Performance Comparison of Pre-, Post-, and Symmetrical Dispersion Compensation using DCF for 64 x 40 Gb/s DWDM System

Sabina[#1], Manpreet Kaur[*2]
[#] M.Tech(Scholar) & Department of Electronics & Communication Eng. SBBS University
Punjab, India
[*] Assistant Professor & Department of Electronics & Communication Eng. SBBS University
Punjab, India

Abstract

Optical wavelength division multiplexing (WDM) system is mostly used for increasing the information carrying capacity than other system. But some factor are deteriorates the performance of all optical system such as chromatic dispersion, polarization mode dispersion, and non-linear effects. In this paper, the 64 channel DWDM optical communication system at 40 Gb/s has been designed and investigated with EDFA as an optical amplifier based on dispersion compensation. Optisystem 7.0 is used for designing and simulation of the proposed system. The three dispersion compensation schemes (pre-, post-, symmetrical-DCF) are investigated & compared. The results of three compensation scheme have been compared in terms of bit error rate (BER) and quality factor. It is observed that both post and symmetrical compensation methods provide better results. This fulfills the requirement such as demand of high capacity and high speed of system.

Keywords — *Dispersion, Dense wavelength division multiplexing (DWDM), Erbium-doped fiber amplifier (EDFA), Bit error rate (BER).*

I. INTRODUCTION

Wavelength division multiplexing (WDM) is a technology in optical fiber communication which multiplexes number of optical carrier signal on to single fiber WDM is described by its wavelength which commonly applied to an optical carrier. Basically, WDM uses multiplexer at transmitter side for combining the signal and demultiplexer at receiver side to spread the signal apart. Due to higher capacity of WDM it is designed to achieve the higher data rate. WDM system enhances the capacity of network without laying more fibers in telecommunication companies. [1]

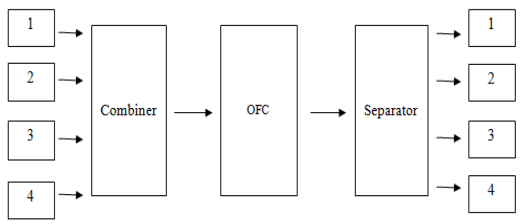


Fig 1: Block Diagram of Optical WDM Transmission System [2]

Attenuation and Dispersion are the two most important factor that affect the performance of fiber optical communication system. Dispersion occurs due to different wavelength or modes of light pulse propagating in fiber at different rates. So, dispersion compensation is required, there are various dispersion compensation techniques such as fiber bragg gratings, dispersion compensating fibers, soliton trasmission etc.

In this paper, the dispersion compensating fibers(DCF) are used as a dispersion compensation techniques.

A. Dispersion Compensation Fibers:

DCF components are more stable, these are not easily affected by temperature, wide bandwidth, so this is most suitable method for dispersion compensation. It is currently used for dispersion compensation in long-haul WDM optical transmission system. The use of DCF is an efficient way to reduce the overall dispersion in WDM network as they have higher negative dispersion coefficient and can be connected to the transmission fiber having the positive dispersion coefficient i.e. the overall dispersion of the link becomes zero. [3], [4]

Dispersion can be compensated by three compensation techniques depending upon the position of DCF:

i. Pre-DCF dispersion compensation
ii. Post- DCF dispersion compensation
iii. Symmetrical- DCF dispersion compensation

In pre- DCF dispersion compensation scheme, the DCF is placed before the single mode fiber (SMF) to compensate the dispersion in SMF.

In post- DCF dispersion compensation, the DCF is placed after the SMF to compensate the dispersion in SMF.

In symmetrical- DCF dispersion compensation, both the schemes (pre-, post-compensation) are used i.e. DCF is positioned before as well as after the SMF to attain the dispersion compensation. [5]

B. Literature Review:

Kaler et al. [6] investigated the pre-, post- and symmetrical dispersion compensation methods for 10 Gbps NRZ links using standard and dispersion compensated fibers. The EDFA is used as a optical amplifier. The reported results of three compensation methods are compared and it is found that the symmetrical compensation method is superior to pre- and post-compensation methods. The achieved maximum transmission distance for post-compensation is up to 288 km.

Randhawa et al. [7] compared the different dispersion mapping techniques like pre-, post- and hybrid compensation in the presence of fiber nonlinearities in 10 and 40 Gbps carrier-suppressed return to zero (CSRZ) systems and it is observed that hybrid compensation provide better results for high speed optical system. Unfortunately, these models have very low capacity and cannot be used for high speed optical communication because it is limited to single channel with 10 Gbps speed.

Tiwari et al. [8] achieved dispersion and power compensation in parallel by using pumped dispersion compensating fiber means Raman amplification has been done by using counter pumped DCF (PDCF).

Anil Agarwal et al [9] investigated the performance of DWDM system using Hybrid & single optical amplifiers in terms of q-factor, bit rate, eye height the performance is measured based on optical amplifiers at different transmission distance . Among these setups EDFA-EDFA performed better than other optical amplifiers at 150 km distance. They find that the output power (36.55 to -3.45 dBm), least BER (-38.96 to 0), large Q factor (12.71 to 0) and good eye diagram for different transmission distance ranging from 50 to 250 km.

Abdel Hakeim M. Huseina et al [10] investigated the spectrum sliced dense wavelength division multiplexed passive optical network (SS-DWDM–PON) as a power efficient and cost effective solution for optical access networks. In this work an AWG demultiplexer is used to operate as slicing system. The high speed SS-DWDM system has been realized and investigated for 32 channels with data rate up to 3 Gbps using broadband ASE source (LED). The 3 Gbps signals both non-return-to-zero (NRZ) and return-to-zero (RZ)were demonstrated in 40 km optical fiber link with BER < 10−12. The results obtained here demonstrate that SS-DWDM is well suited for Fiber-to-the-Home (FTTH) network.

In this paper, the work is extended to 64 channel DWDM system based on dispersion compensation using DCF at 40 Gb/s bit rate

The rest of the paper is organized as followed; Simulation Setup is described in section II. In section III, the results and discussion are presented and section IV concludes the paper.

II. SIMULATION SETUP

The 64 X 40 Gb/s DWDM optical communication system is designed & investigated using the Optisystem 7.0 simulator software based on dispersion compensation using DCF. The three dispersion compensation schemes (pre, post & symmetrical) are designed & investigated in terms of BER & Q-Factor. The parameters used for simulation are described in Table I and fiber parameters are described in Table II.

In the system design, the transmitter segment consists of data source, that generate a pseudo random sequence of bits at 40 Gbps. NRZ pulse generator convert the binary data into electrical pulses that modulates the laser signal using the Mach-Zehnder (M-Z) modulator. The transmitter segment block diagram is shown in "Fig. 3".

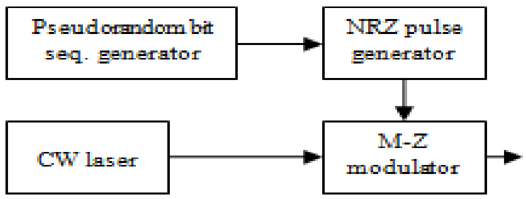


Fig 2: Transmitter section [11]

There are 64 optical sources that are generating the optical signals at different wavelengths with the channel spacing of 100 GHz.

The multiplexer combines the 64 input channels and transmit them over single fiber channel. The transmission channel consists of SMF of length 116 km and DCF of length 23 km with 2 spans; i.e. the total link distance is 278 km. Erbium-doped fiber amplifier (EDFA) is used to amplify the signals.

At the receiver part, the 1:64 demultiplexer is used to distribute the signals to 64 different channels. The output of the demultiplexer is given to APD photodetector and then passes through low pass electrical filter and 3R regenerator. The receiver part block diagram is shown in "Fig. 3".

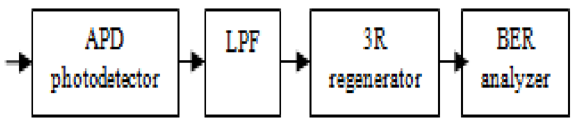


Fig 3: Receiver section [11]

Table I. Simulation Parameters

Parameters	Value
Bit rate	40 Gbps
No of channels	64
Power	10 dbm

Central frequency of first channel	191 THz
Channel spacing	100 GHz
Capacity	64x40 Gbps
EDFA Gain	10-30 Db

Table II. Fiber Parameters

	SMF	DCF
Length (km)	116	23
Attenuation (db/km)	0.2	0.5
Dispersion (ps/nm/km)	17	-85
Dispersion slop (ps/nm^2/km)	0.075	-0.3
Differential group delay (ps/km)	0.2	0.2

The simulation setup of 64 channel DWDM system based on dispersion compensation is shown in "Fig. 4".

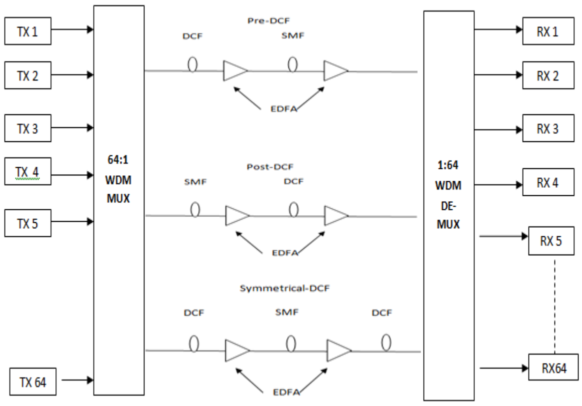
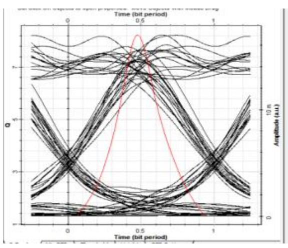
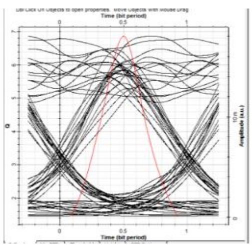


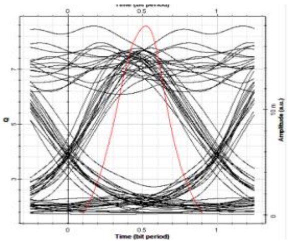
Fig 4: Simulation Setup of 64X40 Gb/s DWDM system

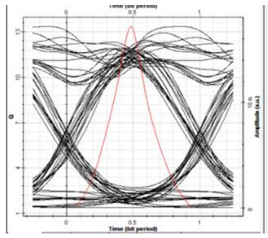
III.RESULT & DISCUSSION

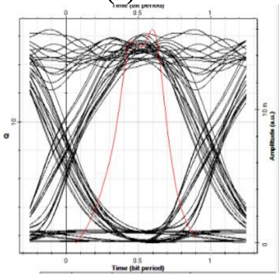
The 64 channel DWDM system based on dispersion compensation has been analyzed at 40 Gbps in terms of bit error rate (BER) and Q-factor. The eye diagrams for the different channels are shown in "Fig. 5, 6 & 7". The parameters, such as BER and Q-factor are tabulated in Table III & IV for the three dispersion compensation techniques.

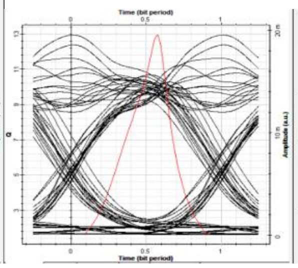

(a) 191 THz

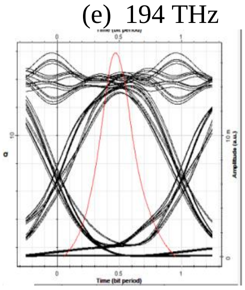

(b) 191.7 THz

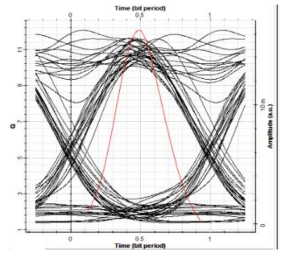

(c) 192.3 THz

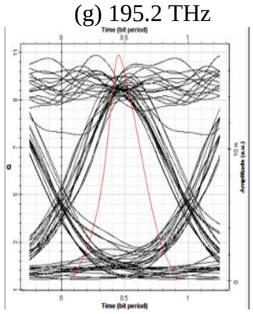

(d) 193.3 THz


(e) 194 THz


(f) 194.7 THz


(g) 195.2 THz


(h)195.8 THz


(i) 196.5 THz

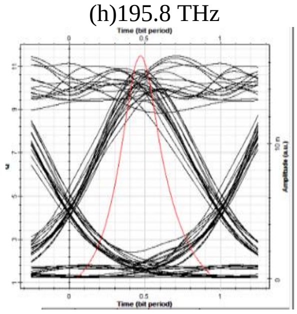
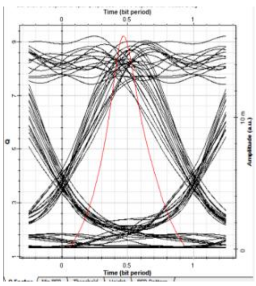
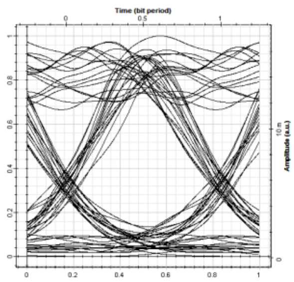
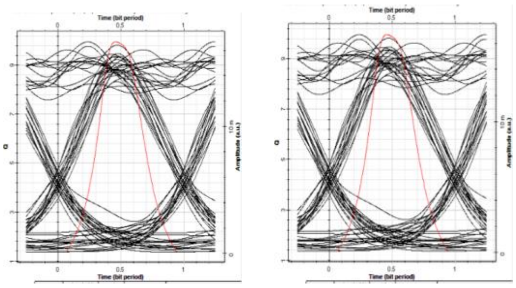

(j) 197.3THz

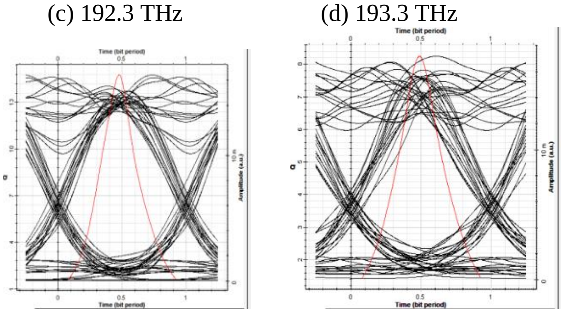
Fig 5: Eye Diagrams of Pre-DCF 64X40 Gb/s DWDM System at Different Channels


(a) 191 THz

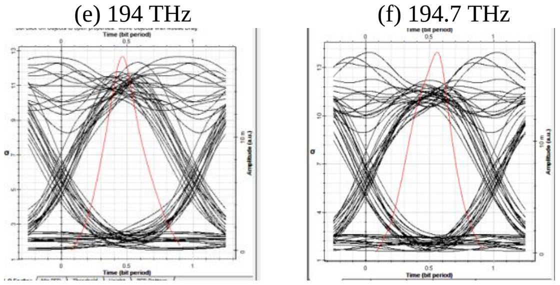

(b) 191.7 THz



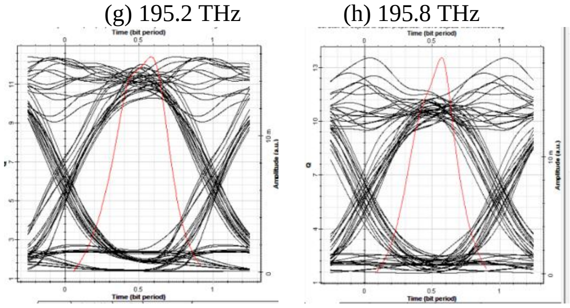
(c) 192.3 THz (d) 193.3 THz



(e) 194 THz (f) 194.7 THz

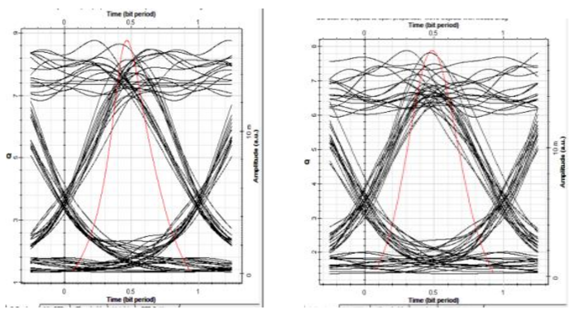


(g) 195.2 THz (h) 195.8 THz

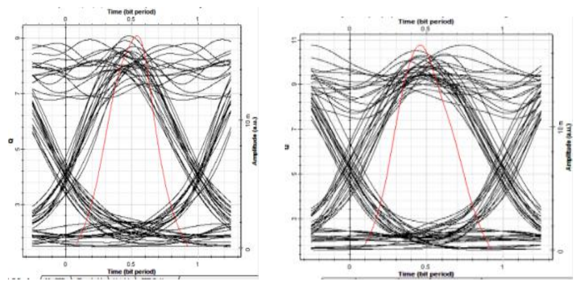


(i) 196.5 THz (j) 197.3 THz

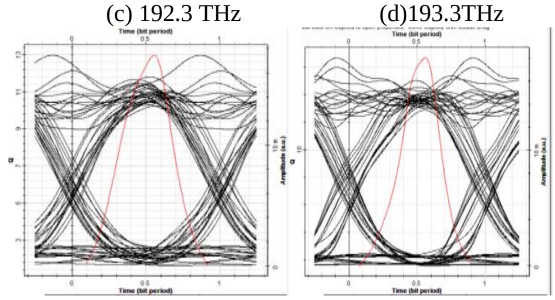
Fig 6: Eye Diagrams of Post-DCF 64X40 Gb/s DWDM System at Different Channels



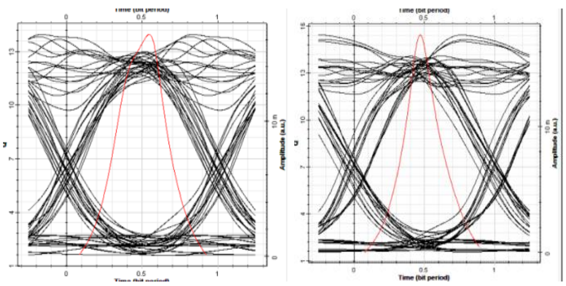
(a) 191 THz (b) 191.7 THz



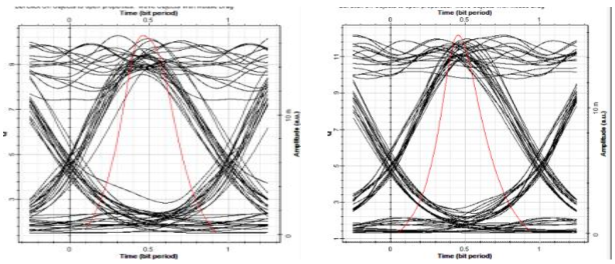
(c) 192.3 THz (d)193.3THz



(e) 194 THz (f) 194.7 THz



(g) 195.2 THz (h) 195.8 THz



(i) 196.5 THz (j) 197.3 THz

Fig 7: Eye Diagrams of Symmetrical-DCF 64X40 Gb/s DWDM System at Different Channels

The Q-Factor & BER values for the 64 X 40 Gb/s DWDM system based on three dispersion compensation schemes are tabulated in Table IV & V respectively & graphs are shown in Fig 8 & 9.

Table III. Q-Factor Three Dispersion Compensation Schemes at Different Channels

Channel Frequency (THz)	Quality Factor		
	Pre	Post	Symmetrical
191	8.23282	9.21417	8.76208
191.7	6.86119	8.24401	7.88059

192.3	8.56534	10.063	9.08418
193.3	10.3511	12.6576	10.7658
194	12.9369	13.9513	12.9584
194.7	10.4547	9.24401	12.6671
195.2	12.8771	13.5421	13.9543
195.8	12.0537	14.766	15.4352
196.5	10.8803	9.95662	10.2754
197.3	11.4582	13.542	12.1861

Table III. Ber For Three Dispersion Compensation Schemes At Different Channels

Channel Frequency	BER		
	Pre	Post	Symmetrical
191	8.86849e-17	1.54842e-20	9.34549e-19
191.7	3.0979e-12	7.9815e-17	1.5845e-15
192.3	5.1506e-18	3.85596e-24	5.03189e-20
193.3	5.8102e-30	4.89436e-37	2.40036e-27
194	1.37447e-35	1.51798e-44	1.03937e-38
194.7	1.37998e-36	1.9047e-35	1.1131e-40
195.2	4.53904e-40	4.38592e-40	1.47757e-41
195.8	9.07797e-34	1.21125e-35	4.70891e-38
196.5	6.98883e-28	1.166775e-22	4.52302e-25
197.3	1.00765e-30	4.38592e-35	1.81588e-34

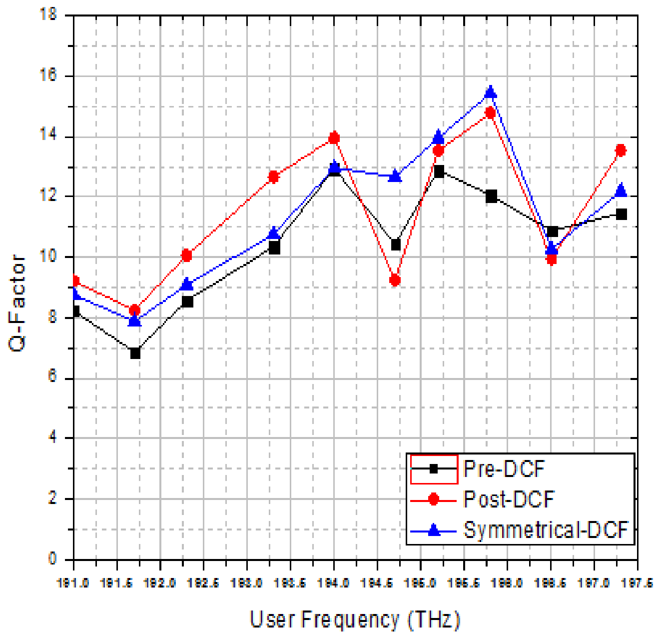


Fig 8: Quality Factor at different channels for pre, post & symmetrical-DCF

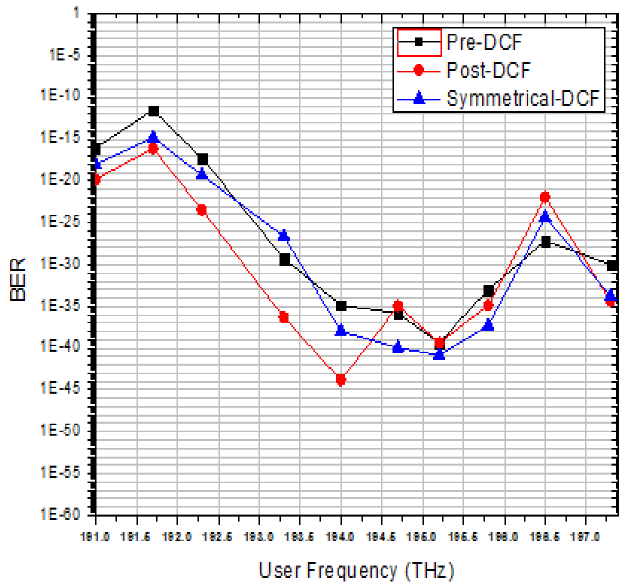


Fig 9: BER at Different Channels for Pre, Post & Symmetrical-DCF

IV. CONCLUSIONS

The paper investigates the 64 channel DWDM system at 40 Gb/s based on dispersion compensation using DCF with 100 GHz channel spacing. The performance of system using three different dispersion compensation techniques is investigated & compared in terms of BER & Q-Factor as shown in graphs & Tables above. The maximum possible distance of the communication link achieved is 278 km i.e. 2 spans of system (116 km SMF and 23 km DCF). From the simulation results, it was found that the post & symmetrical-DCF systems perform better than pre-DCF system.

REFERENCES

[1] Mukherjee B, "WDM Optical Communication Networks: Progress and Challenges", IEEE Journal on Selected Areas in Communications, VOL. 18, NO. 10,pp 1810-1824, 2000.

[2] Senior J M & Cusworth S D, "Devices for wavelength multiplexing and demultiplexing", Optoelectronics, IEE Proceedings, VOL. 136, NO. 3, pp 183- 202, 1989.

[3] Gerd E. Keiser,"A Review of WDM Technology and Applications", Optical Fiber Technology, VOL. 5, pp 3-39, 1999.

[4] Bo-ning HU, Wang Jing, Wang Wei, Rui-mei Zhao, "Analysis on Dispersion Compensation with DCF based on Optisystem". 2nd International Conference on Industrial and Information Systems pp. 40-43 2010.

[5] Jyoti Gujral, Maninder Singh "Performance Analysis of 4-Channel WDM System with and without EDFA" IJECT Vol. 4, Issue Spl - 3, April - June 2013M. Shell. (2002) IEEE

[6] R.S. Kaler, A.K. Sharma, T.S. Kamal, "Comparison of pre-, post- and symmetricaldispersion compensation schemes for 10 Gb/s NRZ links using standard and dispersion compensated fibers", J. Opt. Commun. 209 (2002) 107–123.

[7] R. Randhawa, J.S. Sohal, R.S. Kalar, "Pre-, post and hybrid dispersion mapping techniques for CSRZ optical networks with nonlinearities", Optik 121 (14) (2010) 1274–1279.

[8] U. Tiwari, K. Rajan, K. Thyagarajan, "Multi-channel gain and noise figure evaluation of Raman/EDFA hybrid amplifiers", Opt. Commun. 281 (2008)

[9] Anil Agarwal, Sudhir Kumar Sharma "Performance Comparison of Single & Hybrid Optical Amplifiers for DWDM System Using Optisystem" ISSN: 2278-8735.Volume 9, Issue 1, Ver. VI (Feb. 2014), PP 28-33

[10] Abdel Hakeim M. Huseina, Fady I. El Nahal "Optimal design of 32 channels spectrum slicing WDM for optical fiber access network system" Optik 125 (2014) 5141–5143

[11] Simranjit Singh, Amanpreet Singh, R.S. Kaler "Performance evaluation of EDFA, RAMAN and SOA optical amplifier for WDM systems" Optik 124 (2013) 95–101

[12] Gurinder Singh, Ameeta Seehra, Sukhbir Singh "Investigations on order and width of RZ super Gaussian pulse in different WDM systems at 40 Gb/s using dispersion compensating fibers" Optik 125 (2014) 4270–4273]