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A Review of the Development in Fiber-based optical communication networks: progress and challenges

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ABSTRACT: If a look from the beginning of the Graham Bell's time, the first revolution in communication took place, when the audio signals were converted into electrical form and were transmitted on electrical wires then converted back into the audio form. That was the major breakthrough in the field of communication that time. The primary objective was to just carry voice from one point to another by means of electrical medium. As the time progressed the need for communication, increased that means more and more people wanted to communicate from one point to another and as a result, larger and larger bandwidth was required. So, if a look at the history of communication in brief, the frequency of operation has consistently increased from the audio frequencies to higher and higher. So initially even the communication started in low frequency bands that means in the range of few kilohertz, then the frequency was increased too few megahertz, then the frequency was increased to a few GHz.Today's world the biggest revolution that has taken place is that, if compare to the early part of the 20th century, when the information used to be carried in the form of electrical signals in comparison to that today, most of the places the information is carried in the form of light, which is a very big advantage because the speed of light, it is several orders of magnitude higher than the speed of the electron.

KEYWORDS: Communication links, Loss mechanisms,Classifications of optical fiber.

I.INTRODUCTION

Optical fiber consists of three parts core, cladding and jacket. The refractive index of the core is greater than that of the cladding. A jacket which is outside is just a protective covering as shown in fig.1. It is necessary to have more refractive index of core than that of the cladding for the proper propagation of light in optical fiber. Total internal reflection is the phenomenon, which is necessary for this, so the propagation of the light will be carried out due to the difference in the refractive index of the core and cladding. Optical fibers are available using different materials like the glass or silicon and plastic depending upon the requirements of the application. The refractive index profile and the number of rays, which are being transmitted through the optical fiber is the basic category in which this optical fiber is classified [1]. It has been calculated that it would require about 30,000 kg of copper, if want to send the same amount of information through optical fiber, it will only 0.1Kg. The availability of the resource's copper is very limited the biggest contribution of the optical fibers. The wavelength of optical fiber transmission uses above the visible light spectrum. Typical optical transmission wavelengths are 850 nanometers, 1310 nanometers and 1550 nanometers. The light emitting diodes are used to transmit light through the optical fiber. Lasers are usually used for 1310 and 1550 nanometers in single mode applications, whereas LED are used for 850 and 1300 nanometers in multimode

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applications. LED is slightly cheaper, but lasers are more expensive, and they are used for single mode applications for the highest quality of the data rate [1].

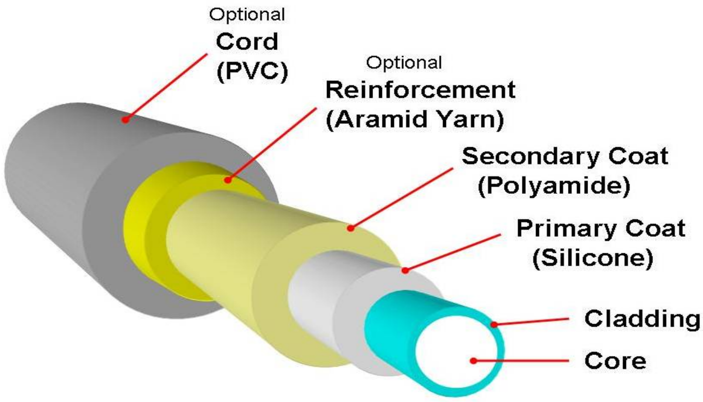

Figure 1 Basic view of an optical fiber

The predominant use of optical technology which has very fast as compared to electric wires and microwave frequencies. The fiber optic system has many attractive features which are superior with electrical systems. Fiber cable is significantly smaller and lighter than the electrical cables to the same job. Fiber cable causes significantly less than the copper cable for the same transmission capacity. There are always the possibilities of ground loop facing a serious problem, especially in the LAN or computer channel environment. An optical connection is safe. Electrical connections always have to be protected from high voltage because of the danger to people touching the wire

II.PRINCIPLES OF OPTICAL FIBER COMMUNICATION

When a light ray is traveling in one medium to different medium and then depending on the refractive index, it reflects back into the original medium without any loss of light. It follows a zigzag path along the length of the fiber as shown in fig 2.

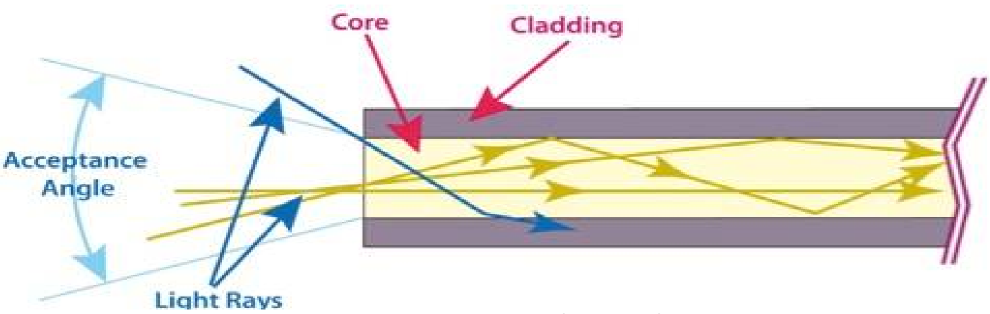

Figure 2 Acceptance angle of optical fiber

A small portion of the incident light steps through the side walls of the fiber. The Light that travels from one end to the other end of the glass fiber is said to have guided through the fiber. The light he stays inside the fiber and does not escape through the wall because of the total internal reflection taking place inside the fiber. This total internal reflection can take place only if the following two conditions are satisfied.

(1) The glass fiber core must have a reflective index, which is higher than the refractive index of the cladding around the core.

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(2) The angle of incidence of the light entering the fiber must be greater than the critical angle.

Consider that has a core which has a refractive index n1 and have cladding which have a refractive index n2. So that n1 is generally greater than n2 as shown in fig 3. It will get reflected inside by total internal reflection. The core and the cladding for the optical fiber system, they are made of silica glass, but of different compositions such that in one it is denser and outer side it is actually rarer the medium. The angle of incidence has to be greater than the critical angle for total internal reflection. The entire optical fiber to ensure that the signals reflect and travel correctly through the core. The light must enter the core through an acceptance angle, because if the angle is more than the light will not be able to go inside the system and it will be lost [2].

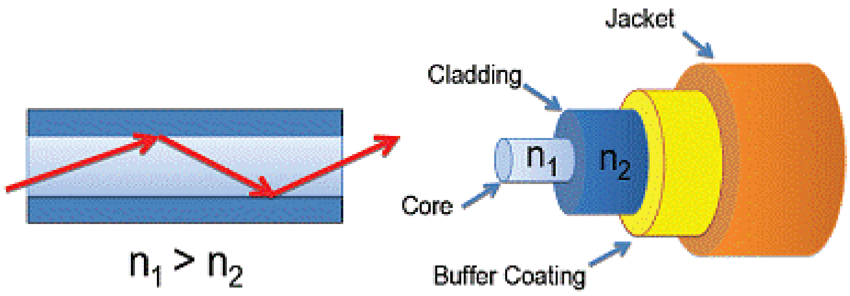

Figure 3 Propagation of light through optical fiber

III.EVOLUTION OF FIBER OPTICS COMMUNICATION

Brief comparison between the optical fiber communication (OFC) and the other available communication technologies.

A. TWISTED PAIR COMMUNICATION LINK
The twisted pair medium can support a very low data rate; telephone lines essentially use.
That communication link, the data rates typically of the order of about 10 kilobits per second. This medium is suited for that since the structure is a completely open structure. This structure has a relatively high electromagnetic interference and also it has a very high loss as the frequency increases. A twisted pair is a good medium for carrying at the low frequency signals, which is used for point-to-point communication.

B. MICROWAVE COMMUNICATION LINK
If I go on the higher frequency side, to use microwave link, which is point-to-point communication, but this is the wireless communication, this mode can be used for long-distance communication, which is much larger compared to the twisted pair and coaxial cable, so typically it can support a bandwidth of a few hundred megahertz.

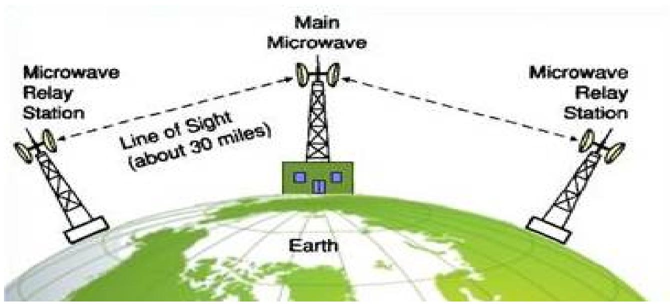

Figure 4 Microwave communication link

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C. SATELLITE COMMUNICATION LINK

The satellite communication can be used for point-to-point communication, but this can also be used for broadcasting applications. So, whenever have a situation from one point to multipoint transmission like a television transmission or any information over a large region without laying cables, satellite communication is one of the best options.

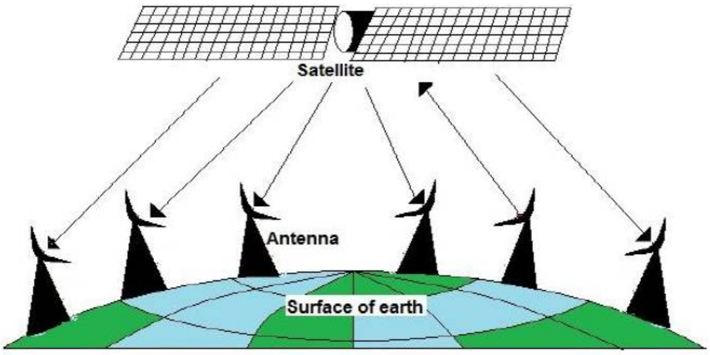

Figure 5 Satellite communication link

In satellite communication, the signals are transmitted from the earth station to the satellite, the satellite reflects the signal back in different frequency and signals is received at the earth station by different receiving antennas.
In satellite communication used typically microwave frequencies. It has a large bandwidth could be of the order of the GHz. One of the problems with satellite communication is very large delay that if using a geostationary satellite. The satellite is located at a very high altitude and there is a substantial delay because of the travel of the signal from the earth station to the satellite and back to the earth as shown in fig.5.

D. COMPARISON WITH SATELLITE VS FIBER OPTICS

If compare these two technologies that media of transmission are essentially complementary to each other. So, here the satellite transmission versus the fiber optic transmission. In satellite a point to multipoint communication, whereas in fiber optics have a cable so the signal can go point-to-point communication. The bandwidth of satellite is large, but not very large, typically of the order of about GHz. Whereas the fiber-optic communication a bandwidth as compared with satellite is very large, which is typically in Terahertz. Satellite once launched is relatively maintenance free, whereas the fiber-optic communication requires the maintenance of the link. The satellite link has a limited, lifetime typically seven to eight years, whereas the fiber-optic link has a very long lifetime typically twenty to twenty-five years. If the satellite is launched, there is no upgrade ability possible so, if design a satellite for 500 MHz bandwidth to operate only with same bandwidth till the life of the satellite, whereas in fiber-optic communication as the technology upgrade possible.

The satellite communication established between any location on the earth, so get an environment which is a mobile environment, a complete flexibility over the domain, over which the signal can be transmitted. Whereas the fiber optic communication, the signal can be sent only on the ground where essentially the fiber has to be laid and then the only signal can reach from one point to another.
From this comparison, these two technologies are not competing for technologies. There are certain advantages of satellite communication, which cannot be obtained from the fiber optic medium and there are certain advantages of fiber optic communication, which cannot be achieved by using the satellite medium. So, essentially these two technologies are complementary in nature and that is the reason the combination of the optical fiber and satellite that is the best combination of transmission of a very high-quality information over very long distances.

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IV.CLASSIFICATIONS OF OPTICAL FIBER

Two types of optical fibers depending upon the number of modes transmitted through the fiber, single mode fiber and Multimode fiber as shown in fig.6.

A. SINGLE MODE FIBERS

In case of single mode fibers from the name itself, it is carrying only one mode, or only one pathway is transmitted by light to travel within the fiber. The core size here is typically about 8.3 micrometers, so this applies in cases where need a very low signal loss and a high data-rate required. It has following only one path of propagation is available. Generally, the V number is less than 2.405. Core diameter is very small which is of the order of micrometers. There is no dispersion effect. Bandwidth of the order of a thousand megahertz [4].

B. MULTIMODE FIBER

It has more than one mode are transmitted through the optical fiber; it is called as Multimode fiber. As seen in the diagram number of rays enter into the optical fiber and propagated through it due to the total internal reflection phenomena. The V number greater than 2.405. Generally, these fibers have a larger core area in order to make optical power easily launched into the fiber. The core size is like 50 – 62.5-micron meter, so earlier case it was an 8.3-micron meter, higher dispersion, low bandwidth, which is 50 megahertz only. Multimode fiber is used generally for short distance communication. Fabrication is less difficult and less costly as compared to single mode fiber.

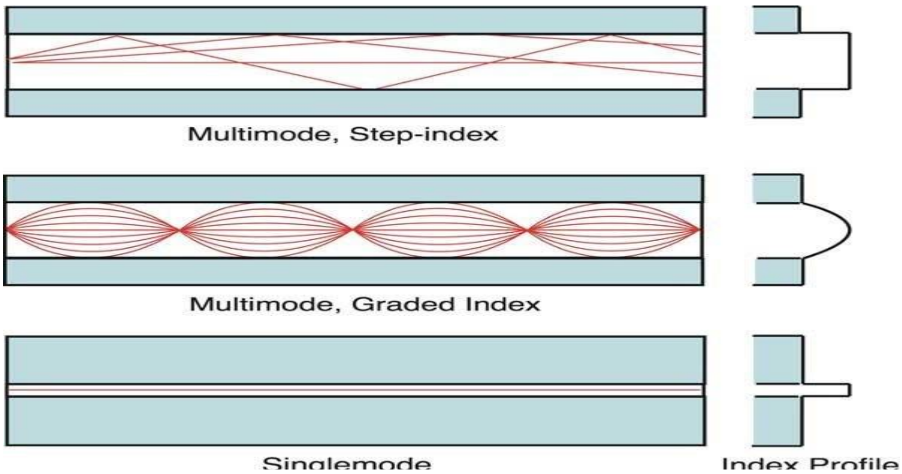

Figure 6 Classifications of optical fiber

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 fibers, step index Multimode fiber, graded index single mode fiber and graded index Multimode fiber.

C. STEP INDEX FIBER

Step index single mode fiber; step means a sudden change the refractive index from one level to another. The step index single mode fiber has the following refractive index where n2 is the refractive index of the core and n1 is the refractive index of the cladding. Only single wave light source is used for this purpose. The main characteristics of step-index single-mode optical fiber are they have a very small core diameter, low numerical aperture, low attenuation, very high bandwidth [4].

Step index Multimode fiber; there is a state change having more core diameter, shape change in the refractive index and the number of rays which have been transmitted to the optical fiber. Various light waves traveling along the core will have different propagation paths of different path length. The light is coming from any point source will have

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several paths, with a different angle of incidence at the boundary layer and meeting the core cladding interface at an angle less than the critical angle [4].

D. GRADED INDEX FIBERS

A graded index optical fiber from the name itself, say that there is some graded or gradient which is associated with the refractive index. This gradient is related to the refractive index of the core. At the center of the core, the refractive index is maximized, and it is slowly decreasing as go away from the core, towards the periphery of the core. So, there is some type of gradient can be a linear gradient, it can be a parabolic gradient, it can be a Gaussian gradient. Gradient means a continuous variation in the refractive index from center towards the periphery, this is related to the core [7].

Graded index singles mode fiber; it is the propagation oflight through the single mode gradedindex fiber is similar to that for thestep index fiber.The light wave travelsalong the axis of the optical fiber orcenter of the optical fiber.

Graded index Multimode fibers; light waves are raised with a large angle of incidence travel more path lengths than those with the smaller angle. The light enters into the optical fibers and it travels as shown in the diagram.

V.BLOCK DIAGRAM OF OPTICAL COMMUNICATION

If want to send more and more information on the channel, then require large bandwidth. The bandwidth is proportional to the operating frequency. So, basically, to use optical communication as a medium for transporting information from one point to another. Typical shown in fig.7 optical fiber link, it would consist of three main components; an optical transmitter which is an LED or Laser, optical medium which is optical fiber and a receiver which is an optical detector.

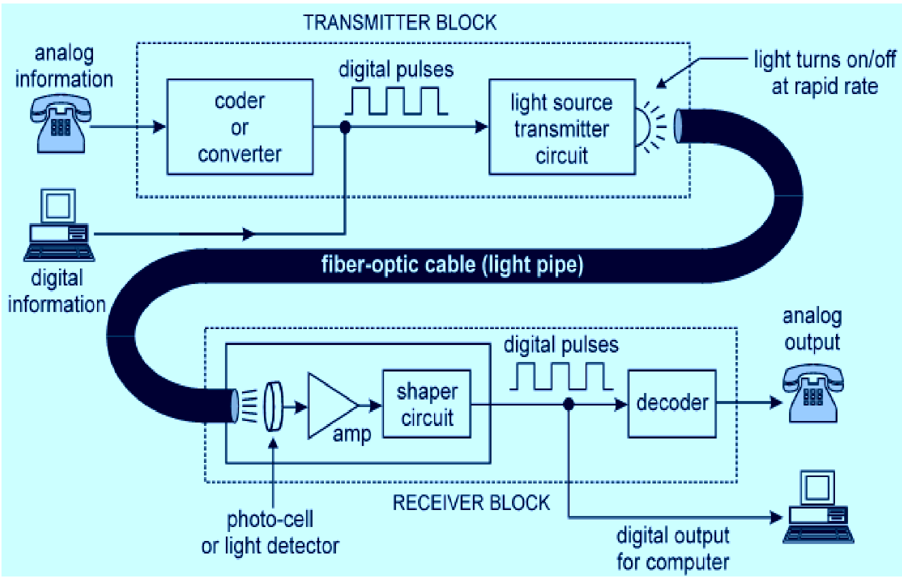

Figure 7 Basic block diagram of optical communication

So, the Input signal have form of electricity, which could be either a conversion of the audio signal or which could be data or which could be video. This signal has to be given to a module, which call its transmitter. This transmitter converts the electrical signal into the optical signal. The transmitter would require a device, which drives, an optical source, which is something like a laser or LED kind of source. So, an electrical signal is given to a driver. The driver drives, an optical source which is a laser or LED, which gives output in the form of light. When the signal

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propagates on optical fiber medium with certain propagation characteristics of optical fiber. The signal has some deterioration so when a signal reaches to the other side, it doesn't reach exactly in the same form as it started from a transmitter. Then the optical signal goes on optical fiber medium. The function of an optical fiber medium is to transfer the optical signal from transmitter to receiver without any noise. Most liked material use in optical fiber, silica because silica fiber can transmit light with very small losses 0.2 dB/km. Even then optical power reduces to only 1% after 100 km. Then light signal a typical deteriorates and corrupted with noise distortions, so must be required to amplify and clean the signal. Over very long-distance communication put a regenerator module in between optical fiber link. The regenerator regenerates the original signal and sends again through optical fiber till reach to the destination [6].

An optical receiver converts the optical signal into the original electrical signal. It consists of a coupler, photodetector and a demodulator. The coupler focuses the receipt optical signal onto the photo detector. The semiconductor photo diode is used as a photo detector because of their compatibility with the whole system. The design of demodulation depends on the modulation formats used by the light wave system. Depend on the amplitude of the electric signal, demodulation done by a decision circuit and identifies bits as 1 or 0. The accuracy of the decision circuit depends on the SNR of the electrical signal generated at the photo detector.

A. FIBER OPTIC TRANSMITTER

The light generated by this optical source or transmitters and guided inside the optical fiber. The light travels inside the optical fiber over hundreds of kilometers and finally, it reaches to the other end of the fiber, this again has to be converted back into the electronic form. Optical sources for fiber communication which satisfies some desirable properties in terms of intensity, radiation pattern, emission wavelength spectral characteristics and response time.The semiconductor diode source is the natural choice for fiber optic system due to high efficiency, compact size, low power consumption and high reliability. So, here's the brief comparison of these two light sources LED & laser [1].

Light emitting diode is a semiconductor diode that emits incoherent narrow spectrum of light when given the forward PN junction of the semiconductor. This effect is a form of electroluminescence. LED have very low in cost compared to communication lasers. This is highly controversial. Connecting to single mode fiber is significantly costlier than connecting to Multimode fiber. Lesser are commonly used within single mode and LED with Multimode. LED cannot produce a short pulse enough to be used at gigabit speed.However, systems using LED operate quite well at speed of up to around 300 Mbps. LED can also be used in analogue quite simply by maintaining a forward bias just larger than the band gap energy, this is one advantage over lasers. LED is relatively low-cost but, it also gives very low power and poor power launching efficiency. LED is not a directional device so, especially for the single mode optical fibers, the power launched is relatively low. The LED is incoherent light source. It has a very large spectral width. It could range from about 30 nanometers to 100 nanometers and consequently, it has very large dispersion. Therefore, the LED transmitters can be used for shorter distance communication [3].

Whereas, if go to the laser diode then the scenario is completely changed, the laser diode is relatively more expensive, but it can give high power, which is useful for long-distance communication. The laser diode gives radiation, which is in the form of a beam so, it has a much better launching efficiency inside the single mode optical fiber. The spectral width of laser diode is of the order of about 1 to 2 nanometers, which should be used for long-distance communication. The laser diode provides the opportunity to make an optical link, which is based on the coherent communication principle.For an optical fiber system that usually used laser source of semiconductor diodes. The semiconductor laser diode was developed in the 1970 and they have best commercial application in a compact disc player. Semiconductor laser is similar to other lasers such as a conventional solid state and gas laser in that the emitted radiation has spatial and temporal coherence. This means that laser radiation is monochromatic and, it produces a directional beam highly of light. Mirrored cavity is used to build up the light in a semiconductor laser. By mechanical necessity, the cavity is long enough for several wavelengths to be produced.

B. FIBER OPTIC RECEIVER

The photo detector that is the device, which detects the light and it converts the optical signal into the electrical current. The light which is typically generated in the optical transmitter is of the order of about maybe 10 mW. If considers a distance of 100 kilometers, and fiber has loss of about 0.3 dB/km, typically signal will undergo a loss of about 30 dB.

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So, if considers 1 mW of power transmitted by the transmitter and there is a loss which is 30 dB that means a factor of thousands, the power which is received on the other side of the optical fiber is 1 micro watt. So, essentially received about very small powers on the detector side of the optical fiber and thus the reason, it should be able to detect very small power. This device should have a very high sensitivity. Silicon material cannot be used for detection of light, especially in that frequency range, which is used for optical communication. A material like germanium, it has a frequency response which covers this frequency band 1.3 micrometers or 1.55 micrometers so, germanium is one of the possibilities for making optical detectors [2].

VI. OPTICAL FIBER COMMUNICATIONS LOSS MECHANISMS

A. DISPERSION PHENOMENA

If put a pulse energy inside an optical fiber, the pulse energy travels by different paths in the form of different rays and as a result, the rays do not reach the other end of the fiber at the same time and have a broadening of the pulse as shown in fig.8. This phenomenon, called as a dispersion because of the multipath propagation of light in the optical fiber. If using a single mode fiber, then obviously this phenomenon is not there [1].

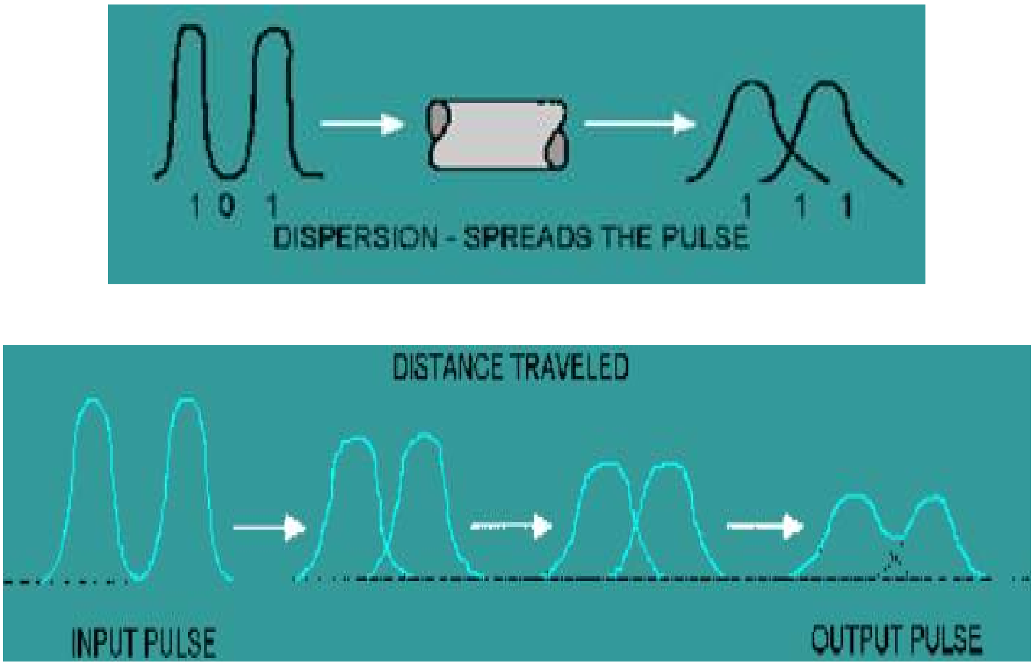

Figure 8 Dispersion phenomena

B. SCATTERING LOSS

Most stronger losses, which inside the optical fiber is called the scattering loss. Inside the optical fiber very small micro centers, which are developed, which have a refractive index little different than the average value, which are distributed all through its length as shown in fig.9. These sizes are very small fraction of a micron, so, when the light tries to propagate through, this phenomenon is very similar to when the microwave signal tries to propagate in the atmosphere and if there are raindrops that micro signal gets scattered by the raindrops. These micro centers have sizes smaller than the wavelength. Scattering of light taking place in all directions and that scattering is called the Rayleigh scattering [7].

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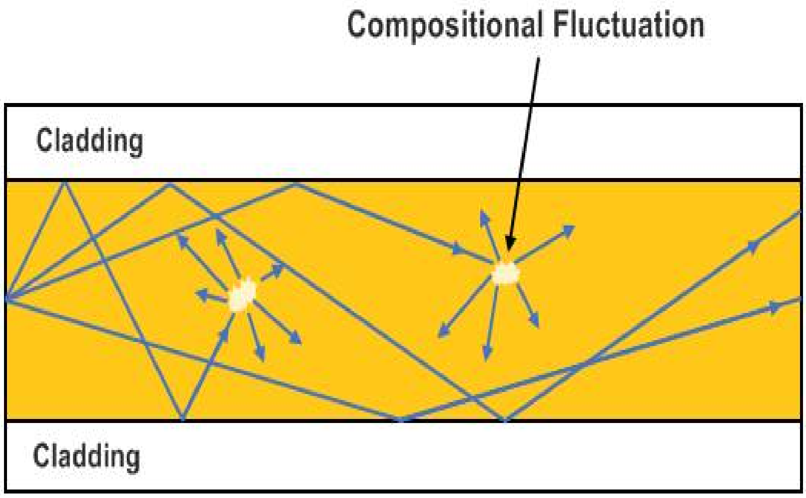

Figure 9 Scattering loss

There are two types of attenuations one is called intrinsic attenuation another is called extrinsic attenuation.

C.INTRINSIC ATTENUATION

Intrinsic attenuation is caused by the impurities in the glass during the manufacturing process. The technological advances have caused manufacturing defects to come down, this attenuation to decrease dramatically since the first optical fiber in 1970.

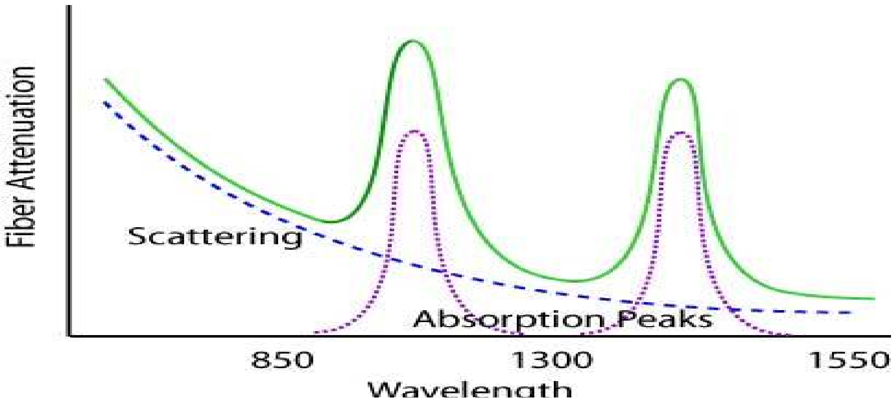

Figure 10 Fiber Attenuation

Today get a much better one so, much less intrinsic attenuation, it depends on the wavelength. So, different wavelength has different attenuation, as shown in fig.10. When a light signal actually hits an impurity in the fiber, two things will occur, it will either scatter or it will be absorbed. So, if it scatters these accounts for the majority about 96 percent of attenuation in the optical fiber. Then the light waves elastically collide with the atoms and light are scattered. If the light is scattered at an angle that does not support internal reflection, then the light gets diverted out of the core and hence the attenuation would occur. Scattering may disturb that critical angle due to impurities. The other intrinsic attenuation problem is due to absorption, the absorption accounts for about 3 to 5% of the fiber attenuation [6]. In this case light signal is absorbed by natural impurities in the glass and convert it to something like vibrational energy or

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similar other form of energy. Absorption can be limited by controlling the amount of impurities during the manufacturing process [1].

D. EXTRINSIC ATTENUATION

There are two external mechanical parts of extrinsic attenuation, one is called macro bending, and another is called micro bending, both of them causes a reduction in optical poweras shown in fig.11. In case of macro bending, these are like large-scale bend that is visible. For example, fiber is wrapped around a particular area, the loss is generally reversible if the bends are corrected. All optical fibers have a minimum bend radius specification because if bend it more than, then rays can escape, so this macro bending can be prevented by maintaining the minimum bend radius for the reduction of the extrinsic attenuation. Second loss is micro bending; it is varying localized, like suddenly there is a bending in the cladding. This may not be clearly visible in inspection. It is related to temperature, tensile stress or crushing force etc. [7].

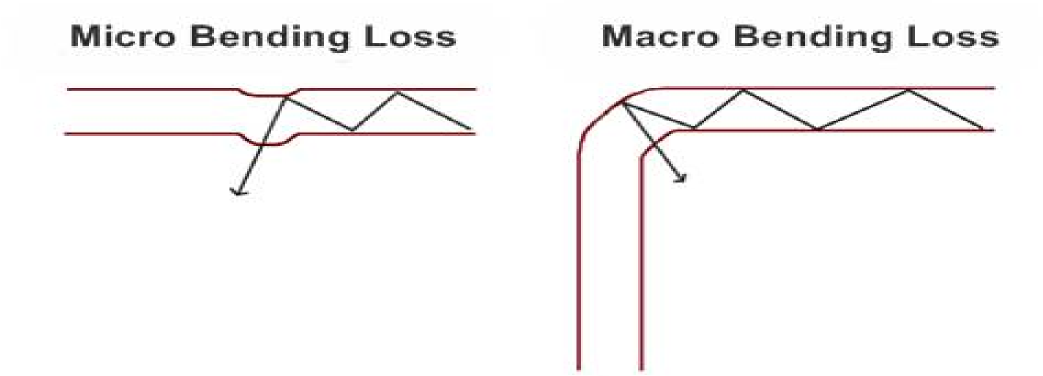

Figure 11 Micro bending and Macro bending loss

VII. CONCLUTION

A single mode fiber is used for higher speeds. They are possible on single mode fiber and it also goes over longer distances. There are many types of losses in fiber due to various reasons, one the main thing is absorbed, it loses energy to the atoms so, atoms absorb some of the photons and get lower magnitude or lower strength of the light signal. So apart from this just lowering of the signal strength, the one problem due to losses. Simple amplification is not always enough, sometimes requiring regeneration the signal. If absorption is concerned, so simply amplify the signal that means increased the strength of the signal that is good enough. So, the absorption loss of strength can be handled that way. Due to chromatic dispersion in very long distances, wave shape will become distorted, so on the other side there will be a tremendous amount of error and that may not be acceptable. Therefore, received signal will amplify, reshape and retain that kind of regeneration used.

REFERENCES

[1] J. Senior, Optical Fiber Communications Principles, and Practice, (Prentice-Hall, Englewood Cliffs,New Jersey, 1985), pp 11.
[2] K. C. Kao and G. A. Hockam, "Dielectric fiber surface wave guides for optical frequency," proceeding of IEE, vol. 133, pp. 1151-1158, (1996).
[3] Agrawal, G.P., 2012. Fiber-optic communication systems (Vol. 222). John Wiley & Sons.
[4] John Wiley & Sons, "Fiber-Optic Communications Systems",Third Edition, (2002).
[5] R.G. Pirich and P. Anumolu, "Next-Generation Fiber-Optic Technology Enablers for Manned & Unmanned ISR Platforms," 2008 IEEE Avionics Fiber-Optics and Photonics Conference, pp.3-4, 2008.
[6] Joseph C. Palais, "Fiber Optic Communication, Prentice Hall, 1998.
[7] G. Keiser, Optical Fiber Communications,3rd ed. New York: McGraw Hill,2000.