Journal of Advanced Research in Technology and Management Sciences
Volume: 05 Issue: 01 ISSN: 2582-3078 January 2023
Available online at: http://www.jartms.org

REVIEW ON OPTICAL FIBER COMMUNICATIONS WITH MULTIPLEXING TECHNIQUES FOR BETTER PERFORMANCE

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***Abstract*— This Optical fiber communications plays significant role in the communication era. In order to improve the communication capacity of the optical fiber communication system multiplexing technology is widely used. Single core optical fiber generally uses dense wave length multiplexing (DWDM) techniques for optical amplification system that can contribute the transmission capacity of about 1Tb/s (=1000Gbit/s).In addition to this, in Single core fibers, Polarization division multiplexing (PDM) is implemented that uses QPSK system which can withhold a transmission capacity of about 10Tbit/s. Higher order Quadrature amplitude modulation (QAM) such as 64 QAM and 128QAM, are also applied in optical systems that can achieve capacity up to 100Tbit/s.As the requirement for capacity is increased beyond 100Tbit/s, it is observed various limitations in the optical transmission medium and transmission system such as limited spectral efficiency and limited optical power. In order to overcome this limitation space division multiplexing (SDM) has been proposed as a high-capacity optical transmission technology that can overcome the physical limitations of conventional single-mode optical fiber. This paper provides a review of different Optical fiber communication techniques.**

***Keywords*— Optical fibers, single core fibers, multiplexing, space division multiple access.**

I. INTRODUCTION

This document is a template. In the year 1966 one of the significant proposal came into limelight as to work on the optical fiber to be as a telecommunications transmission medium. For a long time good amount of attempts and research is performed to make the optical fiber as a very suitable transmission medium in the communication era. But till the end of the 1970 it became a reality since these proposed optical fibers exhibits losses and that a low-loss fiber of 20 dB/ km was achieved in 1970.Later on, the progress in the field of optical-fiber transmission has been obtained tremendously. This happened to be practical due to two achievements in reduction of optical transmission loss in fibers and the improvement of reliability of semiconductor injection lasers. It is known fact that any communication system will experience the losses and the least amount of loss that is experienced in the developing stages is 0.47 dB/km [1]. In this research article a thorough review on the recent progress in the field of optical fiber communications were discussed. This paper presents concepts of recent developments in the research of optical fibers, different optical sources and detectors. Several components are interlinked in the optical communications, a few of such components fiber cables, splices and connectors. [2].

Noticeably, in order to transfer information from one point to another point physical medium like twisted copper wire-pairs, metallic waveguides and coaxial cables were implemented. This communication applications ranges from short medium and long distances. Sometimes it is observed that communication can also be limited to inter-building and intercity range of distances. The optical fiber is a very versatile transmission medium and by engineering these optical-fiber cables may be used in a variety of communication applications. The optical fiber as a transmission medium have lot of advantages such as small size of the fiber, the allowable small bending radius of the fiber cable, the large information capacity, and the flexibility of system growth, the freedom from electromagnetic interference, the immunity from ground-loop problems. Above all these optical fibers can be available with potentially low economy.

Strongly influencing the economic viability of potential optical-fiber systems are the transmission properties of optical loss and pulse spreading (dispersion) attainable in commercially produced fiber cables [3].

Practically speaking the data links within a building may operate at transmission rates on the order of 10 Mbits/s over distances up to several hundred meters; therefore, fiber loss as high as -100 dB/km and pulse spreading as much as -100 ns/km are tolerable [4]. Also low loss transmission medium and techniques are expected to have in the communication systems. This low loss communication system can be exhibited if the repeaters are used at long distances for the transmission of the data with no loss so that they can cover for large distances. Different areas of application will have different requirements on these properties, which, in turn, will influence the selection of devices and components for specific systems. For any communication system to be successful its source of transmission plays a vital role. Several optical sources are found in the literature, among them LED and LASER sources are widely used. Light-emitting diodes (LEDs) without internal gain (PIN photodiodes) at the source point and the photo detectors at the destination side are implemented. To meet the commercial aspects a short optical-fiber data links can be completed with inclusion of the electronics for interfacing with existing equipment. It is known fact that the LEDs and PIN photodiodes are perfectly acceptable for operation at a few Mbits/s in the communication systems. Lasers and avalanche photodiodes that have internal gain are required for the higher-speed systems. Good numbers of experiments were conducted in the optical fiber communication domain for different applications. The requirements for the long distance communications with high-capacity intercity systems that operate at several hundred Mbits/s transmission rates have very stringent requirements. Also their loss must not exceed a few dB/km and dispersion must be well below 1 ns/km. [5]. Different classes of space division multiplexing fibers for optical data transmission are shown in the figure1.

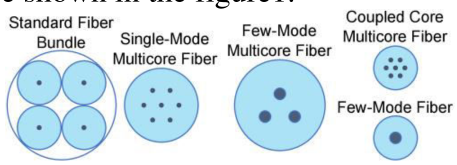

Fig. 1 Five classes of SDM fibers for optical data transmission

II. LOSSES IN OPTICAL FIBERS

The major difficulties that any communication system experience is the losses in the optical fibers. Hence researchers and engineers work very specifically on reducing the losses in the system. For present day communication systems, very low-loss fibers produce mostly by the method of modified chemical vapour deposition (MCVD). MCVD is one among the methods in which extremely pure glass is produced and satisfy the requirements of low losses in the transmission of energy in the optical fibers.According to this method of optical fiber fabrication the silicon tetrachloride (SiC14) gas reacts with oxygen at high temperature to form silica (SiO2). This is deposited on the inner surface of a silica tube used in the fabrication process.[6-8]. finally after sufficient material has been deposited in the inner sides of the tube, it is collapsed at a higher temperature rate into a solid rod or preform, which is then drawn into a fiber structures. Interestingly, several kilometres of optical fiber can be drawn from a single preform.Atmospheric and weather changes in the Wireless Optical fiber communication links show lot of impact on the signal strength and its attenuation. The system must have low complexity and should offer gigabit per second data rates. Specifically these communication systems suffer from atmospheric loss mostly due to fog, scintillation and precipitation signals.

III. MULTIPLEXING IN OPTICAL FIBERS: SPACE DIVISION MULTIPLEXING

Data is to be transmitted from one point to another but due to the increased number of users in utilising the same channel it finds very difficult to share the data to multiple number of users. Hence special kinds of techniques are required to enhance the data transmission capacity. For the recent times it is noticed that the current technology implemented in the transmission of the data mainly the single-mode fibre is used for the data transmission that exceeded its fundamental limit [9]. In order to overcome this limitation novel disruptive technology is needed to evolve and implement based on space division multiplexing (SDM). SDM is investigated with the existing

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transmission technology such as wavelength division multiplexing (WDM) and polarization division multiplexing (PDM) [10].Transmission technology for higher data capacity came into physical existence. For the development of suitable optical fibers for higher data rate transmission is implemented with multicore fibre (MCF) andfew-mode fibre. According to the recent research literature, it is analysed that multicore fiber MCF assistance for SDM technology offers separate multiple channels. In this method each and every path is applied as an independent propagation, therefore the data capacity can be increased. It is found very difficult to maintain the core separation at maximum synchronisation so that the core conflict can be reduced and the efficiency can be improved. The shortcomings that are present in the presence of the MCF were predominated by presenting the delay compensation network method on the receiver side. This uses multiple input-multiple output (MIMO) techniques. In addition, in this method it causes lot of complex configuration of the receiving mode assistance. In contrast to this there is another method called few mode fiber. Few-mode is obtained in various transverse modes using few mode fiber (FMF) along the single core region and each mode was configured as a data-carrying path. These techniques were approached for a span of 5 × 100 Gbps with a distance of 40 km [11] and succeeded. Even though the few mode fiber techniques is successful compared too many other methods, still there are doubts for enhancing data transmission in the long-run without pulse deterioration. Traditionally in the single mode fiber (SMF) propagation, proper amplification of the data signal is performed then after only the data is transmitted. This amplification is performed on the optical signal by using the very rare earth elements and erbium ions. As similar to the amplification process in the single mode fibers in the few mode fibers FMF the amplification and the data transmission for the long distance is achieved by amplifying each mode group that was multiplexed before amplification and de-multiplexed after amplification.

The visible light spectrum is shown in the following figure.

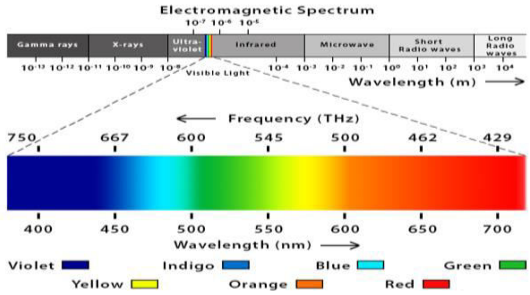

Fig. 2 Visible light spectrum

The visible light falls in the category of the electromagnetic radiation spectrum. This light can be visible to the human naked eye. The colour discrimination and identification can be done with the visible light by the human eye. The spectrum range of the visible light is from 400 nm i.e. 4 x 10^{-7} m, (violet) to 700 nm 7 x 10^{-7} m, (red).

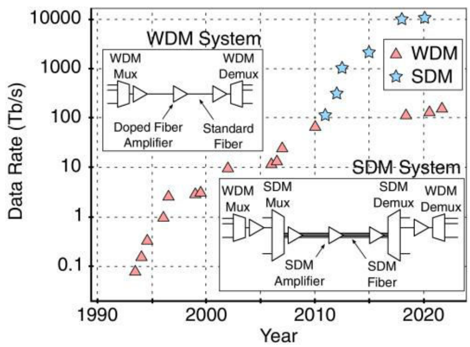

Fig. 3 Evolution of data rate records for WDM systems since 1996 and SDM systems

Figure 3 also shows the evolution of published research demonstrations, setting new per-fiber data rate records in WDM systems using SMF from 1996 and SDM systems from 2011, when they first overtook WDM systems. Also this figure depicts the data rates of WDM systems that have been mostly limited to around 100 Tb/s until recently approaching 200 Tb/s through the adoption of new transmission bands. It is observed that the Space Division Multiplexing Systems that are implemented in the same transmission bandwidths in each spatial channel have achieved data rates virtually 2 times of the order of greater magnitude [13].

Space division multiplexing offers several advantages such as potential for higher data rates,

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different approaches for networking, large power efficiency, and lot of possibilities of integration. With all these advantages SDM technology achieved inclination and boost towards the commercial deployment. In SDM, in free-space optical communications has one of the very attractive features that it is possible to implement multiple laser beams in parallel for transmitting data at a higher overall bit rate. Anyhow in practice these methods did not experienced good more utilisation since the number of practically usable beams is limited. In addition to this the cost also increases very nearly linearly with the number of transmission lines. From the literature it is understood that various kinds of SDM fibers were available and that in particularly multi-core fibers and few-mode fibers, partially with minimized modal differential group delay are available for practical usage. Such fibers are also available for practical use in SDM. Above all there are many types of spatial multiplexers and mode connectors that are widely used in communication systems. Special erbium-doped fiber amplifiers for few-mode fibers and for multi-core fibers have been developed. Further, there are fusion splicers which are suitable for splicing multi-core fibers, sometimes also with increased cleaning diameters. In recent years, a lot of new hardware has been developed for space division multiplexing. Partially, such items are commercially available too. The figure 3 shows the evaluation of SDM.

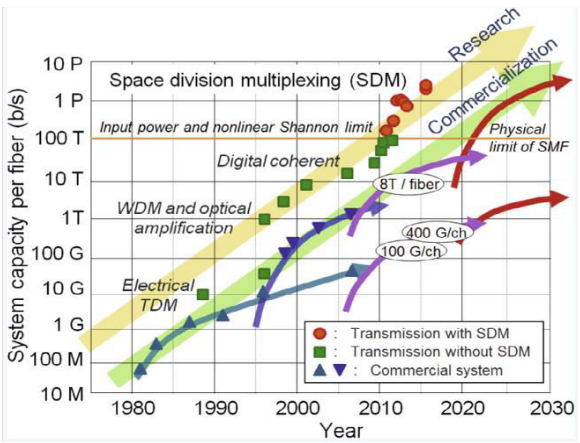

Fig. 3 Showing the evaluation of SDM

IV. LITERATURE REVIEW

In the year 2021 Fang Renet al.proposed and investigated a weakly-coupled ERCF fiber supporting ten modes. Modal characteristic, evanescent field, and bending loss often spatial modes in this fiber are numerically investigated the higher-order mode and larger eccentric distance are more sensitive to bending. In the year 2021 D.Vigneswaran et al. proposed and investigated dual core elliptical core ring core based few-mode fiber (DE-ERCF-FMF) for space division multiplexing (SDM) applications. The inner core supposed to generate maximum of 8 L P modes wherein outer core supposed to generate 12 L P modes. In the year 2021 D.Vigneswaran et al. Designed the ring core-based few-mode erbium-doped fiber amplifier (FM-EDFA) systemfor mode amplifications. The operating wavelength was fixed between 1525 to 1600 nm and the channel capacity was 100 Gbps.In the year 2020 Shuo Chen et.al. Proposed an eight spatial-mode RC-FMF including four different-material-filling side holes. With the cross arranged different-material-filling side holes, the symmetry of refractive index distribution in the RC-FMF can be affected [13].

In the year 2020 Alessandro Corsiet.al. Reported the polarization-maintaining properties of a highly elliptical core fiber surrounded by a trench that was designed to optimize the modal effective indices and bending loss for a total of five spatial modes.

In the year 2018 D.Vigneswaran et al. studied on a novel fiber and is proposed to support few linearly polarized (LP) modes, with the feature of a circular ring-shaped core filled by liquid. The obtained results show that the proposed fiber reduces the confinement loss as well as Differential mode delay over the entire range of the C-band. In the year 2016 WenxingJin proposed few-mode large-mode-area fiber is proposed. This type of fiber consists of 11 conventional cores and 8 air-hole cores circularly arranged around the center core. The bending loss of the fundamental mode less than 10-3 dB/m is available when bending radius is larger than 0.5 m. And effective area over 1400 µm2 could be realized when bending radius ranges from 0.4 m to 0.6 m [14-15].

V.CONCLUSION

With the detailed literature review it is observed that many research studies are shown their interest for generation of modes only without considering the important parameters like time delay, effect of physical characteristics, polarization mismatch, cross talk, and modes with equal excitation. The through discussion on the literature review defines the following research objectives. To generate number of spatial modes using specially designed fiber who has lower delay. To analysis each transverse optical modes under the physical characteristics of fiber such as temperature. To design fiber for few mode assistance having lower cross talk with a low polarization mismatch. To design system in which modes are equally excited with weakly coupling phenomenon. In the process to meet those Research objectives, following research method is expected to adopt in this paper for further work. Design of few mode Fibre and System, propose unique features of fiber assisting ring core pattern. Enumerating number of modes for propagation. To study the performance analysis of fiber and its system configuration.

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