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Optical Fiber Communication - Recent Trends

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ABSTRACT: Basic elements of an optical fiber communication system include the transmitter (laser or LED), fiber (multimode, single mode, dispersion-shifted) and the receiver (PIN and APD detectors, coherent detectors, optical preamplifiers, receiver electronics). Receiver sensitivities of digital systems are compared on the basis of the number of photons-perbit required to achieve a given bit-error-probability, and eye-degradation and error-floor phenomena are described. Laser relative-intensity-noise and nonlinearities are shown to limit the performance of analog systems. Not only can be used in optical fiber communications trunk lines of communication, optical fiber can also play a role in power communication control system, industrial monitoring & control, and now the military has been widely applied, the growing demand for information in various fields based on optical fiber application of communication technology trends are also caused for concern. A complete fiber link is affected by the quality of the fiber itself, but also depends on the fiber optic link field of construction technology and the environment.

I. INTRODUCTION

Optical communications is unchallenged for the transmission of large amounts of data over long distances with low latency and it underlies modern communications networks, in particular the internet.[1] The transmission capacity of optical network technology has made dramatic strides over the decades since its introduction in the early 1970s. The early years of optical communications were characterized by a steady development of technology, a moderate rate of increase of bit rate in the single optical channel supported on these systems and the gradual change of the optical frequency transmission windows from 800 to 1300 to 1550 nm [2]. The latter part of the 1990s saw dramatic increases in system capacity brought about through the use of wavelength division multiplexing (WDM) enabled by optical amplifiers. This technological revolution ignited massive investment in system development both from traditional vendors as well as new entrants, and the capacity of commercial lightwave systems increased from less than 100 Mb/s when they debuted in the 1970s to roughly 1 Tb/s by 2000 [4]. This is an increase of more than 10 000 times in 30 years, but more incredibly, the introduction of WDM resulted in a factor of 1000 increase in just 10 years. This was enabled by the simple addition of more wavelengths to systems which were not limited by the available optical bandwidth. In the last decade, progress has slowed dramatically since the readily available bandwidth has become occupied and increases in capacity now require improvements in the efficiency of the utilization of optical bandwidth. The rapid growth in system capacity catalyzed by WDM resulted in system capacities that exceeded the requirements of network traffic for most of the past decade.

The fiber optic market is expected to grow with a CAGR of 10% from 2019 to 2024.[3]

The future of the fiber optic market looks promising with opportunities in the communication and non-communication segments. The major growth drivers for this market are increasing demand for the internet and growing use of wireless communication systems.

Some of the fiber optics companies profiled in this report include Corning Inc., Prysmian Group, AFL, Finisar, Leoni AG, Furukawa Electric, LS Cable & System, General Cable Corporation, and Finolex.[4]

Some of the features of 'Fiber Optics Market 2019-2024: Trends, Forecast, and Opportunity Analysis' include

- Market size estimates: Fiber optics market size estimation in terms of value (\$M) shipment.
- Trend and forecast analysis: Market trend (2013-2018) and forecast (2019-2024) by application.
- Segmentation analysis: Market size by optical fiber type, cable type, application, and region
- Regional analysis: Fiber optics market breakdown Asia-Pacific, North America, Europe, and Middle East & Africa.
- Growth opportunities: Analysis on growth opportunities in different applications and regions for fiber optics in the fiber optics market.
- Strategic analysis: This includes M&A, new product development, and competitive landscape for fiber optics in the fiber optics market.
- Analysis of competitive intensity of the industry based on Porter's Five Forces model.

One in five mobile connections would be running on 5G networks by 2025 (Mobile Economy Report, GSMA, 2020), while the total data volume of connected IoT devices worldwide is forecasted to reach 79.4 zettabytes (ZBs).

Such intensive bandwidth applications will be mission critical and therefore will demand high-speed, high-capacity, and robust fibre infrastructure.[5]

The Enghouse Integrated Fibre Suite empowers CSPs to enhance workflow efficiency, reduce errors and improve productivity, making the economic performance of fibre more attractive.

III. DISCUSSION

An optical fiber is a thin fiber of glass or plastic that can carry light from one end to the other. The study of optical fibers is called fiber optics, which is part of applied science and engineering. Optical fibers are mainly used in telecommunications, but they are also used for lighting, sensors, toys, and special cameras for seeing inside small spaces. It is sometimes used in medicine to see inside people, like down their throat. Any fiber optic data transmission system will comprise a number of different elements. There are three major elements (marked in bold), and a further one that is vital for practical systems:

- Transmitter (light source)
- Fiber optic cable
- Optical repeater
- Receiver (Detector)

The different elements of the system will vary according to the application. Systems used for lower capacity links, possibly for local area networks will employ somewhat different techniques and components to those used by network providers that provide extremely high data rates over long distances. Nevertheless the basic principles are the same whatever the system.[6]

In the system the transmitter of light source generates a light stream modulated to enable it to carry the data. Conventionally a pulse of light indicates a "1" and the absence of light indicates "0". This light is transmitted down a very thin fibre of glass or other suitable material to be presented at the receiver or detector. The detector converts the pulses of light into equivalent electrical pulses. In this way the data can be transmitted as light over great distances.

Step-index multimode fiber has a large core, up to 100 microns in diameter. As a result, some of the light rays that make up the digital pulse may travel a direct route, whereas others zigzag as they bounce off the cladding. These alternative pathways cause the different groupings of light rays, referred to as modes, to arrive separately at a receiving point. The pulse, an aggregate of different modes, begins to spread out, losing its well-defined shape. The need to leave spacing between pulses to prevent overlapping limits bandwidth that is, the amount of information that can be sent. Consequently, this type of fiber is best suited for transmission over short distances, in an endoscope, for instance. Graded-index multimode fiber contains a core in which the refractive index diminishes gradually from the center axis out toward the cladding. The higher refractive index at the center makes the light rays moving down the axis advance more slowly than those near the cladding. Also, rather than zigzagging off the cladding, light in the core curves helically because of the graded index, reducing its travel distance. The shortened path and the higher speed allow light at the periphery to arrive at a receiver at about the same time as the slow but straight rays in the core axis. The result: a digital pulse suffers less dispersion. [7]

Single-mode Fiber

Single-mode fiber allows for a higher capacity to transmit information because it can retain the fidelity of each light pulse over longer distances, and it exhibits no dispersion caused by multiple modes. Single-mode fiber also enjoys lower fiber attenuation than multimode fiber. Thus, more information can be transmitted per unit of time. Like multimode fiber, early single-mode fiber was generally characterized as step-index fiber meaning the refractive index of the fiber core is a step above that of the cladding rather than graduated as it is in graded-index fiber. Modern single-mode fibers have evolved into more complex designs such as matched clad, depressed clad and other exotic structures.

Multimode Fiber

Multimode fiber, the first to be manufactured and commercialized, simply refers to the fact that numerous modes or light rays are carried simultaneously through the waveguide. Modes result from the fact that light will only propagate in the fiber core at discrete angles within the cone of acceptance. This fiber type has a much larger core diameter, compared to single-mode fiber, allowing for the larger number of modes, and multimode fiber is easier to couple than single-mode optical fiber. Multimode fiber may be categorized as step-index or graded-index fiber. Multimode Step-

index Fiber Figure 2 shows how the principle of total internal reflection applies to multimode step-index fiber. Because the core's index of refraction is higher than the cladding's index of refraction, the light that enters at less than the critical angle is guided along the fiber.

Advantages of optical fiber communication

Bandwidth: Fibre optic cables have a much greater bandwidth than metal cables. The amount of information that can be transmitted per unit time of fibre over other transmission media is its most significant advantage. With the high performance single mode cable used by telephone industries for long distance telecommunication, the bandwidth surpasses the needs of today's applications and gives room for growth tomorrow. [8]

Low Power Loss: An optical fibre offers low power loss. This allows for longer transmission distances. In comparison to copper; in a network, the longest recommended copper distance is 100m while with fibre, it is 2000m.

Interference: Fibre optic cables are immune to electromagnetic interference. It can also be run in electrically noisy environments without concern as electrical noise will not affect fibre. Size - In comparison to copper, a fibre optic cable has nearly 4.5 times as much capacity as the wire cable has and a cross sectional area that is 30 times less.

Weight: Fibre optic cables are much thinner and lighter than metal wires. They also occupy less space with cables of the same information capacity. Lighter weight makes fibre easier to install. **Safety:** Since the fibre is a dielectric, it does not present a spark hazard.

Security: Optical fibres are difficult to tap. As they do not radiate electromagnetic energy, emissions cannot be intercepted. As physically tapping the fibre takes great skill to do undetected, fibre is the most secure medium available for carrying sensitive data.

Flexibility: An optical fibre has greater tensile strength than copper or steel fibres of the same diameter. It is flexible, bends easily and resists most corrosive elements that attack copper cable. **Cost:** The raw materials for glass are plentiful, unlike copper. This means glass can be made more cheaply than copper.

Disadvantages of optical fiber communication

Cost: Cables are expensive to install but last longer than copper cables.

Transmission: Transmission on optical fibre requires repeating at distance intervals.

Fragile: Fibres can be broken or have transmission losses when wrapped around curves of only a few centimetres radius. However by encasing fibres in a plastic sheath, it is difficult to bend the cable into a small enough radius to break the fibre.

Protection: Optical fibres require more protection around the cable compared to copper

III. CONCLUSION AND FUTURE OUTLOOK

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.

Improvements in Laser Technology Another future trend will be the extension of present semiconductor lasers to a wider variety of lasing wavelengths [9]. Shorter wavelength lasers with very high output powers are of interest in some high density optical applications. Presently, laser sources which are spectrally 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

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 [9]. As optical networks become more complex in the future, the use of optical laser neural nodes can be an effective solution.

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

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