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Measurement of Attenuation of the Optical Fiber

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ABSTRACT
The attenuation in optical fiber which is the reduction in power of the light signal as it is transmitted. The longer the fiber and farther light has to travel, the more the optical signal is attenuated. Consequently, attenuation is measured and reported in decibels per kilometer (Db/km) also known as the attenuation coefficient or attenuation rate. There are several causes of optical loss that will be investigated through this experiment. Here we have discussed about the absorption loss of optical fiber at different length. We use software named “Opti system” for the calculation of attenuation and attenuation coefficient.

1. Introduction

A reliable method for transmitting light is to use a wave guide made of non-conductive materials like glass or plastic. These materials are not affected by changes in the atmosphere. In 1870, John Tyndall showed that light could be guided through a stream of water, which led to the development of the dielectric waveguide theory by Hadrons and Debey.
The popularity of optical fiber as a communication medium can be traced back to two significant events. Firstly, the creation of the first operating laser in 1960, and secondly, the calculation by Charles Kao and George A. Hackham in 1966, which suggested that if an optical fibre waveguide could transmit 1% of light over a distance of 1km, it could compete with existing coaxial cables used for communication. At that time, the existing fibres could only transmit light energy to 1% of its original value after 20 meters, and high-quality transmission was not predicted by materials experts. However, in the 1970s, Corning Glass Works developed high-silica glass for fibres, achieving transmission greater than 1% over a distance of 1km; later increased to greater than 40% over 1km. Nowadays, transmission up to 95-97% over 1km can be achieved.
Telecommunication is essential in modern life, and optical fiber plays a crucial role in this system. Optical fibre, also known as fiber optic cable, is a narrow cylindrical pipe that uses light pulses to transmit information from one point to another over long distances.[1][2] It is commonly used in telecommunications networks to transmit data, voice, and video signals, as well as in medical equipment, scientific research, and industrial applications.[3]The core of an optical fibre is less than 10 micrometres in diameter, which is thinner than a human hair. It is surrounded by a cladding layer that lets light travel through the core without escaping into the cladding layer. Total internal reflection is the principle on which optical fibers operate. This phenomenon occurs when the angle of incidence of a light ray is greater than the critical angle, causing the light to bounce off the boundary between the core and the cladding and allowing it to travel down the length of the fibre. Optical fibers have several advantages over traditional copper cables, including higher bandwidth, longer transmission distances, and greater resistance to electromagnetic interference. They are also lightweight and durable, making them ideal for use in harsh environments. A project in fiber optics is a set of laboratory equipment that provides an introduction to the basics of optical fiber technology.
We are going through the whole concept of the fiber optic losses i.e. absorption losses, radiative losses, scattering losses, etc. We discussed the study of attenuation in single mode optical fiber and the experimental procedure of measuring attenuation in optical fiber. After this we also have calculated the attenuation and attenuation coefficient. Variation in attenuation has been shown with the help of graphs and observation table.

2. Basics of Optical Fiber

Optical fiber is a technology that associated with data transmission using light pulses quickly and at higher bandwidth. It is made up of either glass or plastic to transmit light pulse. Optical fibres are long thin strand of very pure glass whose diameter is of the order of 10μm to 1mm.Optical fibre is a flexible transparent fibre and its diameter is slightly thicker than that of human hair.[4]It works on the principle of total internal reflection (TIR). This means that light travels in a zigzag pattern, and only a small number of light escapes through the side walls of the fibre. Most of the light comes out from the other end of the fibre.

STRUCTURE OF OPTICAL FIBER: An optical fiber consists of three main components. Core, cladding and protective jacket or also called plastic coating. The coating protects the fiber from damage but does not contribute to its optical waveguide properties.[5]

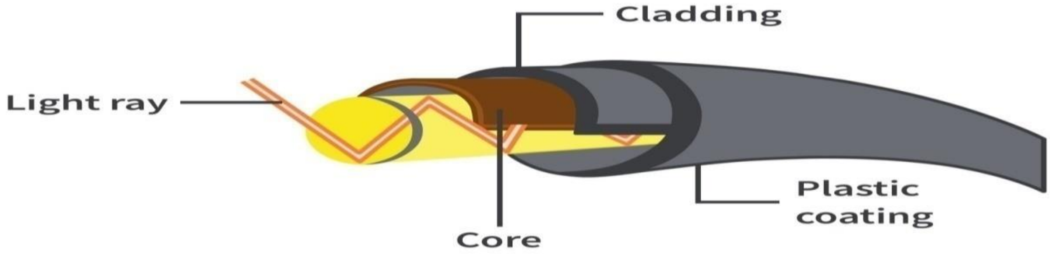


Figure 1 Structure of Optical fiber

Core: An optical fiber has a central part called the core. Its purpose is to guide light through the fiber. The core is very thin and can be made of glass or plastic. Its diameter ranges from 2 to 120 micrometers.

Cladding: The outer layer of an optical fiber that covers the core is called the cladding. It is a thin layer made of either glass or plastic and has different optical properties from the core material. The cladding is usually around 300 micrometers thick.

Cladding having the multiple functions:

(A) Reduces loss of light from core into the surrounding air.

(B) Reduces scattering loss at the surface of core.

(C) Add mechanical strength.

Protective jackets: The outer layer of an optical fiber is called the protective jacket. It is sometimes called the coating or buffer. The core and cladding are inside this jacket, which is usually made of plastic. The protective layer is meant to protect the fiber from physical harm like moisture, crusting, and other dangers.

Fiber attributes: Fiber attributes are those characteristics that are retained throughout cabling and installation processes.[6]

a) Core Characteristics: They have several core characteristics that make them well-suited for these purposes:

- **Material:** The core is the innermost part of the optical fiber, typically made of high-quality glass or sometimes plastic. The material chosen for the core has a higher refractive index compared to the cladding, which is essential for total internal reflection.
- **Function:** The core is responsible for carrying the light signals over long distances by utilizing the principle of total internal reflection. This means that when light enters the core at an angle greater than the critical angle, it will be completely reflected back into the core and won't escape into the cladding.
- **Diameter:** The core diameter can vary, with single-mode fibers having a smaller core diameter (around 2-120 micrometers) and multi-mode fibers having a larger core diameter (typically around 50-62.5 micrometers). Single-mode fibers allow for a single mode (ray) of light to propagate, whereas multi-mode fibers can support multiple modes.
- **Refractive Index:** The refractive index of the core is higher than that of the cladding, which ensures total internal reflection can occur.

b) Cladding characteristics: They have several cladding characteristics that make them well-suited for these purposes:

- **Material:** The cladding is made of a material with a lower refractive index compared to the core. This is usually another type of glass or plastic.
- **Function:** The cladding serves to confine the light within the core by providing a lower refractive index medium. This lower refractive index prevents the light from escaping the core and facilitates total internal reflection.

- **Diameter:** The cladding surrounds the core and typically has a larger diameter than the core. It acts as a protective layer around the core.
- **Refractive Index:** The refractive index of the cladding is lower than that of the core. This ensures that the light is guided through the core.

c) Protective Jacket Characteristics:

Material: The outer layer, known as the protective jacket or coating, is usually made of a polymer material. It serves to protect the fiber from physical damage, moisture, and other environmental factors.

Thickness: The jacket is thicker than the cladding and provides mechanical strength to the fiber. It can range from a few hundred micrometers to several millimeters in thickness.

Flexibility: The jacket also contributes to the flexibility and bendability of the optical fiber. Different jacket materials have varying levels of flexibility.

3. LIGHT TRANSMISSION IN OPTICAL FIBER

The optical fibers which are considered as waveguides can be applied to light transmission applications. The total internal reflection phenomena are necessary for the fine confinements of the light within the waveguide.

Total internal reflection: -

Refractive index defined as the ratio of the velocity of light in vacuum to the velocity of light in the medium. A ray of light travel more slowly in higher denser medium than less denser medium. When light passes from one material to another with different refractive indices (for example, air and glass), it behaves according to certain rules. The light moves through the first material with a refractive index of n_1 and hits the boundary at an angle of θ_1. On the other side of the boundary, the material has a higher refractive index of $n_2$compared to n_1, which causes the light to bend and travel through the second material at an angle of $\theta_2$with respect to the normal. The angles of incidence θ_1 and reflection θ_2 are related to each other. Then the Snell's law of refraction which states that:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

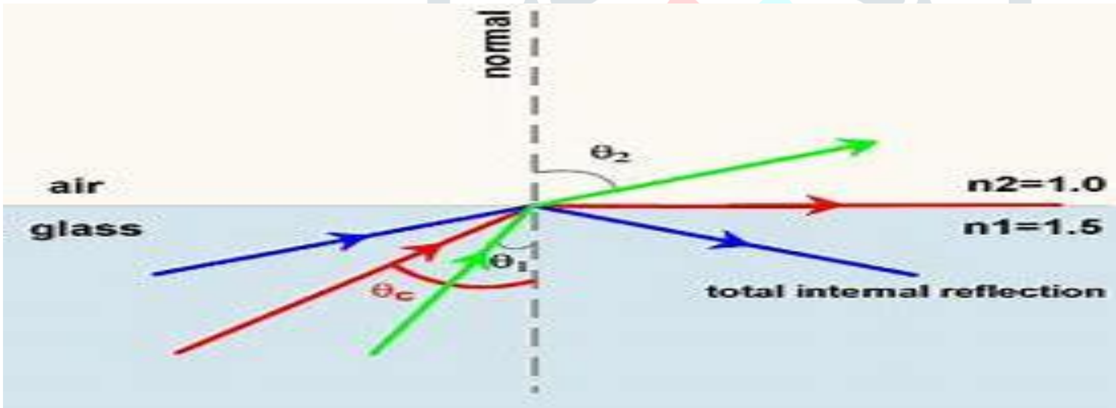


Figure 2 Refractive index

From Snell's law the limiting case of refraction showing the critical ray at an angleθ_c.Total internal reflection where $\theta_1 > \theta_c$

$$\frac{\text{Sin}\,\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

Where, $n_1$andn_2 are the refractive index indices of the two materials.

θ_1 is the incident angle of light.

θ_2 is the angle of refraction.

$\theta_c$is the critical angle.

When light goes from a medium with a higher refractive index n_1 to the lower refractive indexn_2, some of the light reflects back into the original medium. This happens because of the difference in refractive indices. When the angle of refraction is 90° and the refracted ray emerges parallel to the interface between the dielectrics, the angle of incidence must be less than 90°. This is the limiting case of refraction and the angle of incidence is known as the critical angle $\theta_{c.}$ The value of critical angle is given by:

$$\sin\theta_c = \frac{n_2}{n_1}$$

Hence, the above figure shows that total internal reflection occurs at the interface between two dielectrics of differing refractive indices when light is incident on the dielectric of lower index from the dielectric of higher index, and the angle of incidence of the ray exceeds the critical value.

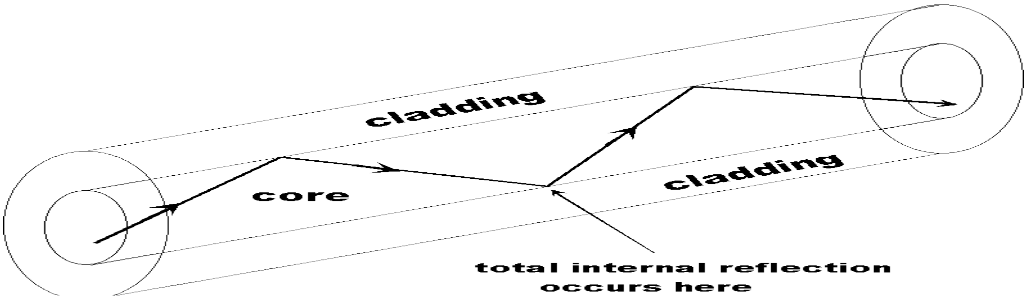


Figure 3 Total internal Reflection in optical fiber

The phenomenon by virtue of which array of light traveling from a denser medium to rarer medium is sent back to the same denser medium provided it strikes the interface of the denser and the rarer media at an angle greater than the critical angle is called total internal reflection of light. Most modern optical fiber is weakly guiding, meaning that the difference in refractive index between the core and the cladding is very small.[7]

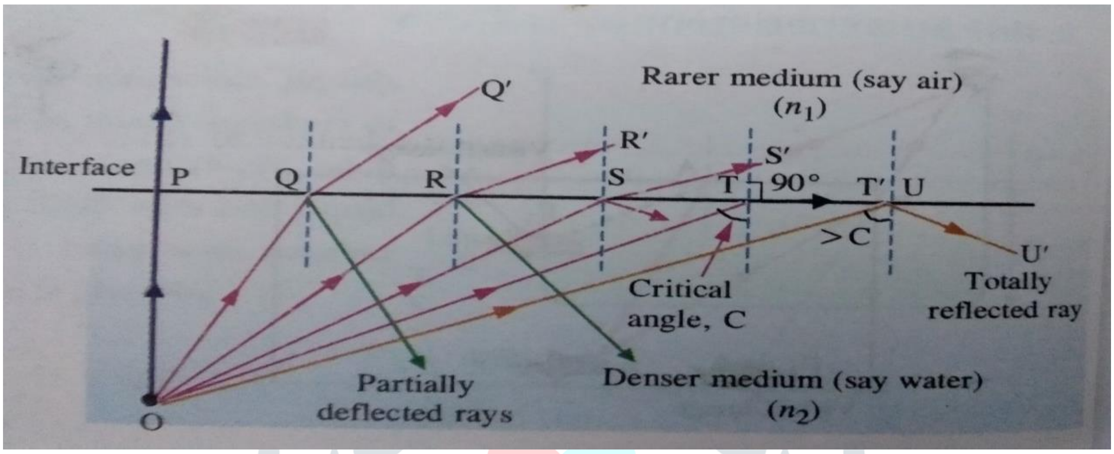


Figure 4 Total internal Reflection

When light shines on the border between two substances of different densities at point Q, it changes direction along the line QQ'. The more the angle of incidence increases, the more the light bends towards the border. At a certain angle of incidence, the refracted light moves along the border and the angle of refraction becomes 90º, also known as the critical angle (C).

If the angle of incidence is greater than the critical angle, there won't be any refracted light and all of the incident light will be reflected in the denser substance. This is called total internal reflection.[8]

Conditions for Total Internal Reflection

(1) The light ray should travel from denser to rarer medium.

(2) The angle of incidence must be greater than the critical angle for the given pair of media.

Critical angle:

When the angle of incidence is continuously increased, there will be progressive increase of refractive angle. At some conditions the refractive angle becomes 90º to the normal. When this happens the refractive light ray travels along the interface. The angle of incidence at the point at which the refractive angle becomes 90º is called critical angle. The critical angle is defined as the minimum angle of incidence at which the ray strikes the interface of two media and cause an angle of refraction equal to 90º.[9]

$$\sin\theta_c = \frac{n_2}{n_1}\sin 90^\circ$$

Critical angle $\theta_c = \sin^{-1}\frac{n_2}{n_1}$

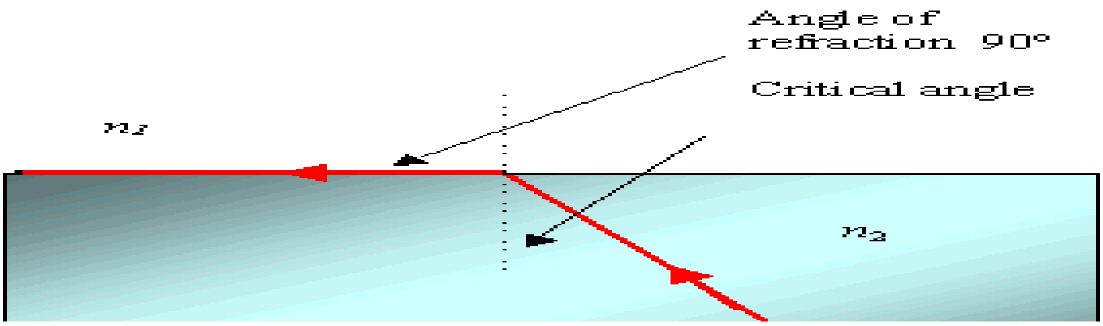


Figure 5 Critical angle

It is important to know about this property because reflection is also possible even if the surfaces are not reflective. If the angle of incidence is greater than the critical angle of a given setting, the resulting type of reflection is called total internal reflection, and it is the basis of optical fibre communication.

Acceptance angle:

The acceptance angle is $\frac{1}{2}$ angle of the maximum cone of light that can enter or exit the fibres. The incident angle is greater than the critical angle so that the light undergoes total internal reflection down the fibre. The acceptance angle of an optical fibre is defined based on a purely geometrical consideration; it is the maximum angle of ray hitting the fibre core which allows the incident light to be guided by the core.

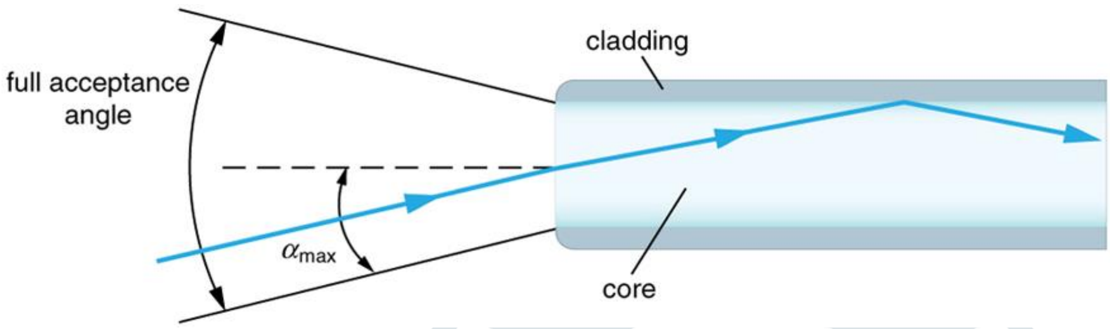


Figure 6 Acceptance angle

The angle of incidence on the core - cladding interface is less than the critical angle due to which part of incident light is transmitted.[10][11]

Hence the light will be transmitted through the fibre for the angle of incidence on the core which is less than the acceptance angle. The acceptance angle is the maximum angle of incidence on the core for which total internal reflection takes place inside the core. The light entering the core in a cone of semi-vertical angle is transmitted in the core through total internal reflection. This cone is known as acceptance angle.

Numerical aperture: Numerical aperture is a characteristic of any optical system. For example, photo detector optical fibre, lenses etc. are all optical system. Numerical aperture is the ability of the optical system to collect the entire light incident on it, in one area. The blue cone is known as the cone of acceptance. As you can see it is dependent on the acceptance angle of the optical fibre. Light wave within the acceptance cone can be collected in a small area which can then we sent into the optical fibre.

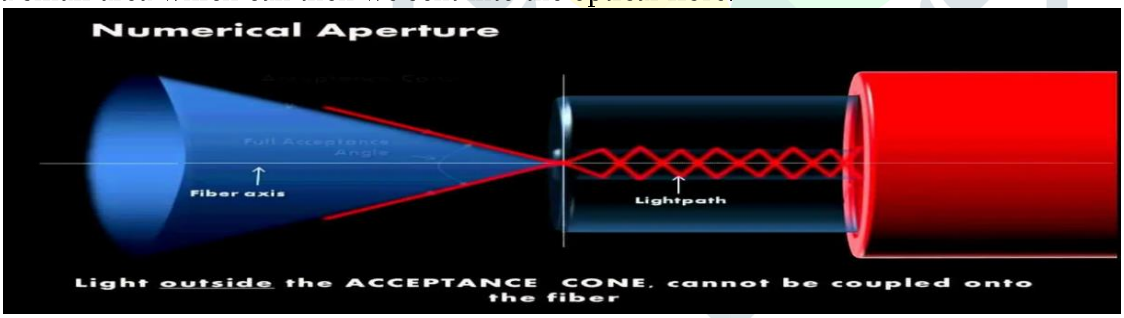


Figure 7 Numerical aperture

In the above figure the measure of maximum angle at which light rays will enter and we conducted down the fibre. This is represented by the following equations:

NA - Numerical Aperture

$$NA = \sqrt{(n_1^2 - n_2^2)} = n \sin\theta$$

Where n is the index of refraction of the medium in which the lens is working (1.00 for air, 1.33 for pure water, and typically 1.52 for immersion oil.[12]

Classification of optical fibers

1.) Based on refractive index profile
2.) Number of modes transmitted through fibre
3.) Tapered fiber

1.) Based on refractive index profiles: Optical fibers are classified into two types based on the refractive index profile of core and cladding. They are

- Step index fiber
- Graded index fiber.

2.) Based on the number of modes propagated through optical fiber:

Mode is the one which describes the nature of the electromagnetic wave in waveguide. Optical fiber is considered as cylindrical waveguide. It is the allowed direction whose associated angles satisfy the conditions for total internal reflection. Based on the number of modes that propagates through optical fiber, they are classified as

1. Single mode fibers
2. Multimode fibers

1. Single mode or Mono mode fibers:

In a fibre, if only one mode is transmitted through it then it is said to be a single mode fibre. It has a very much smaller core that allows only one mode of light at a time to propagate through the core. While it might appear, the multimode fibre has higher capacity; in fact the opposite is true. Single mode fibre is designed to maintain spatial and spectral integrity of each optical signal over longer distances, allowing more information to be transmitted.

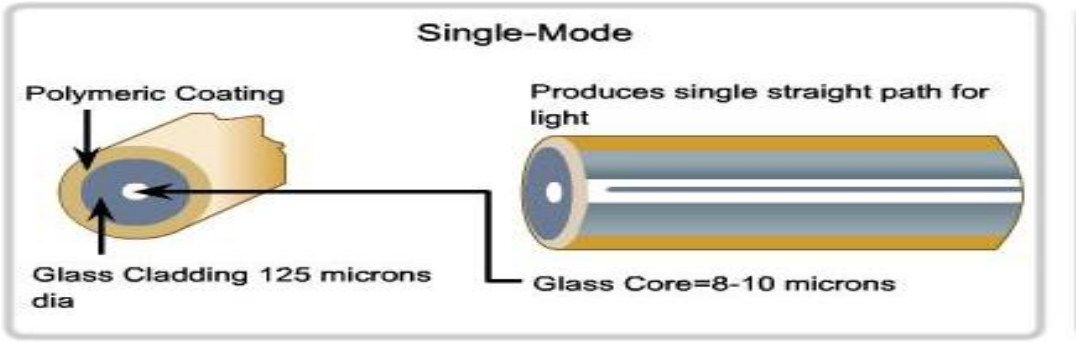


Figure 8 -Single mode fiber

2. Multimode fibers:

Multimode fire was the first type of fiber to be commercialized. It has a much larger core than single-mode fiber, allowing hundreds of modes of light to propagate through the fiber simultaneously. Additionally, the larger core diameter of multimode fiber facilitates the use of lower-cost optical transmitters (such as light emitting diodes [LEDs] or vertical cavity surface emitting lasers [VCSELs]) and connectors.

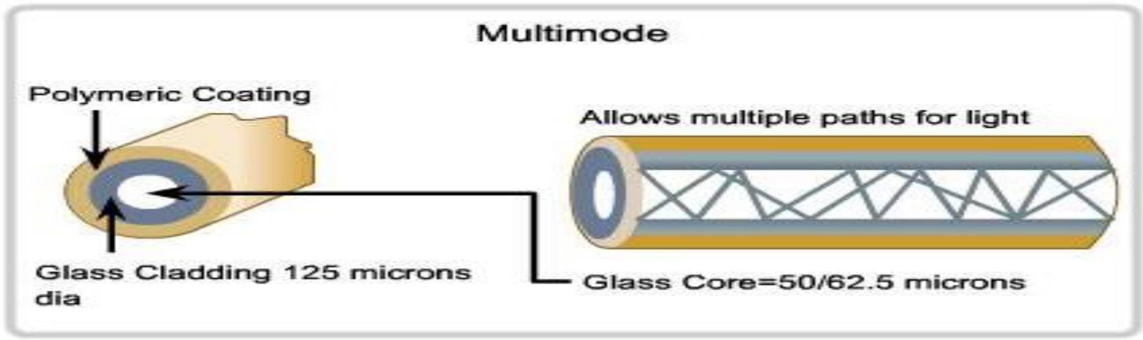


Figure 9 -Multimode fibre

Depending upon the refractive index profile and the number of modes propagated through the optical fiber, they are further classified as

. Step index single mode fiber
. Step index multimode fiber
. Graded index single mode fiber
. Graded index multimode fiber

- **Step index single mode fiber:** The core diameter of this type of fiber is very small i.e., of the order of wavelength of light to be propagated through the fiber. The refractive index profile has step change in the refractive index from core to cladding as shown in Figure

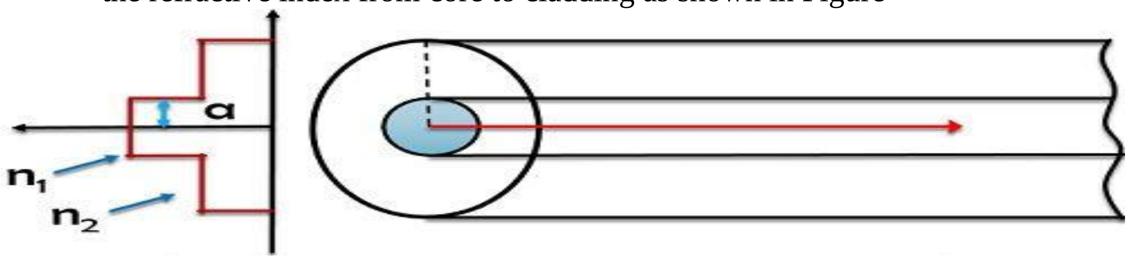


Fig-10 Step Index Single Mode Fiber

- **Step index multimode fiber**: Step-index multimode fibers are mostly used for imaging and illumination. Graded-index multimode fibers are used for data communications and networks carrying signals moderate distances - typically no more than a couple of kilometres.

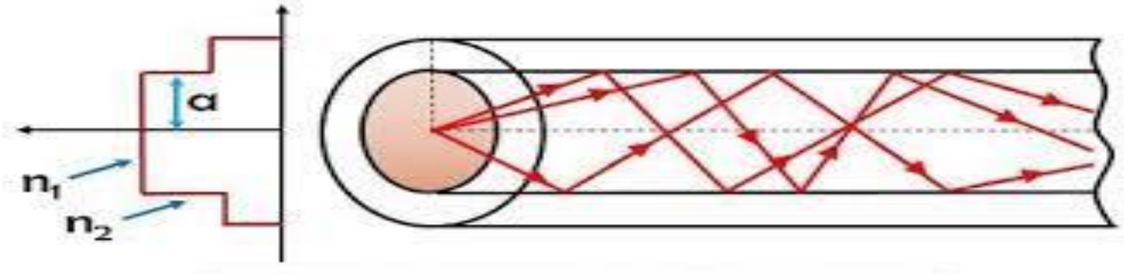


Fig-11 Step Index Multimode Fiber

- **Graded index single mode optical fiber: -**

Graded index optical fiber has a property of gradual variation in refractive index (increasing from the outside of the fiber core to the centre of it). The propagation of light through single mode graded index fiber is similar to that for step index fiber. The light wave travels along the centre of the optical fibre.

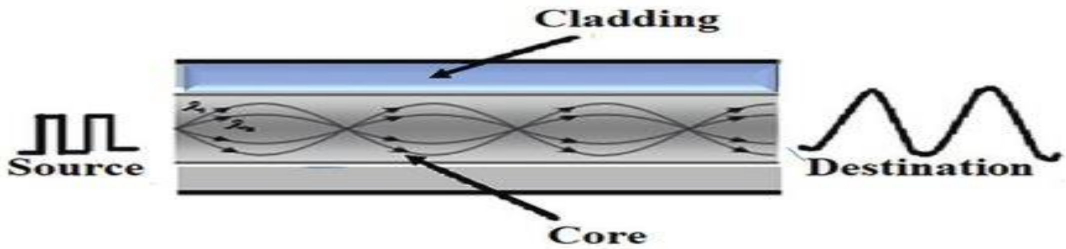


Fig-12 Graded Index Single mode fiber

Graded Index Multi Mode Fiber: -

From the figure it is quite clear that light waves or rays with large angle of incidence travel more path lengths than those with smaller angles. But we know that the decrease of refractive index allows a higher velocity of light energy propagation. Thus, all waves will reach a given point along the fiber at virtually same time. As a result, the transit time dispersion is reduced. This type of light propagation is referred as graded index multimode propagation through optical fiber.

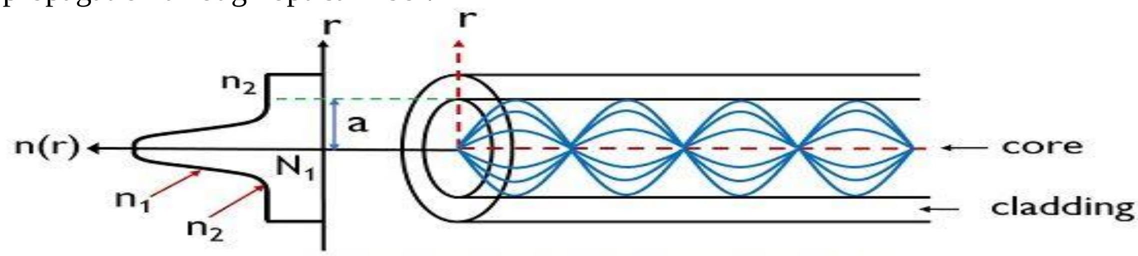


Fig 13 Graded Index Multi Mode Fiber

3.) Tapered Fiber:-Tapered fibers are useful for getting maximum amount of power from a poor-quality laser spot into a fiber. The use of tapered optical fiber is an efficient low-cost method of transforming a poor-quality laser beam into a uniform output spot.

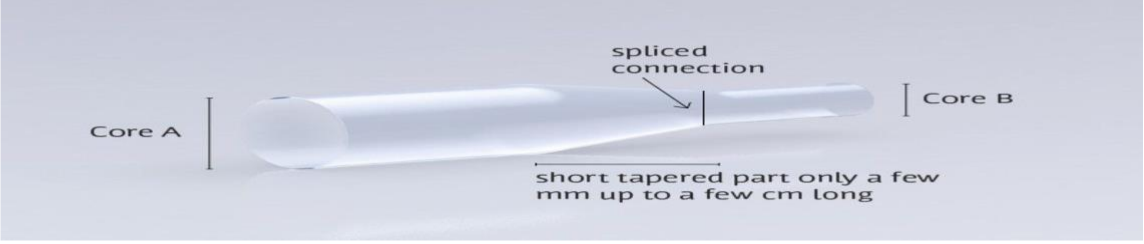


Fig 14 Tapered Fiber

4. ATTENUATION OF OPTICAL FIBER

The attenuation of an optical fiber measures the amount of light lost between input and output. The transmission of information is through these fibers results in loss of information. Total attenuation is the sum of all losses. The losses in optical fiber are absorption loss, scattering loss, dispersion loss and radiation loss and coupling loss.[13][14]

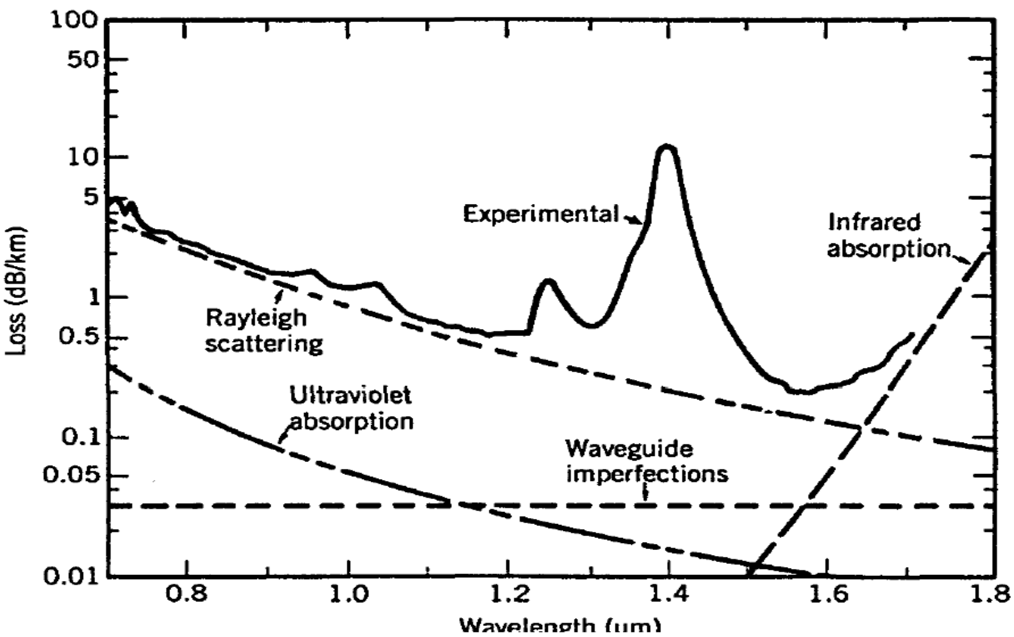


Figure 15 Attenuation of an optical fiber

4.1 Absorption loss:

Due to the presence of impurities in the fiber residues still remain resulting in the absorption. The composition of the fiber and its fabrication of fiber results in absorption loss. There is dissipation of optical power in the fiber cable. The wavelength and its concentration affect the amount of absorption. The two types of absorption losses as explained below:

a) Intrinsic absorption

The electronic absorption bands in the UV region are the main cause of this type of absorption loss. When a photon interacts with an electron, it is excited to a higher energy level and results in the absorption. The characteristic vibration frequency of atomic bonds results in absorption loss in the IR region. The electromagnetic field and the interaction of vibration bonds is the main cause of intrinsic absorption.

b) Extrinsic absorption

Extrinsic absorption is more common than intrinsic loss. They are the outcome of impurities in the fiber during manufacturing. In iron, nickel and chromium there is transition of metal ions to higher energy levels.

4.2 Radiative loss:

The radiative losses or bending losses are more predominant when the fiber is curved or bends. And two types of radiative or bending losses are-

1. **Macro-bending:**
   Macro bending (fiber bends large enough to be seen with the naked eye) loses occur when fibers are physically bent beyond the point at which the critical angle is exceeded. Macro bends are bends having a large radius of curvature relative to the fiber diameter. During installation, if fibers are bent too sharply, macro bend losses will occur. Fibers with a high numerical aperture and low core/cladding ratio are least susceptible to macro bend losses.

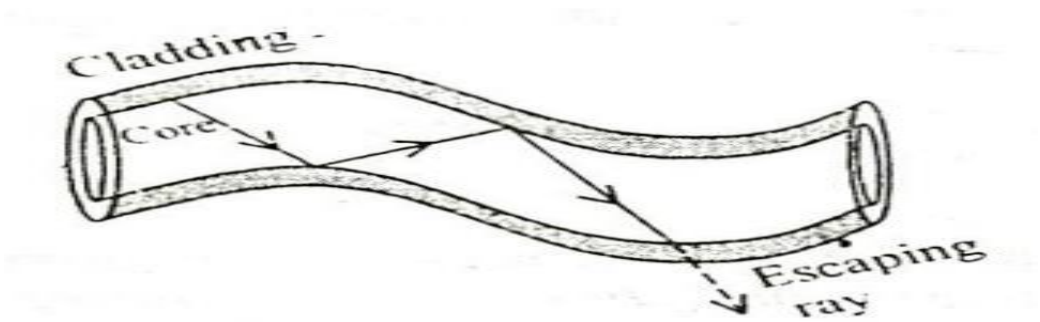


Figure 16 Macro-bending

2. **Micro- bending:**

Micro bending (bends too small to be seen with the naked eye) occurs when pressure is applied to the surface of an optical fiber and uneven coating applications and improper cabling. The pressure applied to the surface results in deformation of the fiber core at the core-cladding interface. External forces are also a source of micro bends. Micro bending losses are induced under conditions of surface pressure such as crushing.

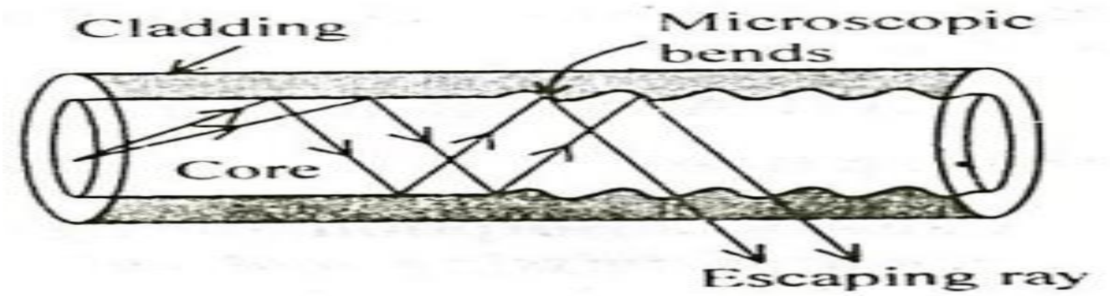


Figure 17 Micro-bending

4.3 Scattering loss: -

Within the fiber when there is interaction of light with density fluctuation scattering occurs. Scattering losses are of different types:

a) Linear scattering losses: -

Linear scattering occurs when the energy is transferred from dominant mode to adjacent mode. In dominant mode the linear scattering is proportional to the input power injected.

b) Non- linear scattering losses:

The optical fiber is said to operate in non-linear mode when the optical power at the output of the fiber does not change proportional with the power change at the input of the fiber.

4.4 Dispersion loss:

In Dispersion the temporal spreading occurs when light pulse propagates through an optical fiber. Sometimes, the propagation time delay causes the pulse to broaden. Dispersion loss has another name which is delay distortion.

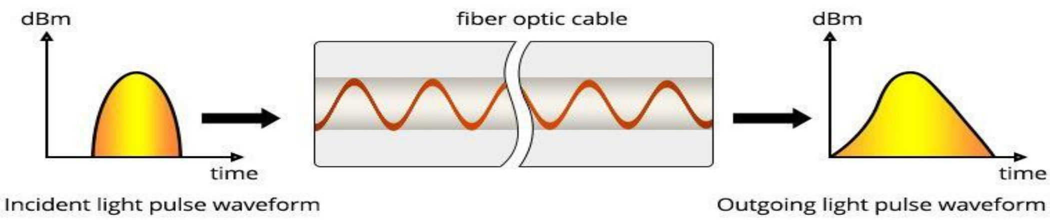
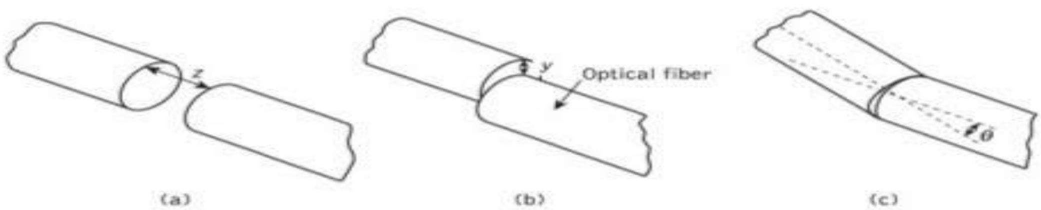


Figure – 18 Dispersion Losses

4.5 Joint Losses: -



Longitudinal misalignment lateral misalignment angular misalignment

Figure - 19 Joint losses in optical fiber

Joint losses in optical fiber refer to the attenuation or reduction in the strength of an optical signal as it passes through a connection point or splice in the fiber optic network. [15]These losses occur due to various factors:

1. **Fiber-to-Fiber Splice Loss:** When two optical fibers are joined together, there is typically some signal loss at the splice point due to imperfections in alignment or refractive index mismatches.
2. **Connector Loss:** Optical connectors, such as SC or LC connectors, can introduce losses when connecting two fiber optic cables. These losses result from imperfect alignment of the fiber cores.
3. **Bend Loss:** If an optical fiber is bent too sharply, it can cause signal loss due to increased optical scattering. This is why proper fiber handling and bending radius are crucial.
4. **Intrinsic Fiber Loss:** The optical fiber itself has inherent attenuation characteristics, meaning the signal strength naturally diminishes as it travels along the fiber's length.

5. **Insertion Loss:** This is the overall loss introduced by the combination of connectors, splices, and other components in an optical system.
6. **External Factors:** Environmental factors like temperature, humidity, and physical disturbances can also contribute to joint losses in optical fiber.

To minimize joint losses and maintain signal integrity in optical fiber networks, technicians use precise splicing and monitorization techniques, high-quality connectors and splicing equipment, and ensure proper fiber handling and management. Regular maintenance and monitoring are also essential to detect and address any issues that may arise over time.

5. OPTICAL FIBER COMMUNICATION SYSTEM:

Sending information over long distances is done through optical fiber communication, which is a dependable and effective method. This process involves transmitting infrared or visible light pulses through a fiber optic cable. Due to the low attenuation characteristics of glass or plastic fibers, the light experiences minimal loss as it travels along the cable. To convert electrical signals into optical signals, a light source is used, which allows for the light signals to represent data in different ways, such as intensity or frequency modulation. Once at the destination, a light-sensitive device, like a photodiode, converts the optical signals back into electrical signals. These electrical signals can then be processed and utilized by communications.

BLOCK DIAGRAM OF OPTICAL FIBER COMMUNCATION SYSTEM

A block schematic of an optical fiber communication system is shown in Figure. This system conveys either the analogy or digital signal from the information source to the destination over the optical fiber cable. The information source provides an electrical signal to a transmitter comprising the driver circuit, optical source and channel coupler. The optical source provides the electrical-optical conversion. It can be either a semiconductor laser or light-emitting diode (LED). The signal transmission medium consists of an optical fiber cable. The receiver consists of a channel coupler, photo-detector and electronic circuits for linear channel and decision circuit. Photodiodes may be used for the detection of the optical signal and the optical-electrical conversion and finally the electrical signal reach the destination. Optical fibre can be used in high transmission applications since they are waveguide. An outer layer of glass or plastic surrounds the optical fibre core, which has a lower refractive index than the fibre core. The complete internal reflection phenomena are necessary to achieve fine confinement of light within the waveguide. Calculate the majority of telecommunication network use fibre optic as data transmission medium.[16]

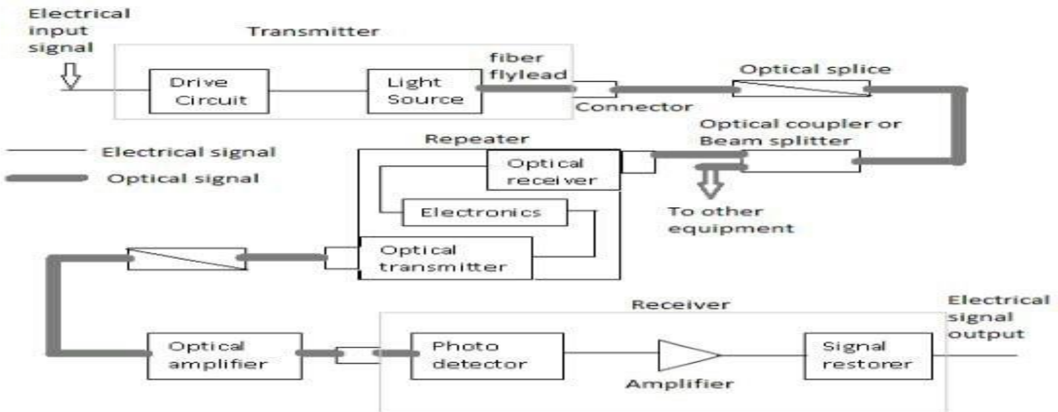


Figure-20 Block diagram of fiber optic communication system

Elements of fiber optic communication system

Modern fibre-optic communication systems generally include optical transmitters that convert electrical signals into optical signals, optical fibre cables to carry the signal, optical amplifiers, and optical receivers to convert the signal back into an electrical signal. The information transmitted is typically digital information generated by computers or telephone systems.

a) **Transmitter:** A transmitter is a device or equipment that sends signals or information in the form of radio waves, electrical pulses, or other means to communicate with or control other devices. Transmitters are commonly used in various applications, including broadcasting radio and television signals, remote control systems, wireless communication, and more.
   - **Driver circuit:** Driver circuit drives the light source.
   - **Light source:** Light source converts electrical signal to optical signal. Light source is used to connect optical signal to optical fibre.

b) **Optical connector**: It is used for temporary non-fixed joints between two individual optical fibres.
c) **Optical splice:** Optical splice is used to permanently join two individual optical fibres.

d) **Optical coupler:** Optical coupler or splitter provides signal to other devices.

e) **Repeater:** Repeater converts the optical signal into electrical signal using optical receiver and passes it to electronic circuit where it is reshaped and amplified as it gets attenuated and distorted with increasing distance because of scattering, absorption and dispersion in waveguides, and this signal is then again converted into optical signal by the optical transmitter.

- **Optical receiver:** The role of an optical receiver is to convert the optical signal back into electrical form and recover the data transmitted through the light wave system.

f) **Optical amplifier:** The principle of optical amplification was invented by Gordon Gould on November 13, 1957. [18] He filed patent No. 804,539 on April 6, 1959 titled "Light Amplifiers Employing Collisions to Produce Population Inversions"[19]An optical amplifier is a device that amplifies an optical signal directly, without the need to first convert it to an electrical signal. An optical amplifier may be thought of as a laser without an optical cavity, or one in which feedback from the cavity is suppressed.

g) **Receiver:** Optical signal is applied to the optical receiver. It consists of photo detector, amplifier and signal restorer. The main component of an optical receiver is a photodetector which converts light into electricity using the photoelectric effect. The primary photodetectors for telecommunications are made from Indium gallium arsenide. The photodetector is typically a semiconductor-based photodiode.

- **Photo detector:** Photo detector converts the optical signal to electrical signal. A photodetector (PDs) is an optoelectronic device that converts incident light or other electromagnetic radiation in the UV, visible, and infrared spectral regions into electrical signals.
- **Amplifier:** An amplifier is an electronic device that increases the voltage, current, or power of a signal. Amplifiers are used in wireless communications and broadcasting, and in audio equipment of all kinds.

h) **k Transmission channel:** It consists of a cable that provides mechanical and environmental protection to the optical fibres contained inside. Each optical fiber acts as an individual channel.

l) Signal restorers: Signal restorers and amplifiers are used to improve signal to noise ratio of the signal as there are chances of noise to be introduced in the signal due to the use of photo detectors. For short distance communication only, main elements are required

6. FIBER ATTENUATION

In this exercise, we will measure the attenuation per unit length of a single mode communications-grade optical fiber, which is a critical fiber parameter. We will also talk about how launching light into the fiber can affect this measurement. Finally, we will calculate the attenuation and the coefficient of attenuation.

MEASUREMENT OF OPTICAL FIBER ATTENUATION

An expression for the amount of optical power which still remains in a fiber after it has propagated a distance, L is given as

$$dB = 10\ \log\frac{P_i}{P_o}$$

The length of the fiber,L is given in kilo meters, and the attenuation coefficient, $\alpha$is given in decibels per kilometre (dB/km).

To determine how much light remains in an optical fiber after it has travelled a certain distance, fiber optic system designers use a specification called fiber attenuation. Measuring fiber attenuation is a simple process that involves launching light into a long fiber, measuring the power at the end, cutting off most of the fiber except for a short length at the input, and then measuring the power transmitted by the shortened length. This method ensures that any loss measured is solely due to the fiber and not from coupling the light source to the fiber. A schematic illustration of the measurement system can be found in Fig. 21, with the mode scrambler explained in the primer section.

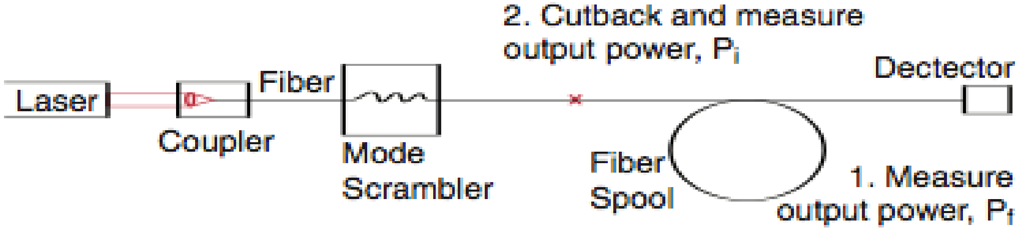


Figure 21: Phasor Diagram of fiber attenuation.

The transmission through the fiber is written as,

$$T = \frac{P_f}{P_i}$$

Where, we have substituted P_i (initial power) and P_f(final power) for I(0)and I(L), respectively. A logarithmic result for the loss in decibels (dB), is given by

$$A(dB) = -10 \ \log \frac{P_f}{P_i}$$

The minus sign causes the loss to be expressed as a positive number. This allows losses to be summed and then subtracted from an initial power when it is also expressed logarithmically.

The attenuation coefficient, α, in dB/km is found by dividing the loss, L, by the length of the fiber, L. The attenuation coefficient is then given by

$$\alpha\left(\frac{dB}{km}\right) = \left(\frac{1}{L}\right)\left[-10\log\left(\frac{P_f}{P_i}\right)\right]$$

The total attenuation can then be found by multiplying the attenuation coefficient by the fiber length, giving a logarithmic result, in decibels (dB), for the fiber loss.

SOFTWARE USED: -For the simulation of attenuation in optical fiber we use the software named "Opti system".

Opti system is an innovative, rapidly evolving, a powerful software design tools that enable users to plan test and stimulate almost every type of optical links in the transmission layer of the of a board spectrum of optical network from LAN, SAN, MAN two ultra long haul. It offered transmission layer optical communication system design and planning from component to system level and visual analysis and scenarios.[26]

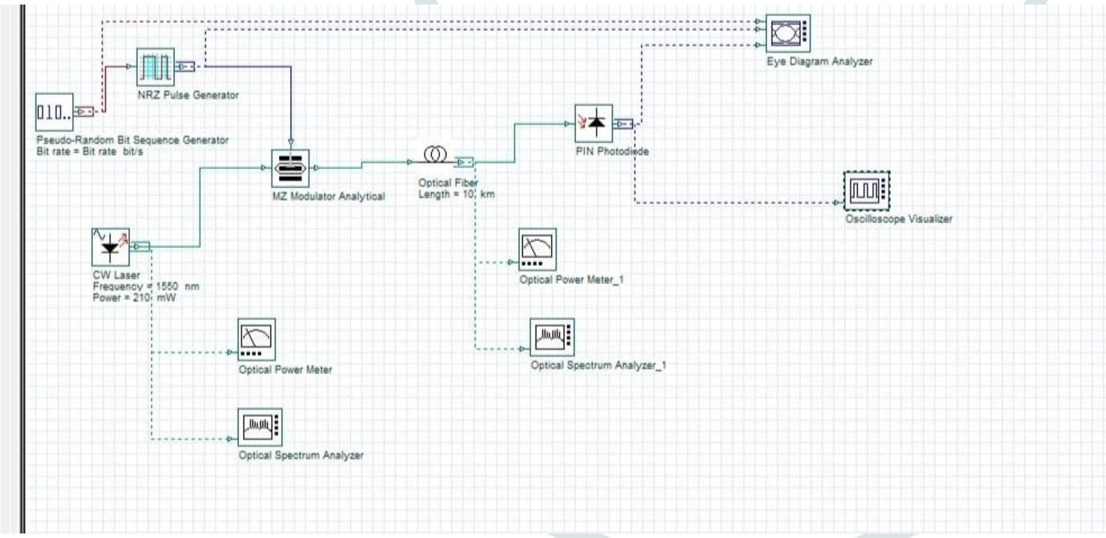


Figure – 22 Schematic of the optic system setup to determine the attenuation of a fiber as a function of length and wavelength

Components used: -

- **Pesedo-Random Bit Sequence Generator: -**the generation of pesedo random bit sequence is particularly used in communication and computing system pseudo random sequence are normally generated using circuit called linear feedback shift resistor.
- **NRZ pulse generator: -**NRZ pulse generator a known return to zero code electrical signal which is depend on the bit sequence input since the pulse generator output is dependent on a bit sequence.
- **CW laser: -**Continuous wave laser emit a continuous laser beam as compared to ultra-fast or pulsed laser that emit a pulse laser beam.
- **MZ modulator analytical: -**Analytical modulator is a device which is used to determine the relative phase shift variation between the two collimated beam derived by splitting light from one single source.
- **Optical fiber: -**In the above we have used single mode glass optical fiber.
- **Pin photodiode: -**Diode with the white and undoped intersonic semiconductor reason between a P type and N type semiconductor we use the pin diode because these diodes are effectively used for RF protection circuits and they can also be utilized as RF switches the pin diode is also used to detect X-rays and gamma ray photons radio frequency

- **Optical power meter**: - an optical power meter is a device which is used to measure the power of an optical.
- **Optical spectrum analyser: -**optical spectrum analyser is precision instrument which is used to measure the optical Spectra based on which the further analysis is often possible.
- **Eye Diagram analyser: -**Eye diagram is used in an electrical engineering to get a good idea of signal quantity and digital domain to generate a Bay form analogous to an eye diagram we can apply infinite persistent to various analog signal as well as the quasi-digital signal such as square wave and pulse and synthesized by arbitrary frequency generator.
- **Oscilloscope visualizer: -** what's the score visualizer provides a visual representation of the signal shapes or waveforms this allows you to measure the properties of waves such as amplitude frequency.

INSTRUCTION SET

To begin the experiment, follow these three steps:

1. Layout from the light runner

Diagram for Opti system

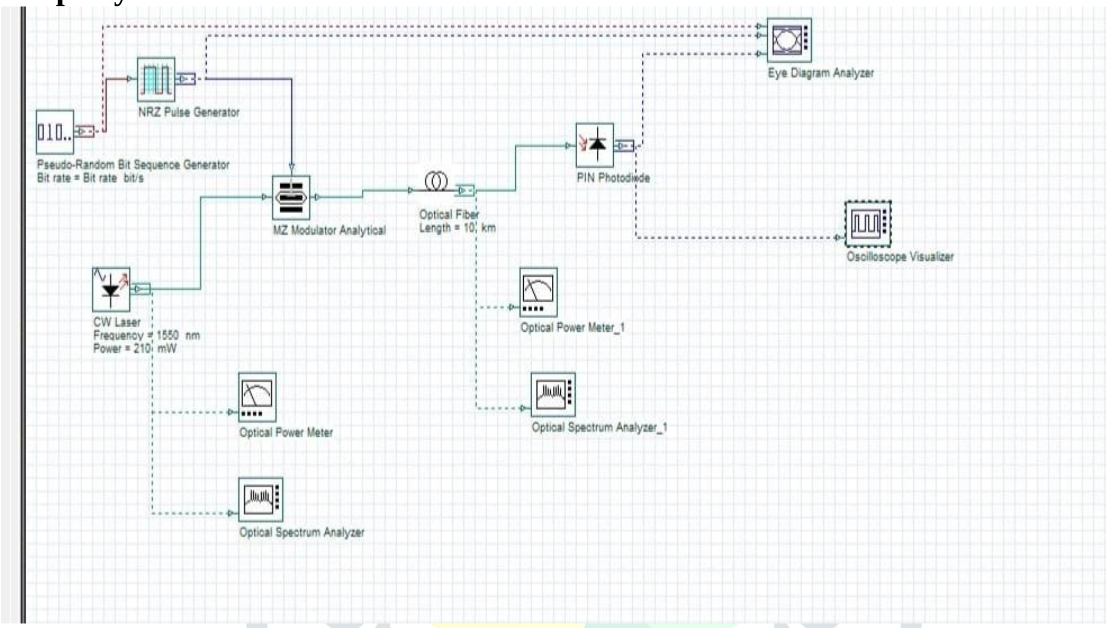


Figure – 23 Circuit Diagram of Attenuation

1. Download the Optisystem software for the simulation of the attenuation single mode optical fiber.
2. Place all the components above the visible.
3. Laser is switched on and is connected to the silicon pin photo detector using path code.
4. The laser power is adjust using the soft control to keep it below the photo diode saturation and the readings are noted as Pi.
5. After disconnecting the path cord the detector, it is connected to the given fibres spool of known length l the other end of the fibres spool is connected to the photo detector and the optical power from the spool is recorded as Po.
6. The experiment is repeated for any of the sea band laser and PD 3 with a 10-kilometre fibre.
7. In the procedure given here instead of cutback method the power exiting a short length and long length is measured. Since an addition fibre of length l has been introduced in the fibre.
8. Run the simulation and record following data
   - ❖ Optical power levels (both mW and dBm)
     - ➢ Both ends of fiber
   - ❖ Optical spectrum
     - ➢ Both ends of fiber
   - ❖ Oscilloscope visualizer spectrum
     - ➢ End of the receiver
9. Set a different fiber length and repeat the simulation and data recording.

Result and discussion:

We have calculated the attenuation and attenuation coefficient. Variation in attenuation has been shown with the help of graphs and observation table. At last, we have concluded whatever we have worked on.

Study of Attenuation:

One of the standard ways of determining the attenuation through an optical fiber is to measure the value optical fiber at two locations separated by a distance L km and using the expression given by formula mentioned below

Formula used

If p_i represents the input power and p_o is the output power after passing through an optical fiber length L km.

Attenuation, A in dB=10 log $\frac{pi}{po}$

Attenuation coefficient, α in dB/km= A/L $\frac{10}{l}\log\frac{pi}{po}$

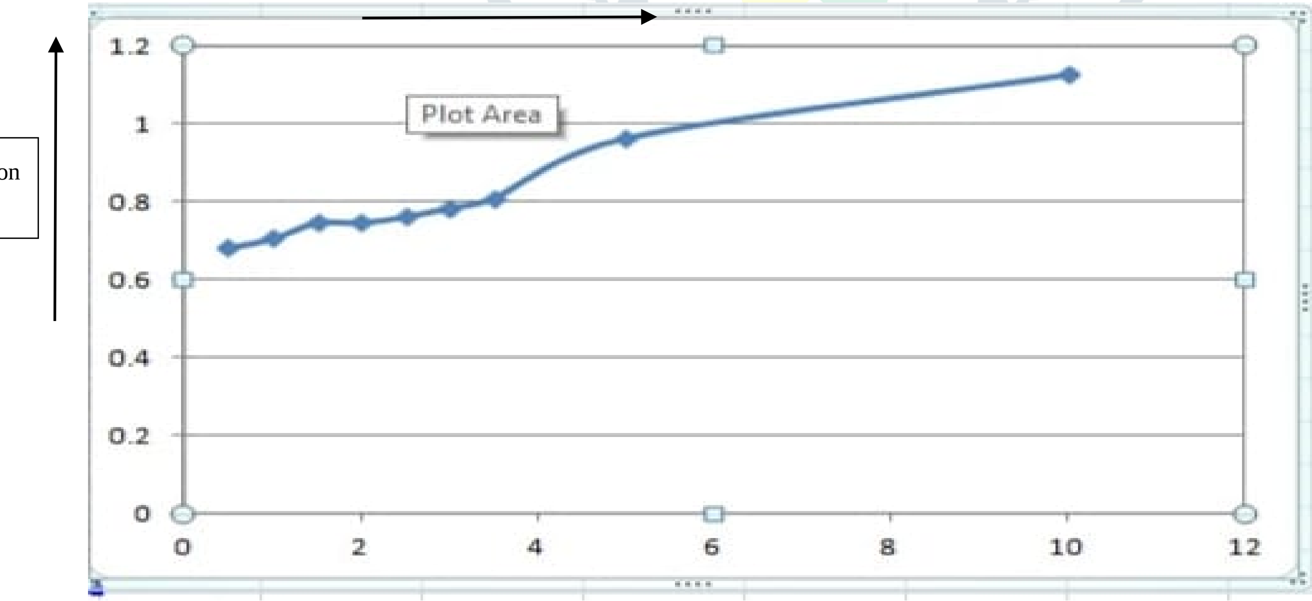
In this we have compared the attenuation with fiber and without fiber. We take Attenuation of fiber as a function of length and wavelength.

Observation table for attenuation: -

Wavelength (nm)	Length L (km)	Input power p_i (mW)	Output power p_o (mW)	Input power p_i (dBm)	Output power p_o (dBm)	Attenuation (dBm)	Att. per km, A/L	Avg. att.
1550	0.5	210	96.41	23.222	19.841	0.6833	1.366	0.8129
1550	1	210	94.023	23.222	19.732	0.707	0.707	0.8129
1550	1.5	210	92.07	23.222	19.64	0.7474	0.4848	0.8129
1550	2	210	90.161	23.222	19.55	0.7474	0.3737	0.8129
1550	2.5	210	88.656	23.222	19.477	0.7634	0.3053	0.8129
1550	3	210	86.638	23.222	19.377	0.786	0.262	0.8129
1550	3.5	210	84.492	23.222	19.268	0.8105	0.2315	0.8129
1550	5	210	78.69	23.222	18.959	0.9649	0.1929	0.8129
1550	10	210	61.86	23.222	17.914	1.127	0.0127	0.812

TABLE - 3

THE GRAPH IS BETWEEN LENGTH AND ATTENUATION



GRAPH -1

Length (km)

In the above graph we have concluded that as we increase the length of the fiber the attenuation is also increasing. Graph between the length of the fiber and attenuation

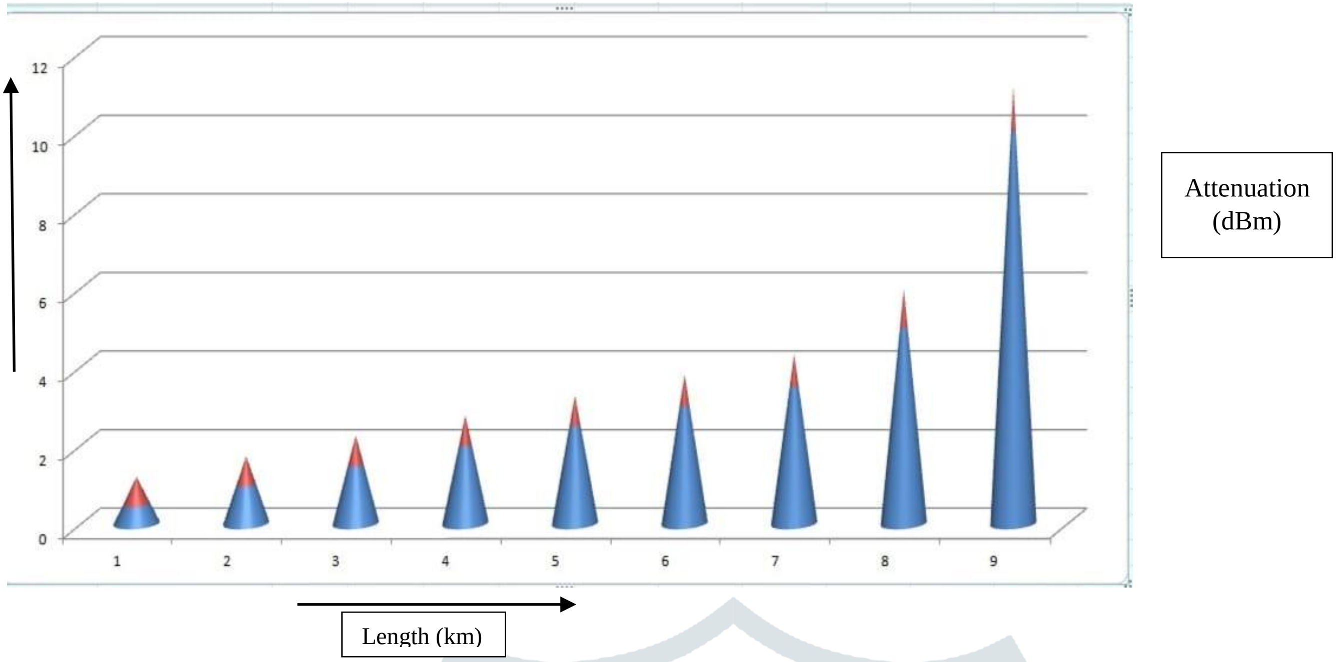
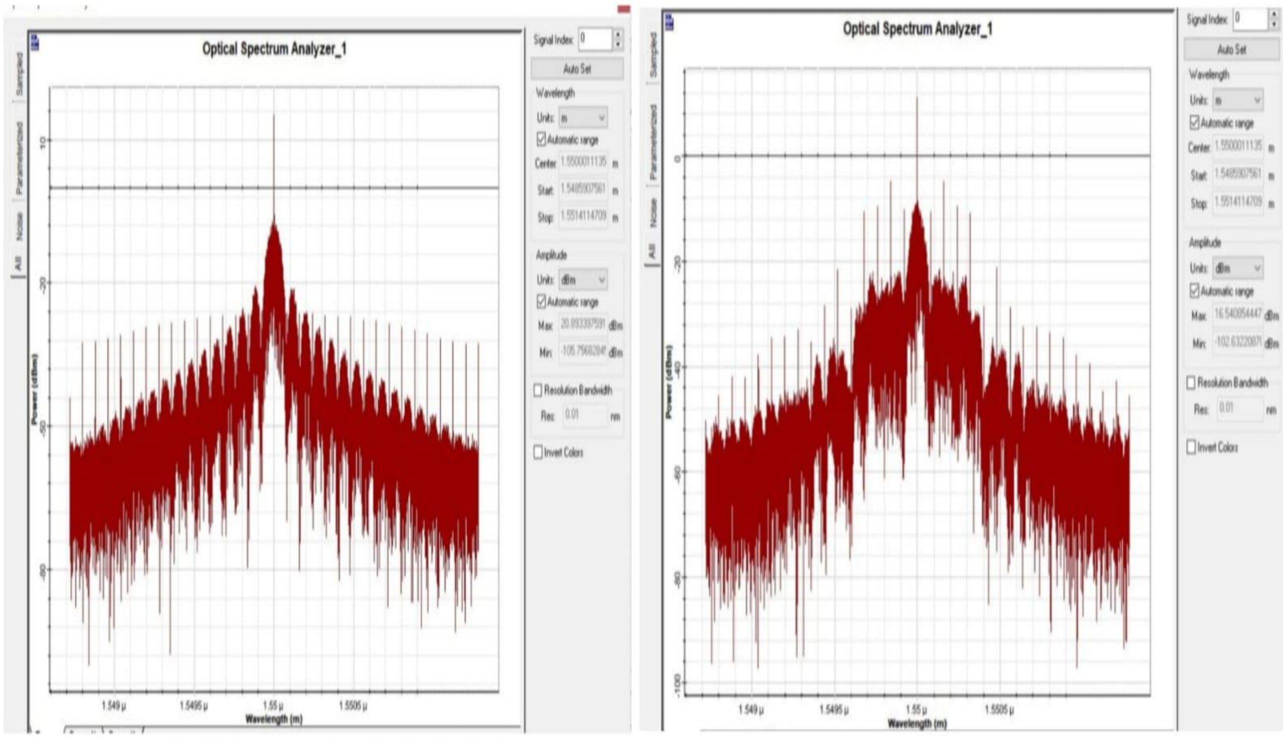


Fig: -Shows the variation of attenuation with length.

GRAPH – 2



(a) (b)

The spectrum of optical carrier suppression with wavelength

(a) Single mode optical fiber length 0.5km

(b) Single mode optical fiber length 10km

GRAPH -3

Analysis and Report

Single mode fiber usually operates in 1310 to 1550 nm region where attenuation is lowest. This makes single mode fibers the best choice for long distance communications. Multimode fiber operates primarily at 850 nm offset by the use of more affordable optical source.

CONCLUSION

Attenuation varies depending on the fiber type and the operating wavelength. There are several causes of optical loss that will be investigated through this experiment. Here we have discussed about the absorption loss of optical fiber at different length. So we concluded that Attenuation is an inevitable phenomenon that occurs during signal transmission in telecommunications. The attenuation increases with increase in the length of the fiber.

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