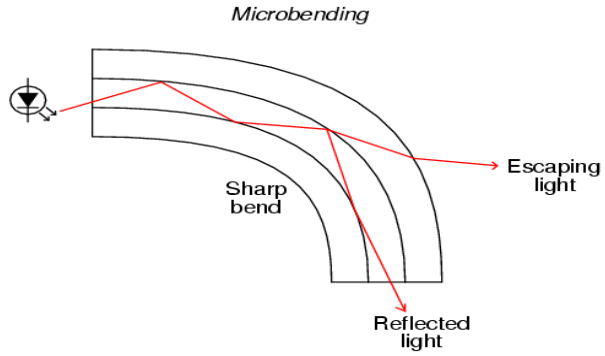

Figure 3. Microbending

Another weakness of optical fiber is signal misinterpretation because of multiple light paths having different gaps over the length of the fiber. Photons don't travel the exact same distance when light is emitted by a source. This phenomenon is obvious in any source of light not conforming to a straight beam, but it is true in devices such as lasers. If the optical fiber is big enough in diameter, photons will have many pathways to travel. All the pathways don't have the same length from one end of the fiber to the other. This kind of optical fiber is known as multimode fiber.

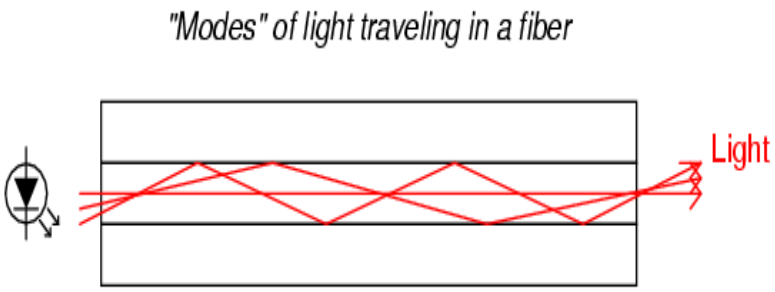

Figure 4. Modes of light travelling in a fiber

Light pulses taking longer path through the fiber arrive at the detector later than light pulses emitted by the LED taking shorter path. The result is called ‘pulse stretching’ which is the distortion of square-wave’s rising and falling edges. This problem worsens as the overall fiber length increases.

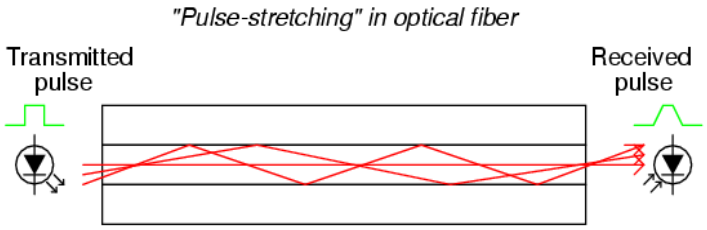

Figure 5. Pulse-stretching in optical fiber

Light modes will be restricted to a single pathway with one length if the fiber core is made small enough. Fiber which is made to allow only a single mode of light is called single-mode fiber. The fiber usually used for long-distance networks is single-mode fiber as it doesn’t face the problem of pulse stretching which is seen in long cables. The disadvantage is that single mode fibers don’t conduct as much light as multimode conducts with only one mode of light. Over long distances, this intensifies the demand for repeater units to improve light power.

5 Mechanisms of attenuation

When light beam or signal travels through transmission medium and its intensity declines, it is called attenuation or transmission loss. Because of the relatively high quality of transparency of modern optical transmission media, fiber optics use units of dB/km through the medium. The medium is a fiber of silica glass that confines that encloses the incident light beam to the inside. Attenuation is an important element in limiting the transmission of a digital signal across large distances. There-

fore, much exploration has been done for both limiting the attenuation and heightening the amplification of the optical signal. Empirical research has shown that scattering and absorption is the main cause of transmission loss in optical fiber. We can make single-mode optical fibers with extremely low loss. It has been found out that we could have seen all the way to the bottom of ocean water if the water was as clear as fiber.

6 Conclusion

While doing this assignment, I tried to learn many physics application and their functionalities. To mention some, Laser light is created using LED for the data transmission in optical fiber. During the propagation of light through optical fiber, the laws of optics like Refraction and Deflections takes place which reminds me of the previous physics course. Optical fiber can be used to transmit power using a photovoltaic cell to convert the light into electricity.

In this assignment I was concentrated on data transmission using Optical fiber. But while reading I learned that optical fiber has a wide range of applications like in the field of medicine, as sensory devices, as hydrophones, sonar uses, as wiring in aircraft, submarines and other vehicles and also for field networking.

This versatile material is worth doing much research in my further studies as I am networking student her in Metropolia. The technology as well is growing at an alarming rate that we see different things being developed every now and then.

References

http://www.allaboutcircuits.com/vol_4/chpt_14/5.html, Accessed May 16/2015

http://en.wikipedia.org/wiki/Optical_fiber#Mechanisms_of_attenuation, Accessed May 16/2015

http://science.jrank.org/pages/2704/Fiber-Optics.html, Accessed May 16/2015

http://www.webopedia.com/TERM/F/fiber_optics.html, Accessed May 16/2015

http://www.electronicsweekly.com/electro-ramblings/industry-comment/only-connect-a-guide-to-fiber-optics-2011-05/, Accessed May 16/2015

http://www.f-n-t.com/whatisfo.htm, Accessed May16/2015

http://www.timbercon.com/uses-of-fiber-optic-cables/, Accessed May 16/2015