Analysis of different modulation formats in spectrum slices free space optical communication system

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Abstract: Free space optics is a potential communication technology that has many advantages such as high speed and large bandwidth. In this work, a cost effective spectrum sliced free space optical communication system is proposed by employing spectrum broadening in highly nonlinear fiber (HNLF). Self phase modulation is used to widen the narrow optical carrier spectrum of laser source and SPM generates high power spectrum slices that are well competent to support 2.5 Gbps data speed. Furthermore , in order to analyze the system, different modulation formats such as compressed spectrum return to zero (CSRZ), return to zero and non return to zero are incorporated. Various physical parameters such as antenna diameters and beam divergence effects are also studied in terms of Q factor and BER.

Index Terms- Self phase modulation, Wavelength division multiplexing (WDM), Non return to zero (NRZ), Return to zero (RZ), compressed spectrum return to zero (CSRZ)

I. INTRODUCTION

At the present time, Free space optics (FSO) has getting attention in free space communication owing to several advantages over radio frequency (RF) communications such as large bandwidth, unlicensed operation as well as security [2]. Free space optical communication is well-liked as compared to fiber optic communication, due to extra suppleness as well as cost-effectiveness, and more speedy simpler for deployment/re-deployment [3]. Presently, wavelength division multiplexed (WDM), which permits to hold several separate and autonomous optical channels, can carry Terabits per second capacities as well as it can be without difficulty incorporated with free space optical systems to significantly enhance the data speed in the system [4]. To cater the demands of bandwidth hungry services, WDM-FSO is a prominent and well competent way out for broadband transmission. However, WDM technology has several disadvantages also such as more complexity and high cost of operation. In order to overcome these limitations, a spectrum slicing technology is good alternate to WDM. Spectrum slicing having less complex operation as compared to WDM, which uses several intensity sources operational at different frequencies [5]. Also, WDM systems are wavelength selective and sensitive to routing of each wavelength to specific port. So, spectrum sliced WDM has identical advantages as wavelength division multiplexing and less complex, low cost, power efficient for future generation networks. Various physical parameters of FSO also play an important role in overall transmission. Transmitter and receiver antenna diameters decide the reach and quality of reception of the system. Beam divergence is a major performance deteriorating factor and needs to be addressed along with attenuation and dispersion. Till now, many research works has been reported to generate spectrum slices [6-8], to boost weak signal with amplifiers [9], beam divergence size [10] scintillation noise compensation [11]. Although, reported techniques are good but either supports less data rate or more complexity. An optimal method of SS-WDM is needed for high speed FSO networks by generating high power slices and minimizing deteriorating effects.

In this research article, a high speed WDM-FSO system based on spectrum slicing through self phase modulation is proposed and system is investigated for various beam divergences, transmitter and receiver antenna diameters and modulation formats.

II. SYSTEM ARCHITECTURE

For the analysis of free space optic system, the simulation software Optiwave Optisystem^{TM} is used. At the transmitter side, a CW laser source with of wavelength 1550 nm generate the continues beam of light which is further coupled into the HNLF of the 2 km length. At the output of HNLF, a wide spectrum is obtained due to nonlinearity called self phase modulation. This wide spectrum is further sliced by demultiplexer into eight equally spaced channels 193.0 THZ to 193.2 THz. These 8 channels are equally spaced by

25 GHz and each carry data speed of 2.5 Gbps to exhibit total speed of 10 Gbps as shown in Table 1. PRBS signal with a word length of 2^{15}-1 independently introduce along with carrier into the modulator, in order to reshape the signal.

Table 1 System specification of proposed system

S.No	Parameters	Values
1	Wavelength	1552.52 nm
2	No. of channels	8
3	Channel spacing	25 GHz
4	Diameters of Tx/ Rx (cm)	Varied from 5,10,15,25
5	Beam divergence (mrad)	0.25,0.5,0.75,1
6	Attenuation	0.1 dB/km
7	Link length	5 km

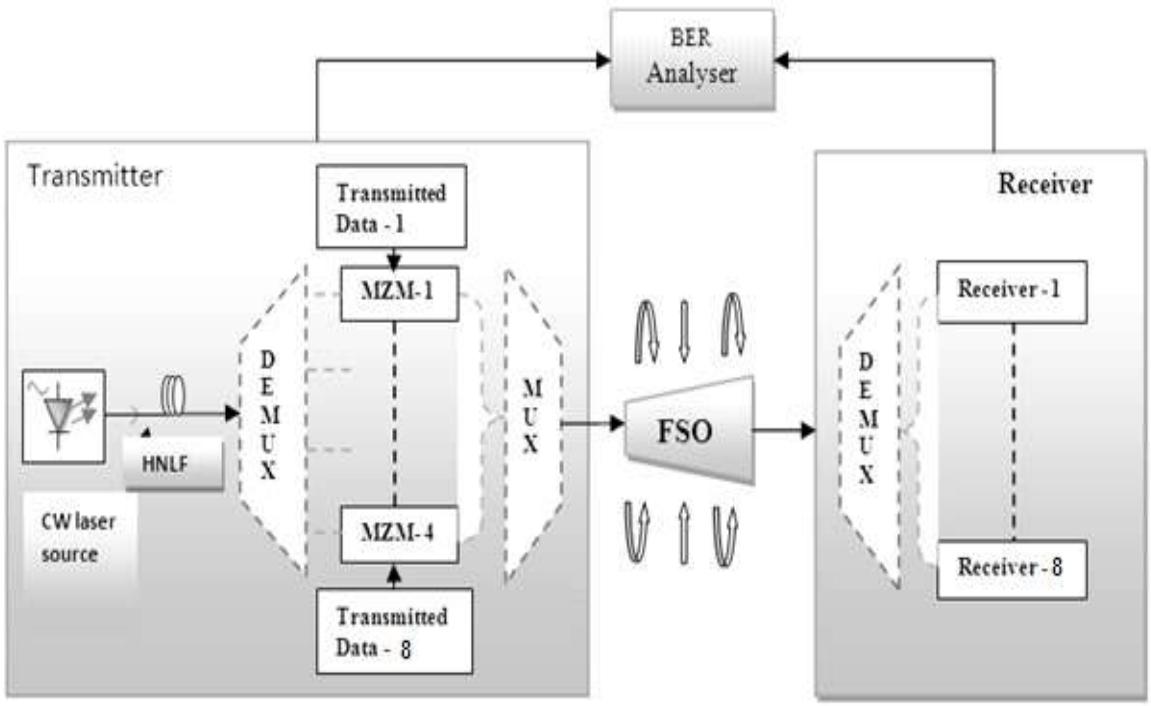

Figure 2 Propose architecture of spectrum sliced FSO system

In order to check the performance of the FSO system the beam divergence angle is varied from 0.25 mrad, 0.5 mrad, 0.75 mrad, 0.1 mrad. Also different modulations and Tx/Rx diameters are also varied to investigate the performance of proposed system. At the receiver side, received signals are reconstructed back to original data stream. After modulation, these signal are multiplexed and send toward receiver wirelessly from transmitter antenna to receiver antenna. The performance of FSO communication system depend upon various parameters like beam divergence, attenuation, line width etc.

III. RESULT AND DISCUSSION

A high speed spectrum sliced WDM free space optical system based on SPM in HNLF is demonstrated in this work. To investigate the performance of system, several factors are taken into account such as distance, modulation formats, beam divergence and Tx/Rx antenna diameters. The performance of FSO system is dependent upon the atmospheric turbulence. The quality of received signal is depends on the distance between the transmitter and receiver of FSO. To determine the quality of received signal, the distance of FSO system is varied from 1 km to 5 km. It is shown that as the distance prolongs; the quality of signal degrades. The Quality factor of FSO system is different for different modulation formats. So it is shown that by using the NRZ, RZ and CSRZ modulation formats, CSRZ provide the best result in terms of Q factor. Figure 2 depicts the graphical representation and it is found the due dispersion tolerance and constant power, CSRZ perform excellent.

Table 2 Q factor values with respect to distance

Distance(km)	NRZ	RZ	CSRZ
1	14.16	12.86	15.2
2	13.91	12.86	14.56
3	12.69	12.01	13.34
4	11.44	11.23	11.54
5	9.44	9.13	9.57

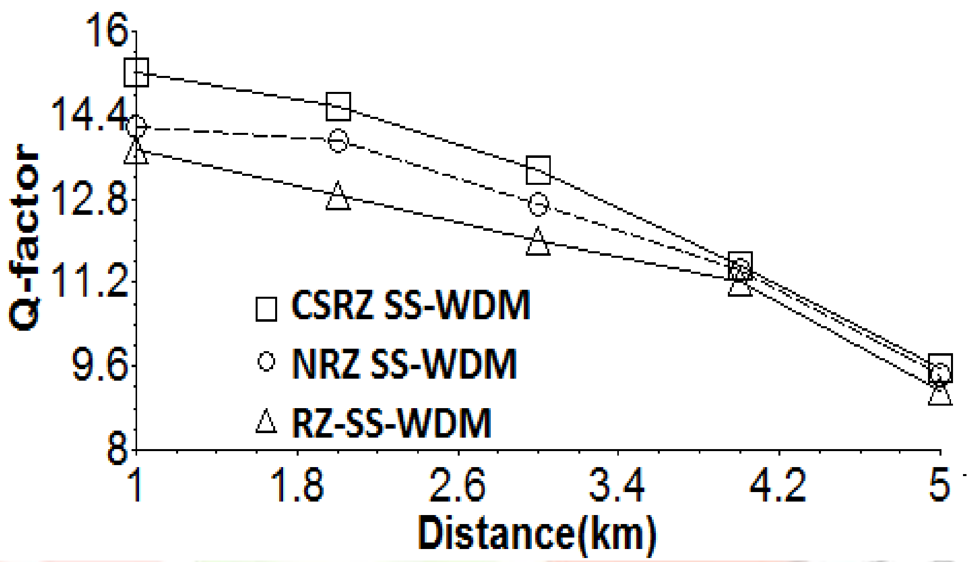

Figure 2 Graphical representation of Q versus distance

Figure 3 depicts the BER versus distance performance for system and patterns are varied inversely to Q factor curve in fig 2. As the BER increase with distance, Q decreases with the distance.

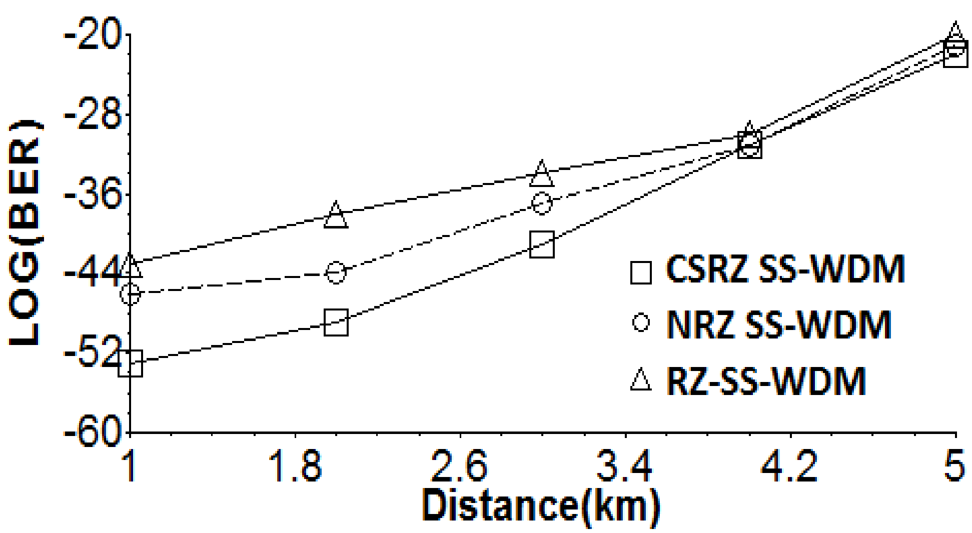

Figure 3 Graphical representations of Distances (km) versus Log (BER)

For further investigation beam divergence angle is varied as 0.25 mrad, 0.5 mrad, 0.75 mrad and 1 mrad. It is analysed that the Bit error rate of received signal is increased with the increase of beam divergence angle and quality of signal is degraded. As shown in figure 4, maximum Q is obtained at 0.25 mrad beam divergence and minimum for 1 mrad. To obtain the less error in the received signal, we should use the beam divergence degrading effects tolerant modulation as CSRZ.

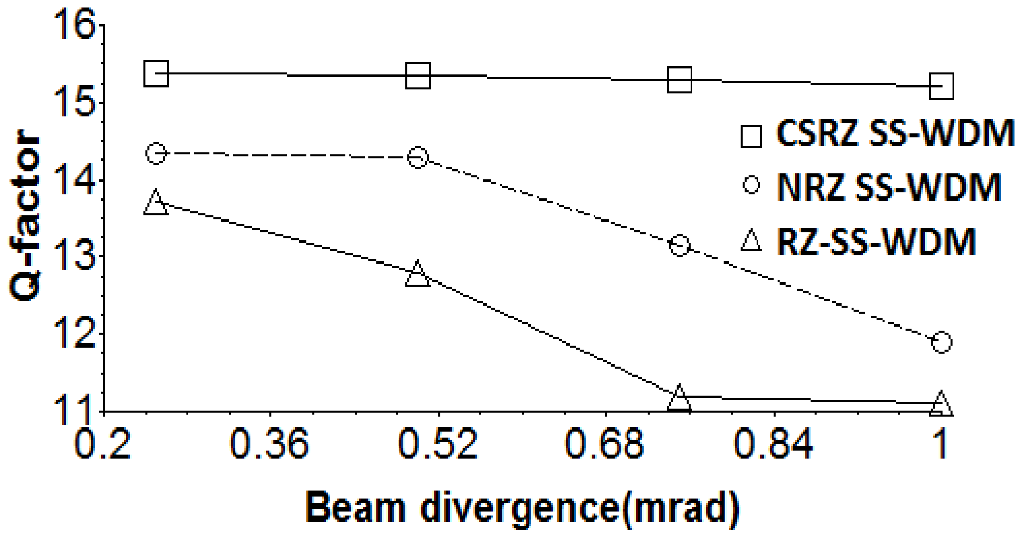

Figure 4 Graphical representation of Q factor versus beam divergence

Further, the performance of a FSO system is analysed by different combination of transmitter and receiver aperture diameters. The diameters of the Transmitter and Receiver are varied as 5 cm, 10 cm, 15 cm and 20 cm. To obtain the maximum power and Q at the reception, we need to increase the aperture size of receiver antenna up to 20 cm. Larger the diameter of RX antenna larger the received power. To analyse the performance of system, NRZ, RZ and CSRZ modulation techniques are used and maximum receiver power, Q factor is obtained by using the CSRZ modulation format as shown in fig 5, 6 respectively.

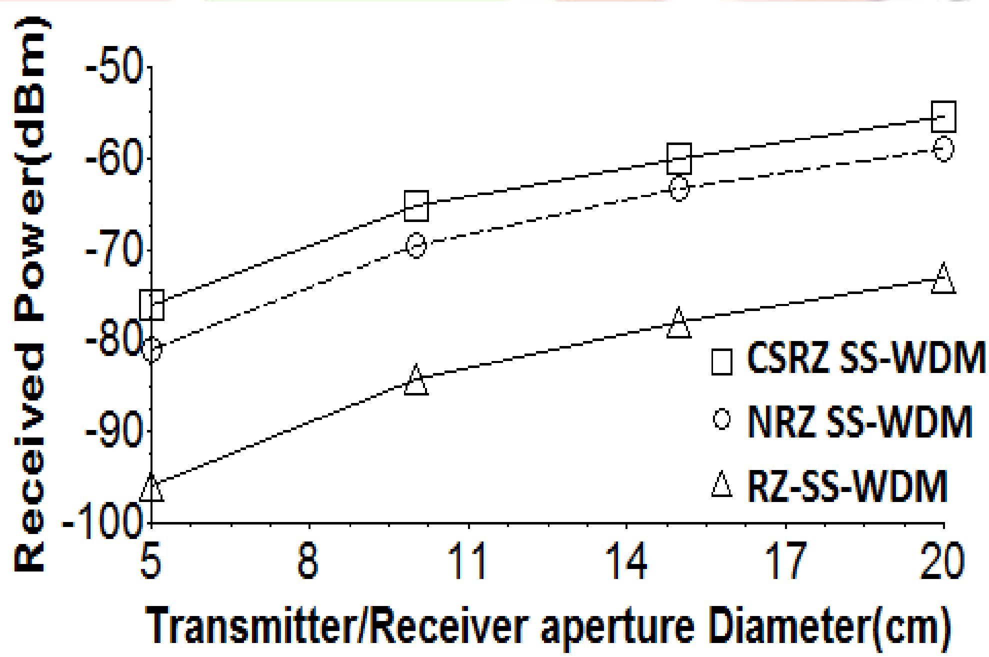

Figure 5 Graphical representation of received power versus Tx/Rx antenna diameters

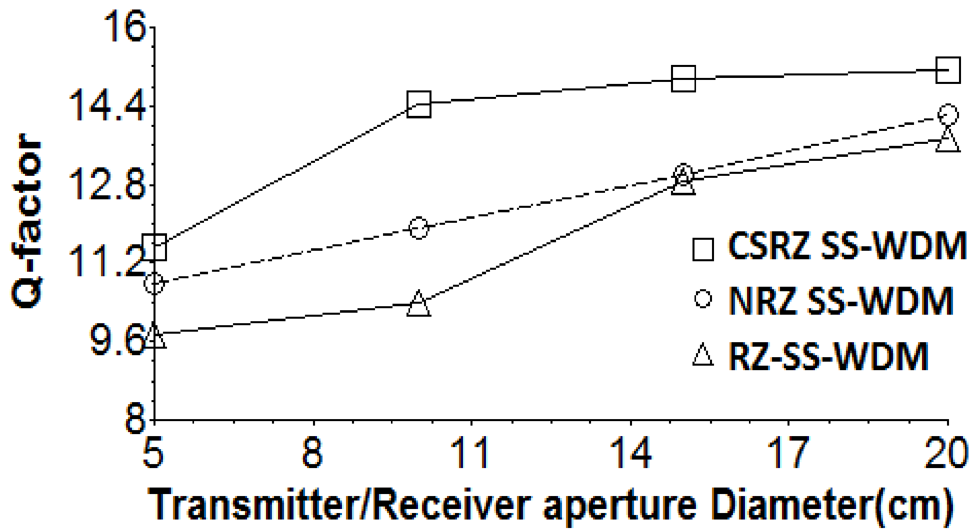

Figure 6 Graphical representation of Q factor versus Tx/Rx aperture diameters

IV. CONCLUSION

In this research article, a 2.5 Gbps and 8 channel spectrum sliced ultra dense WDM free space optical communication is proposed based on self phase modulation in highly nonlinear fiber. Analysis has been carried out for different modulation formats, beam divergence and transmitter receiver diameters. Spectrum sliced free space optical communication system exhibits best performance in case of carrier suppressed return to zero modulation format. Beam divergence effect on performance of the system is very degrading and results revealed that as divergence increases, Q decreases. However, CSRZ is a superior modulation to tolerate the beam divergence effects. It is noteworthy that large aperture diameter of both transmitter and receiver aperture, enhance the system performance. No optical amplifier is used in this work and we successfully transmitter accumulated 10 Gbps over 5 km link distance at 1 mrad divergence.

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