Investigations on Bit Error Rate Performance of DWDM Free Space Optics System Using Semiconductor Optical Amplifier in Intersatellite Communication

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Abstract

In the orbits plenty of satellites are present for remote sensing, navigation, weather forecasting and for many other applications. Intersatellite links are required so that satellites in the orbit can communicate with each other for information exchange and resource sharing. To increase the link range and data rate SOA preamplification can be done.

In this paper effect of input power on distance travelled is noted. Effect of channel spacing on BER is examined. Bit rate support for varying channel spacing values are noted and receiver sensitivity is also investigated for 8 channel DWDM FSO intersatellite link. The bit rate achieved with SOA is 10 Gbps which is high to the bit rate achieved in [1] and with very less input power requirement also the range of communication link achieved is high to [1].

Keywords: SOA (semiconductor optical amplifier), EDFA (erbium doped fiber amplifier), FSO (free space optics), WDM (wavelength division multiplexing), DWDM (Dense wavelength division multiplexing, ISOWC (intersatellite optical wireless communication).

1. Introduction

Free-space optical communication (FSO) is an optical communication technology that uses LOS (line of sight) communication system uses carrier frequency (20 THz - 375 THz range) [3]. In "free space optics" Free space" means air, outer space, vacuum, or something similar. FSO is an emerging broadband wireless access candidate also known as light wave communication. Free space optics (FSO) technology has seen multiple utilization both for military and commercial purposes.

FSO Consume a relatively low power, offer a high security due to beam confinement within a very narrow area and are less sensitive to the electromagnetic interference [4]. It is protocol independent hence it can support multiple platform and Interfaces [5].

In 2001, the world-first ISOWC link was established (between the SPOT-4 and advanced relay and technology mission satellite (ARTEMIS) satellitelites) [1].

With the increasing number of satellites in the orbit, the need of intersatellite communication link is increasing. Inter-satellite links are required to reduce the dependence of satellite to ground station [7]. We have purposed the use of SOA preamplifier in inter-satellite link. SOA can be a good choice for inter satellite links compared to other optical amplifiers. A comparison of all the optical amplifier is made in the table below

Table 1: Comparison of optical amplifiers

Property	EDFA	Raman	SOA
Gain	>40 dB	>25 dB	>30 dB
Wavelength	1530-1560	1280-1650	1280-1650
Polarization Sensitivity	No	No	Yes
Noise figure	5	5	8
Pump power	>25 dBm	>30 dBm	<400 ma
Size	Rack mounted	Bulk module	compact
Switchable	No	No	Yes
Cost factor	Medium	High	Low

From the table it is clear that

- SOA is compact.
- Size of SOA as compared to erbium doped fiber amplifiers (EDFAs) and Raman optical amplifiers is small.
- High-speed capability, low switching energy.
- SOA amplifiers have Large BW.
- SOA can operate at 800, 1300, and 1500 nm wavelength regions. [5]

All these properties make SOA a good choice for optical amplification in intersatellite link.
In the results we have analyzed that SOA use, increases the link distance also the input power used is 10 dBm which is very less to the power level in [1].Whereas in [1] for 8 Gbps link transmission, all the 8 channels in WDM system, launched power is higher than 20 dBm.
The bit rate for each channel is 10 Gbps which is again high compared to [1].
The simulation setup is shown in the figure

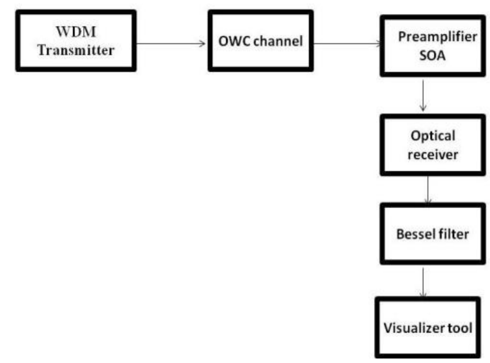

Figure 1: Schematic Diagram of WDM system

On the transmitter side WDM transmitter is used for the transmission of 8 or 16 channels then OWC (optical wireless communication) channel. On the receiver side firstly the SOA preamplification is done to raise the signal strength then optical receiver is employed to receive the signal filtering of the signal is achieved by Bessel filter and then to visualize the signal a visualizer tool is used it can be a eye diagram analyzer or BER analyzer.

2. Results and discussion

2.1 Effects of input power on distance

The transmitter power should be kept low but as with the transmitter power the link range affects. Therefore transmitter power should be kept optimum with desired link range.

A graph is plotted between input power and distance

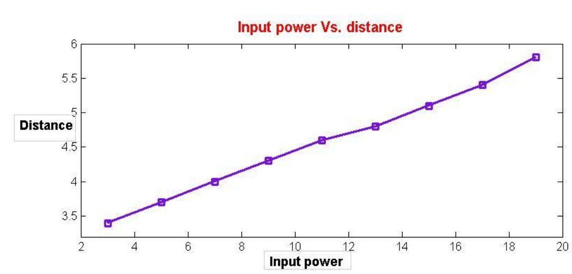

Figure 2: input power vs. distance

From the graph it is clear that as the power at the transmitter is increasing the link range is also increasing correspondingly.

In case of inter satellite communication the optimum value of power is considered with optimum distance and transmitter size. From the figure we can see that at launched power of 3 dBm the link range is 3 Kms when we increase the launched power to 8 dBm the link range is 4 Kms with further increase in the launched power level the distance achieved is increasing at 10 dBm the range increases to 4.5 Kms.

The distance achieved is 30,000 Kms for 8 channels and 11,000 Kms for 16 channels WDM system.

2.2 Effects of channel spacing on BER

The cost of information transfer can be reduced in WDM systems, by increasing the spectral efficiency that is to send maximum information in less bandwidth. This can be done by decreasing the channel spacing, because channel spacing is inversely related to the spectral efficiency.

The spectral efficiency of WDM system is [2]

$$\eta_s = \frac{B}{\Delta V_{ch}} \quad \text{.................................} \ (1)$$

Here B = Bandwidth.

ΔV_{ch} = Channel spacing.

Decreasing channel spacing increases the BER values due to effects like cross talk which degrades the system performance. Due to cross talk the power of one channel is transferred to another channel so decreasing channel spacing overall decreases the performance of the system.

Effects of channel spacing on BER value are studied, the BER results for 100 GHz, 50 GHz and 25 GHz are given in the table below. The investigation of BER for various channel spacing values is done with fixed launched power.

Table 1: BER values of 8 WDM system for channel spacing of 100 GHz, 50 GHz and 25 GHz.

Number of channels	Channel Spacing		
	100 GHz	50 GHz	25 GHz
Channel 1	4.01e-13	4.55e-11	1.90e-12
Channel 2	1.69e-20	5.03e-16	5.12e-17
Channel 3	7.46e-21	1.23e-16	1.12e-18
Channel 4	1.40e-22	5.19e-18	1.68e-19
Channel 5	3.25e-22	3.78e-18	1.86e-18
Channel 6	6.53e-20	4.41e-17	6.42e-16
Channel 7	2.71e-16	5.52e-15	1.46e-12
Channel 8	1.88e-14	3.10e-13	1.55e-9

From the above values it is clear that in 8 channel WDM system with 10 dBm input power, channel spacing can be decreased upto 25 GHz because the BER value is less than the reference BER. That is spectral efficiency is improved without change in the launched power level.

The channel spacing and BER have conflicting behavior. As the channel spacing is decreased the BER value increases likewise. This behavior of BER and channel spacing can be observed from the graph below. The graph is plotted for best channel and the worst with BER as a performance measure.

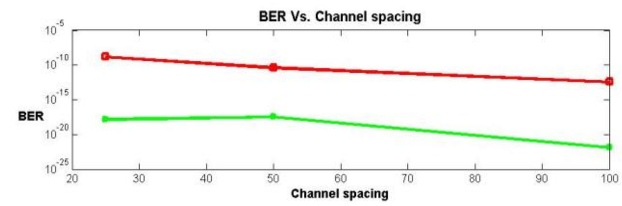

Figure 2: Channel spacing vs. BER

From the graph the least value of BER is observed for channel spacing of 100 GHz and for 25 GHz the Bit error rate is highest.

The channel spacing effects are also studied for 16 channels DWDM system. BER value vs. channel spacing for DWDM system is given in the table below

Table 2: BER value of 16 channel WDM system with channel spacing of 100 GHz, 50 GHz and 25 GHz

Number of channels	Channel spacing		
	100 GHz spacing	50 GHz spacing	25 GHz spacing
Channel 1	5.76e-254	1.40e-142	5.73e-7
Channel 2	0	4.89e-248	4.37e-15
Channel 3	0	2.39e-264	3.70e-11
Channel 4	0	0	8.81e-8
Channel 5	0	0	1.24e-7
Channel 6	0	0	5.27e-11
Channel 7	0	0	3.7e-22
Channel 8	0	0	3.98e-51
Channel 9	2.90e-316	0	1.20e-44

Channel 10	**6.35e-228**	**0**	**2.46e-25**
Channel 11	**1.30e-153**	**0**	**1.51e-7**
Channel 12	**2.95e-98**	**6.93e-244**	**0.00967**
Channel 13	**1.39e-59**	**6.99e-167**	**1**
Channel 14	**8.20e-35**	**2.41e-107**	**1**
Channel 15	**7.18e-20**	**1.95e-65**	**1**
Channel 16	**2.39e-011**	**4.49e-38**	**1**

From the above table it is clear that for 16 channels with 10 dBm launched power channel spacing can be reduced to 50 GHz. With 25 GHz channel spacing many channels BER value is greater than the reference BER value. From channel no.13 to channel no.16 the BER values are 1. Therefore 25 GHz spacing with the parameters in use cannot be used with 16 channels for transmission.

2.3 Bit rate

The spectral efficiency is dependent on two factors one is bit rate and other is channel spacing. Spectral efficiency is directly proportional to the bit rate value and inversely proportional to channel spacing. The investigation here is done by considering both these factors the bit rate is maximized to a value of 10 Gbps and channel spacing values are varied from 100 GHz a low channel spacing of 25 GHz. The bit rate for intersatellite link are investigated for a bit rate value of 10 Gbps for 8 and 16 number of channels with various channel spacing values of 100 GHz, 50 GHz, 25 GHz. It is found in the results that 8 channels with 10 Gbps bit rate can be reduced to a minimum channel spacing of 25 GHz but as we increase the number of channels to 16 the BER values increases and with 25 GHz channel spacing many channels gives BER 1 therefore 16 channels, 10 Gbps bit rate 25 GHz spacing cannot be possible.

Study of intersatellite link with 10 Gbps bit rate is done, the performance is evaluated with the BER analyzer. The investigation is done on 8 channel and 16 channel WDM inter-satellite system.

The graph presents the results for 8 channel and 16 channel BER with 10 Gbps data rate.

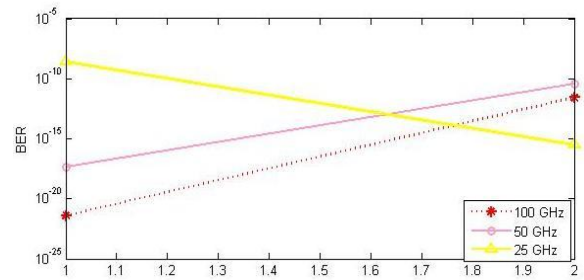

Figure 3: BER values of best and worst channel for 8 WDM system

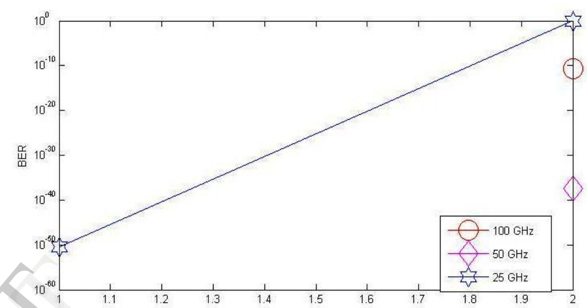

Figure 4: BER values of best and worst channel for 16 WDM system

The graphs shown above represents BER values for the best channel and for the worst channel The values are taken for channel spacing values of 100 GHz 50 GHz and 25 GHz.

It is clear from the graphs that for 8 channel 100 GHz spacing the BER minimum value is 3.77456e-22 and maximum BER achieved is 2.6461e-12 and with 50 GHz spacing the BER values are 4.60688e-18 and 3.83265e-11 for 25 GHz the BER values are 2.47991e-9 and 2.92755e-16.

For 16 channel with 100 GHz spacing the BER values are 0 and 2.3922e-11 for 50 GHz spacing the BER values are 0 and 4.4978e-38 and for 25 GHz the values are 3.988e-51 and 1.

2.4 Receiver sensitivity

The sensitivity of the receiver is the minimum power level required at the receiver to achieve reference Bit error rate.

The sensitivity of the receiver is investigated for channel spacing 100 GHz and lowest channel spacing in our work 25 GHz for 8 WDM system.

2.4.1 For 8 channels 100 GHz spacing

The receiver sensitivity is investigated for two channels. The two channels are one with lowest BER (with wavelength 1551.6 nm) and other with highest BER (with wavelength 1552.6 nm).

Table 3: BER and Q factor for 8 channel WDM with 100 GHz spacing

Input power	Channel 3			Channel 8		
	BER	RX power	Q factor	BER	RX power	Q factor
6 dBm	5.57e-5	-64.23	3.86	0.002	-64.93	2.7
8 dBm	1.08e-9	-62.67	5.98	4.73e-6	-63.90	4.4
10 dBm	2.17e-20	-60.26	9.17	2.04e-12	-62.11	6.9
12 dBm	3.60e-44	-57.14	13.89	8.42e-27	-59.49	10.6
15 dBm	2.42e-138	-51.70	25	9.28e-86	-54.43	19.5

With the input power of 6 dBm the BER values are high than the reference BER value. Therefore cannot be used for transmission. With 8 dBm input power the BER of channel 3 is 1.0815e-9 and for channel 8 it is 4.7348e-6 so this launched input power level also cannot be used for the transmission. By further increase in power level the BER value goes on decreasing. At 10 dBm input power level the BER of channel 3 is 2.172e-20 and for channel 8 the BER value is 2.046e-12 with the respective received power level -60.269 and -62.115. Therefore 10 dBm input power level can be used as a optimum power level as it give BER less than the minimum required BER

2.4.2 8 channels 25 GHz spacing

The data representing BER and Q factor for 8 channels 25 GHz spacing are shown in table. The BER and Q factor are observed for two channels at wavelengths 1550.6 nm (channel no.4) and at 1551.4 nm (channel no. 8).

With minimum launched power the BER values are 0.0001699 and 0.008272 which is very high than the reference BER value. At 8 dBm launched power BER values for channel 4 is 2.7270e-8 and for channel 8, value is 8.2158e-5. With further increase in launched power BER decreases. At 10 dBm input power the BER values observed are 2.9275e-16 and 2.47991e-9 with corresponding received power levels -59.956 and -64.050. Therefore with such low spacing as 25 GHz the optimum power is 10 dBm.

Table 4: BER and Q factor for 8 channel WDM with 25 GHz spacing

Input power	Channel 4			Channel 8		
	BER	RX power	Q factor	BER	RX power	Q factor
6 dBm	0.0001	-65.62	3.58	0.008272	-67.60	2.09
8 dBm	2.7e-8	-63.14	5.43	8.21e-5	-66.25	3.76
10 dBm	2.9e-16	-59.95	8.09	2.47e-9	-64.05	5.84
12 dBm	1.0e-30	-56.34	11.45	2.46e-19	-61.07	8.99
15 dBm	3.9e-65	-50.56	16.99	1.70e-55	-55.71	15.64

3 Conclusion

The results for 8 channel and 16 channel WDM system are presented and discussed. Effects of input power on the link range is studied that with the increase in power at the transmitter side the link range increases and at launched power of 10 dBm the distance achieved for 8 channel WDM system is 30,000 Kms and for 16 channel WDM system it is 11,000 Kms. Effect of channel spacing on BER is examined and found that with 8 WDM system the channel spacing value can be kept to a low value of 25 GHz but with 16 channel WDM the spacing value can be reduced to 50 GHz only. The bit rate support of 10 Gbps is found in the results for 8 channel and 16 channel WDM system for 8 channel upto 25 GHz channel spacing and for 16 channel upto 50 GHz with launched power of 10 dBm. The receiver sensitivity of the receiver is investigated and it is found that 8 channel WDM system receiver is sensitive for input power of 10 dBm.

4. References

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