Fiber Optic Connections

An optical fiber is a flexible & transparent fiber, which is made by drawing glass or plastic. Optical fibers have diameter slightly thicker than that of a human hair.

Fiber Structure:

- Optical fibers are made of glass or plastic.
- Most fibers used in communication have diameter of 0.25 mm to 0.5 mm (including outer coating)
- Optical fibers have a transparent core, which is surrounded by a transparent cladding & this cladding has a protective covering over it.

Based on refractive index profile, there are two categories of optical fibers.

1. Step index optical fibers
2. Graded index optical fibers

In Step index optical fibers: the refractive index profile makes a step change at the core cladding interface and the refractive index of core is greater than that of cladding because when light goes from denser to rarer medium, it bends away from the normal and once the angle of incidence goes beyond certain critical angle, it gets reflected back to the same medium without getting refracted. This is responsible for total internal reflection.

In **Graded index optical fibers:** the refractive index of core is not constant but the refractive index of core decreases as move away from the core. The refractive index of cladding is however, constant. Here also , because of the gradual change in the refractive index , the light appears to take a curved path and undergoes total internal reflection which takes the signal from one point to another.

The optical fiber communication takes place b/w 0.8 mm to 1.7 mm of wavelength of electromagnetic spectrum.

Communication Process:

Message is to be converted first to electrical form using transducers. Now the message converted to electrical form, modulates an optical source like a laser. After this, the light rays containing the message travel through the optical fiber by total internal reflection with very negligible energy loss. Now at the receiving end, photoelectrons like photodiodes or phototransistors etc., are used to convert the light signal back into electrical signal. Then the original message signal is obtained from this electrical signal.

Types of fibers based on modes of propagation:

1. Single Mode fibers (SMF)
2. Multi-Mode fibers (MMF)

Single mode fibers (SMF) support only single propagation path, since they have very small diameter. They are used for long distance communication because of less dispersion and interference. They have greatest transmission bandwidths and lowest losses in communication.

Multi-mode fibers (MMF) can support many propagation paths or transverse modes, as they have larger diameter. They are used for short distance communication because of losses involved in this mode.

Benefits:

- Energy loss is negligible inside the optical fibers while propagation, due to total internal reflection.
- Optical fibers provide very large potential bandwidths since communication takes place at very high frequencies.
- The fibers have very small size and lightweight.
- They provide electrical isolation and are shock resistant since, inside the fiber unlike electric current, light propagates.
- They provide higher degree of signal security since these fibers do not radiate significantly unlike electric copper cables.
- Optical fibers are easy to maintain & the communication system is reliable.

Losses in Optical Fibers:

Though optical fibers have negligible loss in propagation, there are still some losses involved here like

1. Material Absorption which decreases the amount of light that propagates over long distance.
    a. Intrinsic Absorption caused by interaction with one or more components of the glass.
    b. Extrinsic Absorption results from the presence of transition metal ions like iron, chromium, cobalt, copper etc.
2. Linear and Nonlinear Scattering.
    a. Rayleigh scattering losses which is a phenomenon caused due to unequal distribution of molecular densities or atomic densities.
    b. Mie Scattering resulting from the compositional fluctuations & structural inhomogeneity's & defects created during fiber fabrications which causes the light to scatter outside the fiber.
    c. Waveguide Scattering loss is a result of variation in the core diameter, imperfections of the core cladding interface, change in RI of either core or cladding.
    d. Stimulated Brillouin Scattering caused by modulation of light through thermal molecular vibrations within the fiber.
    e. Stimulated Raman Scattering where high frequency optical phonon is generated in scattering processes.
3. Fiber bend losses which affect the total internal reflection.
    a. Macroscopic bending is one where fiber undergoes bends which causes certain modes not to be reflected and therefore causes loss to the cladding.
    b. Microscopic bending is when either core or cladding undergoes slight bends at its surface which causes light to be reflected at angles when there is no further reflection.

4. Dispersion loss where an optical signal along the fiber becomes increasingly distorted. It has two types of dispersion.
    a. Intermodal Dispersion wherein pulse broadening occurs from the propagation delay because of the differences between modes within a multimode fiber.
    b. Intramodal Dispersion which is the pulse spreading that occurs within a single mode. Its further classified as
        i. Material Dispersion which results because of the variation in the refractive index of core as a function of wavelength , because of which pulse spreading occurs even when different wavelengths follow the same path.
        ii. Waveguide Dispersion: when any optical signal is passed through the optical fiber, practically 80% of optical power is confined to core & rest 20% optical power into cladding.

FUTURE TRENDS IN FIBER OPTICS COMMUNICATION

Fiber optics communication is definitely the future of data communication. The evolution of fiber optic communication has been driven by advancement in technology and increased demand for fiber optic communication. It is expected to continue into the future, with the development of new and more advanced communication technology. Below are some of the envisioned future trends in fiber optic communication.

A. All Optical Communication Networks

An all fiber optic communication is envisioned which will be completely in the optical domain, giving rise to an all optical communication network. In such networks, all signals will be processed in the optical domain, without any form of electrical manipulation. Presently, processing and switching of signals take place in the electrical domain, optical signals must first be converted to electrical signal before they can be processed, and routed to their destination. After the processing and routing, the signals are then re-converted to optical signals, which are transmitted over long distances to their destination. This optical to electrical conversion, and vice versa, results in added latency on the network and thus is a limitation to achieving very high data rates. Another benefit of all optical networks is that there will not be any need to replace the electronics when data rate increases, since all signal processing and routing occurs in the optical domain. However, before this can become a reality, difficulties in optical routing, and wavelength switching has to be solved. Research is currently ongoing to find an effective solution to these difficulties.

B. Multi – Terabit Optical Networks

Dense Wave Division Multiplexing (DWDM) paves the way for multi-terabit transmission. The world-wide need for increased bandwidth availability has led to the interest in developing multi-terabit optical networks. Presently, four terabit networks using 40Gb/s data rate combined with 100 DWDM channels exists. Researchers are looking at achieving even higher bandwidth with 100Gb/s. With the continuous reduction in the cost of fiber optic components, the availability of much greater bandwidth in the future is possible.

C. Intelligent Optical Transmission Network

Presently, traditional optical networks are not able to adapt to the rapid growth of online data services due to the unpredictability of dynamic allocation of bandwidth, traditional optical networks rely mainly on manual configuration of network connectivity, which is time consuming, and unable to fully adapt to the demands of the modern network. Intelligent optical network is a future trend in optical network development [2], and will have the following applications: traffic engineering, dynamic resource route allocation, special control protocols for network management, scalable signaling capabilities, bandwidth on demand, wavelength rental, wavelength wholesale, differentiated services for a variety of Quality of Service levels, and so on. It will take some time before the intelligent optical network can be applied to all levels of the network, it will first be applied in long-haul networks, and gradually be applied to the network edge.

D. Ultra – Long Haul Optical Transmission

In the area of ultra-long haul optical transmission, the limitations imposed due to imperfections in the transmission medium are subject for research. Cancellation of dispersion effect has prompted researchers to study the potential benefits of soliton propagation. More understanding of the interactions between the electromagnetic light wave and the transmission medium is necessary to proceed towards an infrastructure with the most favorable conditions for a light pulse to propagate.

E. Improvements in Laser Technology

Another future trend will be the extension of present semiconductor lasers to a wider variety of lasing wavelengths. Shorter wavelength lasers with very high output powers are of interest in some high density optical applications. Presently, laser sources which are spectral shaped through chirp managing to compensate for chromatic dispersion are available. Chirp managing means that the laser is controlled such that it undergoes a sudden change in its wavelength when firing a pulse, such that the chromatic dispersion experienced by the pulse is reduced. There is need to develop instruments to be used to characterize such lasers. Also, single mode tunable lasers are of great importance for future coherent optical systems. These tunable lasers lase in a single longitudinal mode that can be tuned to a range of different frequencies.

F. Laser Neural Network Nodes

The laser neural network is an effective option for the realization of optical network nodes. A dedicated hardware configuration working in the optical domain and the use of ultra-fast photonic sections is expected to further improve the capacity and speed of telecommunication networks. As optical networks become more complex in the future, the use of optical laser neural nodes can be an effective solution.

G. Polymer Optic Fibers

Polymer optical fibers offer many benefits when compared to other data communication solutions such as copper cables, wireless communication systems, and glass fiber. In comparison with glass optical fibers, polymer optical fibers provide an easy and less expensive processing of optical signals, and are more flexible for plug interconnections. The use of polymer optical fibers as the transmission media for aircrafts is presently under research by different Research and Development groups due to its benefits. The German Aerospace Center have concluded that “the use of Polymer Optical Fibers multimedia fibers appears to be possible for future aircraft applications. Also, in the future, polymer optical fibers will likely displace copper cables for the last mile connection from the telecommunication company’s last distribution box and the served end consumer. The future Gigabit Polymer Optical Fiber standard will be based on Tomlinson-Harashima Precoding, Multilevel PAM Modulation and Multilevel Coset Coding Modulation.

H. High – Altitude Platforms

Presently, optical inter satellite links and orbit-to-ground links exists, the latter suffering from unfavorable weather conditions [17]. Current research explores optical communication to and from high altitude platforms. High altitude platforms are airships situated above the clouds at heights of 16 to 25Km, where the unfavorable atmospheric impact on a laser beam is less severe than directly above the ground [18]. As shown in figure 4, optical links between high-altitude platforms, satellites and ground stations are expected to serve as broadband back-haul communication channels, if a high-altitude platform functions as a data relay station.

I. Improvements in Optical Transmitter/Receiver

Technology In fiber optics communication, it is important to achieve high quality transmission even for optical signals with distorted waveform and low signal to noise ratio during transmission. Research is ongoing to develop optical transceivers adopting new and advanced modulation technology, with excellent chromatic dispersion and Optical Signal to Noise Ratio (OSNR) tolerance, which will be suitable for ultra-long haul communication systems. Also, better error correction codes, which are more efficient than the present BCH concatenated codes are envisioned to be available in the nearest future.

J. Improvement in Optical Amplification Technology

Erbium Doped Fiber Amplifier (EDFA) is one of the critical technologies used in optical fiber communication systems. In the future, better technologies to enhance EDFA performance will be developed. In order to increase the gain bandwidth of EDFA, better gain equalization technology for high accuracy optical amplification will be developed. Also, in order to achieve a higher output power, and a lower noise figure, high power pumping lasers that possess excellent optical amplification characteristics with outputs of more than+20dBm, and very low noise figure are envisioned to exist in the nearest future.

K. Advancement in Network Configuration of Optical Submarine Systems

In order to improve the flexibility of network configuration in optical submarine communication systems, it is expected that the development of a technology for configuring the mesh network will be a step in the right direction. As shown in figure 5, while a ring network joins stations along a single ring, a mesh network connects stations directly. Presently, most large scale optical submarine systems adopt the ring configuration. By adopting the optical add/drop multiplexing technology that branches signals in the wavelength domain, it is possible to realize mesh network configuration that directly inter-connects the stations. Research is ongoing, and in the future such network configuration will be common.

L. Improvement in WDM Technology

Research is ongoing on how to extend the wavelength range over which wave division multiplexing systems can operate. Presently, the wavelength window (C band) ranges from 1.53 1.57µm. Dry fiber which has a low loss window promises an extension of the range to 1.30 – 1.65 µm. Also, developments in optical filtering technology for wave division multiplexing are envisioned in the future. M. Improvements in Glass Fiber Design and Component Miniaturization Presently, various impurities are added or removed from the glass fiber to change its light transmitting characteristics. The result is that the speed with which light passes along a glass fiber can be controlled, thus allowing for the production of customized glass fibers to meet the specific traffic engineering requirement of a given route. This trend is anticipated to continue in the future, in order to produce more reliable and effective glass fibers. Also, the miniaturization of optical fiber communication components is another trend that is most likely to continue in the future.

CONCLUSION

The fiber optics communications industry is an ever evolving one, the growth experienced by the industry has been enormous this past decade. There is still much work to be done to support the need for faster data rates, advanced switching techniques and more intelligent network architectures that can automatically change dynamically in response to traffic patterns and at the same time be cost efficient. The trend is expected to continue in the future as breakthroughs already attained in the laboratory will be extended to practical deployment thereby leading to a new generation in fiber optics communications.