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Research Article

Performance Evaluation of Post and Symmetrical DCF Technique with EDFA in 32x10, 32x20 and 32x40 Gbps WDM Systems

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Abstract

In WDM systems, performance is influenced by attenuation and dispersion. To compensate the attenuation, optical amplifiers are used. However, Dispersion Compensation is an important phenomenon in optical fiber communications. Pulse broadening of modulated signals can occur, in case with high data rates (>10 Gbps). In optical Communication, Dispersion Compensating Fibers (DCF) are widely used to compensate dispersive effect. Dispersion Compensation Technology using DCF is used in three configurations (Pre, post and symmetrical DCF). In this paper, WDM System is evaluated at 32x10 Gbps, 32x20 Gbps and 32x40 Gbps with Post Dispersion Compensation technique and Symmetrical Dispersion Compensation technique with EDFA. RZ modulation format is used at transmitter. The results are analyzed by studying Eye Diagrams and the performance is compared for both configurations on the basis of Q-Factor and Bit Error Rate. The analysis is done using Opti-system simulator.

Keywords*: BER, Dispersion Compensation, DCF, Q-Factor, SMF, WDM.*

1. Introduction

Optical Fiber offers very high band-width. For efficient utilization of available band-width, WDM techniques are used, which allows several channels to be routed over a single fiber cable. Fiber optic networks are such network that can meet the growing needs for the communication field having enormous bandwidth potential and good transmission capability. The aim of communication system is to increase the transmission distance and data rate. Therefore, it is desirable to investigate the transmission characteristics of optical fiber, i.e, attenuation and dispersion. These are the two foremost factors that affect the performance of optical fiber communication systems. Optical amplifiers such as EDFA, SOA, Raman amplifiers are used to compensate attenuation. If the transmission distance and data rate exceeds, the dispersion can cause intolerable amount of distortion.

Dispersion is a researchable issue in any communication system as it leads to inter symbol interference due to broadening and thus overlapping of two consecutive pulses resulting an error in the symbol detection. It is especially a problem statement in long distance, high bit rate optical fiber communication systems.

2. Related work

Following few relevant papers have been consulted before initiating the work on the subject as titled.

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Gaurav Soni *et al*. proposed a WDM system with Dispersion compensating fiber and evaluated the link performance at different wavelengths (980 nm, 1300 nm and 1550 nm).

A.H.M. Husein *et al*. proposed the WDM passive optical networks using spectrum slicing. Their work described the power efficient and cost effective solution of Optical Access Networks. The performance analysis was done for both non-return-to-zero (NRZ) and return-to-zero (RZ) line coding formats at 3 Gbps in 40 Km optical fiber link with BER<10^{-12}

Lucky Sharan *et al*. presented design and simulation of 32 channel WDM system at 40 Gbps data rate in the presence of non-linearity with under compensated dispersion. From the various graphs and tables, they successfully proved the superiority of Duo-binary format over NRZ/RZ scheme.

M. Tosson *et al*. presented dispersion compensation techniques for DWDM optical networks. This paper presented the two different techniques using FBG and DCF, to compensate dispersion at bit rate 40 Gbps and cable length of 150 Km.

Praveen Bagga *et al*. presented 32x20 Gbps DWDM system in presence of nonlinearities at different dispersion 2-10ps/nm/km.

M. Kaur *et al*. demonstrated the performance of 32 channel DWDM systems with post-dispersion compensation using DCF at different bit rates (10, 20 and 40 Gbps). The performance of the system had been investigated in terms of quality factor (Q) and minimum Bit error Rate (BER).

In this paper, we have extended the work on post-DCF technique and we have analyzed the performance of symmetrical DCF technique for 32 channel WDM systems at 10 Gbps, 20 Gbps and 40 Gbps.

3. Dispersion compensating fiber (DCF)

The dispersion compensating fiber, to counteract the dispersive effect of optical fiber, was proposed in 1980's. The components of DCF are not easily affected by temperature and band-width because DCF is more stable. The use of DCF is an efficient way to reduce the over-all dispersion in the WDM networks. DCFs having higher negative dispersion coefficient, can be connected to the transmission fiber having positive dispersion coefficient, to overcome the accumulated dispersion. Therefore, causing the total over-all dispersion of the optical link to be zero, after transmission of the signal through long distance of fiber (Gopika*et al*, 2015).

$$D_{SMF} \times L_{SMF} = -D_{DCF} \times L_{DCF} \quad (1)$$

Where, D and L are the dispersion and length respectively.

There are three compensation schemes being opted for dispersion compensation depending upon the position of DCF in the fiber link.

3.1 Pre-compensation

DCF is placed before a certain length of conventional single-mode fiber after the optical transmitter.

3.2 Post-compensation

DCF is placed after a certain length of conventional single-mode fiber near the optical receiver.

3.3 Symmetrical compensation

DCF is placed between two equal lengths of conventional single-mode fiber, which are adjacent to transmitter and receiver (Gaurav *et al,* 2014).

The post compensation and symmetrical compensation techniques have been simulated for analyzing the over-all performance of the system link, specifically in WDM technique.

4. System Design and Simulation Model

The 32 channel WDM system with Post DCF and Symmetrical DCF is designed and simulated using Opti-system 12 Software. The 32 channels are transmitted at 10 Gbps, 20 Gbps and 40 Gbps speed with channel spacing 100 GHz in the frequency range from 191-194.1 THz. RZ modulation format is used.

The block diagram of 32 channel WDM system using Post DCF technique is shown in fig.1, in which a DCF of 16 Km with EDFA is used, to compensate for the accumulated dispersion.

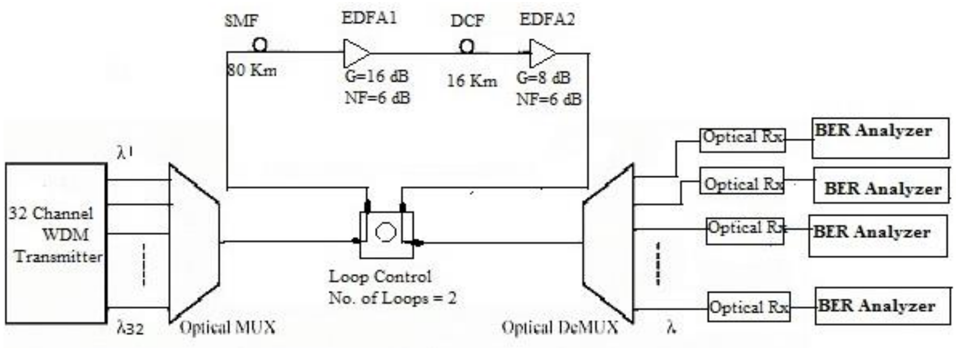

Fig.1 Block diagram of 32 channel WDM system using post DCF technique

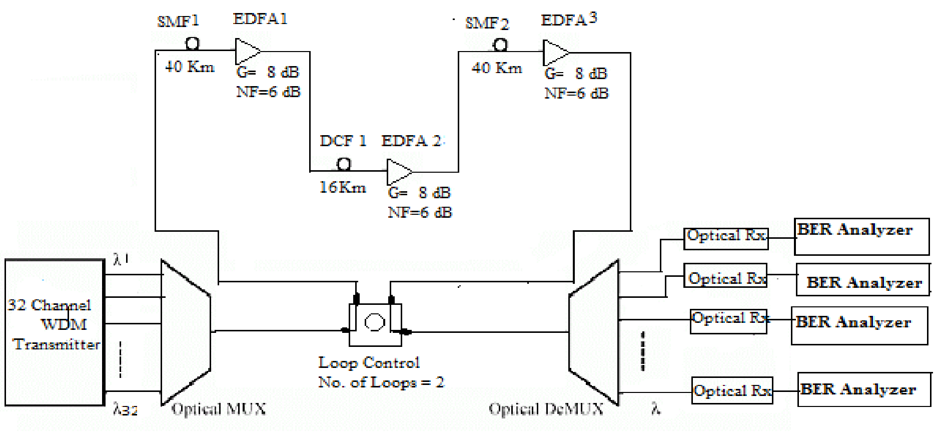

Fig.2 Block diagram of 32 channel WDM system using symmetrical DCF technique

The block diagram of 32 channel WDM system using symmetrical DCF technique is shown in fig. 2, in which a DCF of 16 Km with EDFA is used between two equal lengths of 40 Km SMF to compensate for the dispersion.

A 32 channel WDM transmitter is used, the output from this WDM transmitter is fed to an optical multiplexer, that has 32 input ports to combine the signals and transmit over a single fiber link. EDFA is used in the system to compensate for attenuation losses. Optical channel consists of 80 Km of SMF and 16 Km of DCF. Loop control is used, that defines the number of round trips that the signal makes through the loop by setting the number of loops, the number of loop is set at 2. At the receiver side, the de-multiplexer converts the single input to 32 outputs and then optical receiver is used to convert the optical signal into electrical form. The signal is analyzed using BER analyzer for Q-Factor, Minimum BER and Eye Diagram.

In table I, parameters used for simulation and in table II, fiber parameters are given.

Table 1 Simulation Parameter

Parameter	Value
Carrier Frequency of 1st channel	191 THz
Channel Spacing	100 GHz
Data Rate	10,20,40 Gbps
Sequence Length	64
Sample/bit	256

Table 2 Fiber Parameter

Parameter	SMF	DCF
Length (Km)	80	16
Attenuation (dB)	0.2	0.5
Dispersion (nm/ps/km)	17	-80
Differential Group Delay	0.5	0.5
PMD Coefficient	0.5	0.5

5. Results and Discussion

In this paper, the 32 channels are used to transmit the data with a data rate of 10 Gbps, 20 Gbps and 40 Gbps using two dispersion compensation techniques-post DCF technique and symmetrical DCF technique. The results are evaluated in terms of Eye diagram, Q-Factor and minimum Bit Error rate.

5.1 Post-DCF technique

Table III shows the readings of Q-Factor and minimum BER at randomly selected five channels at transmitter power level 0 dBm for 10 Gbps, 20 Gbps and 40 Gbps data rates using post DCF technique.

Table 3 Q Factor and Min. BER for Post DCF Technique at 0 dbm Power

Channel	At 10 Gbps		At 20 Gbps		At 40 Gbps	
Freq.(THz)	Q Factor	Min. BER	Q Factor	Min. BER	Q Factor	Min. BER
Ch 1 (191.0)	93	0	43	0	6	$5.8x10^{-11}$
Ch 8 (191.7)	16	$5.0x10^{-63}$	17	$3.6x10^{-69}$	4	$1.4x10^{-05}$
Ch15(192.4)	13	$1.4x10^{-40}$	12	$5.9x10^{-38}$	5	$1.9x10^{-08}$
Ch24(193.3	12	$4.9x10^{-35}$	10	$5.4x10^{-26}$	6	$3.9x10^{-12}$
Ch32(194.1)	16	$6.5x10^{-78}$	19	$1.8x10^{-87}$	10	$1.2x10^{-26}$

Table 4 Q Factor and Min. BER for Symmetrical DCF Technique at 0 dbm Power

Channel	At 10 Gbps		At 20 Gbps		At 40 Gbps	
Freq.(THz)	Q Factor	Min. BER	Q Factor	Min. BER	Q Factor	Min. BER
Ch 1 (191.0)	25	$1.3x10^{-145}$	27	$5.9x10^{-167}$	8	$6.9x10^{-17}$
Ch 8 (191.7)	13	$5.8x10^{-43}$	15	$7.0x10^{-56}$	7	$8.5x10^{-12}$
Ch15(192.4)	12	$8.2x10^{-35}$	12	$2.5x10^{-37}$	7	$1.9x10^{-14}$
Ch24(193.3	13	$8.8x10^{-40}$	13	$5.5x10^{-40}$	8	$2.0x10^{-16}$
Ch32(194.1)	26	$4.5x10^{-172}$	24	$5.5x10^{-129}$	7	$1.3x10^{-14}$

From table III, it can be observed that in case of Post DCF technique, the results of Q Factor and minimum BER are acceptable at 10 Gbps and 20 Gbps data rates but at 40 Gbps the results are not satisfactory.

5.2 Symmetrical DCF technique

Table IV, shows the results with symmetrical DCF technique, which provides comparatively higher Q Factor and better Bit Error Rate at 40 Gbps data rate. From table IV, it is observed tha the results with symmetrical DCF technique, provides comparatively higher Q Factor and better Bit Error Rate even at 40

Gbps data rate. The results became acceptable at the receiver and the over-all system has become more stable.

The eye diagrams for first channel (191 THz) at data rates, 10 Gbps, 20 Gbps and 40 Gbps for post-DCF technique at 0 dBm is shown in fig. 3

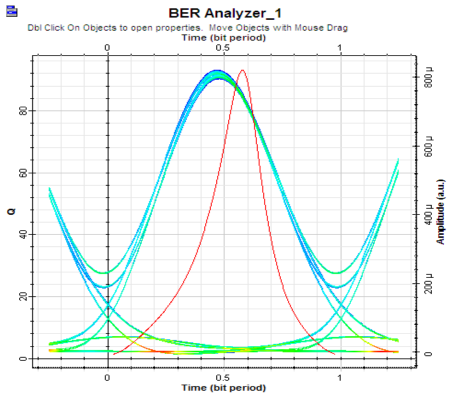

Fig. 3(a) At 10 Gbps

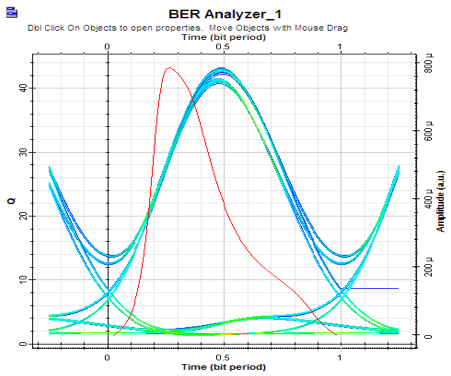

Fig. 3(b) At 20 Gbps

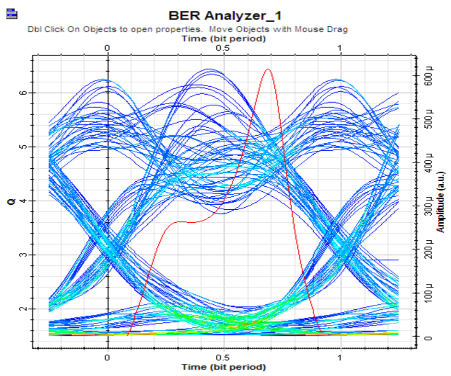

Fig. 3(c) At 40 Gbps

Fig.3 Eye diagrams for Post DCF Technique

Figure 3 shows the Eye Diagram of WDM System with Post DCF technique. Performance is better, if the opening of eye is maximum. When the data rate increases, the quality of eye diagram deteriorates gradually.

The eye diagrams for first channel (191 THz) at data rates 10 Gbps, 20 Gbps and 40 Gbps for symmetrical DCF technique at 0 dBm is shown in fig. 4.

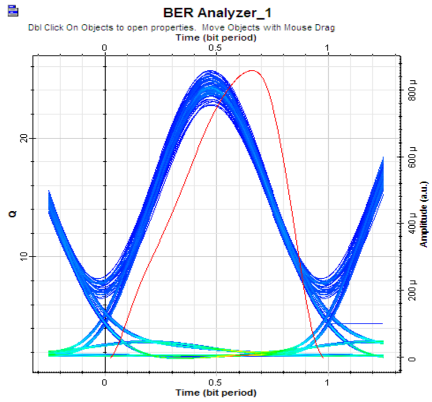

Fig.4(a) At 10 Gbps

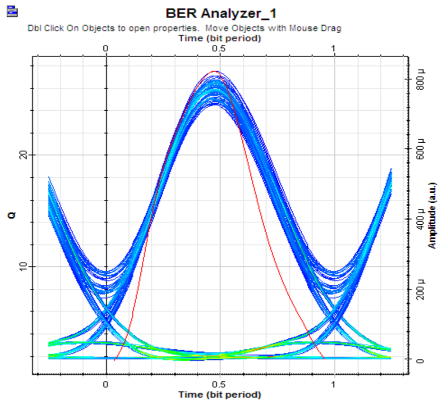

Fig.4(b) At 20 Gbps

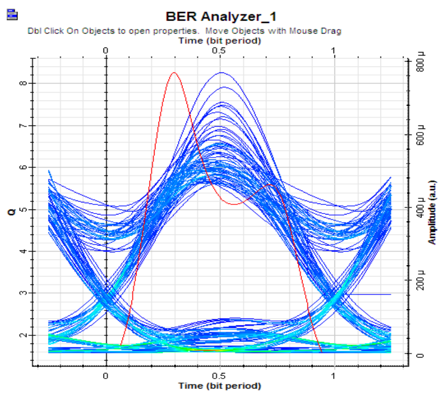

Fig.4(c) At 40 Gbps

Fig. 4 Eye diagrams for Symmetrical DCF Technique

From fig. 4, it can be observed that, at data rate 40 Gbps, the Eye diagram of symmetrical DCF technique is quiet good than in case of Post DCF technique.

Figure 5 shows the graph of Frequency Vs. Q Factor at three different data rates (at 10 Gbps, 20 Gbps and 40 Gbps) for post DCF technique.

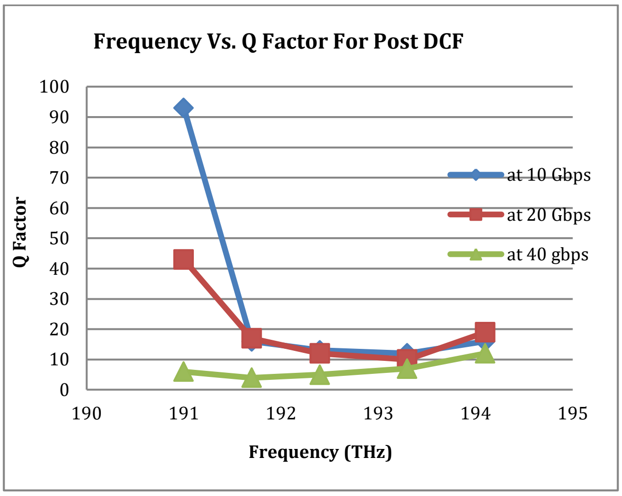

Fig.5 Quality Factor at different channels for Post DCF technique at 10, 20, and 40 Gbps

From fig. 5, it can be observed that the WDM system with post DCF technique, provides acceptable value of Q Factor at 10 Gbps and 20 Gbps, but at 40 Gbps, the Q factor is slightly lower at some channels.

Figure 6, shows the graph of Frequency Vs. minimum Bit Error Rate for Post DCF technique for three different data rates.

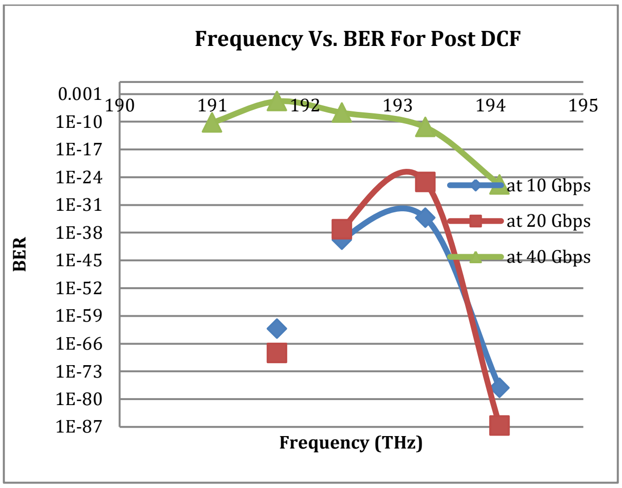

Fig.6 Min. BER at different channels for Post DCF technique at 10, 20, and 40 Gbps

From fig. 6, it can be observed that the value of minimum Bit Error Rate for post DCF technique at 10 Gbps and 20 Gbps is good, but at higher data rate, the Bit Error Rate performance is degraded. At 40 Gbps, the value of BER is not acceptable for all channels, which is > !0^{-9}.

Figure 7 shows the graph of Frequency Vs. Q Factor for Symmetrical DCF technique at 10 Gbps, 20 Gbps and 40 Gbps data rates

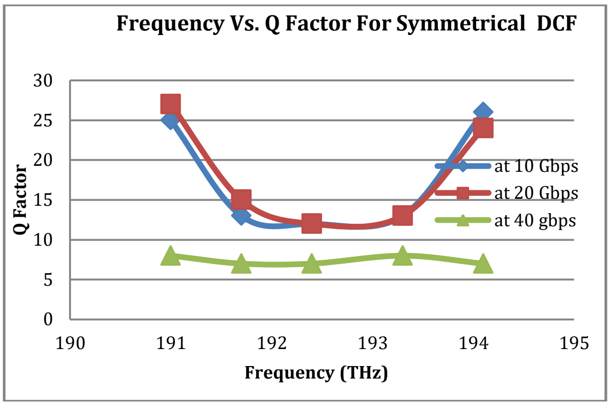

Fig.7 Quality Factor at different channels for symmetrical DCF technique at 10, 20, and 40 Gbps

The graph obtained from WDM system with Symmetrical DCF technique shows that the Q factor, which is more than 7 for all channels even at 40 Gbps.

Figure 8, shows the graph of Frequency Vs. minimum BER at three different data rates for Symmetrical DCF technique.

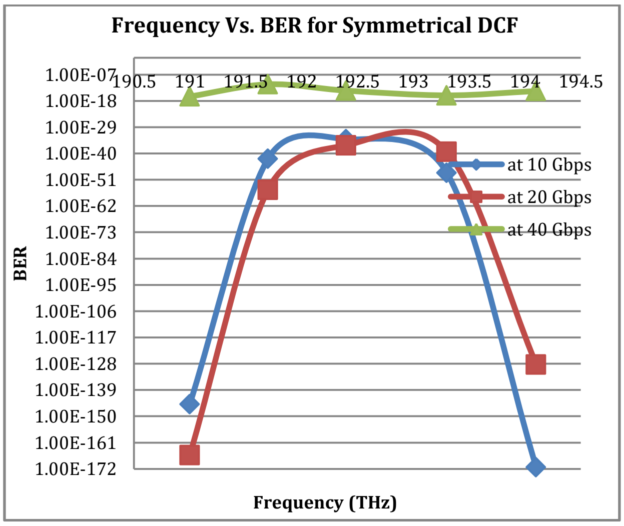

Fig.8 Min. BER at different channels for Symmetrical DCF technique at 10, 20, and 40 Gbps

From fig. 8, it can be observed that the BER achieved with Symmetrical DCF technique is acceptable at 10 Gbps, 20 Gbps and 40 Gbp. In the case of Symmetrical DCF, the value of minimum Bit Error Rate is observed to be less than 10^{-9} even at 40 Gbps for all channels.

Conclusion

In this work, we have evaluated the 32x10, 32x20 and 32x40 Gbps WDM system using EDFA and dispersion compensating fiber using both, post DCF and symmetrical DCF technique. Both the techniques are implemented to compare the WDM system at three different data rates. Post DCF technique and Symmetrical DCF techniques are compared in terms of Eye Diagram, Quality Factor and minimum Bit Error Rates. From the obtained results, it can be concluded that the symmetrical DCF technique performs better than post DCF technique in 32 channel WDM systems.

References

Manpreet Kaur, Himali Sarangal (2015), Simulative Investigation of 32x10, 32x20 and 32x40 Gb/s DWDM Systems with Dispersion Compensating Fibers." *International Journal of Signal Processing and Pattern Recognition*, vol.8,No.8, pp.127-134.

ManpreetKaur and HimaliSarangal, (2015), Performance Comparison of Pre-, Post-, and symmetrical Dispersion Compensation Technique using DCF on 40 Gbps WDM Systems. *International Journal of advanced Research in Electronics and Communication Engineering (IJARECE)*, vol.2 No. 3.

M. Tosson, Walid S. El-Deeb, A.E. Abdelnaiem, (2015), Dispersion Compensation Techniques for DWDM Optical Networks. *International Journal of advanced Research in Computer and Communication Engineering,* vol.4 Issue 8,.

Gopika P. and Sunu Ann Thomas, (2015), Performance Analysis of Dispersion Compensation using FBG and DCF in WDM Systems. *International Journal of advanced Research in Computer and Communication Engineering,* vol.4 Issue 10

Praveen Bagga and Himali Sarangal (2015), Simulation of 32x20 Gb/s WDM and DWDM System at Different Dispersion. *International Journal of advanced Research in Computer and Communication Engineering,* vol.4 Issue 3.

Mulayam Yadav, A .K. Jaiswal , Neelesh Agrawal, Navendu Nitin (2015), Design Performance of High Speed Optical Fiber WDM Systems with Optimally Placed DCF for Dispersion Compensation, *International Journal of Computer Applications,* vol.122-No.20.

Gaurav Soni, Rupinderjit Kaur (2014), Performance analysis of WDM link using Dispersion Compensating Fiber at different wavelength. *IEEE International Conference on Contemporary Computing and Informatics*, pp.1240-44.

A.H.M. Husein and F.I.El Nahal (2014), Optimal Design of 32 channels Spectrum slicing WDM for Fiber Access Network System, *International Journal for Light and Electron Optics,* vol.125, pp 5141-5143.

S. Singh, A. Singh, R.S Kaler, (2013). Performance Evaluation of EDFA, Raman and SOA Optical Amplifier for WDM Systems. *Optic* 124, pp. 95-101.

Lucky Sharan, V.K. Chaubey, (2012), Design and Simulation of Long Haul 32x40Gb/s Duo-binary DWDM Link in the presence of Nonlinearity with under Compensated Dispersion. *IEEE, 3rd International Conference on Photonics, Malaysia*, pp.210-214.

S. Spolitis. V. Bobrovs, G. Ivanovs, (2011), Realization of Combined Chromatic dispersion Compensation methods in High Speed WDM Optical Transmission Systems, *Electronika IR,* no.10

Sheetal A, Sharma A.K., Kaler R.S., (2010), Simulation of high capacity 40 Gbps long haul DWDM system using different modulation formats and dispersion compensation schemes in the presence of Kerr's effect. *Optic (Elsevier*), 121, 739-749.