Basic Principles and applications of Optical Communication

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Abstract - The advent of optical fibers and lasers and their widespread use in communication has given a new direction to the information age in the form of optical fiber communications. The optical fiber technology is going to be the main technology of twenty first century and is going to affect every sphere of our lives. The rapid growth of internet is already an indication of this exciting future. This paper discusses some basic principles and applications of optical communication.

I. INTRODUCTION

The emerging optical fiber technology is playing the most important role in the present day information super highways. Few years back the optical fiber technology was actually slowing down due to higher cost compared to other communication technologies. But the rapid growth and expansion of internet has forced the fast development of optical fiber technology to provide speed in the Gbit/s range. A decade ago, such a high speed was just a dream and a few hundred Mbit/s was supposed to be moderately high. In optical communication the light carrier propagates in the extremely thin optical fiber with the advantages of very large information capacity which is freedom from electromagnetic interference, providing security and minimum possible losses as shown in Fig. 1. Due to all these advantages, the optical fiber technology is going to be the main communication technology in the twenty-first century. Besides communication, the optical fiber sensors area is becoming another important area.

Since the airwaves are becoming severely overcrowded, restrictions and regulations of frequency governing the transmission of information by radio are present. There is a simply little room left in the radio frequency spectrum to add more information transmitting channels. For this reason, many companies and individuals are looking toward light as a way to provide the needed room for communications expansion. By using modulated light as a carrier instead of radio, an almost limitless, and so far unregulated, spectrum becomes available.

Nowadays, single laser light source as semiconductor laser that emits a narrow wavelength (color) of light has already been developed to transfer at a rate in excess of 60 GHz (60,000MHz). However, with the addition of more light sources, each at a different wavelength (colors), even more information channels could be added to the communications system without interference.[1] Color channels could be added until they are numbered in the thousands. Such an enormous information capacity would be impossible to duplicate with radio.

II. THE OPTICAL-FIBER TRANSMISSION LINE AND TRANSMITTED LIGHT

The Optical-Fiber Transmission Line is the structure of an optical transmission line consists of a central part called the core, of refractive index \( n_1 \), surrounded by a material called the cladding, of lower refractive index \( n_2 \). Thus, electromagnetic waves can be confined in the core region and transmitted by total internal reflection at the core/cladding boundary as shown in Fig. 2. And it has extremely high bandwidth which is capable of 2 Gbps and it has a very high noise immunity, resistant to electromagnetic interference. [2] Furthermore it needs repeaters only 10's or 100 km apart. The wave equation is different from plane wave as shown in Fig. 3.

It seems it has lots of advantages of optical communication. It is being so widely used because it has small loser and more reliable than coaxial cable and faster also. Also enormous transmission capacity is a benefit of using the optical communication line. And no electrical connection, no EMI are important characteristics of these lines too. For this reason the security economies have a curious of the characteristic of optical communication. And first of all, it is very cheaper than coaxial cable.

However, it also have a disadvantage, though. The need for optical conversion is a bit pain staking reason being is because it takes a lot to convert optical to analog it take expensive equipment, and energy loss would think is the biggest
problem reason being is it takes a lot of units to keep the flow of information to a normal level. It is also a bit of a pain to control the direction of the information when there is damage to the cable and if the cable needs to be repaired, it is also a make a big problem because it is hard to fix correctly and if not, it can make information hard to travel.

III. APPLICATION OF THE OPTICAL COMMUNICATION

In the optical communication, a transmission technology is developed to transmit a lot of information to long distant places. This is classified into the wire optical transmission technology and the wireless optical transmission technology. Because the wireless optical transmission technology is restricted by distance, the wire optical transmission technology is used generally used. The fields of the transmission technology contain the multi-transmission, optical amplification and dispersion compensation.

(1) The multi transmission

As the Internet is developed rapidly, high-speed transmission to contain a large amount of information is an important factor in the communication system. The technology of optical communication is able to satisfy this requirement. The optical communication system has a wide bandwidth in the frequency domain because the information is transmitted through fast optical carriers. Theoretically, the usable bandwidth in the optical communication is several tens THz, but it goes up to up to 10GHz commercially. Because the multi transmission is a technology that uses multiple communication channels, it satisfies user’s need to transmit a lot of information much faster. The kinds of multi transmission are the wave division multiplexing (WDM) and time division multiplexing (TDM). The WDM is a technology that uses the optical coupler that multiplies several optical input signals having other wavelength, and to use the optical demultiplexer that divides signal package to be transmitted through one optical fiber into each output signal. Fig. 4. shows the principle of WDM. In the WDM, the optical signal information to have various wavelengths is transmitted from multiple input channels to multiple output channels. Before the invention of WDM, an optical signal transmission had only one wavelength through which one optical fiber was available. The advantages of WDM are ease to design network, possibility to construct high-level communication system, and low cost. Therefore, this is used internationally at this time. The TDM together with WDM is considered as a technology to transmit a lot of information. This is a method that transmits the time-divided input data (Time Slot) toward the multiple output channels through one transmission line. The system of TDM is shown as Fig. 5. In this, we can see that only one divided optical signal is transmitted during a cycle of time.

(2) The optical amplification

The optical amplifier is a device that amplifies small optical signals to larger ones. Because of this device, there are many advantages to increase transmission distance, to reproduce an optical signal without distortion, to transform the optical signal to electric one, etc. The optical amplification is classified into the addition of rare earth metal, the Raman amplification, and the semiconductor amplification. The technology to add rare earth metal is an amplified method to be doped by that metal. The EDFA is an amplification to dope optical fiber by a special element, Er. It is that if the semiconductor laser-diode to have 0.98µm or 1.48µm wavelength is pumped to an optical fiber to contain Er, the wavelength of this diode is converted to 1.55µm due to the energy of material. 0.98µm and 1.48µm wavelength is the absorbing energy band of Er3+ion. If energy absorption occurs in this band, stable electrons in this band are changed into unstable ones. Conversely, the energy radiation is an opposite concept of this process. The principle of EDFA is shown as Fig. 6. It is a useful technology because of the ability to amplify small optical signals to large ones without designing the complex modules. The Raman amplification is a technology that uses the inductive effect of Raman dispersion. The Raman amplifier plays a role to change the energy of pump into the transmission signal by this effect. The advantage of this technology is possibility to amplify a signal to have any wavelengths in all bandwidth. However, in general optical fiber, the inductive effect of Raman dispersion is very small. Therefore, very long optical fiber and strong source pump should be needed for sufficient amplification. For example, the amplification at 1.55µm wavelength requires a strong source pump laser device to operate at 1.445µm wavelength. Two solutions of this problem are suggested until now. The first solution is to use the serial Raman amplifier. If this is used, it is possible to amplify at 1.3µm wavelength bandwidth. The second solution is to use the multiple source pump lasers. The key point of this technology is adding some pumps without loss. In general, the Raman amplification is applied together with the method of adding rare earth metal at present time. The semiconductor amplification is a technology to use the semiconductor amplifier, not the optical fiber
The operating process of amplifier is an inductive radiation the same as the method of adding rare earth metal. In 1.55 \( \mu m \) wavelength, material to use is InP as the main layer, InGaAs, InGaAsP as the active layer, respectively. The structure of semiconductor is a form like bulk or quantum well. The size of semiconductor amplifier output is limited by the strength of saturated optical signal. If the input increases gradually, the inductive radiation also increases. Because of this process, consumed carriers are more than supplied carriers. As a result, an input amplification has limitation. The amplifier to operate at a special wavelength is used to solve this problem because this amplifier has a constant output for variable input carriers.

3) The dispersion compensation

The optical transmission ratio is determined by (the) various dispersions (color, transmission, and polarization) and the frequency response of the receiver. The color mode dispersion (CMD) and transmission mode dispersion (TMD) is almost resolved due to the development of technology of laser diode. However, the polarization mode dispersion (PMD) is not resolved completely until now. As the speed of transmission increases, the PMD causes many problems on the optical transmission. The color mode dispersion yields a distortion to be occurred by the difference of signal speed. If this phenomenon happens, generally, it causes the interference between each signal symbols. There are usually three compensating technologies about this dispersion. The first method is to use the optical fiber as compensating the dispersion. General optical fiber has positive dispersion and positive slope of dispersion. However, because the compensating optical fiber has negative dispersion and negative slope of dispersion, it is easy that color dispersion is compensated in this way. The second method is to use the HOM optical fiber. By installing this fiber, non-linearity in the transmission line vanishes nearly. The third method is to use the virtual imaged phase array technology. The structure of compensating device in this way is made of lens, glass board, and 3D (3-dimension) mirror. Because a form of mirror is variable, positive and negative dispersion is gained in this method. As a result, the dispersion is compensated effectively. The PMD makes a distortion to be caused from the time delay between polarized optical signals. The transmitted orthogonality between each optical signal yields this delay. To solve this problem, there are three compensating technologies. The first is optical compensation. This method is to install the controller of polarization at the receiving module. Because of this, the polarization of optical signals is arrayed. The second is a technology to use the controller of polarization and the PMF that is an optical fiber to maintain polarization. This removes the time delay. The third is to use the controller of polarization, two divider of polarization, and variable device of optical time delay. This technology is a compensating method to control two device-controller and variable device- alternately.

4) The optical switching technology

This technology is defined as connecting between the input ports and output ports of user’s need. The optical cross connect (OXC), optical add/drop (OAD), and wavelength transformation is contained in this technology. The OXC plays a role to route optical signals from input port to output port. If the capacity of transmission line is insufficient, the OXC sets additional channel, that is, the routing. As a result, it is possible to construct reliable network of the optical transmission. As the WDM technology is developed, more optical signals are transmitted through a lot of channels. Because of this, it is necessary to add or drop channels. The optical add/drop multiplexer (OADM) is a device to perform this requirement. The basic principle is shown in Fig. 7. The device of wavelength transformation is to avoid traffic collision in line. The typical technology for this device is to use the Gain-Saturation phenomenon in semiconductor amplifier.

IV. CONCLUSION

This article has briefly reviewed the state of the technology and possible future directions for fiber-optic networks. It is clear that significant engineering issues must be addressed and many systems and management problems must be solved before ubiquitous fiber networking is achieved. Cost will not be a trivial issue, but the economics of these optical systems favor them if the bandwidth is in demand. As global infrastructures begin to emerge and a host of broadband services appear and deliver economical service to users at offices and homes, optical networking will become a serious candidate for widespread implementation. While initiatives will continue to be critical in the development of this technology, it is important for the broader set of implementation issues to be actively addressed in order to ensure an all-optical network at a reasonable cost.
REFERENCES


