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Simulative Investigation of 32x5Gb/s DWDM-FSO System Using Semiconductor Optical Amplifier Under Different Weather Conditions

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***Abstract*— Free space optics (FSO) technology has many advantages such as high data rate/ speed, and bandwidth. Despite of these, it has the drawback of attenuation offered by the different weather conditions, which can degrade the system's performance. In this paper, 32x5Gb/s channel DWDM-FSO system has been designed and investigated using two types of receivers under worst weather conditions and also achieved the maximum possible link range with low Bit Error Rate (BER) by using semiconductor optical amplifier with APD receiver. It has been realized that the system can operate successfully for the transmission up to 391 km with PIN receiver while with APD receiver; the transmission distance can be extended to 439 km under clear weather condition. Results showed that there is major improvement in transmission distance and quality factor under worst weather conditions. The findings demonstrated that such a DWDM FSO communication can provide the advantages of optical wireless links for long transmission distance and high data rate.**

Keywords*— Free Space Optics, Bit Error Rate, semiconductor optical amplifier, wavelength division multiplexing.

I. INTRODUCTION

The ever increasing bandwidth requirement of present communication systems is the driving force behind research in free space optics [1]. Free space optical communication guarantees abundant bandwidth, which translates into high data rate capabilities. Free Space Optics (FSO) is a communication technology that uses light as carrier and free space as medium to transfer information between transmitter and receiver separated by certain distance. FSO link is a wireless link between a transmitter and a receiver in optical communication system.The data which has to be transmitted is modulated on the intensity, phase and frequency of the carrier signal [2]. It has various advantages over conventional fibre optical system such that the capital investment for the installation of FSO system is less than a fifth as compared to ground based fiber optic technology [3]. The most important advantages of using FSO are high data rate, low bit error rate, easy to install, no RF license and immunity to electromagnetic interference. But the atmospheric attenuation is key issue faced by FSO systems which affect the system link performance. It occurs due to fog and haze mostly but it also depends upon dust and rain. Humidity, water-vapours, signals absorption, smoke, beam scintillation, spreading and wandering are also some of the factors which can affect the FSO system performance [4]. FSO systems operate in the infrared (IR) range of spectrum. It desires an unobstructed line-of-sight between the transmitter and receiver for proper operation of an FSO system. FSO systems operates around 850 and 1550 nm wavelengths and the frequencies corresponding to this range of wavelengths is around 200 THz.1550nm wavelength is preferred because of more eye safety and reduced solar background radiation[5]. Some common applications are metro network extensions, Wireless Video surveillance and monitoring, last-mile access, disaster recovery, Security, enterprise connectivity, fiber backup, backhaul, service acceleration and broadcasting applications [6]. The bit error rate (BER) and maximum quality factor are most important factors which decides the quality of transmission of any system [1]. A BER of data increases with the increase in attenuation [7].

The main objective of any communication system is to increase the transmission distance and speed. In the field of FSO communication, the wavelength division multiplexing (WDM) promising technique to overcome atmospheric attenuation and has high-capacity so high data rate with long distance transmission is also possible [5].

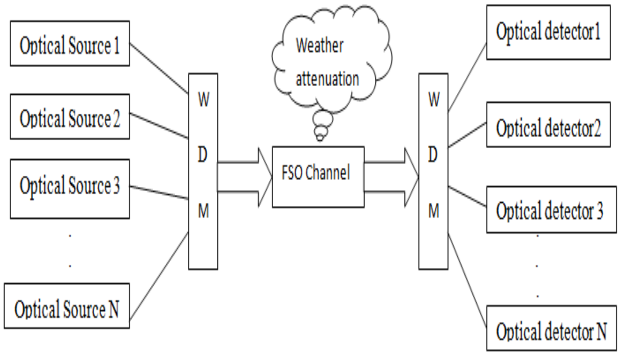

Fig. 1 FSO-WDM System

It is a multiplexing technique in which the multiple optical signals are multiplexed on a single medium using different wavelengths as shown in figure1. So WDM approach can be applied in FSO systems to maximize bandwidth usage in cheaper way [8]. WDM system is designed to overcome the problem of FSO signal degradation due to atmospheric disorder in order to achieve high data rate and maximum link range [9]. The amplification of optical signal can be done by optical amplifiers such as RAMAN, EDFA or SOA [10]. In this paper SOA is used for amplification of optical signal because of its unique properties such as Size of SOA is compact as compared to erbium doped fiber amplifiers (EDFAs) and Raman optical Amplifiers, High-speed capability, low switching energy [11]. SOA amplifiers have huge BW & can operate at 800, 1300, and 1500 nm wavelength regions. All these properties makes SOA is good choice for optical amplification [11] [12]. Laser power has plays important role in designing any system; so lesser this value, higher will be the quality of system [1].

In this paper, the work has been extended from work reported in [1], [2] by presenting less input power requirement, improved transmission distance with low bit error rate (BER) and high Q factor by using efficient optical amplifier under worst weather condition . From the results, it has been analyzed that by using SOA as a amplifier, the system performs better in terms of bit error rate and quality factor with increased link distance as compared to [1] and [2].

The rest of the paper is organized as follows: Section II described the simulation setup. In Section III simulation results have been reported and conclusion is given in Section IV.

II. SIMULATION SETUP

Fig. 2 shows the simulation design of 32-channel WDM-FSO communication system with100GHz channel spacing. Fig. 3 shows the components of WDM Transmitter. The system is designed in opti-system software. FSO system has three basic sections i.e. Transmitter, FSO channel, and Receiver. The transmitter part consists of Pseudo-Random Bit Generator, NRZ Pulse Generator, CW Laser array, WDM multiplexer and Mach-Zehnder Modulator. NRZ Pulse generator converts the Binary sequence of data in to electrical signal. The output of CW laser array source is given to WDM Multiplexer. The outputs of data source and WDM-MUX are applied to the Mach–Zehnder modulator which modulates the intensity of optical signals from the optical source array. FSO link consists of transmitter FSO channel and receiver. The output optical signal of modulator is transmitted over FSO channel under different weather conditions.

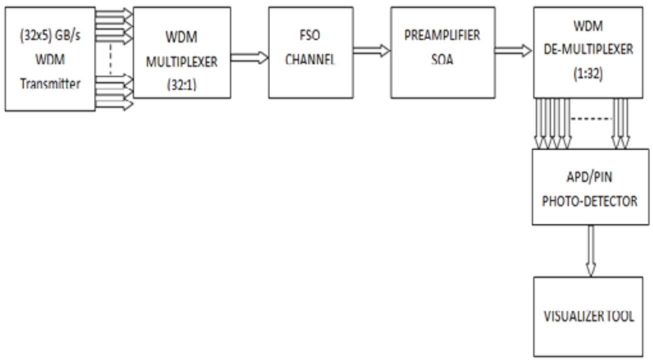

Fig. 2 Simulation setup of 32-channel WDM over FSO communication system.

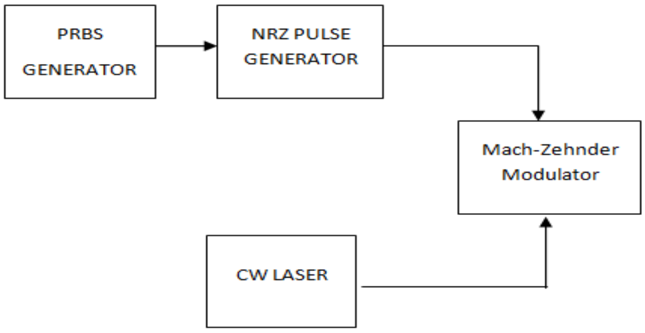

Fig. 3 Components of WDM Transmitter

Table I. Simulation parameters

Parameter	Value
Bit rate	5 Gbps
Laser wavelength (λ)	1550 nm
Cw array laser frequency	193.1-196.2THz
Transmitter aperture diameter	10 cm
Receiver aperture	20cm
Beam divergence	1 mrad

At the receiver side firstly the SOA pre-amplification is done to increase the signal strength then optical WDM-Demultiplexer is used to separate these different signals. Select selection is used next to the output of WDM Demultiplexer. APD or PIN detector is used to detect the optical signal and converted into electrical form. Now Low pass Bessel filter with 1.8GHz bandwidth is used to filter the signal and then to measure the error of the signal a BER analyzer is used. With proper parameters, WDM based FSO system can be optimized to achieve a

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On 21st April 2017
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maximum link range of operation. These system design parameters are given in Table (I). The quality of the received signal is considerably depends on the conditions of the FSO channel and the WDM system design.

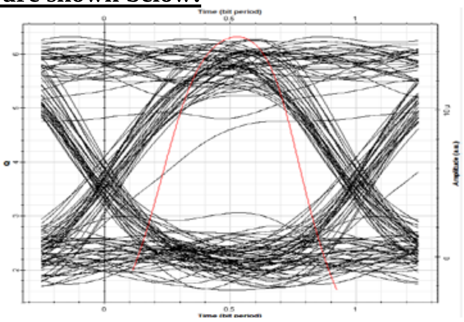
III. SIMULATION RESULTS AND DISCUSSIONS

Maximum range which can be transmitted at minimum BER is increased by using SOA pre-amplification. In this paper, simulated results demonstrate the performance of 32 channel DWDM-FSO link at 5Gbps data rate along with APD receiver under worst weather conditions. The two types of receivers used are PIN and APD respectively. Table II and table III illustrate the results for various weather conditions for APD and PIN receiver respectively. It can be seen that for the clear weather condition the Maximum achievable link range of 539 km is achieved for the targeted value of minimum BER (10^{-10}) by using SOA pre-amplifier along with APD receiver while a range of 6.01 km is achieved at BER of 3.37196e-10 in heavy rain condition. Fig. 4 shows the eye diagram of APD receiver with maximum range of 539 km at BER of 1.47364e-10 and fig.5 shows the eye diagrams for PIN receiver under different weather conditions and the maximum Range of 391 km is achieved under very clear weather condition at acceptable minimum BER. The eye opening and BER for the clear, light haze, heavy haze, light rain and heavy rain for APD and PIN are shown in Fig. (3) and Fig. (4) respectively. Large eye opening results to less BER and good communication. The results shows that Maximum link distance is achieved at acceptable minimum BER values for different atmospheric conditions with optimized values of laser power and data rate.

Table II: Performance analysis of system under different Weather conditions with APD receiver

Weather Condition	**Attenuation (dB/m)**	**Laser Power (dBm)**	**Max. Link Range (Km)**	**BER**	**Q-Factor**
Very clear	0.15	10	539	1.47364e-10	6. 30082
Clear	0.299	10	287	1.72864e-10	6.27981
Light haze	0.61	10	150.2	1.77267e-10	6.26912
Heavy haze	2.62	10	39.3	1.86271e-10	6.26185
Light rain	6.80	10	16.27	2.47346e-10	6.21754
Heavy rain	19.77	10	6.01	3.37196e-10	6.16877

Eye diagrams at different weather conditions using APD receiver are shown below:



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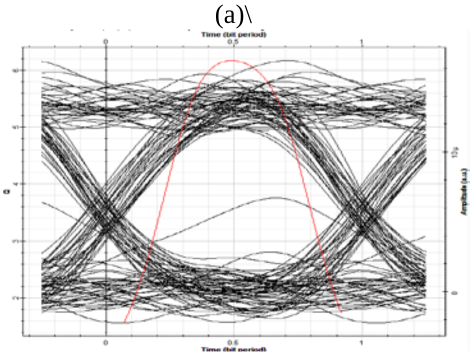

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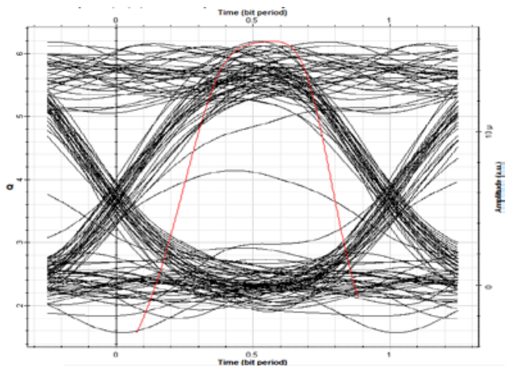

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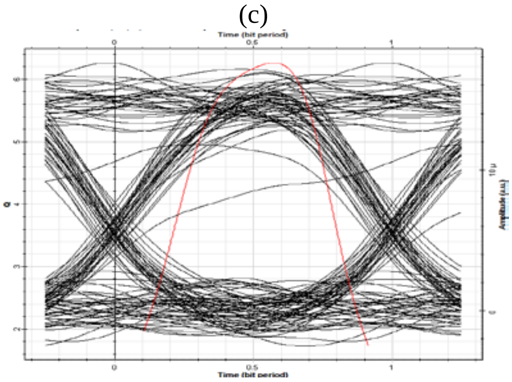

(d)

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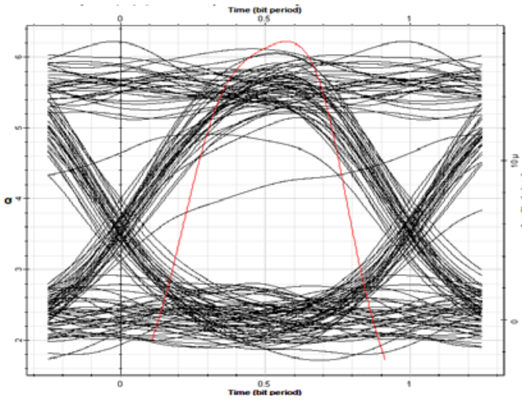

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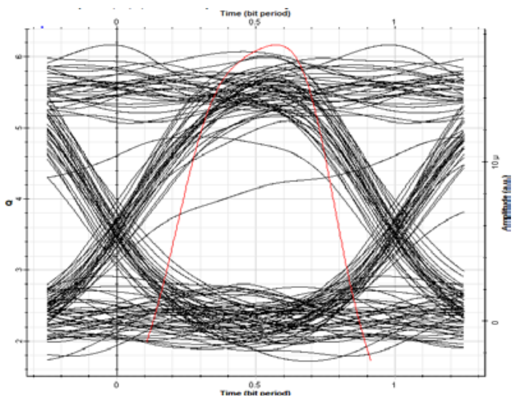


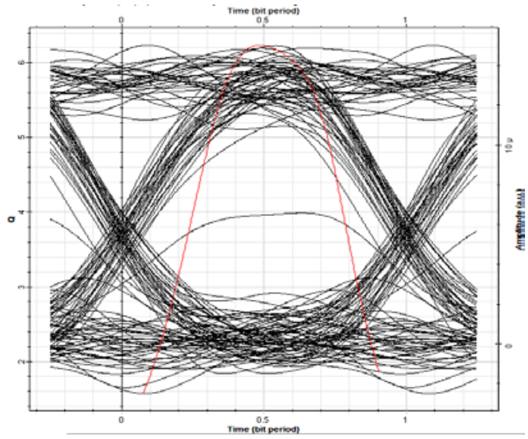
(f)

Fig. 3. Eye diagrams for different conditions: (a) very clear sky, (b) clear sky, (c) light haze, (d) heavy haze, (e) light rain& (f) heavy rain

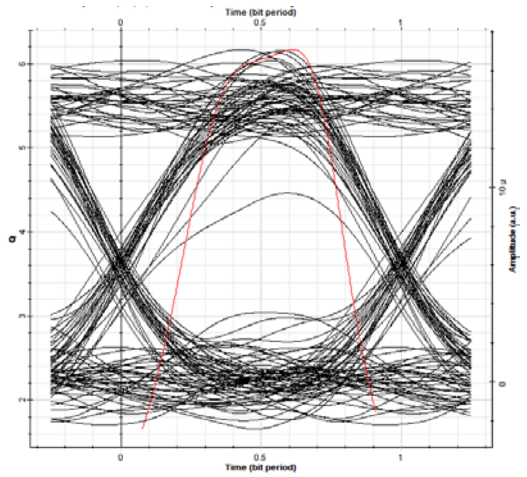
Table III: Performance Analysis of System Under Different Weather Conditions with PIN Receiver

Weather Condition	**Attenuation (dB/km)**	**Laser Power (dBm)**	**Max. Link (Km)**	**BER**	**Q. Factor**
Very clear	0.15	10	509	2.1066e-10	6. 24591
Clear	0.299	10	212.5	3.4923e-10	6.16563
Light haze	0.61	10	144.4	3.6933e-10	6.15925
Heavy haze	2.62	10	37.44	3.6805e-10	6.14876
Light rain	6.80	10	15.75	5.9924e-10	6.07914
Heavy rain	19.77	10	5.85	8.169 e-10	6.02965

<u>Eye diagrams at different weather conditions using PIN receiver are shown below:</u>



(a)



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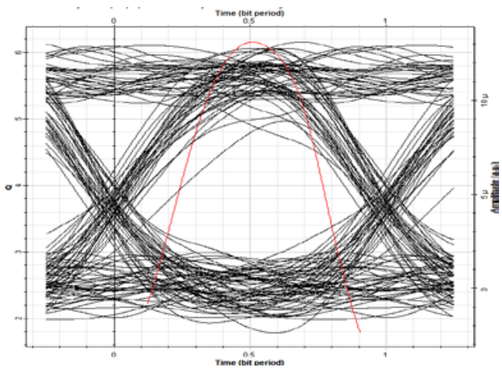

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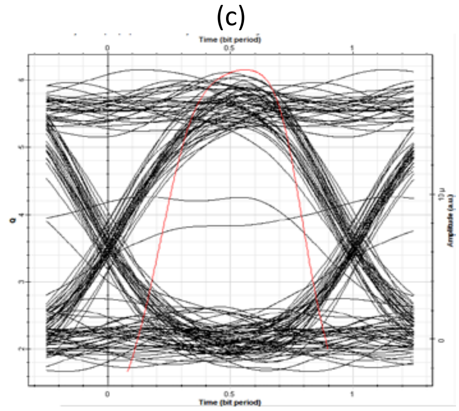

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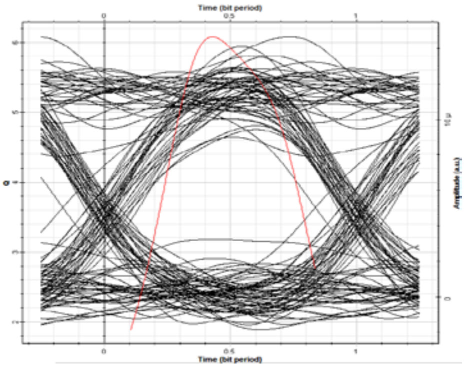

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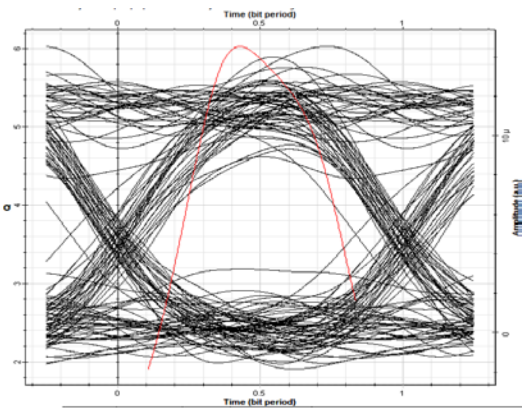
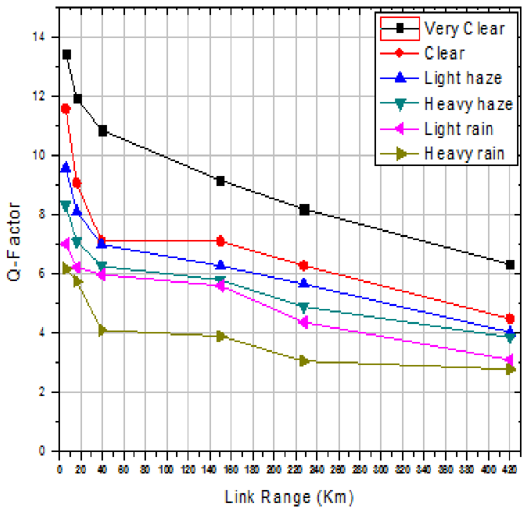
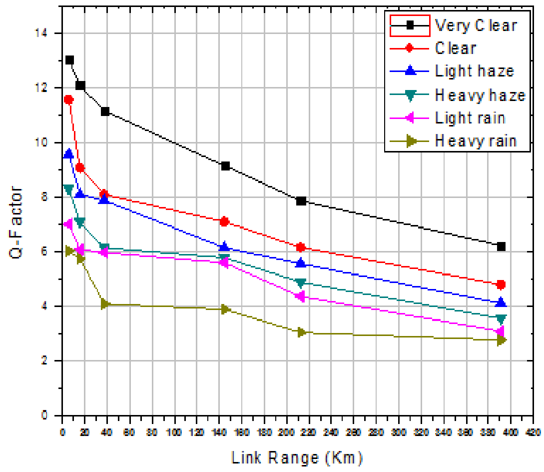


(f)

Fig. 5.Eye diagrams for Different Weather Conditions: (a) Very Clear (b) Clear (c) Light Haze (d) Heavy haze (e) Light rain & (f) Heavy rain



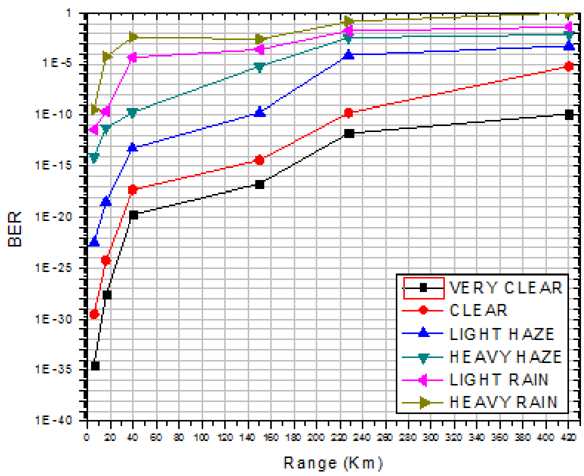
(a)



(b)

Fig.6. Q-factor v/s range (a) using APD receiver (b) using PIN receiver

The graphs in Fig. 6 demonstrate the Q. factor with respect to link distance under different weather conditions for APD and PIN receiver respectively. The increase in the attenuation leads to decrease in Quality factor.



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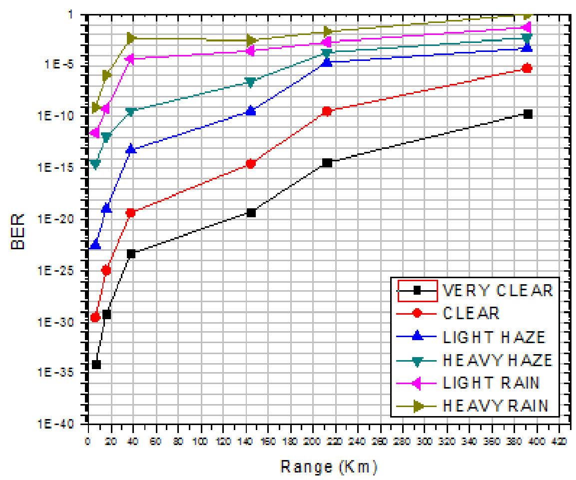

(b)

Fig.7. BER v/s link range (a) using APD receiver (b) using PIN receiver

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Fig. 7 shows the graphs of the BER v/s link range under different weather conditions for APD and PIN receiver respectively. From the graphs, it has been observed that the APD receiver performs better than PIN receiver under different atmospheric conditions.

IV. CONCLUSION

In this paper, the transmission performance of 32 x 5 GB/s channel WDM-FSO link using NRZ modulation along with two types of receivers, APD and PIN receiver using SOA pre-amplification has been investigated under the influence of worst weather conditions. This paper investigated the 32x5 Gbps DWDM over FSO link using NRZ modulation. However, transmission range increases with the decreasing factor of attenuation in DWDM over FSO communication system. From simulation results, it has been observed that the DWDM-FSO system can work up to 420 km with BER of (greater or equal to 10^{-10}) by using SOA amplification. It is concluded that the system with pre amplification along with APD receiver, FSO system can work up to 420km with acceptable BER of 10^{-10} under clear weather condition. With the increase in atmospheric attenuation as the weather situation gets worst, the maximum achieved distance can be extended up to 6.01 km and 5.85 km for heavy rain condition for APD and PIN receivers with acceptable BER of 3.37196e-10 and 8.15619 e-10 and Q-factor of 6.16877 and 6.02965 respectively. So SOA amplifier with APD receiver shows the better link performance as compared with PIN receiver because the maximum achievable distance is quite high and BER performance is better.

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