Investigation on Multi-Beam Hybrid WDM for Free Space Optical Communication System

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Abstract- Free Space Optical (FSO) communication is being realized as an effective solution for future accessing networks, offering light passed through air. In this paper, multi-beam Hybrid Wavelength Division Multiplexing (HWDM) is designed for FSO and its parameters such as bit error rate and receiver sensitivity are analyzed with respect to link distance. For investigation, four CWDM (1510nm, 1530nm, 1570nm and 1570nm) channel and eight DWDM channels (1537.4nm, 1538.2nm, 1539nm, 1539.8nm, 1540.6nm, 1541.4nm, 1542.2nm and 1543nm) are considered whose corresponding channel spacing is 20nm and 0.8nm, respectively. In addition, the impact of BER and receiver sensitivity are analyzed while increasing the number of beams between transmitter and receiver, and the EDFA amplifier is incorporated at the receiver end in order to enhance the receiver signal strength. The maximum signal traveling distance by implementing EDFA at the proposed design is investigated. The system is designed to handle the quality of transmission for 12 user, each at the data rate of 2.5Gbps.

Key Words: Free space optical communication, Hybrid Wavelength Division Multiplexing, multi-beam, bit error rate, erbium doped fiber amplifier, link distance.

1. INTRODUCTION

Now a days Free Space Optical communication (FSO) is one of the major topics in the world of wireless and optical communication and it is the line of sight technology. Highly narrow beam is used in spite of the high data rate, which uses highly narrow beam propagating in free space to transmit data between two or more points. FSO technology is as same as the fiber optics communication [1]. However, FSO has the advantages such as low cost, security not necessary, license free, attractive solution for high data rate and voice transmission [2]. The quality and data rate of FSO are depends on weather conditions, and atmospheric attenuation namely on rain, fog and snow [3].

Wavelength Division Multiplexing is employed in FSO to transmit various wireless service signals independently at the same time [4]. There are two types of WDM, such as Dense Wavelength Division Multiplexing (DWDM) and Coarse Wavelength Division Multiplexing (CWDM). DWDM channels are with the channel spacing of 1.6nm/0.8nm/0.4nm and CWDM channels are with channel spacing of 20nm [5]. In CWDM system the wavelength range is 1260nm-1625nm and for DWDM is 1470nm-1625nm. The crosstalk of the DWDM channels is higher than CWDM systems as DWDM channel spacing is narrower. The combination of CWDM and DWDM signals are transmitted through free space in hybrid WDM-FSO system [6].

In the literature, so far there is no much attempt is made in hybrid WDM-FSO. However there are some attempts is made to for hybrid WDM using single beam [7-13] and multi-beam concept where they have considered only DWDM channels with the channel spacing of 0.8 nm over the wavelength range of around 850 nm and 1550nm. Also, the authors have not considered CWDM channels [14-18]. In this work, the FSO system is designed by considering eight DWDM channels and four CWDM channels.

In this paper multi-beam hybrid WDM-FSO system is designed and the network parameters such as BER and Receiver sensitivity are analyzed with respect to link distance. Initially, the maximum link distance at very clear condition is estimated while increasing the numbers of beams between transmitter and receiver. Further, the impact of transmission distance is investigated by positioning Erbium Doped Fiber Amplifier (EDFA) at the receiver end.

The remaining part of the paper is organized as follows: The design of multi-beam hybrid WDM-FSO system is discussed in section 2. The effect of link distance, BER, receiver sensitivity is analyzed by increasing number of beams between transmitter and receiver, which is reported in section 3. Finally, section 4 concludes the paper.

2. MULTI-BEAM HYBRID WDM-FSO SYSTEM MODEL

The proposed multi-beam hybrid WDM-FSO system is illustrated in Fig. 1, which is divided into three parts namely, transmitter, receiver and FSO link or atmospheric conditions. The transmitter section consists of CW laser, Mach-Zehnder modulator, Pseudo-Random bit sequence (PRBS) generator, NRZ pulse generator and 12:1 demultiplexer. Four CWDM channel spaced by 20nm and a set of 8 channels spaced by 0.8nm is given to the 12:1 demultiplexer and it is transferred to the destination through free space. The output beam of 12:1 demultiplexer is transferred using six laser beams. In a receiver section all the six beams are collected and separated into single beam profile using demultiplexer. APD photodiode is used to convert optical signal into electrical signal, followed by low pass Bessel filter to filter the unwanted signal.

The wavelength for designed DWDM channels are 1537.4nm,1538.2nm,1539nm,1539.8nm,1540.6nm,1541.4nm, 1542.2nm, 1543nm and for CWDM channels are 1510nm,1530nm,1550nm, 1570nm. The simulation parameter of the proposed system is listed in Table 1.

Table 1.Simulation parameters of Hybrid WDM FSO system

S. No.	PARAMETERS	VALUES
1	Data rates	2.5Gbps
2	Launch power	20dBm
3	Channel spacing: CWDM/DWDM	20nm/0.8nm
4	Laser line width: CWDM/DWDM	10MHZ/2500MHZ
5	Transmitter's & receiver's apertures	30cm
6	Dark current	10NA
7	Extinction ratio	30dB
8	WDM bandwidth: CWDM/DWDM	10GHZ/20GHZ

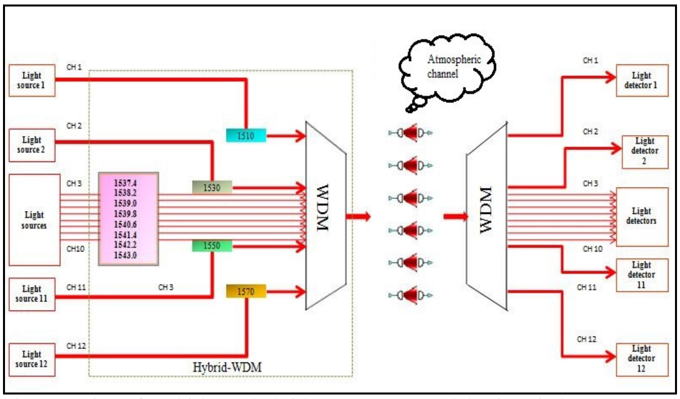


Fig.1: Design of multi-beam hybrid WDM-FSO model using six beams.

3. SIMULATION RESULTS AND DISCUSSIONS

In this section, the arrived simulation results for Hybrid WDM at very clear condition using six beam for the channels centered at 1537.4nm (DWDM) and 1550nm(CWDM), and impact of link distance while increasing the number of beams are discussed. The parameters for FSO system such as Bit Error Rate (BER), receiver sensitivity, Q factor and link distance are estimated for proposed multi-beam hybrid WDM-FSO system.

The effect of BER with respect to link distance of the proposed multi-beam hybrid WDM–FSO system are analyzed at for DWDM and CWDM channels by increasing the number of beams. In this present work, the maximum link distance is estimated by considering very clear condition. The average link distance for 12 beams with the minimum BER (10^{-9}) for DWDM channels and CWDM channels are depicted in Fig.2 (a) and Fig. 2(b), respectively. From the simulation, it is noticed that the maximum travelling distance for DWDM channel centered at 1537.4nm is 629km and for CWDM channel at 1550nm is about 316km.It is noticed that the link distance for CWDM channels are reduced than DWDM Channels as the linewidth of the CWDM channels are higher than DWDM channels.

In order to analyze the performance of all the HWDM channels (DWDM and CWDM), authors considered six beams between the transmitter and receiver. Fig. 3(a) and Fig. 3(b) represent BER vs receiver sensitivity while varying distance for DWDM and CWDM channels, respectively. The minimum receiver power required to attain the desired BER (10^{-9}) for DWDM channels are about -15.6dBm and CWDM channels -11.5dBm. The data rate 2.5Gbps is considered to get the above mentioned results.

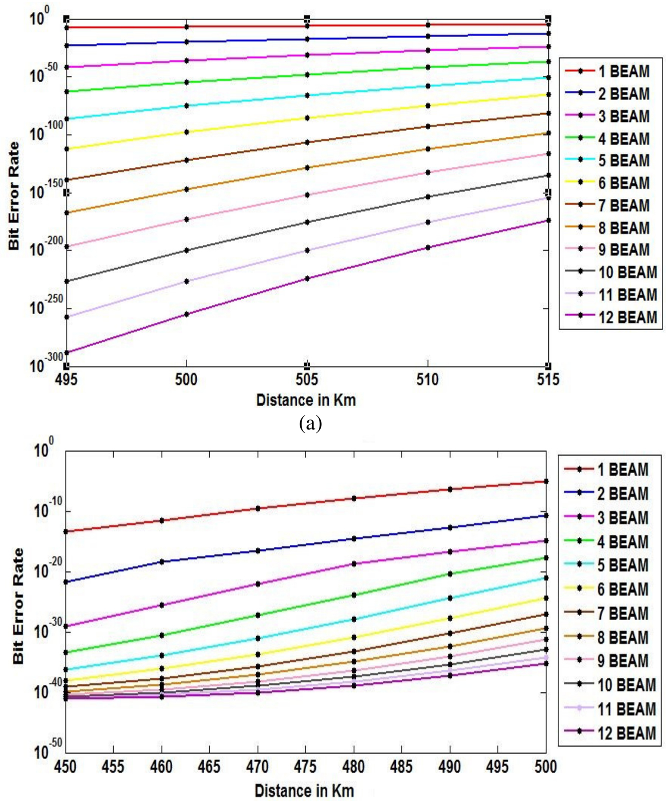


Fig.2 (a): BER vs Distance for DWDM (b) BER vs Distance for CWDM system at very clear condition

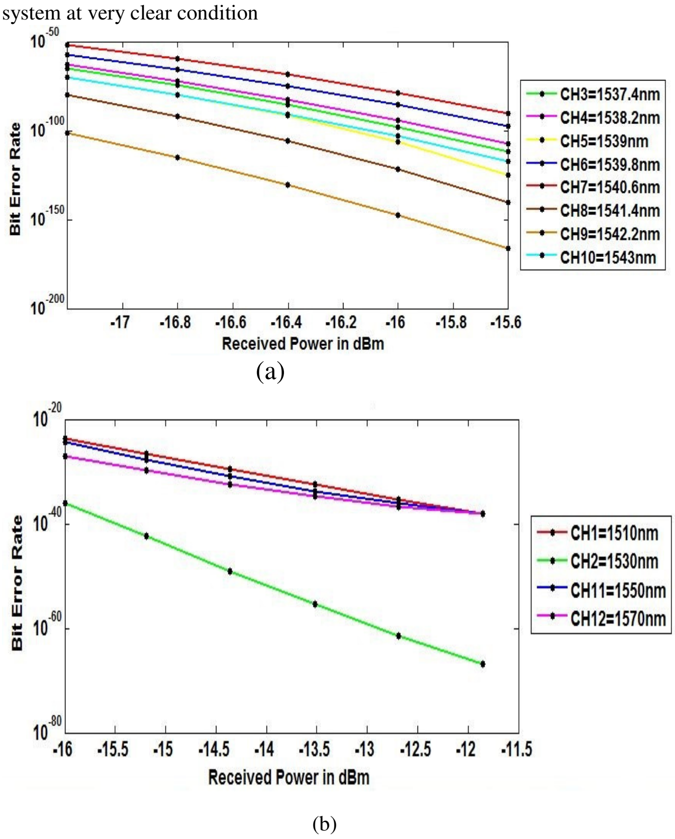


Fig.3 (a): BER vs Received power for DWDM (b) BER vs Received power for CWDM system at very clear condition

Table2. Maximum link Range for all combination of 12 beam under very clear condition for each channel without using amplifier

Beams	Travelling distance in Km DWDM channels								Travelling distance in Km CWDM channels			
	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10	CH1	CH2	CH 11	CH 12
1	495	491	493	489	492	503	507	496	475	474	479	491
2	531	528	531	526	528	540	544	532	511	510	515	527
3	553	550	552	547	550	562	566	554	533	532	537	549
4	569	565	567	563	565	578	582	570	548	547	552	565
5	581	577	580	575	578	589	594	582	560	559	564	577
6	591	587	589	585	587	599	605	592	570	569	574	587
7	599	596	598	594	596	608	612	600	579	578	583	596
8	606	603	605	600	603	615	619	607	586	585	590	602
9	613	609	612	607	610	622	626	614	592	591	596	609
10	619	615	617	613	615	627	632	620	598	597	602	615
11	624	620	623	618	621	633	637	625	603	602	607	620
12	629	625	627	623	625	637	642	630	608	607	612	625

Table.3 Maximum link Range for all combination of 12 beams under very clear condition for each channel with amplifier.

Beams	Travelling distance in Km DWDM channels								Travelling distance in Km CWDM channels			
	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10	CH1	CH2	CH 11	CH 12
1	616	626	629	640	640	647	628	649	614	590	577	597
2	654	665	667	678	678	685	666	687	652	629	615	635
3	677	687	696	701	701	708	689	710	675	651	637	658
4	693	702	706	717	717	724	706	726	691	667	653	674
5	706	716	719	730	730	737	718	740	703	680	666	686
6	716	726	729	740	740	747	728	749	714	690	676	697
7	725	735	737	749	749	756	737	758	722	698	684	705
8	732	742	745	756	756	763	744	765	730	706	692	713
9	739	749	752	763	763	770	751	772	737	712	698	719
10	745	755	758	769	769	776	757	778	743	718	704	725
11	750	760	763	775	775	781	762	784	748	724	710	731
12	755	765	768	779	779	786	767	788	753	729	715	736

The maximum travelling distance of HWDM channels while increasing the number of beams between transmitter and receiver is listed in the table. Author's considered very clear atmospheric condition in order to estimate the maximum travelling distance. The attenuation for very clear condition is 0.065dB/km which is reported in [3]. At 12 beams, the maximum link distance for DWDM and CWDM channels are about 630km and 625km, respectively. It is also investigated the link distance is not constant for all the DWDM and CWDM channels because of its nature of wavelength. The wavelength having its own attenuation while travelling in the free space hence the distance is not constant.

From the table 2, it is observed that the transmission distance is keeping on increasing while increasing the number of beams. If the beams are increased the signal strength is increased, hence, the transmission distance is enhanced by considering more number of beams. Besides the link distance for DWDM channels are greater than CWDM because of higher line width in CWDM channels. As the line width is higher the signal is easily attenuated. The link distance is increased by 23% while adding a new beam with respect to the conventional one.

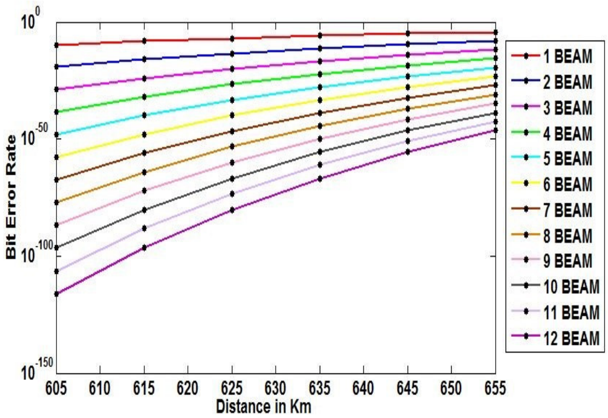


Fig.4 (a): BER vs Distance for DWDM (1537.4nm) system at very clear condition with amplifier.

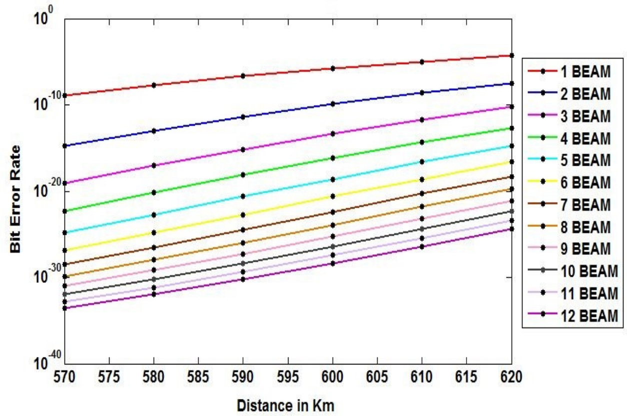
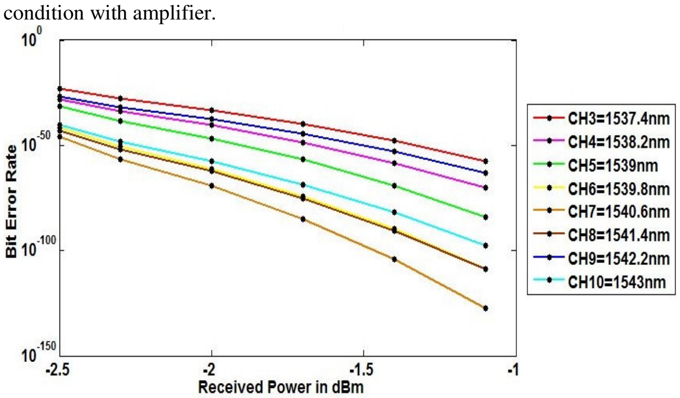
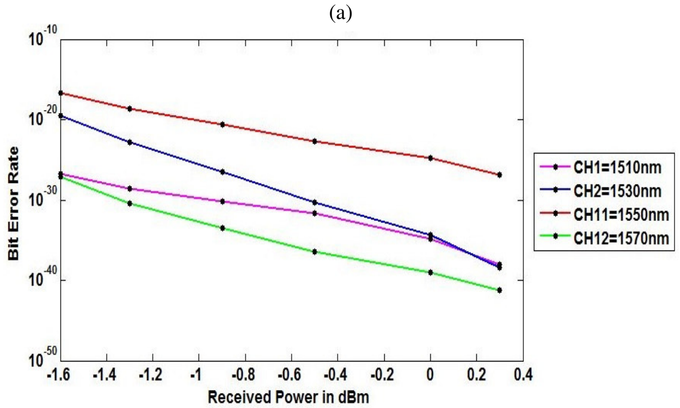


Fig.4 (b): BER vs Distance for CWDM (1550nm) system at very clear condition with amplifier.



(a)



(b)

Fig.5: (a) BER vs Received power for DWDM (b) BER vs Received power for CWDM system at very clear condition with amplifier

The link distance can be further increased by increasing the number of beams, however the cost of the system will be increased linearly. In an alternate way, the optical amplifier will be incorporate at the receiver end which in turn the received signal strength will be increased. In this present work EDFA is considered. The maximum travelling distance at BER of 10^{-9} is estimated for DWDM and CWDM channels which are depicted in Fig 4(a) and Fig 4(b), respectively. The average link distance for DWDM channels after incorporating EDFA is 773 km and for CWDM channels it is about 733 km. The BER vs receiver sensitivity is estimated by implementing EDFA for DWDM and CWDM channels as shown in Fig 5(a) and 5(b), respectively. The maximum link distance while increasing the number of beams by considering the CWDM/DWDM channels are reported in Table 3.

From the result it is noticed that after insertion of amplifier, the link distance is increased significantly. The maximum link distance for CWDM system is limited to the channel width and nature of wavelength. In addition link distance is increased while increasing the number of beams. When the number of beams is increased the distance travelled by data is improved by 3% when using amplifier.

4. CONCLUSION

In this paper, Hybrid WDM-FSO multi beam system is proposed, designed and the network parameters namely BER, Receiver sensitivity are analyzed by varying the number of beams between source and destination. The FSO network becomes an excellent option for problem areas where the FSO lacks. The Hybrid WDM-FSO multi beam network can be a right candidate to solve the last mile problems and the rapid increases in capacity without any new infrastructure. From our result, It is concluded that the proposed Hybrid WDM FSO system performs better than the conventional WDM-FSO with acceptable BER over FSO for the transmission of 2.5Gbps data rate. By considering 12 beams in the free space channel, the attained link distance at very clear condition is about 628km, however, the link distance is further enhanced upto 760km since the EDFA is implemented at the receiver side. From this simulation, it is investigated that the maximum signal travelling distance for DWDM system is higher than the CWDM system as the line width of CWDM is higher. Further, the link distance is keeping on increasing while increasing the number of beam between the transmitter and receiver. The Hybrid WDM system is newly implemented in FSO system which gives significant improvement in results therefore this attempt could be employed for future FSO networks.

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