Research Paper PHYSICS

Historical Development of Optical Communication Systems

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ABSTRACT

The need of communication is an all time need of human beings. For communication some channel is needed. Optical communication systems can be used over distances of several thousands of kilometers with huge information carrying capacity by using optical amplifiers. Fiber is one channel among many other channels for communication.

KEYWORDS Bandwidth, optical fiber and dispersion.

1.1.1: INTRODUCTION:

Now we are in the twenty first century, the era of `Information technology'. There is no doubt that information technology has had an exponential growth through the modern telecommunication systems. Particularly, optical fiber communication plays a vital role in the development of high quality and high-speed telecommunication systems. Today, optical fibers are not only used in telecommunication links but also used in the Internet and local area networks (LAN) to achieve high signaling rates[3].

1.1.2: Historical perspective of optical communication

The use of light for transmitting information from one place to another place is a very old technique. In 800 BC., the Greeks used fire and smoke signals for sending information like victory in a war, alertting against enemy, call for help, etc. Mostly only one type of signal was conveyed. During the second century B.C. optical signals were encoded using signaling lamps so that any message could be sent. There was no development in optical communication till the end of the 18th century. The speed of the optical communication link was limited due to the requirement of line of sight transmission paths, the human eye as the receiver and unreliable nature of transmission paths affected by atmospheric effects such as fog and rain.

In 1835, Samuel Morse invented the telegraph and the era of electrical communications started throughout the world. The use of wire cables for the transmission of Morse coded signals was implemented in 1844. In 1872, Alexander Graham Bell proposed the photo phone with a diaphragm giving speech transmission over a distance of 200 m. But within four years, Graham Bell had changed the photophone into telephone using electrical cur-rent for transmission of speech signals[1]. In 1878, the first telephone exchange was installed at New Haven. Meanwhile, Hertz discovered radio waves in 1887. Marconi demonstrated radio communication without using wires in 1895. Using modulation techniques, the sig-nals were transmitted over a long distance using radio waves and microwaves as the carrier.

During the middle of the twentieth century, it was realized that an increase of several orders of magnitude of bit rate distance product would be possible if optical waves were used as the carrier [5].

Table 1 shows the different communication systems and their bit rate distance product. Here the repeater spacing is mentioned as distance. In the old optical communication sys-tem, the bit rate distance product is only about 1 (bit/s)-km due to enormous transmission loss (10^5 to 10^7 dB/km). The information carrying capacity of telegraphy is about hundred times lesser than a telephony. Even though the high-speed coaxial systems were evaluated during 1975, they had smaller repeater spacing. Microwaves are used in modern commu-nication systems with the increased bit rate distance product. However, a coherent optical carrier like laser will have more information carrying capacity.

So the communication engineers were interested in optical communication using lasers in an effective manner from 1960 onwards. A new era in optical communication started after the invention of laser in 1960 by Maiman. The light waves from the laser, a coherent source of light waves having high intensity, high monochromaticity and high directionality with less divergence, are used as carrier waves capable of carrying large amount of infor-mation compared with radio waves and microwaves. Subsequently H M Patel, an Indian electrical engineer designed and fabricated a CO_2 laser[6].

1.1.3: Unguided optical communication

The optical communication systems are different from microwave communication systems in many aspects. In the case of optical systems, the carrier frequency is about 100 THz and the bit rate is about 1T bit/s. Further the spreading of optical beams is always in the forward direction due to the short wavelengths. Even though it is not suitable for broad-casting applications, it may be suitable for free space communications above the earth's atmosphere like intersatellite communications. For the terrestrial applications, unguided optical communications are not suitable because of the scattering within the atmosphere, atmospheric turbulence, fog and rain. The unguided optical communication systems played

Table 1. Bit rate distance product.

System	Bit rate distance product (bit/s) - km
Old optical communication	1
Telegraph	10
Telephone	10^3
Coaxial cables	10^5
Microwaves	10^6
Laser light in open air	10^9

an important role in the research between 1960 and 1970. For longer range unguided optical communication systems the neodymium laser (1.06 □m) and the carbon dioxide laser (10.6 □m) were the most favorable sources[2]. Using narrow bandgap compound semicon-ductors like indium sulphide (for neodymium laser) and cadmium mercury telluride (for CO_2 laser) one can have better detection using heterodyne detection techniques.

2.1.1: RESULT AND DISCUSSION

To guide light in a waveguide, initially metallic and non-metallic wave guides were fab-ricated. But they have enormous losses. So they were not suitable for telecommunica-tion. Tyndall discovered that through optical fibers, light could be transmitted by the phe-nomenon of total internal reflection. During 1950s, the optical fibers with large diameters of about 1 or 2 millimetre were used in endoscopes to see the inner parts of the human body.

Optical fibers can provide a much more reliable and versatile optical channel than the atmosphere, Kao and Hockham published a paper about the optical fiber communication system in 1966. But the fibers produced an enormous loss of 1000 dB/km. But in the atmosphere, there is a loss of few dB/km. Immediately Kao and his fellow workers realized that these high losses were a result of impurities in the fiber material[4]. Using a pure silica fiber these losses were reduced to 20 dB/km in 1970 by Kapron, Keck and Maurer. At this attenuation loss, repeater spacing for optical fiber links become comparable to those of copper cable systems. Thus the optical fiber communication system became an engineering reality.

2.1.2 : Different types of fibers

We know that the light or the optical signals are guided through the silica glass fibers by total internal reflection. A typical glass fiber consists of a central core glass (50 □m) surrounded by a cladding made of a glass of slightly lower refractive index than the core's refractive index. The overall diameter of the fiber is about 125 to 200 □m. Cladding is necessary to provide proper light guidance i.e. to retain the light energy within the core as well as to provide high mechanical strength and safety to the core from scratches.

Based on the refractive index profile we have two types of fibers (a) Step index fiber (b) Graded index fiber.

(a) *Step index fiber:* In the step index fiber, the refractive index of the core is uniform throughout and undergoes an abrupt or step change at the core cladding boundary. The light rays propagating through the fiber are in the form of meridional rays which will cross the fiber axis during every reflection at the core cladding boundary and are propagating in a zig-zag manner as shown in figure 1a.

(b) *Graded index fiber:* In the graded index fiber, the refractive index of the core is made to vary in the parabolic manner such that the maximum value of refractive index is at the centre of the core. The light rays propagating through it are in the form of skew rays or helical rays which will not cross the fiber axis at any time and are propagating around the fiber axis in a helical (or) spiral manner as shown in figure 1b[3].

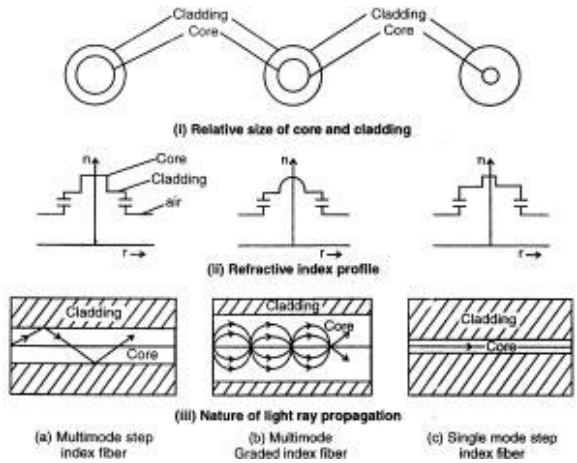


Figure 1. Different types of fibers.

Based on the number of modes propagating through the fiber, there are multimode fibers and single mode fibers. Mode is the mathematical concept of describing the nature of propagation of electromagnetic waves in a waveguide. Mode means the nature of the electromagnetic field pattern (or) configuration along the light path inside the fiber.

Conclusions:

Modern electronic communication use radio waves and microwaves to carry information over copper wires and co-axial cables. However, the information carrying capacity of these wires is restricted.

If light is used in place of radio and micro waves, the number of signal transmission capacity can be enhanced tremendously and it possesses wide bandwidth.

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