Impact of Travelling Wave Semiconductor Optical Amplifier on WDM-FSO System under Fog Attenuation

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Abstract: ***Free Space Optics Technology has emerged as a key technology for the development of communication system with intrinsic high level data security. Free Space Optics technology can cooperate with Wavelength Division Multiplexing technology to provide an advanced and robust communication network by establishing optical connectivity in multiple applications. The author is focusing on primary challenge to FSO channel based network, the effect of fog attenuation, on combined WDM-FSO system. The effort in this paper is to propose an appropriate solution to this problem by the addition of travelling wave semiconductor optical amplifier with WDM-FSO system. The whole system performance will be analyzed on FSO based 8 channels WDM network through evaluation of bit error rate and received power. Visualization of eye diagram and optical spectrum will also be used for performance analysis.***

Keywords: FSO, WDM, Fog, Travelling wave semiconductor optical amplifier.

1. Introduction

One of the viable technologies in the field of communication is optical wireless communication (OWC). The technology has been emerged for next generation indoor and outdoor broadband wireless applications. Indoor OWC or Infrared optical communication and Outdoor OWC or Free space optical communication are two types of OWC. The superiority of FSO communication over infrared optical communication is the requirement of direct line of sight (LOS) and point-to-point narrow beam laser link from optical transmitter to receiver with multi-Gbps data transmission rate capacity over a distance of 1-4 km [1], [2], [3].

Wavelength Division Multiplexing (WDM), a Passive Optical Network candidate, can be integrated with FSO system in order to offer huge bandwidth capacity which ensures multiservice and multicasting opportunity [4], [11]. In this paper the author focuses on the effect of atmospheric attenuation on the integrated WDM-FSO system and proposes an appropriate way to counter fog when deploying WDM-FSO system network is through the addition of travelling wave semiconductor optical amplifier (soa) with the system architecture.

2. FSO Challenge: Atmospheric Attenuation

Atmospheric attenuation is caused by absorption and scattering processes. The covering area of FSO system is limited by it. It can be defined by Beer's law in equation (1):

$\tau\alpha = e^{-(\beta_{abs}+\beta_{scat})}R$ (1)

Where, β_{abs} = absorption coefficient, β_{scat}= scattering coefficient, R= link distance, τ=atmospheric attenuation [4], [12].

Fog is one of the most significant factors which influence the range and reliability of an FSO link more than rain and snow. It is the form of vapor which is composed of water droplets. It hampers the passage of light through a combination of absorption, scattering and reflection by reducing the levels of power density and intensity of FSO beam for longer distance [5].

3. WDM-FSO System

3.1 System Design

In this paper, the simulator software Optisystem 7.0 is used to simulate the implementation of WDM-FSO system architecture.

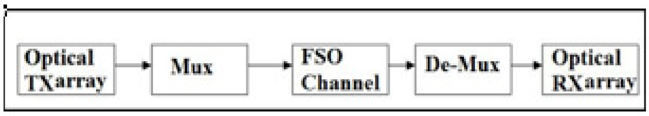

Figure 1: Block diagram of WDM-FSO system

Figure 1 shows the simulation block diagram of WDM-FSO system. Optical transmitter (TX) is the Transmission module which consists of Continuous wave (CW) laser, Pseudo random binary sequence (PRBS), Non return to zero (NRZ) electrical pulse generator and Mach zehnder modulator. In this project, the transmitter part of the simulation module uses 8 laser arrays. The modulated laser arrays are multiplexed into a single optical signal using multiplexer and then it is propagated through FSO link which is the transmission link. De-multiplexer splits the single optical signal into several optical signals. Each of the optical signals is received by each of the receiver modules. Optical receiver (RX) is the Receiver module that consists of Avalanche Photodetector (APD), Bessel low pass filter and 3R Regenerator [6], [4].

In this simulation, FSO channel is considered under the effect of fog attenuation. When the signal travels through FSO channel, the signal becomes weak due to fog atmospheric condition. Therefore, the system requires an optical amplifier immediately after the FSO channel in order to improve the strength of the weak signal due to its low signal to noise ratio or high bit error rate caused by fog.

In this project, 3 types of optical amplifier including EDFA, Raman and Travelling wave semiconductor optical amplifier are used. EDFA or Erbium Doped Fiber Amplifier amplifies a weak optical signal when it is pumped by semiconductor lasers to a high energy state and then drop to a lower state and releases its energy. Raman Amplifier also amplifies the weak signal by pump laser and additionally by directional coupler. The amplification of raman amplifier takes place inside the transmission fiber. Travelling wave soa is an optical amplifier which causes polarization sensitive type amplification by the occurrence of a change in the carrier density of its material when a weak optical signal is injected into it. The carrier density occurs by releasing some of the energies of its electrons in the form of photons to adjust with the initial wavelength of the weak optical signal [7],[8],[9],[10].

3.2 Design Parameter

Several Specifications for WDM-FSO system architecture under fog weather condition are represented in Table 1.

Table 1: WDM-FSO System Architecture Specification

Parameters	*Value*
Transmission Bit Rate	10000000000 bits/s
Link distance	1 km
Optical transmitted Power	8.66 dB
Transmitter aperture diameter	2.5 cm
Receiver aperture diameter	8 cm
Beam divergence	2 mrad
Transmitter loss	1.8 dB
Receiver loss	1.8 dB
Sensitivity of Receiver	-18 dBm
Signal attenuation (Fog)	84.904 dB/km
Length of EDFA	5 m
Forward Pump Power of EDFA	100 mW
Length of Raman Amplifier	1 km
Power of Pump Laser (Connected with Raman Amplifier)	100 mW
Injection current of Travelling wave SOA	0.305 A
Dark current	10 nA
Gain of photodetector	3
Responsivity of Receiver	1 A/W

3.3 Performance Parameter

Few parameters, received power and maximum bit error rate (BER) will be used for the evaluation of WDM-FSO system performance. Maximum BER is calculated using equation (2) by using the obtained maximum Q factor from the simulation result [6].

$$BER \approx \frac{1}{\sqrt{2\pi Q}} \exp\left(\frac{-Q^2}{2}\right) \quad (2)$$

3.4 Results

Table 2 shows the effect of using travelling wave soa on the performance parameters of WDM-FSO system. The used frequency of channel 1 corresponding to optical transmitter in implemented model for simulation is 193.1 THz. Number of implemented channels corresponding to optical transmitters are 8 and the spacing between the implemented two consecutive channels corresponding to optical transmitters is set to 100 GHz. Table 2 shows the simulation output of 8 channels corresponding to optical receivers in implemented WDM-FSO system architecture under fog attenuation. The whole simulation output is shown in relation to insertion of different amplifiers in the system configuration.

Fig. 2 and 3 show the effect of different wavelength on BER corresponding to different channels (1 to 8) of the WDM-FSO system performance. Fig. 4, 5 and 6 show the eye diagrams of a particular channel for the placement of EDFA, raman amplifier and travelling wave soa in the system configuration. The similar comparison result is also obtained from other channels too. The comparison shows that the insertion of travelling wave soa in the system architecture ensures wider eye opening than EDFA and raman amplifier.

Fig. 7 and 8 represent the optical spectrum before and after amplifying the signal by travelling wave soa. Comparison of these two figures justifies that the replacement of travelling wave soa immediately after FSO channel amplifies the power level for each of channels from -100 dBm to ~ 12 dBm.

Table 2: Simulation output of WDM-FSO system architecture under fog attenuation

No of Channel	*Minimum BER*			*Max BER*	*Received Power, dBm*		
	EDFA	*Raman*	*SOA*	*SOA*	*EDFA*	*Raman*	*SOA*
1	1	1	1.36591e-005	.0059e-005	-19.377	-100	-10.739
2	1	1	2.47979e-006	.7550e-006	-19.134	-100	-10.847
3	1	1	6.34338e-006	.4672e-005	-18.588	-100	-10.827
4	1	1	6.26624e-006	.4232e-005	-18.408	-100	-10.807
5	1	1	6.806e-006	.5538e-005	-18.132	-100	-10.886
6	1	1	5.99222e-006	.3876e-005	-18.507	-100	-10.827
7	1	1	6.80871e-006	.5485e-005	-18.256	-100	-10.815
8	1	1	7.37735e-006	.6719e-005	-17.742	-100	-10.808

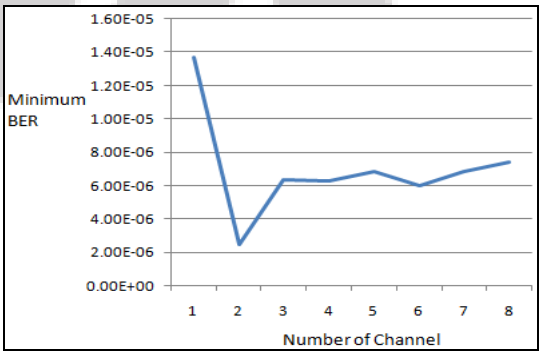

Figure 2: Graphical Representation of Minimum BER in relation to increasing wavelength for corresponding channel (1-8)

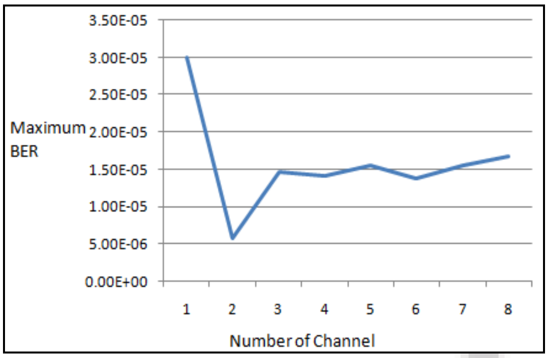

Figure 3: Graphical Representation of Maximum BER in relation to increasing wavelength for corresponding channel (1-8)

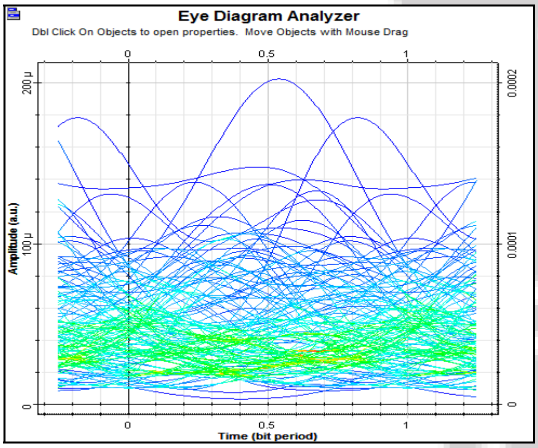

Figure 4:Eye Diagram of a particular channel corresponding to a optical receiver in the presence of EDFA

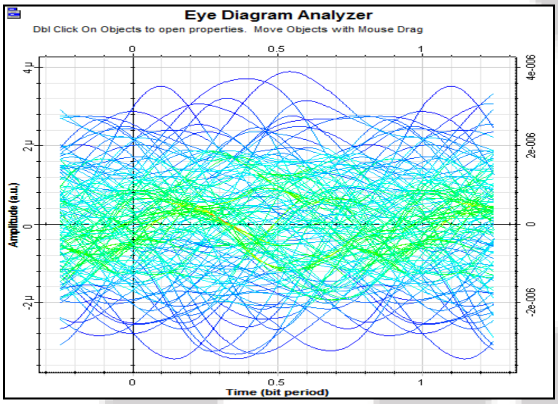

Figure 5:EyeDiagram of a particular channel corresponding to a optical receiver in the presence of Raman Amplifier

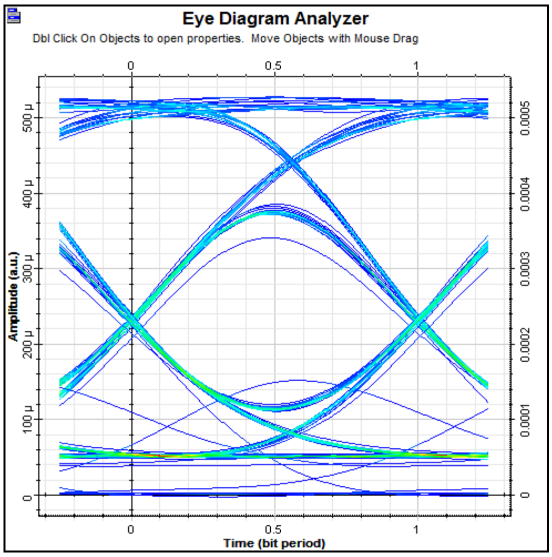

Figure 6: EyeDiagram of a particular channel corresponding to a optical receiver in the presence of SOA

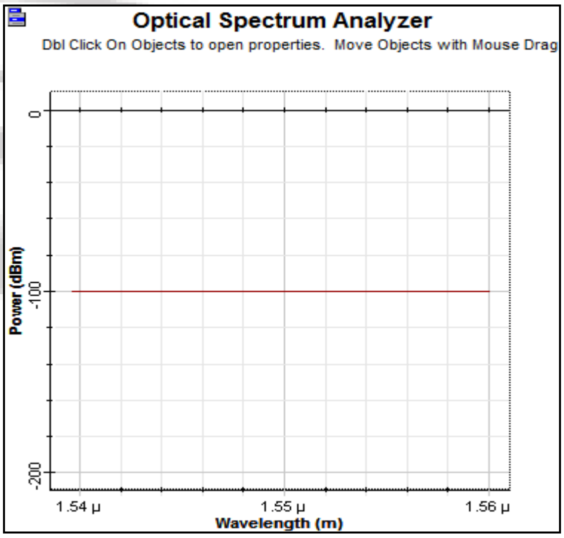

Figure 7: Optical Spectrum of 8 channels corresponding to optical receivers without the presence of SOA

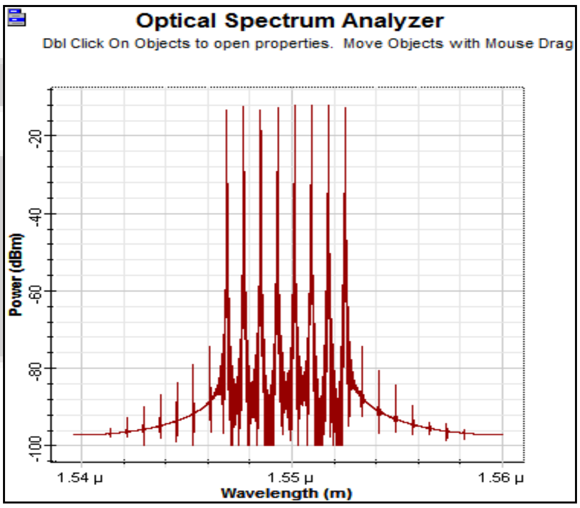

Figure 8: Optical Spectrum of 8 channels corresponding to optical receivers with the presence of SOA

3.5 Discussion

From Table 2 shown above, BER appears to decrease and received power appears to increase after the insertion of travelling wave soa in the system configuration. The signal attenuation in the range of ~85 dB/km influences the system performance. Therefore the signal needs to be amplified due to its low signal to noise ratio or high bit error rate. The comparison of Table II proves that the distorted signal due to fog attenuation is amplified more suitably by travelling wave soa than other amplifiers including EDFA and raman amplifier. From the Table 2, the travelling wave soa gives the lowest minimum and maximum BER of 2.47979e-006 and 5.7550e-006 respectively which are at channel 2 along with highest received power of -10.886 at channel 5. The graphical simulated result from Figure 2 and Figure 3 show that BER for all channels are almost same which proves that crosstalk and interface of WDM network are avoided because of 100 GHz spacing between the channels.

From the result in Figure 4 and 5, eye diagrams in relation to the insertion of EDFA and raman amplifier show that the amplitude in data signal is completely distorted. No communication link is established here. In presence of travelling wave soa in Figure 6, it can be predicted that eye opening increases. From Figure 6, addition of travelling wave soa produces a better eye diagram of eye height 0.000112653. The improving of eye height in the simulation result is surely assessing the higher data capability of transmitting and receiving.

From Fig. 7 and 8, travelling wave soa ensures that that travelling wave soa is well suited after FSO channel in WDM-FSO network due to its power amplification capability. From Result analysis, the author shows that Travelling Wave SOA is an efficient device for the amplification of a weak optical signal. It can be concluded that because of the polarization sensitive type amplification, necessity of travelling wave soa in WDM-FSO system is feasible.

4. Conclusion

The author has investigated the performance on 8 channels WDM based network in FSO link to provide multiple services through FSO technology. Fog attenuation is the main obstacle between transmitter and receiver in the evolution toward optical access based WDM network. The author focuses on this problem and also suggests a solution by the addition of travelling wave soa.

This link design with parameter specification would help to plan for the implementation of higher bandwidth WDM-FSO system. Since FSO transmission is totally dependable on weather condition, WDM-FSO system can be established with travelling wave soa according to its amplification capability of the weak signal.

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Author Profile

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