Wavelength Division Multiplexing /Multi-Beam Free-Space Optics Link for Different Rain Attenuations with EDFA

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ABSTRACT
In Today's world Free Space Optics has much importance as a cost, license free and large bandwidth for high data rates applications. Single and multiple beams Free Space Optics systems are designed and examine to produce the best system for handling the effect of atmospheric climate conditions. Combination of Wavelength Division Multiplexing and multi-beam free-space optics is a favorable technique to overcome medium and heavy rain attenuations, that provide a expressive improvement in the link distance, received optical power, and Q-factor. This paper describe design and simulation of combination of Wavelength Division Multiplexing based multi beam Free Space Optical link with Erbium Doped Fiber Amplifier for different rain conditions and analyses the performance of the system. In this paper, a combination of sixteen channels, Wavelength Division Multiplexing and multi-beam Free Space Optics network having sixteen wavelengths with standard channel spacing of 0.8 nm (100 GHz). And an addition of Erbium Doped Fiber Amplifier is to improve the strength of weak signals. The system performance is analyzed with the help of Bit Error Rate, received optical power, Q factor and eye diagram.

Keywords
EDFA, BER, Q-factor, Combination of WDM and multi-beam FSO

1. INTRODUCTION
Free-space optical communication is a line of sight technology in which modulated beam of visible or infrared light is transmitted over free space for telecommunications. It enables optical transmission of voice, data and video communications up to 2.5 Gbps without deploying optical fiber cable. FSO bring many advantages to modern communications including high data rate, large bandwidth, low power, license free spectrum, higher safety of transmission due to narrow optical beams etc. The increasing demand for high-capacity telecommunication links and the speed limitation of single-wavelength links has resulted in a widely use of Wavelength Division Multiplexing (WDM) in advanced light wave networks. Hence WDM network can be used in FSO systems to improve the system performance with high speed and long distance. The combination of WDM and multi-beam FSO network are used to provide a meaningful improvement in the distance of link, received power and BER.[1] And Erbium doped fiber amplifier is used to amplify the distorted signal caused by rain attenuations as it gives better performance than the usual electronic amplification.[5] Geometric losses and atmospheric attenuation are the main causes of degradation in the link but there are other factors also like scintillation, turbulence and multipath fading.[6]

The prime aim of this research work is to experimentally characterize and investigate the atmospheric channel effects on the performance of FSO link. The simulator enables to study the effects of atmospheric impairments, *e.g*. rain (heavy or medium), fog, turbulence and smoke on the optical beam propagating through the FSO channel for a range of wavelength. The simulation tool used is OptiSystem V 0.7

2. EXPERIMENTAL SETUP
2.1 Combination of WDM and multi-beam FSO system
In the paper, the advance performance of the system can be examined by using EDFA with combination of WDM and multi-beam FSO in a link. The performance can analyze on two climate conditions are heavy and medium rain. Fig.1 Block diagram of Combination of WDM and multi-beam FSO system

In a transmitter and receiver block, the main components used are: Laser Diode, Mach-Zehnder Modulator, Wavelength Division Multiplexer Avalanche Photo Detector, Free Space Optics, End User, Optical Splitter, Optical combiner, Low Pass Filter. The Combination of WDM and multi-beam FSO system is used for 16 channels with optical splitter and combiner. And in a base station have 16 transmitters which give optical carrier signals at various wavelengths ranges from 1535nm to 1550nm with channel spacing of 100GHz (0.8nm). For link improvement of combination of WDM and multi-beam FSO system, have 16 subsystems. Each subsystem comprise of PRBS generator and NRZ pulse generator. A Continuous Wave laser is used with input power 7.7 dBm. The output of Non Return Zero pulse generator and Continuous Wave laser is input of MZ Modulator. From that, an optical amplifier is used to build up the signal strength. The signals are multiplexed into one downlink signal using WDM MUX carrying 16 wavelengths (1550, 1549.2, 1548.4 ....1539.6, 1538.8… and 1535) nm. The multiplexed signal is spitted into four beams using an Optical Splitter. The four beams are sent through FSO Channel. The channel has some attenuation and geometrical losses. The value of receiver aperture is large in the simulation because of higher attenuation. For heavy rain and medium rain, the attenuation values are 19.2dB/km 15.5dB/km respectively. And the spitted signals are combined by Optical Combiner. After that WDM DEMUX with same specifications of WDM MUX is used to Demultiplexer all the signals.

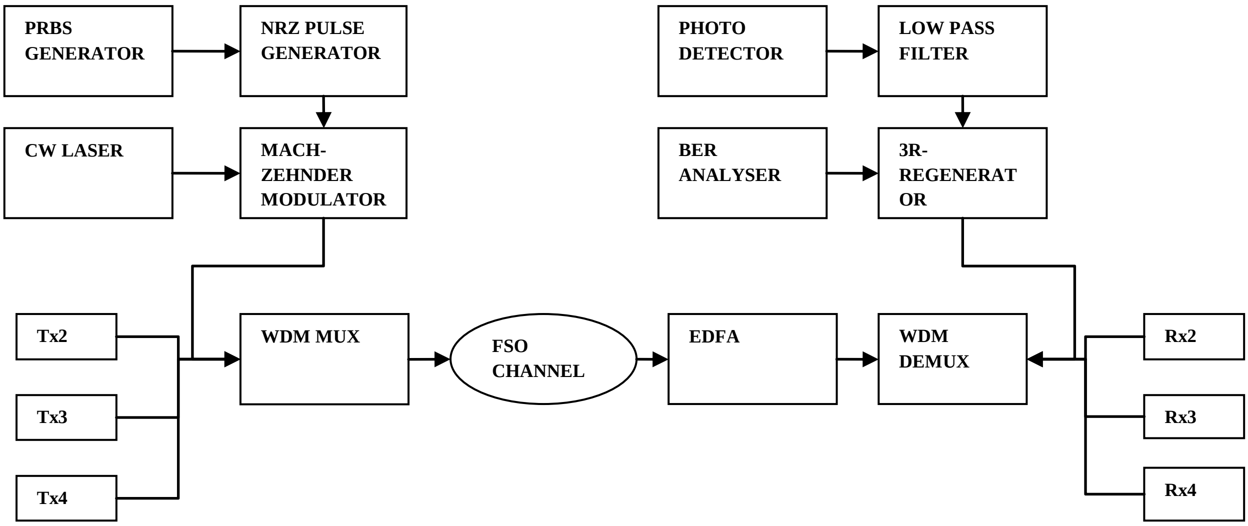

Fig.1 Block diagram of Combination of WDM and multi-beam FSO system

These signals are then sending to respective End users. End User is provided by an Avalanche Photodiode photo detector whose gain is 3 and sensitivity is 1A/W, After a APD, a low pass Bessel Filter is used. and regeneration (3R) is used to reshaping, retiming and regenerating the signals. BER analyzer and optical power meter are used to measure all the parameters for optimizing the link. In this simulation, signal attenuation has been considered as 19.27 dB/km and 15.5dB/km for heavy and medium attenuations respectively. Here, Erbium doped fiber amplifier is used to amplify the distorted signal caused by rain attenuations as it gives better performance than the usual electronic amplification. In EDFA, amplification occurs when the pump laser excites the erbium ions, whose parameters reaches to wide bandwidth, high gain, high saturation output, and low noise are the characteristics of Erbium doped fiber amplifier.

2.2 Systems with and without EDFA

There are two system designed in this project: Fig.2 System I consist of 16 channels WDM AND multi-beam FSO without EDFA and Fig.3 System II consist of 16 channels Combination of WDM and multi-beam FSO with EDFA. Comparison is done between these system by using parameter received optical power (dBm) and Q-factor.

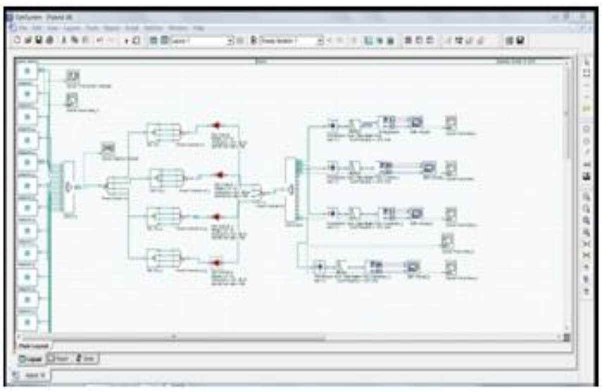

Fig.2 System I consist of 16 channels WDM AND multi-beam FSO without EDFA

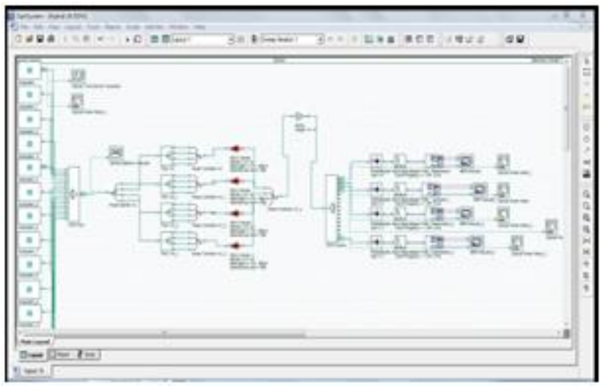

Fig.3 System II consist of 16 channels WDM AND multi-beam FSO with EDFA

Table 1 Parameters of System setup

PARAMETER	VALUE
Data Rate	2.5Gb/s
Wavelength	1550nm
Power	7.7 dBm
Gain	35 dB
Number of input ports	16
Bandwidth	10GHz
Channel Spacing	0.8 nm
Range	1000 to 4000 m
Transmitter Aperture diameter	10cm
Receiver Aperture diameter	30cm
Gain	3
Responsibility	1 A/W
Dark current	10 nA

3. RESULT

The performance of WDM AND multi-beam FSO system in the absence and presence of EDFA is analyzed in this section. While analyzing the performance of both the system I and system II at heavy rain condition, it is observed that Q-factor of System II is much better than System I as shown in Fig.4

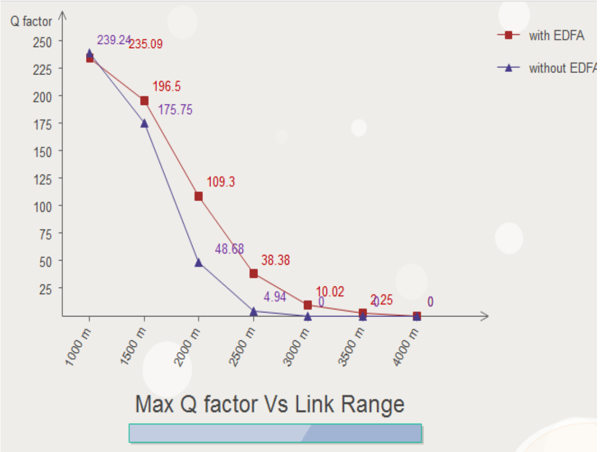

Fig.4 Max Q factor Vs Link Range

Also the received optical power in system II is more than that of System I as shown in Fig.5

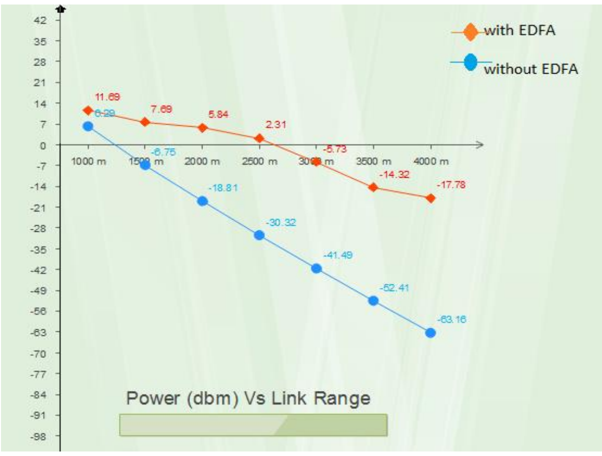

Fig.5 Power (dbm) Vs. Link Range

Here, received optical power for heavy with EDFA and without EDFA at receiver 1 is shown in Fig.6 and Fig.7

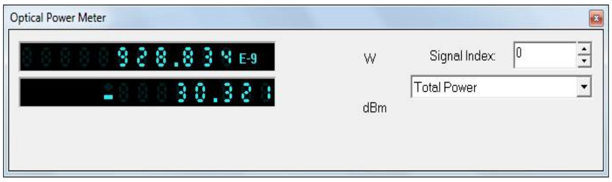

Fig.6 Power without EDFA

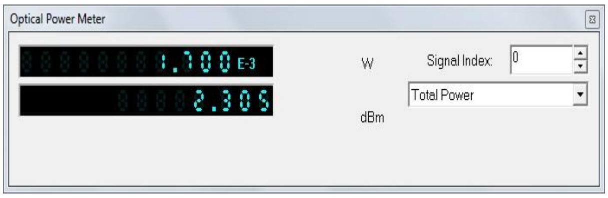

Fig.7 Power with EDFA

Eye diagram of WDM AND multi-beam FSO system under heavy rain attenuations in the presence of EDFA is shown in Fig.9. It is found that after the insertion of EDFA in WDM AND multi-beam FSO system, the system performance is improved under different rain attenuations .For heavy rain, optimized link range is 2500 m the Q factor is, without EDFA and with EDFA

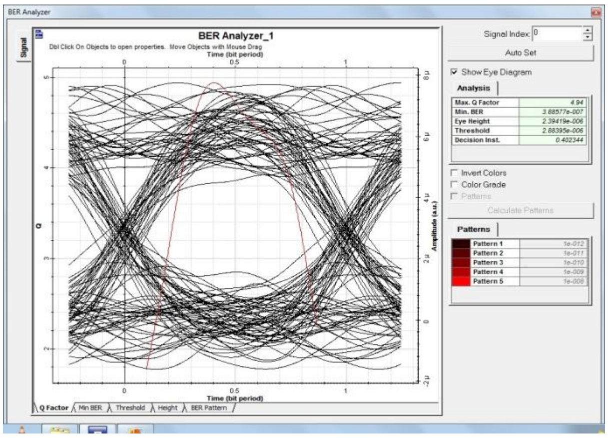

Fig.8 Eye Diagram without EDFA

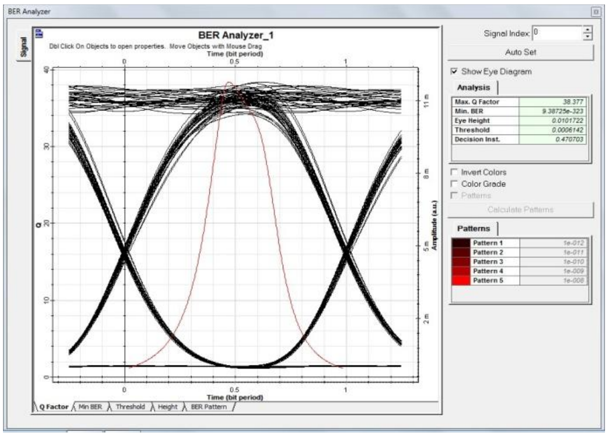

Fig.9 Eye Diagram with EDFA

Table 2 Comparison of results between with EDFA and without EDFA

	With EDFA			Without EDFA		
Link Range	**Q factor**	**BER**	**Power (dBm)**	**Q factor**	**BER**	**Power (dBm)**
1000 m	**235.091**	**0**	**11.690**	**239.241**	**0**	**6.289**
1500 m	**196.501**	**0**	**7.692**	**175.748**	**0**	**-6.750**
2000 m	**109.303**	**0**	**5.836**	**48.6838**	**0**	**-18.807**
2500 m	**38.377**	**~0**	**2.305**	**4.94**	**3.543*10^03**	**-30.321**
3000 m	**10.0197**	**1.569*10^-10**	**-5.734**	**0**	**1**	**-41.487**
3500 m	**2.2519**	**0.0100819**	**-14.324**	**0**	**1**	**-52.414**
4000 m	**0**	**1**	**-17.781**	**0**	**1**	**-63.165**

4. CONCLUSION

Free Space Optical Communication provides wide applications in all fields. Faster installation, license free spectrum, no need of digging is required in FSO communications. In this project, the simulation results in absence and presence of EDFA in the receiver side of WDM AND multi-beam FSO system are investigated. And The Combination of WDM and multi-beam FSO system has provided a major improvement. The simulation result has been observed in terms of Q factor and minimum bit error rate. A significant reduction in the values of BER and increase in the value of Q factor is observed with presence of EDFA in WDM AND multi-beam FSO system. It is concluded that the introduction of EDFA increases the accuracy and reliability of the system under rain attenuations which will be useful for real time applications. In future, the capacity of the combination of WDM and multi-beam FSO system can be increased up to 32 channels WDM.

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