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Mitigation of PMD over DWDM system using polarization interleaving

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In order to achieve long haul transmission distance in DWDM systems, polarization mode dispersion (PMD) and non-linear impairments affecting system performance have to be minimized. This paper proposed polarization interleaving strategy for 40 Gbps DWDM systems to remove PMD, 3rd order nonlinearity between neighboring channels by adjusting a state of polarization using linear polarizers so that adjacent channels are orthogonal to each other. The proposed system had the acceptable value of Q factor at all fiber lengths i.e. Q factor of polarization interleaved system was 16 and conventional DWDM system was 3.2 at 720 km fiber length. It was observed that signal quality increases with polarization interleaving, which leads to increase in transmission distance. Then a comparison of three different electrical filters i.e. Gaussian, rectangular and Bessel filter at receiver was performed for different optical fiber lengths which show that Bessel filter had improved performance with polarization interleaving. Also better eye opening was observed for different fiber lengths with proposed technique. At particular instance Q factor for Bessel, Gaussian and rectangular filters were 12, 9.9 and 8 for 864 km fiber length.

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Keywords: Polarization interleaving, DWDM, Q factor, Polarization mode dispersion, Long haul transmission

1. Introduction

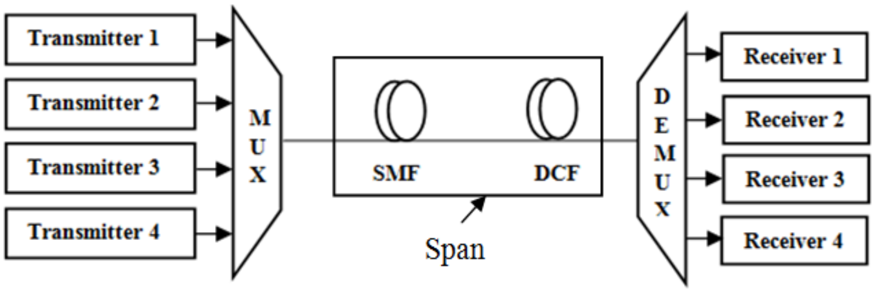
Wavelength division multiplexing have significant role in high capacity optical transmission systems which allows large amount of data to be transferred through optical fiber with different wavelengths. To increase capacity of fiber optics communication in WDM systems, most effective technique is to increase number of channels or bit rate per channel in WDM systems [1-3]. Optical light passing in WDM system offers some degree of freedoms i.e. phase, state of polarization and frequency. However, these systems suffer from undesirable effects which influence efficiency of system and leads to degradation in performance of system due to non-linearities[4]. Severe degradation occurs when there are large numbers of channels in WDM systems [5]. In addition to non-linear effects, depolarization of wave due to random birefringence degrades orthogonality of polarized signals and is difficult to demultiplex at receiver [6].

There are three polarization effects that lead to impairments in the long-haul optical fiber transmission systems: PMD, polarization dependent loss (PDL), and polarization dependent gain (PDG) [7-8]. Lin et al. [9] investigated PMD effects due to cross phase modulation in WDM systems. Kaur et al. [10] described method to suppress FWM power in hybrid topology consisting of ring and bus network using optical phase conjugation. Abdl et al. [11] presented approach for reduction of four wave mixing by using polarization interleaved system and behavior of proposed system with WDM system was analyzed. Borne et al. [12] mitigated non-linear penalties in 2×10 Gbps polarized multiplexed NRZ system by polarization interleaving of channels. Abd et al. [13-14] presented approach to suppress FWM by using different polarized optical signals based on polarization interleaving. Also Abd et al. [15] described smart filter based approach for reduction of FWM. YS Atiya et al. [16] described Channel Crosstalk Impact on OCDMA Performance using Diagonal Code and Optimized Shaping

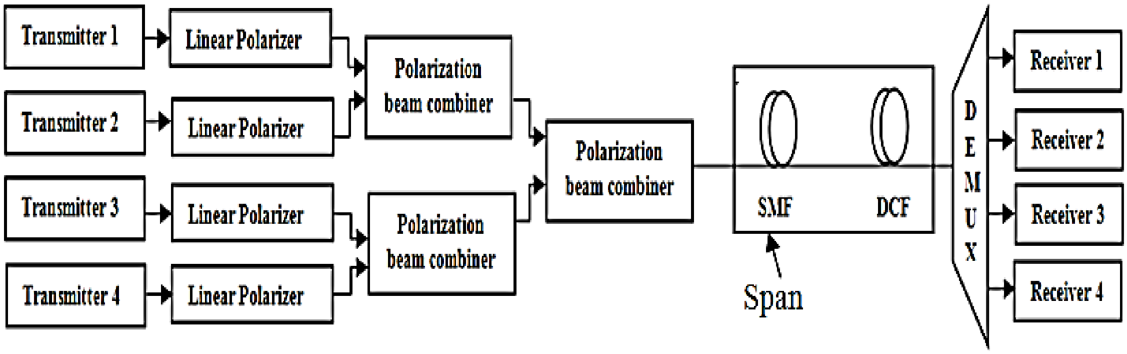
Previously proposed architectures involve transmission of signal at a short distance and compensate the four wave mixing in WDM system. It can be extended to mitigate the PMD effect and nonlinearities in DWDM system. In this paper, polarization interleaving techniques has been used to reduce PMD as well as non-linearities. After introduction, the paper is sorted out as follows: In section II, the system setup of proposed framework is discussed. In section III, results and discussion is clarified and conclusion is drawn in section IV.

2. Simulation setup

Fig. 1 shows block diagram of conventional DWDM and polarization interleaved DWDM system. In polarization interleaving, channels are divided into odd and even channels, further, passed through linear polarizers to change the state of polarization of channels in such a way that adjacent channels are orthogonal to each other i.e. odd channels are passed through linear polarizer with angle 45^0 while even channels through linear polarizer of 135^0. After that channels are combined through polarization beam combiner, they are passed through optical transmission link consisting of loop span with optical fiber of 40 km having dispersion 16.75 ps/nm km, attenuation 0.2 dB/km, followed by dispersion compensating fiber with dispersion of -80 ps/nm km.



(a)

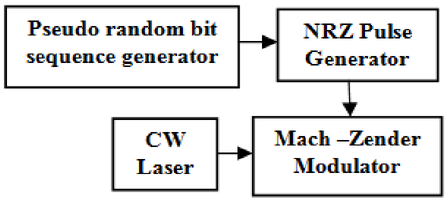


(b)

Fig. 1. Block diagram of (a) Conventional DWDM system (b) Proposed polarization interleaved system

When conventional DWDM system is used the fiber length is set to 8 km, and all channels have same state of polarization. The length of optical fiber is varied by varying number of loop spans of transmission link. We have used a dispersion compensating fiber (DCF) for decreasing the overall dispersion of the fiber link. After propagation through optical fiber, signal is passed through receiver and is analyzed by using BER analyzer. Fig. 2 shows internal block diagram for transmitter and receiver of system. In transmitter; continuous wave (CW) laser array of four lasers is considered producing carriers with 1 THz spacing

These CW lasers are connected with mach-zender modulator which is also connected to non-return to zero pulse generators and at receiver side, demultiplexer is used to separate multiplexed signals and is then detected through photodiode followed by electrical low pass Bessel filter and after that eye diagram analyzer is used to measure system performance.



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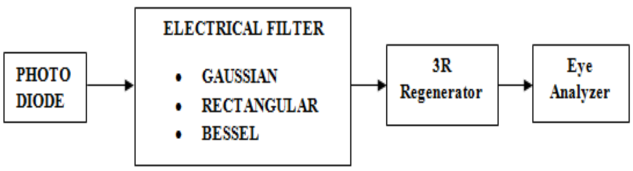
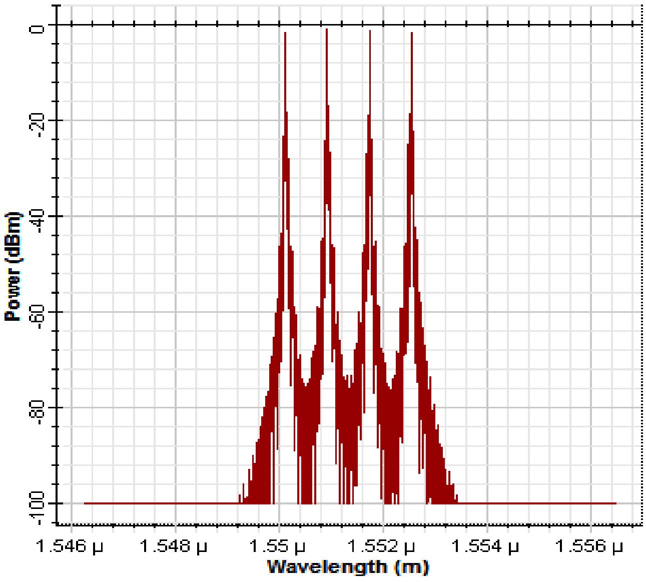


(b)

Fig. 2. Internal block diagram of (a) Transmitter (b) Receiver of each channel in proposed system

3. Results and discussion

Fig. 3 shows optical power spectrum of conventional DWDM system (a) after multiplexing and (b) after propagation distance of 720 km. It is observed that spectrum is distorted and broadened after propagation through fiber representing induced nonlinearities and PMD. Fig. 4(a) and (b) represents optical power spectrum for polarized interleaving system. Both spectrums are same representing mitigation of PMD, nonlinearities in received signal.



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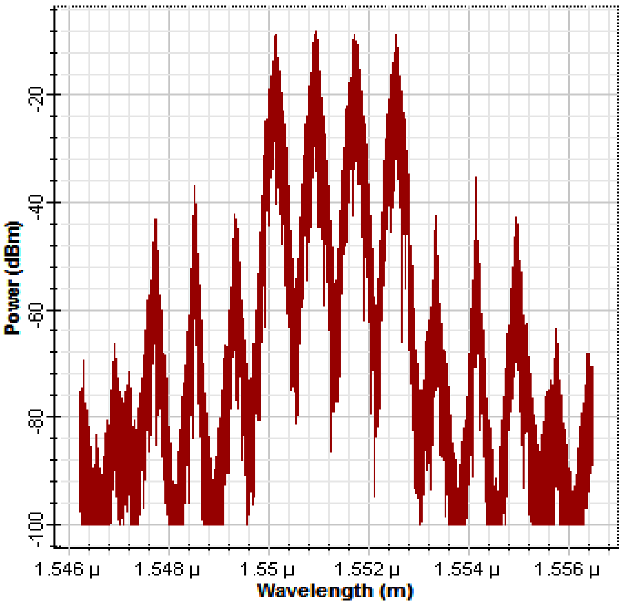
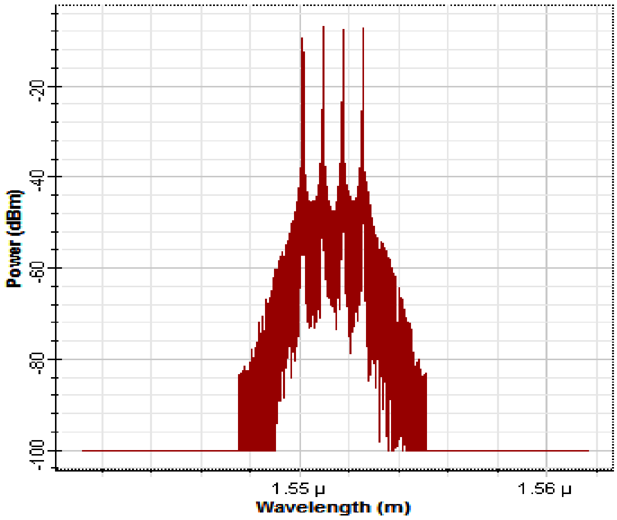


(b)

Fig. 3. Optical spectrum for conventional DWDM system after (a) Multiplexed signal (b) Propagation distance of 720 km



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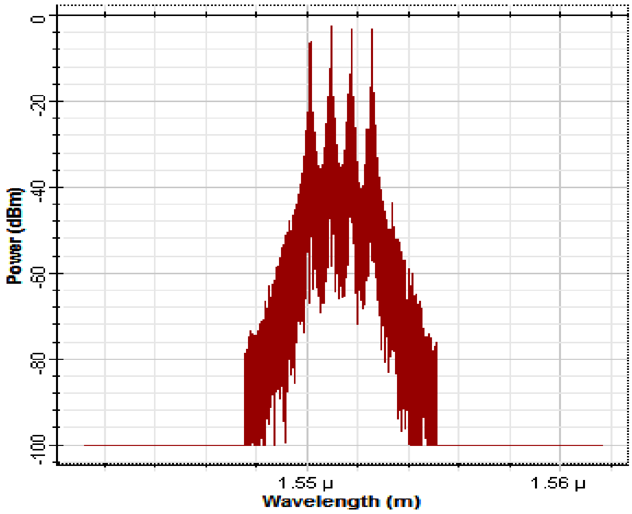


(b)

Fig. 4. Optical spectrum for polarization interleaved DWDM system after: (a) multiplexed signal (b) propagation distance of 720 km

Fig. 5 represents Q factor as a function of fiber length for both conventional DWDM and polarized interleaved DWDM system. From graph, we observed that signal quality increases with polarization interleaving, which leads to increase in transmission distance. In this case, we have achieved long haul distance of 1440 km with acceptable range. For particular fiber length i.e 720 km, proposed system have Q factor of 16 whereas conventional DWDM have Q factor of 3.5.

At receiver side, we have proposed different type of electrical filter i.e. Gaussian, rectangular and Bessel filter and compared the results to each other as shown in Fig. 6. It is observed that Bessel filter shows better performance as compared to rectangular and Gaussian filter. After Bessel filter, Gaussian filter shows good performance and rectangular filter shows worst performance. At particular Instance, Q factor for Bessel, Gaussian and Rectangular are 16, 12.9 and 11 at 720 Km fiber length.

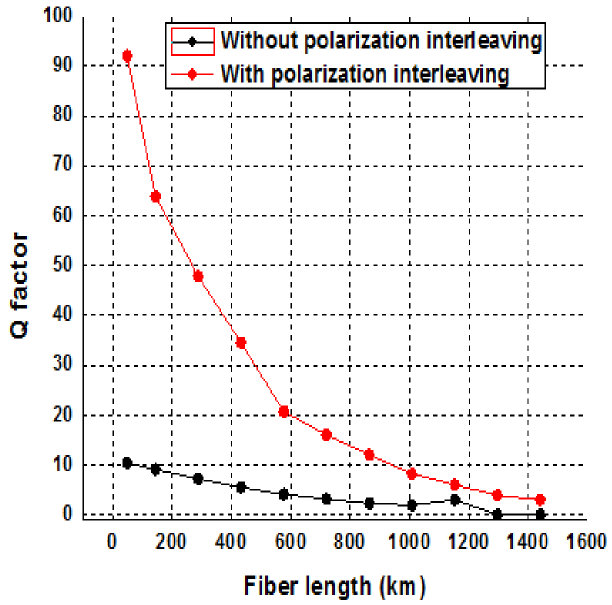


Fig. 5. Graphical representation of Q factor with varying fiber length with and without polarization interleaved system (color online)

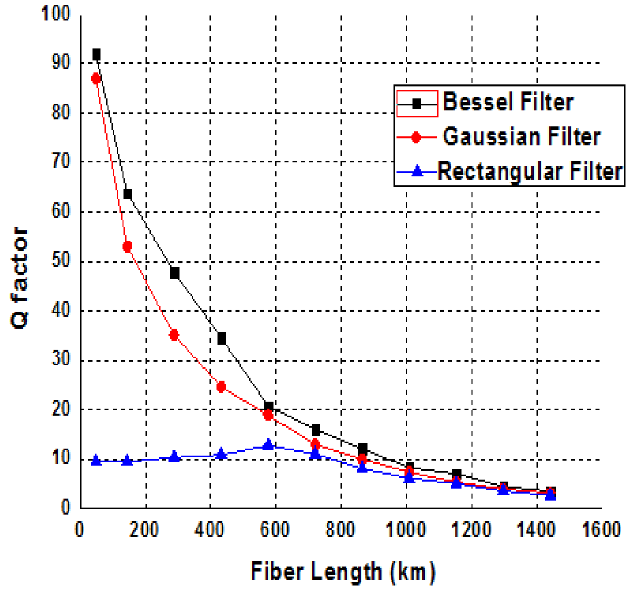


Fig. 6. Graphical representation of Q factor with varying fiber length for Gaussian, Bessel, and rectangular filter (color online)

From Fig. 5 and 6 it can be observed that the proposed system provides high quality factor on polarization interleaving with Bessel filter. For further clarity, the eye diagrams over the system has been observed with and without polarization. An eye diagram shows the signal quality amid fast advanced signal transmission. The closure of eye diagram represents distortion in the signal waveform due to noise and intersymbol interference. In this way, an open eye diagram corresponds to minimum signal distortion.

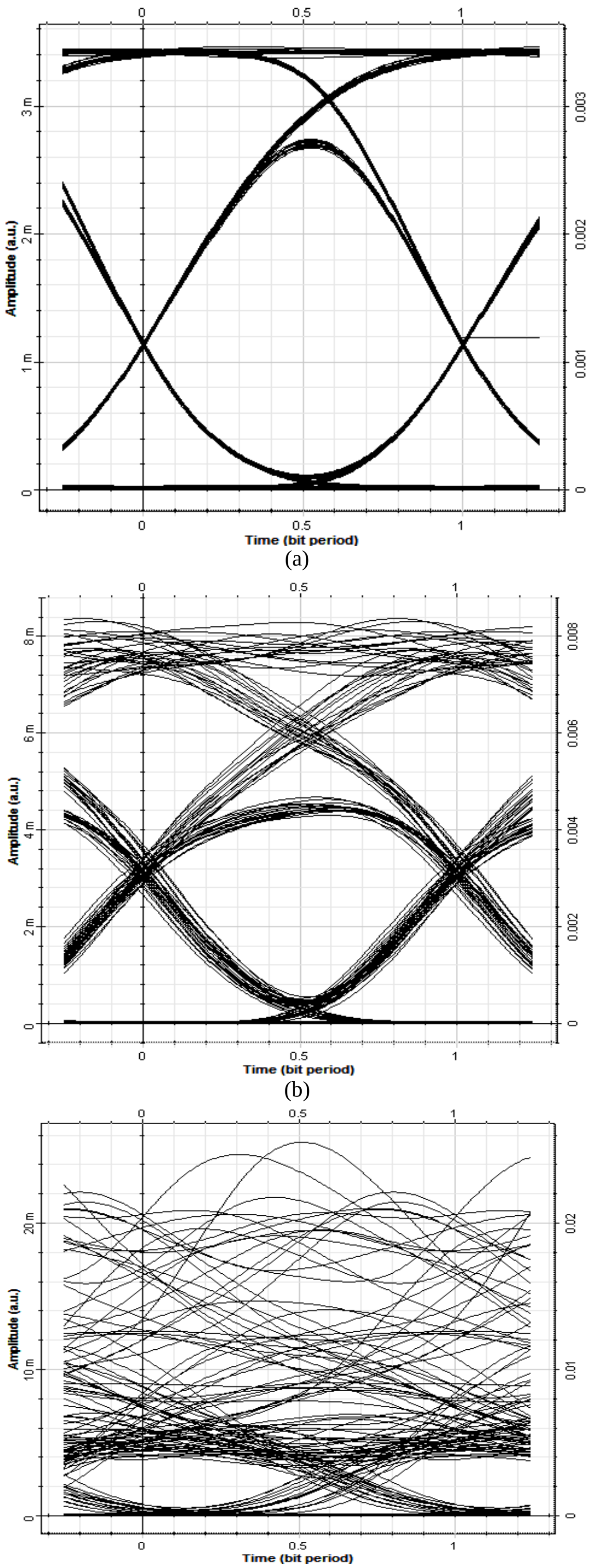
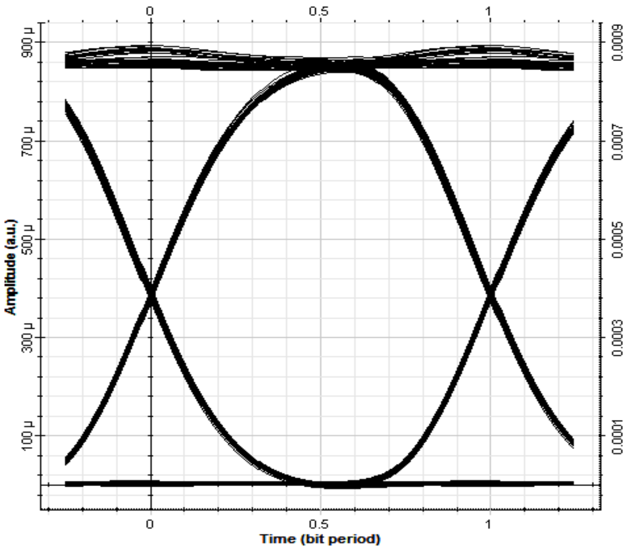


Fig. 7. Eye diagram for conventional DWDM system at: (a) 48 km (b) 576 km (C) 1152 km



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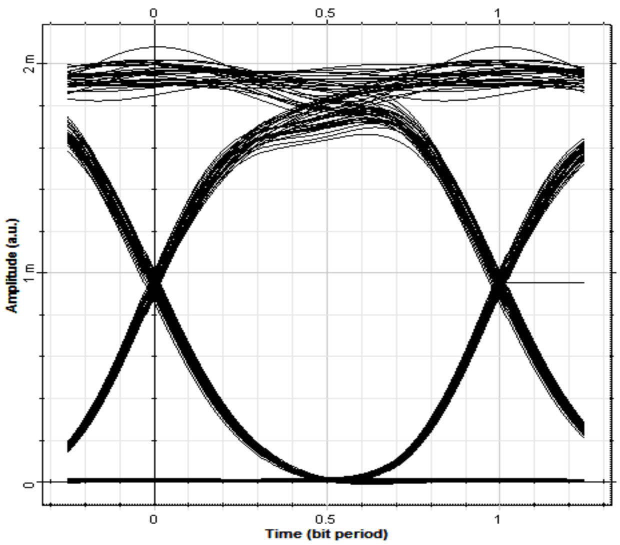

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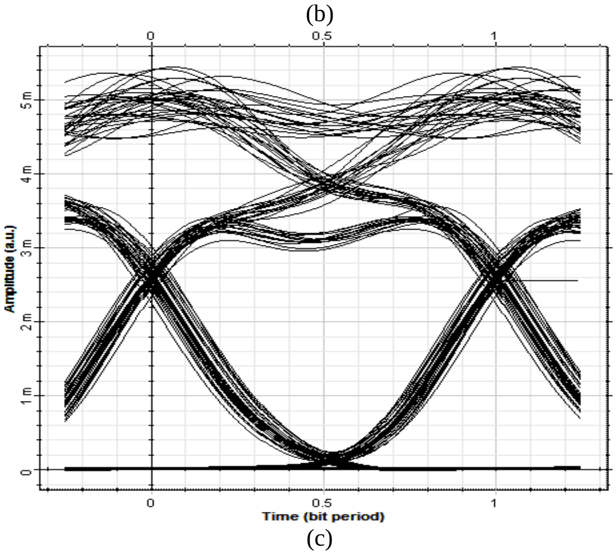

(c)

Fig. 8. Eye diagram for polarization interleaved system at: (a) 48 km (b) 576 km (C) 1152 km

Fig. 7 and 8 show the eye diagrams for uplink signal at a fiber length of 48 km, 576 km and 1152 km. When polarization interleaving is used in system then we achieved better eye opening for long haul transmission as compared to conversational system.

4. Conclusion

In this paper, the performance of polarization interleaved DWDM system using linear polarizers was analyzed and compared with conventional DWDM system to mitigate the nonlinearities and PMD over fiber. It was observed that proposed system had more Q factor than conventional DWDM for particular fiber lengths and transmission distance of 1440 km was observed with acceptable value of Q factor. Also, different electrical filters were compared at receiver side with each other for best suitability with system setup. And Bessel filter showed better performance than Gaussian and rectangular filter at different length of optical fiber. Also eye diagrams over the system were observed. The findings prove that the polarization approach significantly reduced the non-linearity through fiber transmission. It can be concluded that using polarization interleaving, we can send the data at high speed on long distance with good quality of signal.

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