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Ultra Dense Performance Enhanced Spectrum Sliced FSO

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ABSTRACT

In this paper, free space optical communication with spectrum slicing from semiconductor optical amplifier is presented. Diverse weather instabilities are investigated on system and their effect has been observed. Self phase modulation is a principle which is responsible for spectrum broadening. Link length of 10 km has been achieved at data rate of 5 Gbps using spectrum sliced FSO. Utmost goal is to save bandwidth by spacing channels at ultra close spacing (50 GHz) and to save cost of the system by incorporating cheap amplifier such as semiconductor optical amplifier for generation of spectrum slices. Proposed system is economical, simple, and performance enhanced.

General Terms
Simulation work

Keywords*: Free Space Optical Communication, Self Phase Modulation, Wavelength Division Multiplexing, Spectrum Slicing, Q factor, and BER.*

I. INTRODUCTION

Optical wireless communication is the engaging technology in the field of communication and provides us with the fastest transmission than microwave and RF technology [1]. Optical fiber communication is incorporated in the communication networks due to advantages such as potential to cater high speed, large capacity, and immune from interferences and has high security. However, optical fibers take large time for deployment and wastes money in trenching, to get rights of way, and permits [2]. FSO is investigated widely due to numerous advantages like license free, large bandwidth, and operates on low power [3]. FSO communication is prone to weather effects which degrades the FSO performance. There weather instabilities are different intensities of rain, fog haze etc [4] [5]. Numerous research works are done to cope up with problems of atmospheric effects [6].

In [7], author investigated the width of beam at distant locations and also in other research works techniques tested are Orthogonal Frequency Division Multiplexing [4], Gamma Gamma fading [6], and diversity [8]. Multi channels are employed in free space to boost the capacity of WDM systems and also narrow channel spacings are considered. These days, in order to reduce cost of the multi channel systems, spectrum slicing is employed in FSO systems. Wavelength division multiplexing based systems needs separate lasers for each channel and this increases the cost of the system. Spectrum slicing based system does the same task as WDM systems however at the cost of one laser [9]. Therefore, spectrum slicing provides edge over WDM in terms of low complexity and power efficiency with low cost operations. Demonstration of FSO systems with spectrum slicing are studied by incorporating different techniques such as arrayed waveguide gratings [10], amplifier spontaneous noise [11], and super-luminescent diodes (SLDs) [12]. However, potential of these techniques to cater high speed data are less and also these systems have less capacity. FSO has potential to support high capacity and data rates and therefore cost effective, high speed, and high capacity spectrum slicing technique based FSO systems are needed.

In this paper, a spectrum sliced free space optical channel is demonstrated using nonlinear effect self phase modulation in SOA in order to provide low cost multichannel system. Different weather instabilities are taken into consideration at 5 Gbps data speed and ultra dense frequency spacings.

II. PRINCIPLE AND SYSTEM SETUP

For the simulation of the low cost kerr effect dependent spectrum sliced free space optical system incorporating SOA, a prominent tool Optiwave'sOptisystem is considered. As discussed earlier, spectrum slicing technology is cutting edge technique as compared to WDM technology. In WDM technology, number of laser sources required equal to the channels of the system. Due to this reason, cost of WDM systems is very high and on contrary, spectrum slicing has potential to cater large data, can support large number of channels and offer low cost system. Further, advanced pulse shape formats can boost the system performance by suppressing dispersion effects. Generally used advanced pulse shape formats are modified duo-binary return to zero, compressed spectrum return to zero etc. However, these pulse shapes makes the system complex and therefore non return to zero modulation becomes optimal choice. Spectrum broadening for slicing is proposed in many reported works however, power of slices is low and less broadening is observed. Therefore, our utmost goal of this research is to increases broadness of spectrum, and power of each slice so that capacity enhances and performance also. In this work, nonlinear effects of semiconductor optical amplifier are taken into account for the broadening of spectrum. Self phase modulation is a nonlinear effect which is considered for the broadening of spectrum. In order to accomplish spectrum broadening, high power laser signal typically at 30 dBm is fed to the SOA and frequency of laser signal is fixed to 193.1 THz. Figure 1 depicts the kerr effect dependent spectrum sliced free space optical system incorporating SOA in a prominent tool Optiwave'sOptisystem.

In SOA, when low power signal is launched, carrier which are excited by injection current, start amplifying the input signal. However, when high power is fed to the SOA, carriers of the amplifier starts vibrations and modulates the refractive index of the amplifier due to which speed of the input signal changes. Change in the signal introduces the phase fluctuation and this lead to SPM effect of spectrum broadening. For making system bandwidth efficient, channel spacing of 50 GHz is employed and 4 frequencies are incorporated in this work from 193 THz to 193.150 THz. A continuous stream of binary bits at 5 Gbps is generated by pseudorandom bit generator and pulse shaping is done by NRZ linecoder. Electrical pulse shaping is converted into optical pulse shapes with the employment of intensity modulator which gets drive from NRZ and slices of spectrum. All four signals are accumulated with multiplexer and drive of signal is given to 5 cm transmitter antenna and FSO channels is considered with 1 m/rad beam divergence and 20 cm receiver antenna.

III. INVESTIGATION AND PARAMETERS OF ATMOSPHERIC TURBULENCES

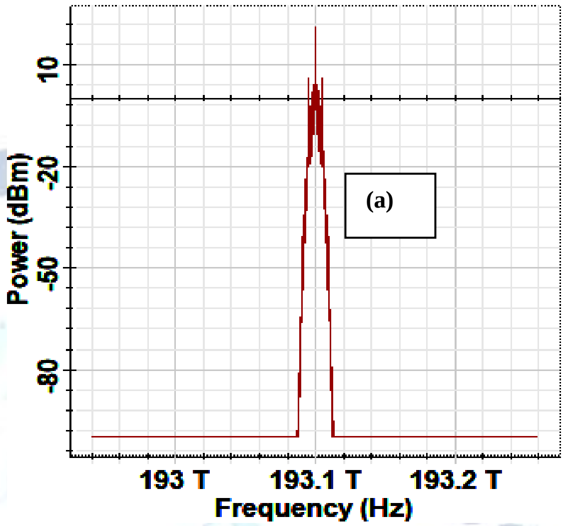
FSO signals are deteriorated by the weather conditions and this is utmost problem in free space communication. Major weather conditions are haze, snow, rain etc and as mentioned in [13]-[14], attenuation values are given for each condition. Table 1 shows the attenuation values of each weather condition.

Table 1 attenuation values of each weather condition

Weather condition	Attenuation (dB/Km)
Clear weather	0.11
Haze	4
Mild Rain	6.27
Medium Rain	9.64
Fog	22

IV. RESULTS AND DISCUSSIONS

For the simulation design, investigation and results, optisystem is used and it has wide library of components to analyze the signal. Optical spectrums of the laser, before and after SOA are depicted in Figure 2. It depicts that optical spectrum of narrowband source gets broadened due to the nonlinearity in SOA. Figure 3 represents the multiplexed optical spectrums of 4 slices that are sliced after spectrum broadening due to SPM in SOA.



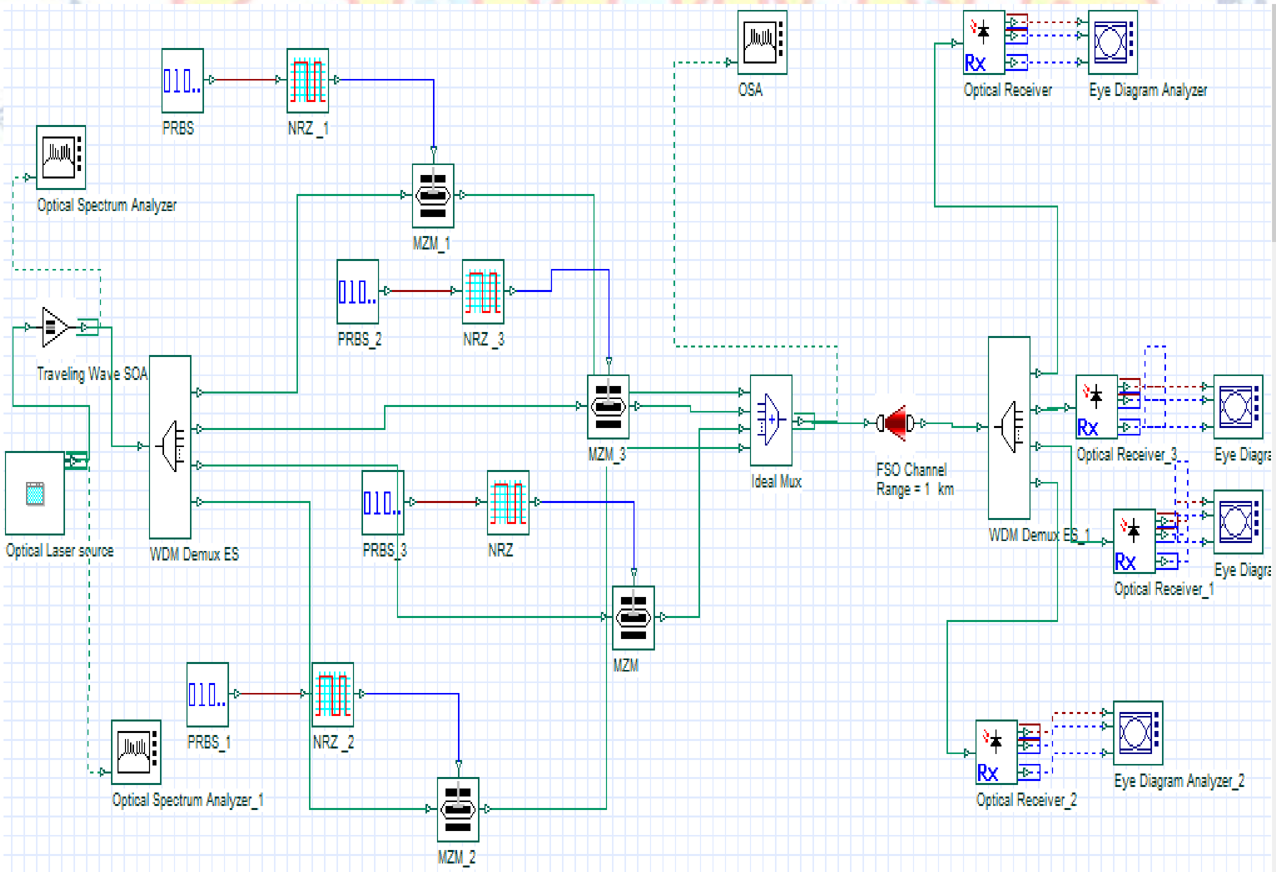


Fig 1: kerr effect dependent spectrum sliced free space optical system incorporating SOA in a prominent tool Optiwave'sOptisystem

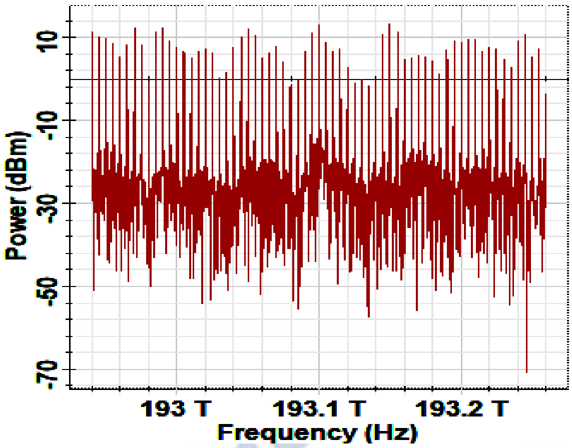


Fig 2: A continuous wave laser spectrum (a) without (b) with self phase modulation in SOA

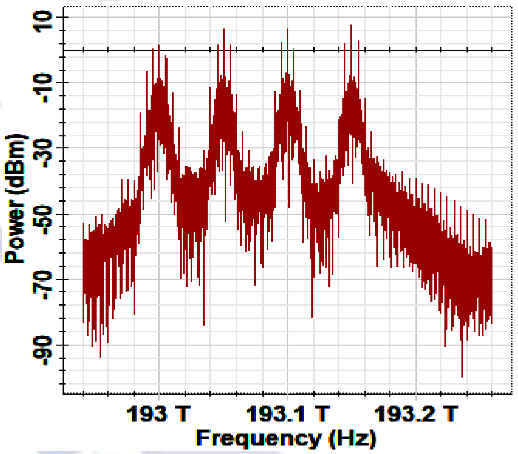


Fig 3: Representation of four multiplexed spectrums slices channels at OSA

Free space optical link is evaluated under different intensities of rain and also fog, clear weather are considered. Distance is prolonged 1-5 km and received Quality factor is studied. Clear weather affects the signal of FSO with very negligible attenuation and significant degradation is seen when frozen water droplets are there in weather (Fog). Figure 4 represents the Quality for diverse weather condition when distance is changed from 1-5 km. Results revealed that Q factor for clear weather is 35.3 to 27.54 when distance is 1 km and 5 km respectively. For mild, medium rain, haze and fog, Q factor is 33.84-0, 32.59-0, 34.21-0, and 9.47-0 respectively. After the investigation, it is evident that maximum distance of 14 km is

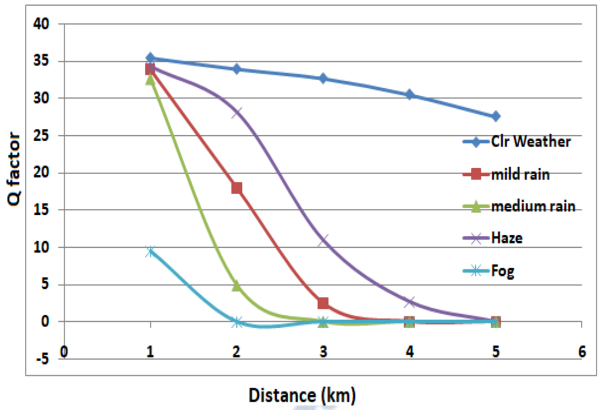


Fig 4: Representation of spectrum sliced FSO in terms of Q vs Distance for diverse weather conditions

covered under clear weather, 3.5 km under haze, 1.2 km under fog, 2.8 km under mild rain and 1.7 km under medium rain.

Figure 5 represents the Quality for diverse weather condition when distance is changed from 1-5 km. Clear weather affects the signal of FSO with very negligible attenuation and within acceptable limit of BER system cover 14 km and significant degradation is seen when frozen water droplets are there in weather (Fog) where system cover only 3 km within acceptable BER. Reason for the increase in errors is weather instabilities, attenuation, dispersion and scattering of light.

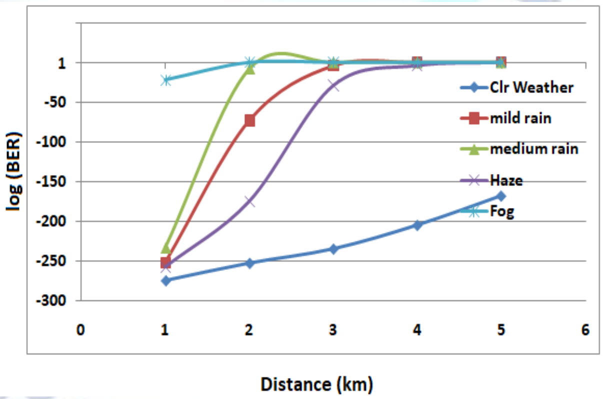
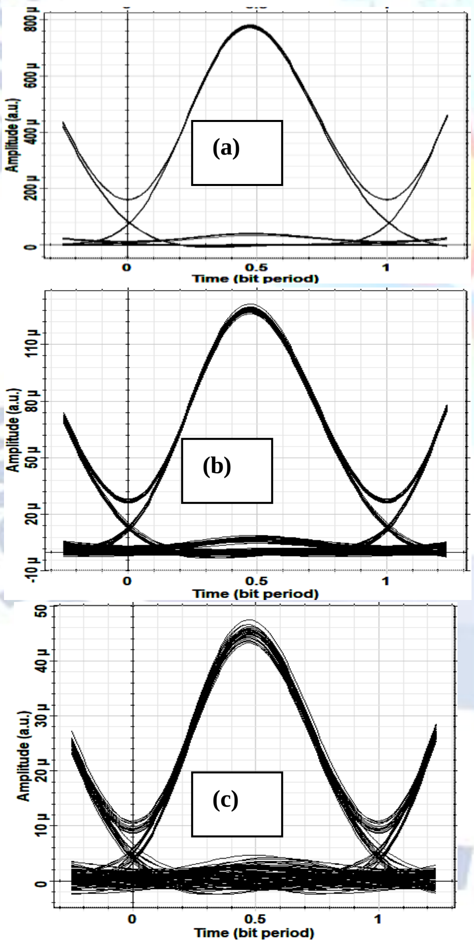


Fig 5: Representation of spectrum sliced FSO in terms of log BER vs Distance for diverse weather conditions

Separation of signals after the transmission through FSO is accomplished with the help of de-multiplexer and four individual signals are taken. All the signals then passed through photodetector for the electrical data onversion and further processed with noise removal with low pass filter. A 3-R regenerator placed after LPF for re-timing, re-shaping and re-amplification followed by BER analyzer.

Table 2 Different values of log BER and Q factor for varied distances in proposed system (clear weather)

Distance (km)	SS-FSO	
For 1 mrad Beam divergence	Q-factor	Log (BER)
1	35.37	-274
2	33.89	-252
3	32.63	-234
4	30.47	-204
5	27.54	-167



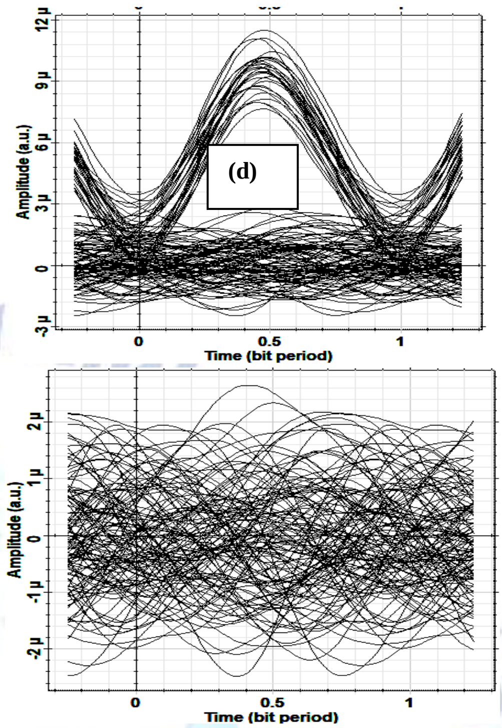


Fig. 6 Eye diagram for (a) Clear weather (b) Haze (c) mild Rain (d) medium rain (e) Fog

In order to access the final Q factor and bit error rate, bit error rate analyzer is essential component which is placed in the end of receiver. Figure 6 depicts the eye diagrams for diverse weather conditions such as (a) Clear weather (b) Haze (c) mild Rain (d) medium rain (e) Fog. It is perceived that the eye opening is maximum in case of clear weather, and worst in fog. Eye opening trend in terms of wide opening is like clear weather, haze, mild rain, medium rain and fog.

V.CONCLUSION

A high speed 5 Gbps spectrum sliced free space optical channel is demonstrated in proposed work based on self phase modulation in semiconductor optical amplifier. A Semiconductor Optical Amplifier (SOA) is channel for the generation of high power wide band spectrum for spectrum slicing. Analysis has been carried out for different atmospheric instabilities such as clear weather, haze, mild rain, medium rain, and fog. Maximum link range is observed in the case of clear weather is 14 km and the system works for 1.2 km in the case of Fog. Dense channels spacing and 4 channels are considered in the work and system is promising, low cost architecture for high speed FSO communication. BER for SS-WDM FSO at 5 km is in the case of clear weather calculated as 10-167.

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