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Impact of Optimization filters in Single Mode Fiber: A Review

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ABSTRACT*:* Single Mode Fibers are gaining popularity for long distance transmission. These fibers have found their application in a variety of application. Optical filtering is used in the single mode fibers for improvingthe transmission capacity and distance, increasing spectral efficiency and for gaining good performance. This paper will discuss the concept of single mode fibers, their design types, optical filtering, various optical filters, and the things or tools that can be utilized for filtering in the single mode fibers communication system. The paper is organizedintovarious sections.The first section is introduction sectionwhich providesextensive detail about single mode fibers, its designs, optical filtering, VCSEL, Mach-Zehnder Modulator and non-return zero encoding scheme. The next section is literature review that provides the views of various authors regarding optical filtering influence in the single mode fiber cables. After that findings section discusses thetechniques and results obtained in the research by different authors.

KEYWORDS: Single mode fibers, optical filtering, Mach-Zehnder Modulator, Non-return zero (NRZ)

I. INTRODUCTION

1.1. Single Mode Fibers

Single-mode fibers one of the types supported by the optical fibers. Single–mode fibers consist of a small diametric core that allows only one mode of light to pass through the cable. This fiber can achieve the lower attenuation than the multi-mode fibers. This cable has the better fidelity of each pulse of light and allows the signal to travel longer distances. Single mode fibers usually have a diameter of 8.3 to 10 microns, and core to cladding diameter ratio in this fiber is generally from 9 microns to 125 microns. These fibers are used for long distances, higher bandwidth requiring applications like Colleges, Telecommunication CATV companies, universities, and universities.

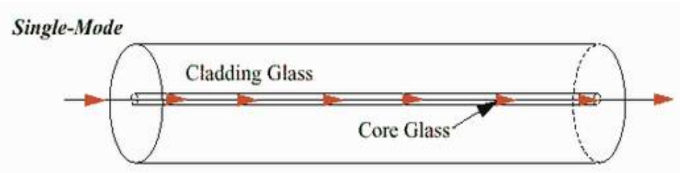

Figure 1: Single mode fiber

Earlier single mode fibers were characterized as step index a fiber in which refractive index of the core of the fiber is a step high as compared to cladding, unlike the graded index fibers. Today single mode fibers have designed with sophisticated designs like depressed clad, matched clad and so on. Thiscan support fifty times more distance than supported by multimode and provide higher transmission rates also. It is costly due to its higher bandwidth and long distance transmission capacity [1] [5].

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1.2. Basic Cable Designs of Single-Mode Fibers:

There are two designs for single mode fiber: Loose-tube cable and tight-buffered cable.

- **Loose-tube cable** design consists of up to 12 fibers for each buffer tube along with a maximum per fiber count of more than 200 fibers. These fibers are used in installation in outside plant in North –America. Color coded plastic buffer tube used inside the loose-tube cable design protect and house optical fibers. Water penetration is impeded by gel filling compound. Insulation of fibers forms stresses of environmental load and installations are done by using the excessive length of the fiber. Dielectric central member is surrounded by the buffer tubes, which then acts as an anti-buckling element. The aramid yarn is used in the cable core as a strength member and core is extruded using the jacket of polyethylene. In case there is a need for armoring, then an additional jacket can be extruded over the shield which forms a corrugated steel tape.
- **Tight-buffered cables** use buffering material that is in direct contact with the fiber. This design of the cable is suitable for the jumper cables that can connect outsidecables to the terminal equipment and can link various devices in the form of network. This kind of designed cables is used in the buildings. This design of cable is suitable for providing the rugged structure for the cable that can able to protect fibers during routing, handling, and establishing a connection. Fiber used inside the cable helps in keeping the load away from the cable. This kind of designed cables are used as patch cords, pigtails and jumpers for termination of loss tube cables into the optoelectronic transmitters and receivers and also some other components.

1.3. Main Parameters of a Single-Mode Fiber Link

The main parameters of a single mode fiber linkare discussed below:

Numerical Aperture and Core Size: a Numerical aperture for the single mode fiber is small, and core size is narrow so that it allows passing of only one row.

Center Wavelength and Reach: Center wavelength in the fiber is from 1310 nm to 1550nm. Single-mode fiber's reach is limited based on the polarization mode dispersion and chromatic. The reach of the single fiber optic can also limit based on the optical signal over noise ratio degradation. One can use the Fabry-Perot lasers if there is a need for short reach applications and DFB can be utilized for longer reach application.

Dispersion: This parameter affects the single mode fibers by same means it impacts the multi-mode fibers. The difference here is that, in the single-mode fiber, the dispersion is due to the chromatic and polarization mode dispersion. The dispersion leads to spreading of the pulse [1].

OSNR: OSNR stands for Optical Signal over Noise Ratio. This is the parameters that need consideration in the single-mode fibers when DWDM links are amplified using EDFAs. DWDM applications require OSNR that is large and can able to distinguish noise pulse and data pulse [3].

1.4. Optical Filtering

Optical Filtering is the process of selecting or rejecting wavelengths or range of wavelengths. This process uses the optical filters for transmission or rejection of the wavelengths. Fiber optical filters are capable of connecting with the fiber optic system and able to select or reject wavelengths. Opticalfilters are utilized in a variety of applications such as life science, defense industries, and clinical chemistry and so on. These filters can be of two types. That are low pass or high pass. A low-pass optical filter passes the shorter wavelength, and it rejects longer wavelengths. A high pass filter performs just opposite to the low pass filter which means it passes the longer wavelength of light through the filter while rejects shorter light wavelengths.

Optical filters offer many applications like these can be used for elimination of unwanted signals of lights; balancing the response of photo detector, tuning of wavelength and can be used for spectral analysis of optical signals. Filters can be band pass, edge dichroic, notch filters, color substrate and ND. Band pass filters are the filters that can transmit a portion of the spectrum, and these filters reject all other wavelengths. An edge dichroic filter can transmit wavelengths that are found by it as greater than the cut on or that are found shorter than the cut-off wavelengths of light. A notch

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filter canreject a portion of the spectrum and transmits all other wavelengths of light. A color substrate filters use the inherent transmission properties of the material for the purpose of communication. Lastly, ND filter can reduce the transmission across the spectrum portion [6].

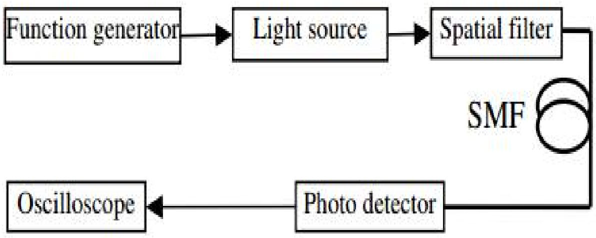

Fig-1: Optical Filtering [8]

1.5. Optical Filtering Influence On Single Mode Fibers:

As it is known that optical filtering can be performed using various filters like bandpass, notch, and edge and so on. But the question is what is the influence of performing optical filtering in the single mode fibers?The answer to this question is that use of optical filtering or optical filters in the single mode fibers leads to many benefits which are for example it can help in achieving the increase in spectral efficiency, increase in transmission capacity of single-mode fibers, increase in transmission distance, and help in error free transmission of data. So, optical filters usage leads to achieving excellent overall performance in the single mode fiber communication system [3] [5] [6] [8].

1.6. Components Used in Optical Filtering:

1. Vertical cavity surface emitting laser (VCSEL)

VCSEL is a particular kind of a laser diode that can be used in the optical fibers for the purpose of improving efficiency and increase in speed of the data transmission. This laser diode technology can emit energy at the rate of 850 nanometers, and 1300 nanometres. Gallium arsenide,Aluminum gallium arsenide, and indium gallium arsenideare used in the production of VCSELs. The VCSELS provide reliability, the significant coupling efficiency smaller threshold value and excellent beam quality, etc. [1].

2. Mach-Zehnder Modulator

This modulator is used in the optical fibers to control the optical wave's amplitude. In this modulator, the input waveguide is broken into two waveguide arms and after that voltage is applied on one of them. Then induction of phase shift is done for the wave that is passing through the arms. The conversion of the waves into the amplitude modulation is carried out when the two arms are recombined.[1]

3. Non-Return to Zero

The non-return to zero is an encoding scheme that comes under the category of the polar encoding techniques. This non-return to zero plan is the commonly used and easiest method for the transmission of the digital signals. This scheme utilized two kinds of voltage levels for representing the digital signal that is negative and positive voltage. In this, oneis demonstrated as the positive voltage, and 0 is described as the negative voltage.[5]

II.LITERATURE REVIEW

M. V. Sudhakar et al. [2015] examined the influence of the optical filtering on the transmission capacity. This examination of optical filtering was doneon the single mode fibers. The research analyzed the two filters known as Butterworth and super-Gaussian for maximizing the performance of the single mode fibers. The design used the

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VSCEL and NRZ optical signal for SMF transmission at 10 Gb/s without external modulator and encoder. The results indicated that the proposed filters helped in increasing the transmission capacity in the single mode filters [1].

A. Agarwal et al. [2003] demonstrated the high optical filtering for gaining the ultra-high capacity transmission. The research analyzed all Raman single wide band transmission with a spectral efficiency. The modulation format was chosen that was based on pulse like structure. Analysis results showed that filtering helped in achieving nonlinear propagation, better receiver sensitivity and good performance [2].

I. Morita and N. Yoshikane [2004] examined the modulations formats that can be used for optical filters and also investigated systems performance. The formats like CS-RZ-OOk signal and CS-RZ-DPSK were studied in thesurvey. The investigation results clearly described that optical filtering was resulted in achieving the spectral efficiency [3].

I. Khan, M. J. Oleszko [2013] specified a high capacity optical fiber link design to meet the demand for increasing traffic in the telecommunication systems. They verified and simulated 40 Gbps single fiber link. Use of the Rsoft-optsim software was done for simulation. The proposed design used the link length of 1000 km, and bit error rate was 4.29e-10. The use of eight WDM channels was done for achieving higher data transmission rates. The results showed that data transmission of rate 320 Gbps is possible [4].

M. V. SUDHAKAR et al. [2014] presented an approach for error free transmission in optical networks. Here the method of optical filtering was specified by using vertical cavity surface emitting laser surface that operated at 1550.127 nanometres along with 10 GB per second. NRZ signal was generated using the band pass filter and Mach-Zehnder modulator. Also, Butterworth and super-Gaussian filters were used. The resulted obtained showed that the proposed filtering design helped in enhancing the single mode fiber length [5].

S. M. Tripathi et al. [2010] presented a simple, easy and efficient optical fiber which was known as optical band pass/band stop filter and it was based on single-multi-single-mode fiber tunable bandwidth. The research provided the idea that with the setting of temperature and strain tuning parameters, one can switch the filter into band pass and band stop modes. The results revealed that proper change in parameters like temperature and pressure could lead to a shift inscreen mode [6].

R. J. Essiambre et al. [2010] specified a method for estimation of capacity links of the fiber optical systems. The research presented the basic idea about the digital communication including brief detail of signal to noise ratio and optical signal to noise ratio. Modulation techniques were also discussed. The phenomenon of transmission in the optical fiber networks wasconsidered along with the problems and requirement of use of optical filtering. The research further evaluated the capacity limit measure for fiber channel using ring constellations [7].

M. V. Sudhakar et al. described the spatial filtering to increase transmission capacity in single mode fibers. The optical fibers IIR and Bessel were used to enhance the data rate in SMFs. The simulation was done in this research to demonstrate that it resulted in achieving more transmission capacity [8].

T. Mori et al. [2013] showed the model dispersion compensation for multi-mode fibers. The model dispersion compensation was explained using the electrical adaptive. The paper showed that 20 km 50 km core GIMMF had achieved in spite of the fact that mode conversions were introduced by 2 to 5 km axial deviations occurring in the transmission line [9].

J. Yu, J. Zhang [2016] presented the recent development that was carried out for high-speed optical transmission. The spectral efficiency and band rate signal transmission were reported along with digital signal processing. DSP led to simplify the advanced modulation designs and processing and compensation of impairments in the digital domain both at receiver as well as transmitter side. The progress on multi-mode multiplexing and multi-core multiplexing was also discussed. Results obtained showed that DSP could help in improvement of signal performance, reduction in time consumption and led to spectral efficiency. Also, multi-mode and core multiplexing could improve the system capacity [10].

P. J. Winzer, R. J. Essiambre[2006] discussed the modulation designs for optical transport networks. The modulation schemes were used to transmit dataonmulti-gigabit second per channel data rates. Intensity modulation format was

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compared with RX performance. The discussion about CD, narrowband and PMD filtering and Kerr nonlinearity was also presented. Thus paper provided the idea about modulation designs that can be used in optical networking [11].

III.FINDINGS

The table includes the findings of literature review showing different techniques used for filtering in optical communication systems in previous researches.

Table 1: Different techniques for optical filtering

Author	Techniques	Results
M. V. Sudhakar et al. [2014]	Butterworth and super-Gaussian filters.	The increase in the transmission capacity.
A. Agarwal et al. [2003]	All Raman single wide band transmission.	Better receiver sensitivity and good performance.
I. Morita and N. Yoshikane[2004]	CS-RZ-OOk signal and CS-RZ-DPSK.	Achieved the spectral efficiency.
I. Khan, M. J. Oleszko[2013]	High capacity optical fiber link design.	Transmission of rate 320 Gbps achieved.
M. V. Sudhakar et al. [2014]	Optical filtering.	Enhanced the single mode fiber length.
S. M. Tripathi et al. [2010]	Bandpass/band stop filter.	Change of filter mode.
R. J. Essiambre et al. [2010]	Ring constellations.	Achieved good performance.

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M. V. Sudhakar et al.	Spatial filtering.	Increased transmission capacity.
T. Mori et al. [2013]	Model dispersion compensation.	Achieved 20 km 50 km core GIMMF.
J. Yu, J. Zhang [2016]	DSP algorithm	Improved system capacity, spectral efficiency.

IV.CONCLUSION

In this paper, the discussion about the single mode fiber, its cable design, optical filtering, and optical filtering components is given. The study provided the brief knowledge of the concept that optical filtering using the various kinds of filters like band pass filters, notch filters, edge filter, color substrate filters and ND filters can be performing filtering in the optical fibers. The outcome of using the optical filtering on the optical fiber networks lead to improvement in spectral efficiency, increase in transmission capacity and distance.This study shows that optical filtering can be used to improve the overall efficiency of the singlemode fibersfor transmissionof data.

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