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Wavelength Division Multiplexed Free Space Optical System with Polarization Diversity Polarization Crosstalk Suppression

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ABSTRACT

Wavelength division mult iplexing is a potential competitor for future Free space optical networks in order to deliver ultra-high capacity and high speed systems that can be performed using compact, light weight, and low power optical equipments. This study investigates how the 16 x 20 Gb/s WDM-FSO system can perform better by introducing polarisation diversity and a modified return to zero advanced modulation format. By using a WDM system with a channel spacing of 50 GHz, the high speed system is achieved to meet the large bandwidth requirements of data services in FSO. A polarisation interleaving approach is used in the system to reduce polarisation crosstalk and nonlinearities between adjacent WDM channels.

Keywords: Wavelength division mult iplexing (WDM), Free space optical (FSO), SOP (state of polarization, PI (polarizationinterleaving), Polarization ext inction ratio (PER)

INTRODUCTION

Pressure on traditional low speed radio system architecture has been put on by the growth of internet connections and traffic in the range of new services. Free space optical communication displays traits in common with widely used technologies like fibre optics and wireless [1]. Free Space Optical (FSO) communication has received a lot of attention recently due to its advantageous advantages over optical cable connection [2]. Numerous studies have been conducted in the past to address the needs for high-speed data and to provide affordable architecture [3]. Additionally, FSO strengthen communication due to negligible interception utilising P2P (point to point) laser signals. The advantages of FSO communications include high bandwidth and capacity, license-free operation, low power consumption, and the avoidance of trenching costs and other expenses associated with optical fibre communication[4] -[5].

FSO is a strong candidate and has drawn interest due to its uses and many benefits for the geographical areas of India where the deployment of optical fibre is not feasible. Atmospheric degrading conditions like haze, medium rain,mild rain, fog, high rain,etc. [6] that enervate the connection and become the reason to shut down the network broadcast are factors that impair the performance of FSO. Numerous studies have been conducted, theories have been advanced, and

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methods to reduce the impacts of turbulence have been presented [7-8]. The impact of wide beam and atmospheric disturbance on free space communication are also examined in [9]. Additionally, for free space optical channels, advance modulations of OFDM (orthogonal frequency division multiplexing), aperture averaging, diversity, and FSO signal amplification are examined. Wavelength division multiplexing has been used to increase FSO capacity at high data rates and extremely small channel spacings. WDM-based access networks that accommodate a large number of users are built using spectrum slices from the available spectrum.

Wavelength division multiplexing (WDM), which can provide extensive coverage over atmospheric disturbances in FSO, is shown as adaptable and reliable through bidirectional transmission and capacity multiplication. As a result, a high-speed FSO system-based polarisation interleaved wavelength division mult iplexing (PIWDM) architecture is suggested in this study objective. The best course of action is to meet the high-speed data requirements, hence the system was thought up and demonstrated for 20 Gbps. The system uses several states of polarisation to reduce polarisation crosstalk and interchannel interference, which improves performance. Additionally, extremely dense channel spacing of 50 GHz is provided between neighbouring channels before the FSO channel in order to maximise system bandwidth. It has been found that polarisation interleaving systems perform better than traditional WDM FSO systems.

THEORY OF POLARIZATION DIVERSITY

Many systems—but not all—have polarised laser intensities. The electric field oscillates in a certain path orthogonal to the transmission of the laser intensity in a state of linear polarisation, which is what this term denotes. However, directed electrical fields are not consistently produced by fibre lasers. The laser output may, however, simultaneously have the same powers in two different polarizations without any correlation between the amplitudes that result.

The polarisation state is unstable for a number of reasons, including temperature drifts and erratically switching between different directions. A type of polarisation fixing device is typically required to generate the pure single direction fluctuation of the electrical field vector. The polarisation extension ratio (PER), which is defined as the ratio of powers in the various polarisation directions and derived by noting the orientation-dependent power transmission of a polarizer, is typically used to quantify the degree of a certain state of polarisation. By polarising the adjacent channels, polarisation diversity is a useful technique for reducing the impact of inter-channel nonlinear effects. The architecture of WDM systems is extended to ensure that the bit flows in two nearby channels are orthogonally polarised. To keep channels orthogonal, polarizations are modified using linear polarisation controllers. The fundamental principle of suppression is that in PI systems, SOPs are orthogonal, and that cross phase modulation and four wave mixing are entirely dependent on the state of polarisation of adjacent channels. Therefore, inter channel collisions produce less phase changes and offer better outcomes.

SYSTEM SETUP

Optiwave or Optisystem, a well-known and complete simulation tool, is used to realise spectrum-sliced free space optical communication. Figure 1 depicts the proposed WDM free space optical network at 20 Gbps employing modified return to zero (MDRZ) in downstream. Novelty of the system is use of polarization interleaving in WDM FSO to combat with the polarization and inter-

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channel crosstalk. System proposed is symmetrical and also centralized lightwave that supports 16 WDM channels in this work. Internal structure of modified return to zero (MDRZ) system is depicted in Figure 2. A laser light wave source at 193.1 THz frequency and 0 dBm input power is used. In order to examine the impact of no nlinear deprivations on the system, the polarisation of the even and odd channels is altered.

The orthogonal component is removed while the linear polarizer broadcasts the linear polarisation component that is aligned with its transmission axis. Odd channels from 1 to 15 have the same polarisation, and the state of polarisation (SOP) in the linear polarizer is locked at 0 degrees. The polarisation state of even channels 2 through 16 is 90 degrees orthogonal to that of odd channels. The investigated range for the proposed link is 9 Km. All WDM channels are modulated in central office with MDRZ modulation. From this point, downstream communication in Free space optical network initiates. The modulated MDRZ –WDM signals are accumulated with the two multiplexer of configuration 8 x 1, as well as the mu ltiplexed signal is transmitted over 9 km FSO link.

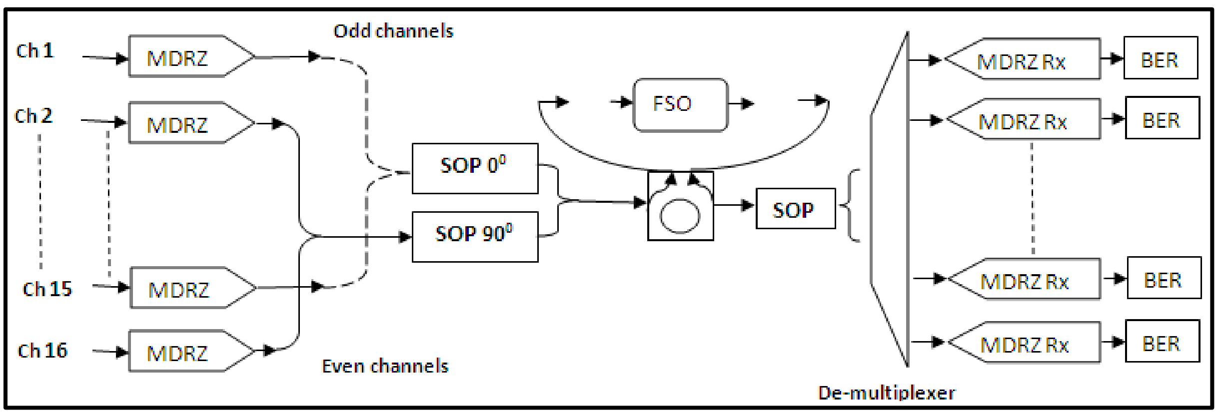

Fig. 1 polarisation interleaved WDM FSO system block diagram

After transmission of 9 km, signal is de-multiplexed by 1 x 16 wavelengths with frequency spacing of 50 GHz as shown in figure 2. Receiver section consists of photo-detectors that receives drive with time delay. By taking into account shot, heat, and ASE (Amplifier spontaneous noise) distort ions, a p-i-n photodetector with 100% transient response and 10 nA dark current is installed in the receiver. The received data is re-sampled, re-shaped, and re-amped using a 3-R regenerator. The decision-making component known as a BERA calculates the final received quality factor,BER,SNR, and other parameters of the received signals. Low pass filter, PIN photo-diode, and an eye diagram analyzer are in that order.

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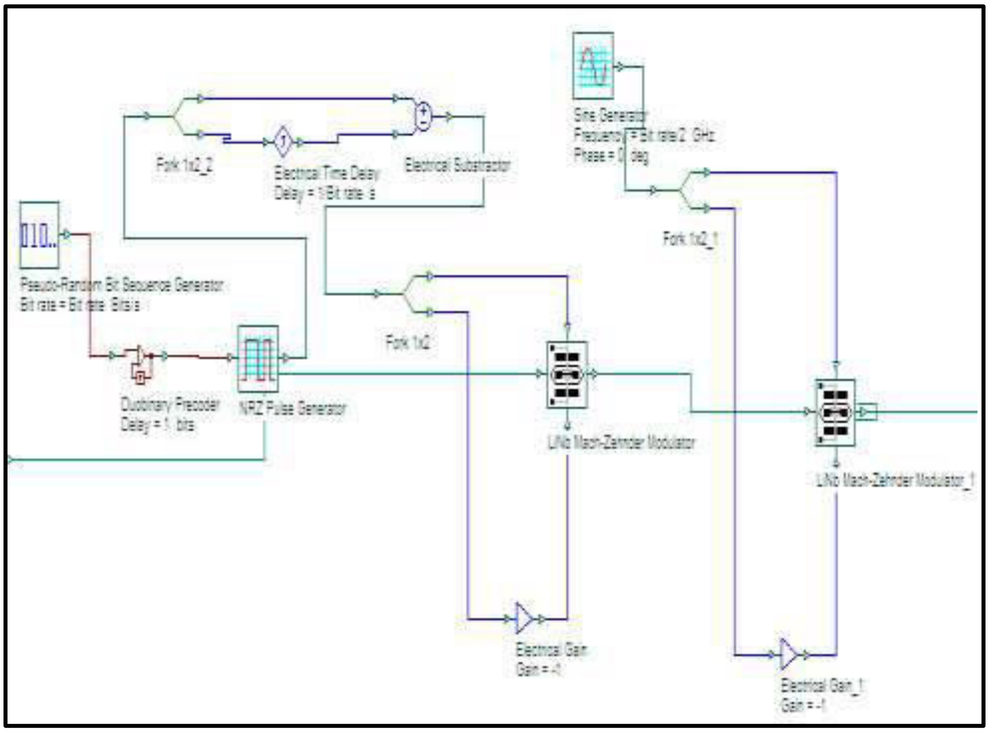

Figure 2 Internal structure of modi fied return to zero

Internal structure of modified return to zero (MDRZ) system is depicted in Figure 2

RESULTS AND DISCUSSIONS

In order to design a polarization crosstalk suppressed systems, a free space optical network employing polarizat ion interleav ing is proposed. A system consists of 16 wavelengths and each wavelength is modulated with MDRZ modulation for down stream at central office. Two WDM multiplexers are used in order to separately combine the 8-8 wavelengths. Even wavelengths and odd wavelengths are combined differently with these two multiplexers. Then odd channels are fed to polarizat ion rotator that pass only horizontal polarization signals and even channels are projected to orthogonal polarizer. Polarizations combined and signal sent over 9 km long stretch of FSO and followed by 1 x 16 de-multiplexer. Received wavelengths are received with receiver that consists of photodetector, low pass filter and BER analyzer. First and foremost, the investigation of proposed system has been done by taking different distances into consideration. Loop length is varied from 1 km to 9 km with the gaps of 2 km as depicted in Figure 3.

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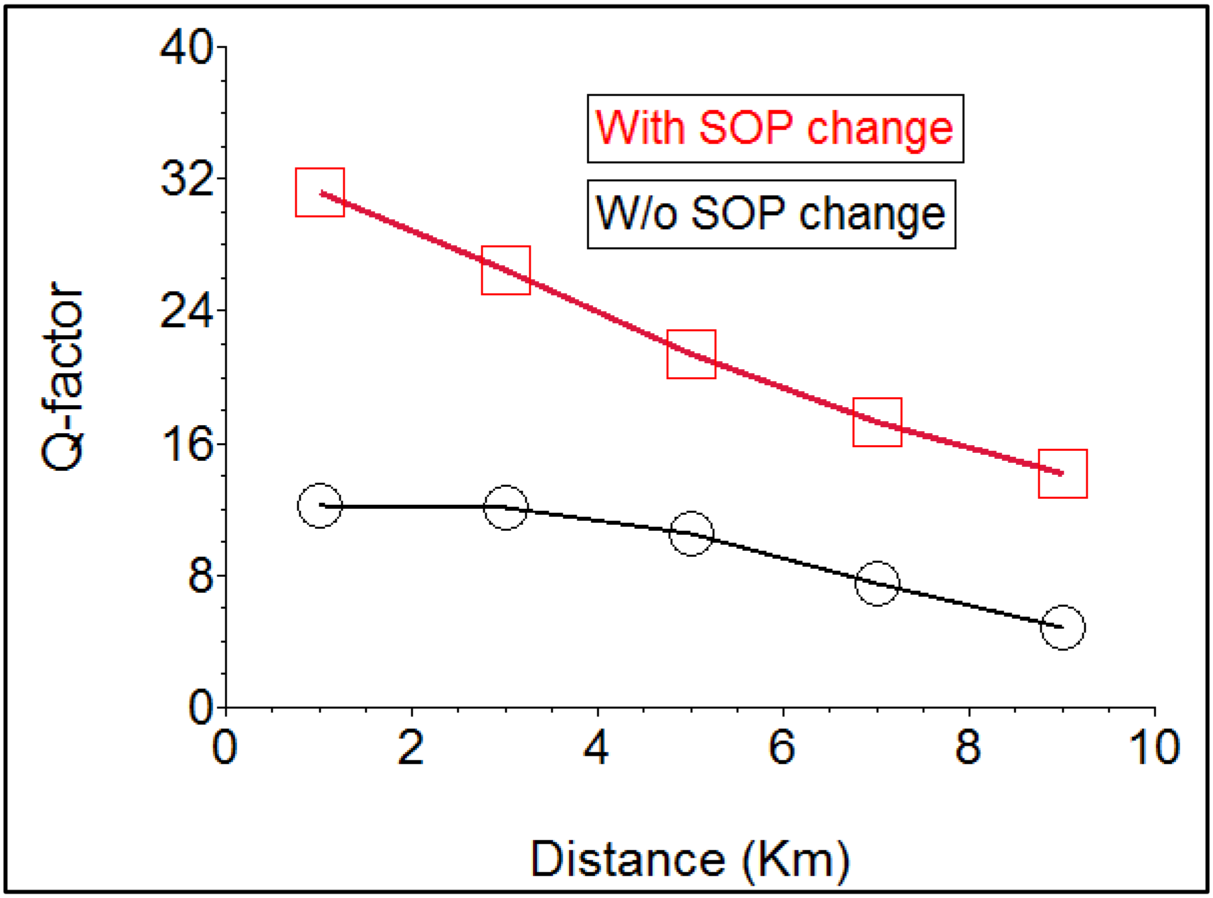

Figure 3 Q factor representation versus distance

Q factor from the Eye diagram analyzer is recorded to evaluate the outcomes. The graph of Q factor versus distance for WDM-FSO with and without polarisation interleaving is shown in Figure 4.6. It is reported that with the increase in the link length, there is significant reduction in Q factor of the signal. Also, two different scenarios are proposed by considering the polarization interleaving and without polarization interleaving. Q factor decreases due to numerous factors such as the attenuation, pulse broadening, crosstalk among different channels etc. However, in this work, analysis is accentuated on polarizat ion crosstalk that emerges in mult i-channel WDM systems and plays a vital role in signal degradation. It is evident from the investigation that because of the different states of polarization in even and odd channels of the proposed system, Q factor is obtained well in case of with PI system than without polarizat ion interleaved system. This is due to the fact that different states of polarizat ions, minimize the interaction of signals between different wavelengths. This phenomenon led to a significant enhancement in Q factor and it is seen tha t when polarization interleaving is eliminated, Q factor decrease sharply and valid for 8 km distance as compared to with polarization interleaved system as given in Table 1.

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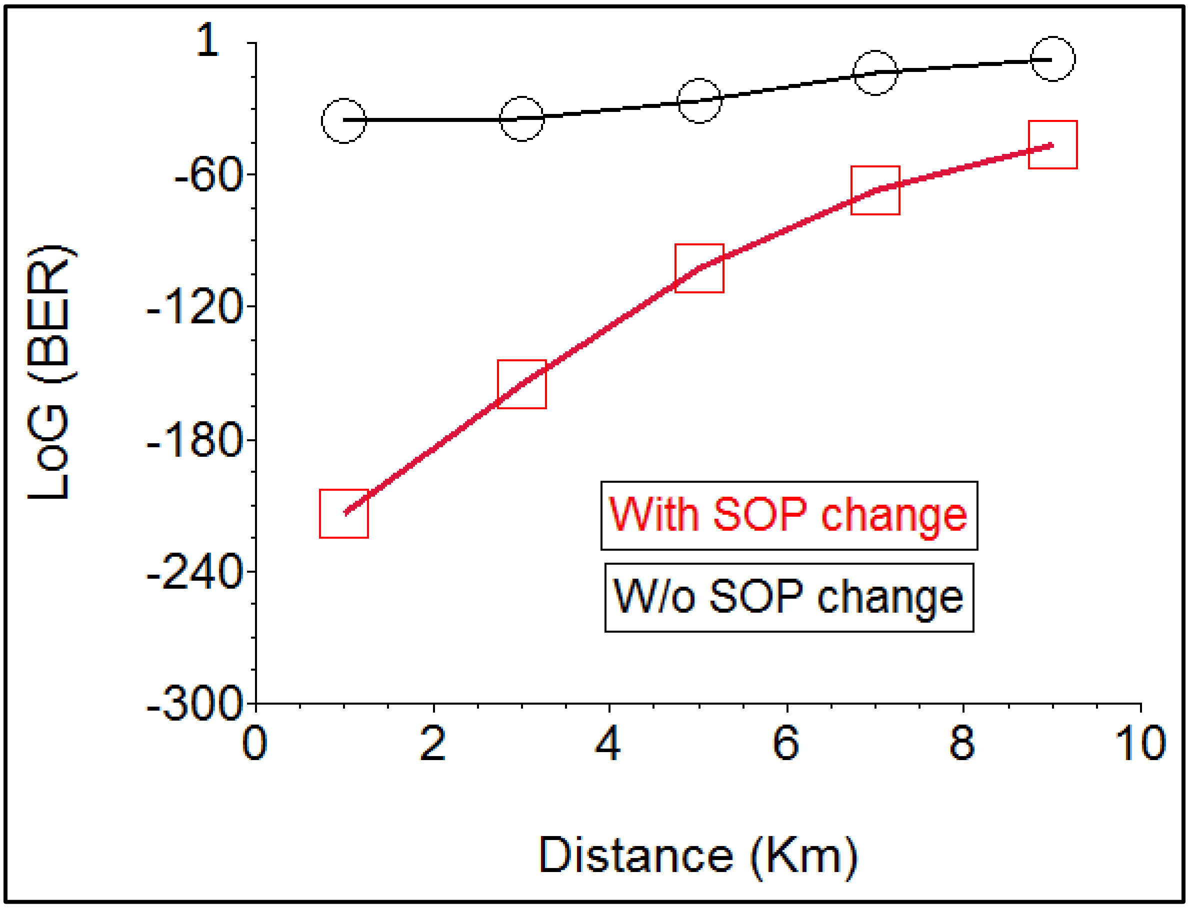

Figure 4 LoG (BER) versus distance of WDM FSO system

The LoG (BER) values for links with lengths ranging from 1 km to 9 km are shown in Figure 4. It is clear that bit mistakes grow as distance increases. Bit error rate is a crucial metric for assessing system performance. In proposed system that incorporates polarization interleaving, exhibits less errors as compared to without interleaved WDM free space optical network. Modified return to zero advanced modulation format is employed in the system to suppress the crosstalk between WDM channels.

However, MDRZ has done another task of inter symbol interference suppression due to two different phases. Other problem is al so exists that is the inter channel interference in WDM FSO. LoG (BER) is more in without polarizat ion interleaved system and thus polarization inter leaving is recommended to use for better results. Distance is considered for the evaluation of the systems in terms of Q factor and BER. However, the next study is on the effect of input power on the system performance. Results such as Q factor, LoG (BER) and signal to noise ratio are accessed for investigation. So, in the proposed WDM free space optical network, launched power is varied from the laser source from 0 dBm to 4 dBm with the difference of 1 dBm. Figure 5 depicts the variation of Q factor with the launched power for with and without polarizat ion interleaved system. From the results as given in Table 2, it is observed that with the more power coupling into FSO, Q factor tends to increase. Increase in launched power serve as a power budget in the system.

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However it is also seen that high power input initiates the nonlinear effects due to the variation in power of adjacent chann els. But, in this setup power is limited to 4 dBm and this power level do not initiates the nonlinear effects. It can be seen that a WDM free space optical network with polarisation interleaving offers a higher Q factor than one without. The system's LoG (BER) versus launched power is shown in Figure 6. It is observed that power increase, improves the BER and provide less BER for high powers that are launched in optical fiber. Bit error rate is more in the case of simple WDM passive optical network without incorporation of polarization interleaving.

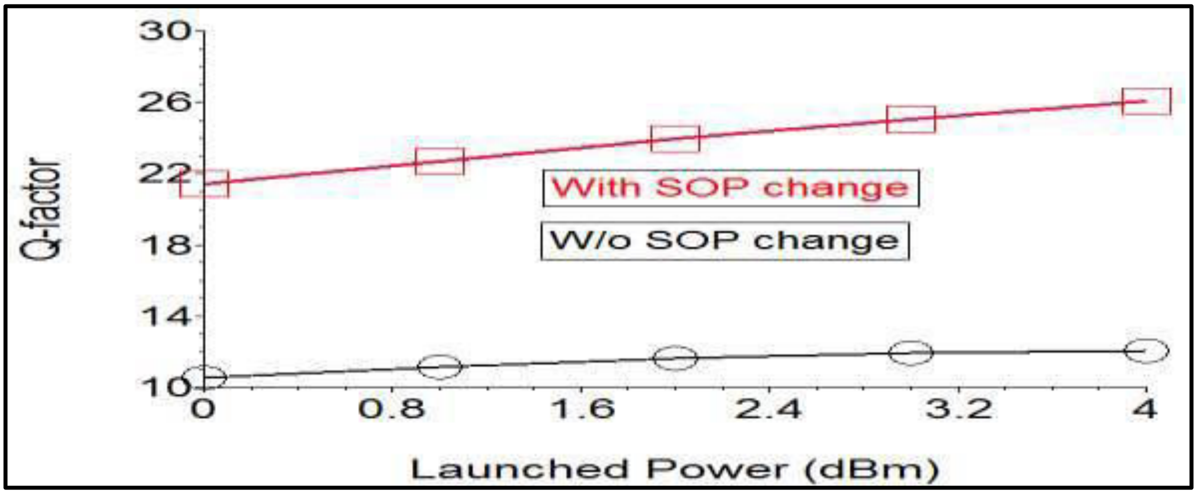

Figure 5 Representation of launched powers versus Q factor of WDM FSO system employing wi th and without polarization interleaving

Table 2 Values of Q factor vs launched power

Power (dBm)	With PI	W/O PI
0	21.42	10.52
1	22.71	11.17
2	23.93	11.62
3	25.06	11.91
4	26.1	12.06

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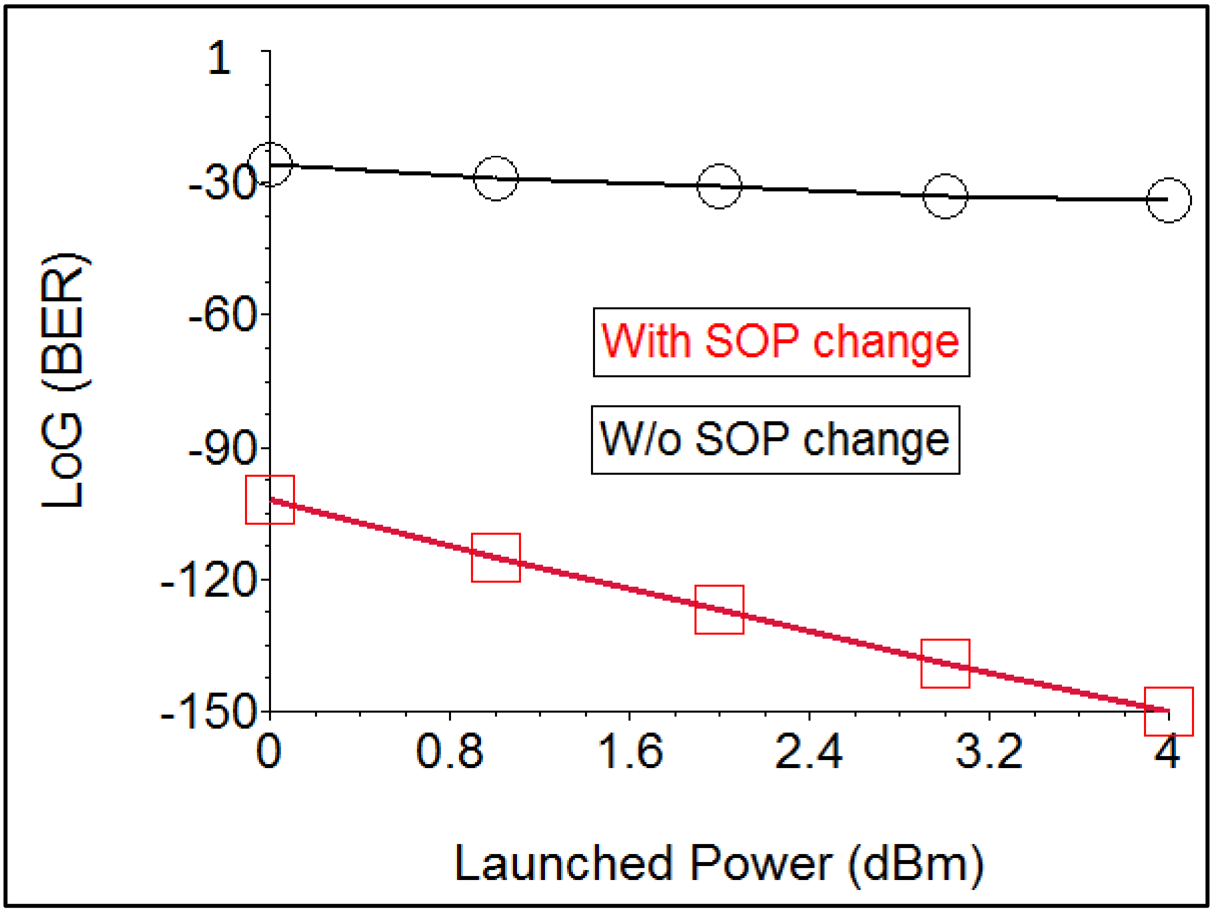

Figure 6 LoG BER versus input power

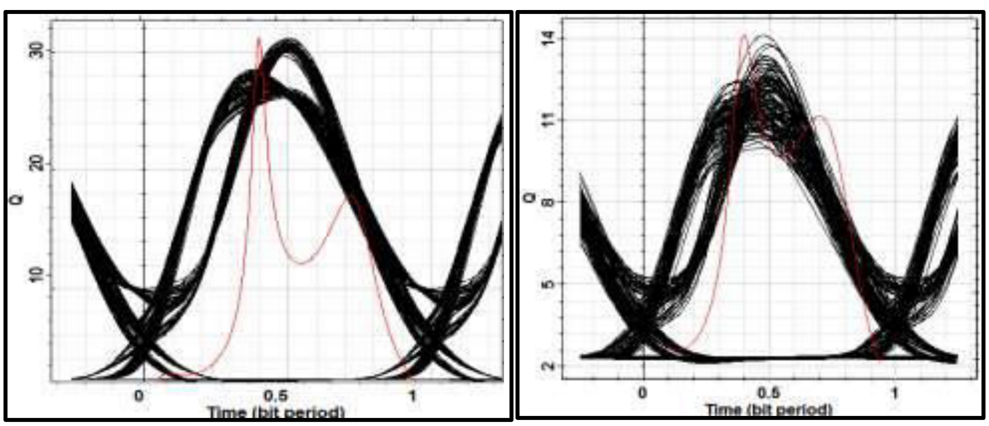

Figure 7 Eye diagrams for polarization interleaved WDM-FSO at (a) 1 km and (b) 9 km

Eye diagram of the system with and without polarization interleaving depicted in Figure at different link lengths. It is reported that Eye opening is more in case of 1 km link distance and closer increase with the increase in the distance. This is due to t he fact that there significant attenuation, dispersion in the free space optical link. It is reported that at 1 km eye height is more as c ompared to 9 km and jitter is also less. More thickly the eye diagram appears , more are the errors and less is the Q factor.

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So from the analysis it is suggested to use the WDM FSO polarization interleaved system for the future applications.

Conclusion

In this work, a WDM-FSO system to suppress inter channel and polarization crosstalk is proposed. This research explores the performance enhancement of 16 X 20 Gb/s WDM-FSO system incorporating polarizat ion diversity. The high speed system is attained to fulfill the wide bandwidth requirements of data services in FSO by employing WDM system at channel spacing of 50 GHz. Results are compared in two different systems such that with and without polarizat ion interleaved WDM-FSO system. It is observed that WDM-FSO with polarization interleaving cause fewer errors and provide enhanced performance as compared to without polarization system. At lower distances and less power levels, Q factor reported minimum and BER is more. Systems using MDRZ and polarization interleaving works successfully for 9 km and polarization crosstalk effects are suppressed. Thus, this is an ultimate solution to WDM free space optical systems to support long distances as well as high data rate.

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