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Fiber Optics Communication

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For global broadband networks, fiber optic systems serve as critical telecommunications infrastructure. In today's applications, a wide bandwidth signal transfer with less delay is essential. Optical fibers are presently the transmission medium of choice for long-distance and high-data-rate transmission in telecommunication networks because they offer massive and unparalleled transmission bandwidth with little delay. The overview of fiber optic communication systems in this paper includes a discussion of their core technologies as well as the direction they are taking in terms of technology.

I. INTRODUCTION

The high and quickly rising consumer and business demand for more telecommunication capacity and internet services is the main factor driving the widespread adoption of fiber optic communication, as fiber optic technology is capable of providing the necessary information capacity (larger than both wireless connections and copper cable). More data can now be transmitted over longer distances with a single optical fiber thanks to technological advancements.

Wavelength division multiplexing considerably increases the transmission capacity of optical communication networks [1]. Since optical signal processing is more effective than electrical signal processing, it is a desirable feature for future optical networks to be able to process data entirely in the optical domain for the purposes of amplification, multiplexing, demultiplexing, switching, filtering, and correlation.

Despite the associated benefits of utilizing optical fiber for communication (such as its high reliability over long distances, low attenuation, low interference, high security, very high information capacity, longer life span and ease of maintenance), research is still ongoing to further improve on the present fiber optics communication system, and also to solve some of the challenges facing it. Future optical communication systems are envisioned to be more robust than the present system. This paper is organized as follows. Section II describes the basic principles of fiber optics communication. Section III looks at the history and evolution of fiber optics communication while section IV presents some envisioned future trends in fiber optics communication. In section V, we draw the conclusion for the paper.

II. BASIC PRINCIPLE OF FIBER OPTIC COMMUNICATION

Fiber optic communication is a method of transmission that works by sending brief light pulses along an optical fiber from one location to another. The data that is conveyed is primarily digital data produced by computer systems, cable television providers, and telephone services. A low-loss material, typically silicon dioxide, is used to create an optical fiber, which is a dielectric cylindrical waveguide. Total internal reflection is used to guide light pulses along the axis of the fiber because the core of the waveguide has a refractive index that is slightly higher than that of the outer medium (cladding) [4]. An optical transmitter that converts electrical signals to optical signals for transmission across optical fibers, a cable that contains many bundles of optical fibers, and optical amplifiers make up fiber optic communication systems.

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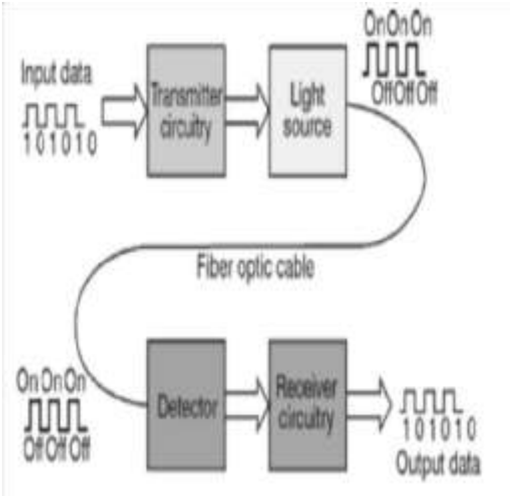

Fig.1. Basic fiber optic communication system [5]

Step-index optical fiber, which includes single-mode optical fiber and multimode optical fiber, and graded-index optical fiber are the two main categories into which optical fibers can be divided. The core diameter of single-mode step-index optical fiber is less than 10 micrometers, and it only permits one light channel. The core diameter of multimode step index optical fiber is more than or equal to 50 micrometers, allowing for many light channels that cause modal dispersion. Graded-index optical fibers have a core refractive index that gradually decreases away from the core's center. This increased refraction at the core's center causes some light rays to travel more slowly, which allows all of the light rays to arrive at the receiver almost simultaneously and reduces dispersion. Table 2

III. EVOLUTION IN FIBER OPTICS COMMUNICATION

Corning Glass Works pioneered the development of optical fiber in 1970. GaAs semiconductor lasers were created at the same time to transmit light through fiber-optic connections. The first generation fiber optic system was created in 1975; it ran at a wavelength of 0.8 m, a bit rate of 45 megabits per second, and a repeater spacing of 10 km. GaAs semiconductor lasers were utilised in this system.

The second generation of fiber optic communication, which was created in the early 1980s, operated at a wavelength of 1.3 m and utilised In GaAsP semiconducting lasers. On single-mode fiber with 50-kilometer repeater spacing, these fiber optic systems were able to operate at bit rates of up to 1.7 gigabits per second by1987.

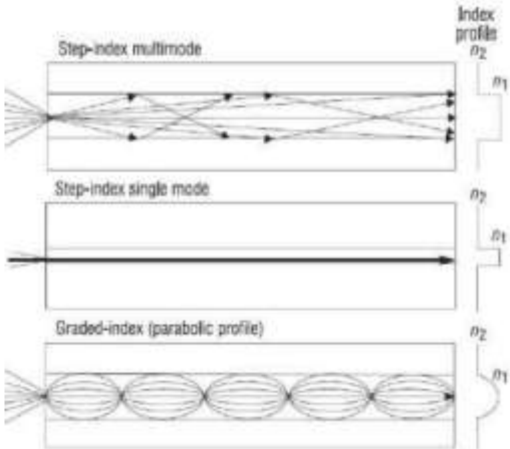

Fig.2. Optical Fiber Modes [6]

In 1990, the 1.55 m-wavelength third generation of fiber optic communication was created. On a single longitudinal mode fiber with 100-kilogram repeater spacing, these systems were capable of data rates of up to 2.5 gigabits per second.

In order to enhance data speeds, the fourth generation of fiber optic networks used wavelength division multiplexing (WDM) and optical amplifiers in place of repeaters. Submarine cables had been used to show transmission over 11,300 km at a data rate of 5 gigabits per second by 1996 [7]. Dense Wave Division Multiplexing (DWDM) is used in the fifth generation of fiber- optic communication networks to substantially boost data rates. Also being investigated is the idea of optical solitons, which are pulses that can maintain their shape by minimising the effects of dispersion. The development of fiber-optic communication is depicted in Figure 3.

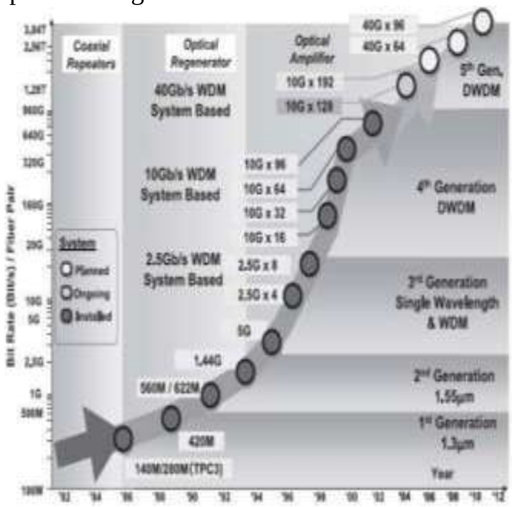

Fig.3. Generations of Fiber Optics Communication [8]

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IV. FUTURE TRENDS OF FIBER OPTICS COMMUNICATION

The future of data communication is undoubtedly fiber-optic connectivity. Technology development and rising demand for fiber optic communication have propelled fiber optic communication's evolution. With the development of new and more sophisticated communication technology, it is anticipated that this trend will continue in the future. Some of the anticipated developments in fiber-optic communication are listed below. All optical communication networks, in general

A network of all-optical communication is expected to result from all-fiber-optic communication that will operate entirely in the optical domain. In such networks, there will be no electrical manipulation at all; all signals will be processed in the optical domain. Currently, electrical signals are processed and switched; therefore, optical signals must first be transformed into electrical signals before they can be switched and directed to their intended locations. The signals are transformed back into optical signals following processing and routing, so they can be sent over great distances to their intended location. The inability to achieve very high data rates is due to the additional network latency caused by this optical-to-electrical conversion and vice versa.

Since all signal processing and routing takes place in the optical domain, all optical networks have the additional advantage of not requiring the replacement of the electronics when the data rate increases [9]. Before this can happen, though, problems with wavelength switching and optical routing must be resolved. There is currently research being done to identify a successful remedy for these problems.

B. Multi – Terabit Optical Networks

Multi-terabit transmission is made possible by dense wave division multiplexing (DWDM). The desire to create multi terabit optical networks is a result of the rising demand for bandwidth availability on a global scale. There are currently 100 DWDM channels and 40 Gb/s data rate four terabit networks.

With 100Gb/s, researchers hope to increase bandwidth even further. Future bandwidth availability could be made achievable by the ongoing decline in the price of fiber optic components.

C. Intelligent Optical Transmission Network

Traditional optical networks currently rely primarily on manual configuration of network connectivity, which is timeconsuming and unable to fully adapt to the demands of the modern network. This is due to the unpredictable dynamic allocation of bandwidth, which makes it difficult for traditional optical networks to keep up with the rapid growth of online data services. Future developments in optical networks will focus on intelligent optical networks, which will be used for a variety of purposes including traffic engineering, dynamic resource route allocation, scalable signalling, bandwidth on demand, wavelength rental, wavelength wholesale, differentiated services for various Quality of Service levels, and more. Before the intelligent optical network can be utilised at all network levels, some time will need to pass.

D. Ultra – Long Haul Optical Transmission

Research is being done on the restrictions placed on ultra-long distance optical transmission as a result of flaws in the transmission medium. Researchers are investigating thepossible advantages of soliton propagation as a result of the dispersion effect cancellation. To build a system with the best circumstances for a light pulse to propagate, further knowledge of the interactions between electromagnetic light waves and the transmission medium is required

E. Improvements in Laser Technology

The expansion of current semiconductor lasers to a larger range of lasing wavelengths will be another development in the future [12]. Some high-density optical applications are interested in shorter-wavelength lasers with very high output powers. Currently, chirp management is used to spectrally shape laser sources to account for chromatic dispersion. Chirp management refers to the process of causing the laser to suddenly shift its wavelength when a pulse is fired, thereby minimising the chromatic dispersion that the pulse experiences. It is necessary to create the tools that will be used to characterise these lasers. Additionally, single-mode tunable lasers are crucial for developing coherent optical systems in the future. These tunable lasers emit light in a single, adjustable longitudinal mode. with a variety of various frequencies in mind.

F. Laser Neural Network Nodes

The realisation of optical network nodes can be accomplished with the laser neural network. The capacity and speed of telecommunication networks are anticipated to be significantly increased by a specialised optical hardware

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arrangement and the usage of ultra-fast photonic sections [12]. The employment of optical laser neural nodes can be a good solution as optical networks become more complicated in the future.
When compared to alternative data communication options including copper

G. Polymer Optic Fiber

When compared to alternative data communication options including copper cables, wireless communication technologies, and glass fiber, polymer optical fibers have a number of advantages.Polymer optical fibers are more flexible for plug connectors and offer an easier and less expensive means of processing optical signals than glass optical fibers [13]. Due to their advantages, polymer optical fibers are currently being researched by many research and development groups as a transmission medium for aeroplanes. The use of polymer optical fibers for multimedia applications looks feasible for future aircraft uses, according to the German Aerospace Centre's analysis [14]. Additionally, copper cables for the last-mile connection from the last distribution box of the telecommunications firm are anticipated to be replaced in the future by polymer optical fibers.

H. High – Altitude Platforms

There are optical satellite-to-satellite linkages and orbit-to ground connectivity at the moment [16], with the latter being hampered by unfavourable weather [17]. Optical communication to and from high-altitude platforms is currently being researched. Airships called high altitude platforms are positioned between 16 and 25 kilometres above the clouds, where a laser beam is less negatively impacted by the atmosphere than it would be if it were over the ground [18]. If a high-altitude platform serves as a data relay station, optical linkages between high-altitude platforms, satellites, and ground stations are anticipated to act as broadband back-haul communication channels, as depicted in figure 4.

Fig.4. Laser Communication Scenarios from HAPs [4]

I. Improvements in Optical Transmitter/Receiver Technology

It's crucial to provide good quality transmission in fiber optic communication even for optical signals with distorted waveforms and low signal-to-noise ratios. Research is being done to create optical transceivers that use cutting-edge modulation techniques, have excellent chromatic dispersion, and can tolerate high optical signal to noise ratios (OSNRs), making them ideal for ultra-longhaul communication systems.
Additionally, it is anticipated that improved error correction codes, which are more effective than the current BCH concatenated codes, will become available soon.

J. Improvement in Optical Amplification Technology

One of the essential technologies utilised in optical fiber communication networks is the erbium-doped fiber amplifier (EDFA). Better technologies to improve EDFA performance will be created in the future. A better gain equalisation technology for high-accuracy optical amplification will be developed in order to expand the gain bandwidth of EDFA. High-power pumping lasers with outstanding optical amplification characteristics, outputs of more than +20 dBm, and a very low noise figure are also anticipated to exist in the near future in order to attain a larger output power and a lower noise

K. Advancement in Network Configuration of Optical Submarine Systems

The development of a technology for configuring the mesh network is anticipated to be a step in the correct direction for increasing the flexibility of network setup in optical underwater communication systems. As seen in figure 5, a mesh network connects stations directly as opposed to a ring network, which combines stations along a single ring. Presently, the ring structure is used by the majority of large optical underwater systems. A mesh network arrangement that directly connects the stations is achievable by utilising optical add/drop multiplexing technology, which branches signals in the wavelength domain. Such network configurations will become ubiquitous in the future as a result of current research.

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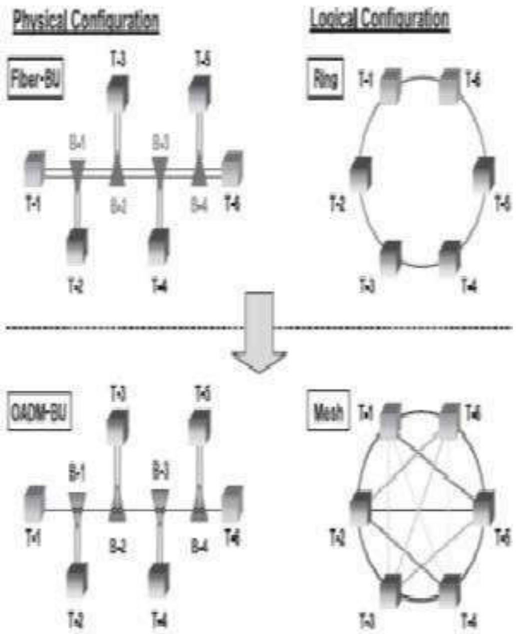

Fig.5. Optical Network Configurations [8]

L. Improvement in WDM Technology

The wavelength range over which wave division multiplexing systems can operate is still being researched. The wavelength window (C band) currently starts at 1.531.57 m. A range extension to 1.30–1.65 m is promised by dry fiber with a minimal loss window. Future advancements in wave division multiplexing optical filtering technologies are also anticipated

M. Improvements in Glass Fiber Design and Component Miniaturization

Currently, different impurities are added to or taken out of glass fibers to alter their ability to transmit light. As a result, it is possible to adjust how quickly light travels down a glass fiber, enabling the creation of glass fibers that are specifically tailored to fulfil the requirements of a given route's traffic engineering. Future trends are expected to follow this one in order to develop glass fibers that are more dependable and efficient. Another trend that is most likely to persist in the future is the miniaturisation

V. CONCLUSION

The fiber optic communications market has undergone tremendous growth over the past ten years and is one that is constantly changing. More work needs to be done to accommodate the demand for higher data rates and more sophisticated switching methods and more sophisticated network topologies that are both cost-effective and dynamically change automatically in response to traffic patterns. Future advancements already made in the laboratory are anticipated to be translated into real-world applications, ushering in a new generation of fiber-optic communications.

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