Abstract—Optical fiber communication system has a very high information carrying capacity. The single mode and multimode fibers are being used for sending the signals. As an optical pulse propagates through the fiber it suffers dispersion. The dispersion in a single mode fiber is much less than in a multimode fiber. The bandwidth can be divided into hundreds channels using wavelength division multiplexer.

Keywords—optical fiber; communication network; optical amplifiers; fiber dispersions.

I. INTRODUCTION

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information. First developed in the 1970s, fiber-optic communication systems have revolutionized the telecommunications industry and have played a major role in the advent of the Information Age. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world [1-5].

The process of communicating using fiber-optics involves the following basic steps: Creating the optical signal involving the use of a transmitter, relaying the signal along the fiber, ensuring that the signal does not become too distorted or weak, receiving the optical signal, and converting it into an electrical signal. The transfer of ultra-stable frequencies between distant laboratories is an important issue for a large number of high-sensitivity experiments in metrology and fundamental physics, for example tests of the fundamental constants stability [1].

II. TRANSMITTERS

The most commonly-used optical transmitters are semiconductor devices such as light-emitting diodes (LEDs) and laser diodes. The difference between LEDs and laser diodes is that LEDs produce incoherent light, while laser diodes produce coherent light. For use in optical communications, semiconductor optical transmitters must be designed to be compact, efficient, and reliable, while operating in an optimal wavelength range, and directly modulated at high frequencies. Early optical fiber links use amplitude modulation of an optical carrier to transmit RF and microwave frequencies [2]. In its simplest form, an LED is a forward-biased p-n junction, emitting light through spontaneous emission, a phenomenon referred to as electroluminescence. The emitted light is incoherent with a relatively wide spectral width of 30-60 nm. LED light transmission is also inefficient, with only about 1% of input power, or about 100 microwatts, eventually converted into launched power which has been coupled into the optical fiber. However, due to their relatively simple design, LEDs are very useful for low-cost applications. Communications LEDs are most commonly made from gallium arsenide phosphide (GaAsP) or gallium arsenide (GaAs). Because GaAsP LEDs operate at a longer wavelength than GaAs LEDs (1.3 micrometers vs. 0.81-0.87 micrometers), their output spectrum is wider by a factor of about 1.7. The large spectrum width of LEDs causes higher fiber dispersion, considerably limiting their bit rate-distance product (a common measure of usefulness). LEDs are suitable primarily for local-area-network applications with bit rates of 10-100 Mbit/s and transmission distances of a few kilometers. LEDs have also been developed that use several quantum wells to emit light at different wavelengths over a broad spectrum, and are currently in use for local-area WDM networks. Today, LEDs have been largely superseded by VCSEL (Vertical Cavity Surface Emitting Laser) devices, which offer improved speed, power and spectral properties, at a similar cost. Common VCSEL devices couple well to multi mode fiber. A semiconductor laser emits light through stimulated emission rather than spontaneous emission, which results in high output power (~100 mW) as well as other benefits related to the nature of coherent light. The output of a laser is relatively directional, allowing high coupling efficiency (~50%) into single-mode fiber.
The narrow spectral width also allows for high bit rates since it reduces the effect of chromatic dispersion. Furthermore, semiconductor lasers can be modulated directly at high frequencies because of short recombination time. Commonly used classes of semiconductor laser transmitters used in fiber optics include VCSEL (Vertical Cavity Surface Emitting Laser), Fabry–Pérot and DFB (Distributed Feed Back). Laser diodes are often directly modulated, that is, the light output is controlled by a current applied directly to the device. For very high data rates or very long distance links, a laser source may be operated continuous wave, and the light modulated by an external device such as an electro-absorption modulator or Mach–Zehnder interferometer. External modulation increases the achievable link distance by eliminating laser chirp, which broadens the linewidth of directly-modulated lasers, increasing the chromatic dispersion in the fiber. The schematic diagram of the optical communication system has been shown in fig-1.

III. RECEIVERS

The main component of an optical receiver is a photodetector, which converts light into electricity using the photoelectric effect. The photodetector is typically a semiconductor-based photodiode. Several types of photodiodes include p-n photodiodes, p-i-n photodiodes, and avalanche photodiodes. Metal-semiconductor-metal (MSM) photodetectors are also used due to their suitability for circuit integration in regenerators and wavelength-division multiplexers. Optical-electrical converters are typically coupled with a transimpedance amplifier and a limiting amplifier to produce a digital signal in the electrical domain from the incoming optical signal, which may be attenuated and distorted while passing through the channel. Further signal processing such as clock recovery from data (CDR) performed by a phase-locked loop may also be applied before the data is passed on.

IV. FIBER CABLE TYPES

An optical fiber consists of a core, cladding, and a buffer (a protective outer coating), in which the cladding guides the light along the core by using the method of total internal reflection. The core and the cladding (which has a lower-refractive-index) are usually made of high-quality silica glass, although they can both be made of plastic as well. Connecting two optical fibers is done by fusion splicing or mechanical splicing and requires special skills and interconnection technology due to the microscopic precision required to align the fiber cores[4].

Two main types of optical fiber used in optic communications include multi-mode optical fibers and single-mode optical fibers. A multi-mode optical fiber has a larger core (≥ 50 micrometers), allowing less precise, cheaper transmitters and receivers to connect to it as well as cheaper connectors. However, a multi-mode fiber introduces multimode distortion, which often limits the bandwidth and length of the link. Furthermore, because of its higher dopant content, multi-mode fibers are usually expensive and exhibit higher attenuation. The core of a single-mode fiber is smaller (<10 micrometers) and requires more expensive components and interconnection methods, but allows much longer, higher-performance links. In order to package fiber into a commercially-viable product, it is typically protectively-coated by using ultraviolet (UV), light-cured acrylate polymers, then terminated with optical fiber connectors, and finally assembled into a cable. After that, it can be laid in the ground and then run through the walls of a building and deployed aerially in a manner similar to copper cables. These fibers require less maintenance than common twisted pair wires, once they are deployed. Specialized cables are used for long distance subsea data transmission, e.g. transatlantic communications cable. New (2011-2013) cables operated by commercial enterprises (Emerald Atlantis, Hibernia Atlantic) typically have four strands of fiber and cross the Atlantic (NYC-London) in 60-70ms. Cost of each such cable was about $300M in 2011. source: Halifax Chronicle-Herald. Another common practice is to bundle many fiber optic strands within long-distance power transmission cable. This exploits power transmission rights of way effectively, ensures a power company can own and control the fiber required to monitor its own devices and lines, is effectively immune to tampering, and simplifies the deployment of smart grid technology.
V. OPTICAL AMPLIFIERS

The transmission distance of a fiber-optic communication system has traditionally been limited by fiber attenuation and by fiber distortion. By using opto-electronic repeaters, these problems have been eliminated. These repeaters convert the signal into an electrical signal, and then use a transmitter to send the signal again at a higher intensity than it was before. Because of the high complexity with modern wavelength-division multiplexed signals (including the fact that they had to be installed about once every 20 km), the cost of these repeaters is very high. An alternative approach is to use an optical amplifier, which amplifies the optical signal directly without having to convert the signal into the electrical domain. It is made by doping a length of fiber with the rare-earth mineral erbium, and pumping it with light from a laser with a shorter wavelength than the communications signal (typically 980 nm). Amplifiers have largely replaced repeaters in new installations.

VI. WAVELENGTH-DIVISION MULTIPLEXING

Wavelength-division multiplexing (WDM) is the practice of multiplying the available capacity of optical fibers through use of parallel channels, each channel on a dedicated wavelength of light. This requires a wavelength division multiplexer in the transmitting equipment and a demultiplexer (essentially a spectrometer) in the receiving equipment. Arrayed waveguide gratings are commonly used for multiplexing and demultiplexing in WDM. Using WDM technology now commercially available, the bandwidth of a fiber can be divided into as many as hundreds channels to support a combined bit rate in the range of terabits per second.

VII. BANDWIDTH-DISTANCE PRODUCT

Because the effect of dispersion increases with the length of the fiber, a fiber transmission system is often characterized by its bandwidth-distance product, usually expressed in units of MHz×km. This value is a product of bandwidth and distance because there is a trade off between the bandwidth of the signal and the distance it can be carried. For example, a common multi-mode fiber with bandwidth-distance product of 500 MHz×km could carry a 500 MHz signal for 1 km or a 1000 MHz signal for 0.5 km. Engineers are always looking at current limitations in order to improve fiber-optic communication, and several of these restrictions are currently being researched. Each fiber can carry many independent channels, each using a different wavelength of light (wavelength-division multiplexing (WDM)). The net data rate (data rate without overhead bytes) per fiber is the per-channel data rate reduced by the FEC overhead, multiplied by the number of channels (usually up to eighty in commercial dense WDM systems as of 2008). For instance, NTT was able to achieve 69.1 Tbit/s transmission by applying wavelength division multiplex (WDM) of 432 wavelengths with a capacity of 171 Gbit/s over a single 240 km-long optical fiber on March 25, 2010. This was the highest optical transmission speed recorded at that time.

VIII. FIBER MATERIAL DISPERSION

For modern glass optical fiber, the maximum transmission distance is limited not by direct material absorption but by several types of dispersion, or spreading of optical pulses as they travel along the fiber. Dispersion in optical fibers is caused by a variety of factors. Intermodal dispersion, caused by the different axial speeds of different transverse modes, limits the performance of multi-mode fiber. Because single-mode fiber supports only one transverse mode, intermodal dispersion is eliminated. In single-mode fiber performance is primarily limited by chromatic dispersion (also called group velocity dispersion), which occurs because the index of the glass varies slightly depending on the wavelength of the light, and light from real optical transmitters necessarily has nonzero spectral width (due to modulation). Polarization mode dispersion, another source of limitation, occurs because although the single-mode fiber can sustain only one transverse mode, it can carry this mode with two different polarizations, and slight imperfections or distortions in a fiber can alter the propagation velocities for the two polarizations. This phenomenon is called fiber birefringence and can be counteracted by polarization-maintaining optical fiber. Dispersion limits the bandwidth of the fiber because the spreading optical pulse limits the rate that pulses can follow one another on the fiber and still be distinguishable at the receiver. Some dispersion, notably chromatic dispersion, can be removed by a 'dispersion compensator'. This works by using a specially prepared length of fiber that has the opposite dispersion to that induced by the transmission fiber, and this sharpens the pulse so that it can be correctly decoded by the electronics.

IX. ATTENUATION

Fiber attenuation, which necessitates the use of amplification systems, is caused by a combination of material absorption, Rayleigh scattering, Mie scattering, and connection losses. Although material absorption for pure silica is only around 0.03 dB/km (modern fiber has attenuation around 0.3 dB/km),
impurities in the original optical fibers caused attenuation of about 1000 dB/km. Other forms of attenuation are caused by physical stresses to the fiber, microscopic fluctuations in density, and imperfect splicing techniques.

X. TRANSMISSION WINDOWS

Each effect that contributes to attenuation and dispersion depends on the optical wavelength. The wavelength bands (or windows) that exist where these effects are weakest are the most favorable for transmission. These windows have been standardized, and the currently defined bands are the following:

<table>
<thead>
<tr>
<th>Band</th>
<th>Description</th>
<th>Wavelength Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>O band</td>
<td>original</td>
<td>1260 to 1360 nm</td>
</tr>
<tr>
<td>E band</td>
<td>extended</td>
<td>1360 to 1460 nm</td>
</tr>
<tr>
<td>S band</td>
<td>short wavelengths</td>
<td>1460 to 1530 nm</td>
</tr>
<tr>
<td>C band</td>
<td>conventional (“erbium window”)</td>
<td>1530 to 1565 nm</td>
</tr>
<tr>
<td>L band</td>
<td>long wavelengths</td>
<td>1565 to 1625 nm</td>
</tr>
<tr>
<td>U band</td>
<td>ultralong wavelengths</td>
<td>1625 to 1675 nm</td>
</tr>
</tbody>
</table>

Note that this table shows that current technology has managed to bridge the second and third windows that were originally disjoint. There was a window used below the O band, called the first window, at 800-900 nm; however, losses are high in this region so this window is used primarily for short-distance communications. The current lower windows (O and E) around 1300 nm have much lower losses. This region has zero dispersion. The middle windows (S and C) around 1500 nm are the most widely used. This region has the lowest attenuation losses and achieves the longest range. It does have some dispersion, so dispersion compensator devices are used to remove this.

XI. CONCLUSION

The networking of the optical communication has been discussed. The physics of its different parts has also been discussed. It has been concluded that the optical communication is completely based on the optical fiber. This acts as a breakthrough for the technological revolution in the communication network by the increase of information carrying capacity and high speed devices.

XII. REFERENCES