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Analysis and Comparison of Dispersion Compensation by DCF Schemes & Fiber Bragg Grating

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ABSTRACT

This current research article explained about the dispersion compensating fibers and employed for improving the already installed 1310-nm systems to work at 1510nm wavelength. Traditional fibers are denoted by large core radii (5-6µm) and zero dispersion occurs at 1310nm. At this wavelength attenuation is high than 1550 nm but low pulse broadening. New fiber with zero dispersion was established to utilize the low loss window around 1550 nm. These fibers are known as DCFs with a triangular refractive index profiled core. By using DCF minimum loss as well as zero dispersion can be attained. In our research work, for dispersion compensation after each fiber optical amplifiers are used. Different dispersion parameters of single mode fiber are120 km long, 16 ps/nm-km and overall dispersion is 16 × 120 = 1920 ps/nm. With the help of 24 km long DCF dispersion can be compensated and total transmission distance is 120 × 2 =240 km for individual. In case ofpost-compensation DCF is deposited after SMF and fiber placement follows the sequence SMF, DCF in symmetrical compensation. Dispersion Compensation by fiber Bragg Gratings in also modelled.

Keywords: OpticalCommunication (OC), Dispersion compensation (DC), Single Mode Fiber (SMF), Multi-mode fiber (MMF), Dispersion compensation Fiber (DCF), Fiber Bragg Gratings.

1. INTRODUCTION

The fiber optic industry has witnessed a rise after huge development in optical communication and it has become popular day by day due to technical and scientific progress in this particular field [1]. The major applications of optical fibers has been in area of telecommunications, fiber optic sensors, fiber optic devices and components and integrated optics. Development in these areas has helped us to understand various properties and its principles [2].The optical fiber is a waveguide used for transmission of light and optical communication are mostly used for modern communication links of global network [3].For information transmission in optical communication systems, firstly information is converted into light pulses or into light and then information is send from transmitter to receiver. At the receiver end the original information can be obtained from light pulses [4]. During transmission light pulses becomes broadens in time as it propagates through the fiber, this phenomena is called dispersion. Due to dispersion transmitted information gets distorted [5]. Dispersion in optical fiber happens primarily for two reasons:

(1) The propagation times for different rays varies when they travelled through an optical fiber. (intermodal dispersion) and

(2) Any given source emits over a range of wavelengths and because of the intrinsic property of material, different wavelengths take different times to propagate along the same path (material dispersion) [23].

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Dispersion in single mode fibersis an intramodal effect due to group velocity dependence on wavelength and the amount of signal distortion depend on the optical source spectral width [6]. In multimode fibers the dispersion exists that is called intermodal. These types of dispersion occuras a result having different group velocities at the same frequency [7].Dispersion compensation is very crucial issue for optical communication. Dispersion compensation means compensating or controlling the chromatic dispersion of optical elements. Before detecting the actual signal it is very important to compensate the dispersion with the help of dispersion compensating techniques [8]. For high data rates above 40 Gbit/s, pulse broadening or dispersion become much stronger because spectral bandwidth of the signal becomes larger. It is then generally not adequate to compensate the second-order dispersion only; one also needs to deal with higher-order dispersion [9]. In future, the telecommunication network will be completely composed by optical fibers. Optical communication is a new technology due to its rapid development and the broad range of application. It becomes the denotation of the new technological revolution in the world. As a main transmission of various information tools, it is of great importance in the future information society. Now, optical communication systems are becoming more complex because these systems often include multiple signal channels, different topology structure, nonlinear devices and non-Gaussian noise sources, which make their design and analysis quite complex and require high-intensity work. Opti-system will allow the design and analysis of these systems become quickly and efficiently [24]. We used Optisystem software in this research work.

2. MATERIAL AND METHODS

Dispersion compensation is a challenging issuein optical communication and with high data rate broadening of signal can occurs. Each signal would strongly overlap with a large number of neighbored signal called inter-symbol interference without dispersion compensation and signal will distort strongly due to inter-symbol interference. Therefore, it is essential to compensate the dispersion before receiving the signals at the receiver [10].To control the chromatic dispersion in optical fiber is called Dispersion compensation and our goal is to avoid excessive broadening and distortion of signals. Pulse broadening and distortion of signals at high data rate such as 40 Gbit/s or 160 Gbit/s, becomes stronger as compare to low data rates due to spectral bandwidth [11]. Compensation of second order dispersion is not enough but also compensation of higher-order dispersion is necessary. A distortion of signal occurs due to uncompensated third-order dispersion. The dispersion compensation fibers for communication system are being installed at a wide range but the problem with installation of DCFs already existing i.e. for best results where the DCF is to be inserted in channel [12].

The first step will be designing and simulation of the pre, post and symmetric dispersion compensation systems. This will be done by using Optiwave's Optisystem software. Firstly the study about software will be done. The optisystem software is easy to use, flexible, powerful and fast and the optisystem components library includes hundreds of components that enable to enter parameters that can be measured from real devices.By using model design in optisystem software, the parameters such as bit rate, link distance will be varied to achieve best Q-factor [18]. The Comparison analysis of systems will be done using the optisystem version 7.0. The analysis of BER, Q-factor and eye diagrams is done by using BER analyzer visualizer.In this research paper,we will discuss three dispersion compensation techniques to compensate fiber dispersion i.e pre-, post-, and symmetrical compensation. Firstly dispersion compensatingfibers (DCFs) is used. After that we present the how dispersion compensation effect the performance of the system. In these simulations, NRZ modulation formats are used and receiver sensitivity is -28 dBm for 2.5 Gbps and -25 dBm for 10 Gbps.

2.1. Pre-Compensation and Post dispersion compensation using DCF

Pre compensation and post-compensation caseconfiguration is shown in figure1 and figure 2. In dispersion pre compensation dispersion scheme, components are placed in sequence- DCF-SMF this leads to give

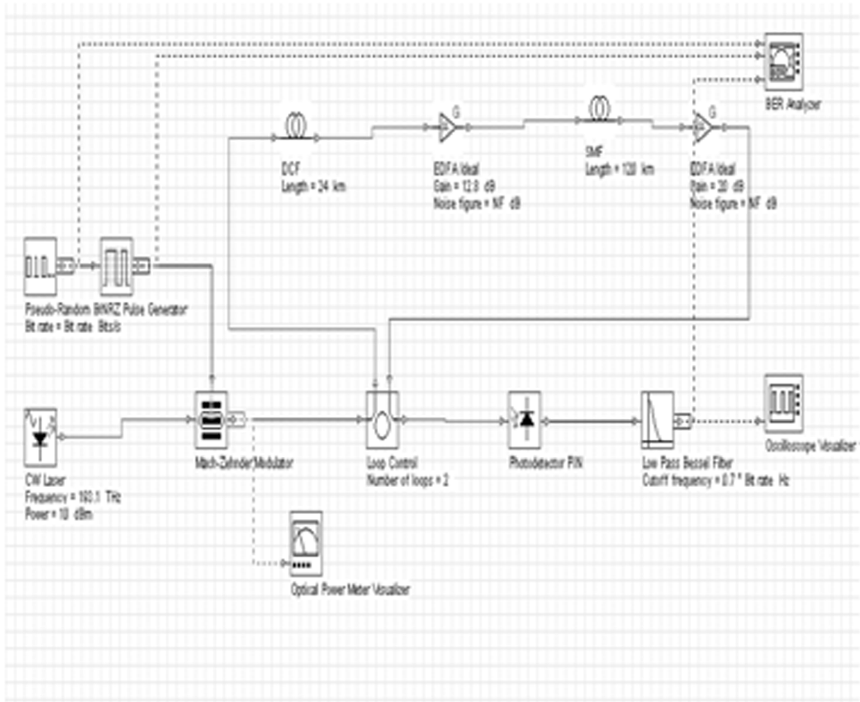


Figure 1: Dispersion pre compensation system setup

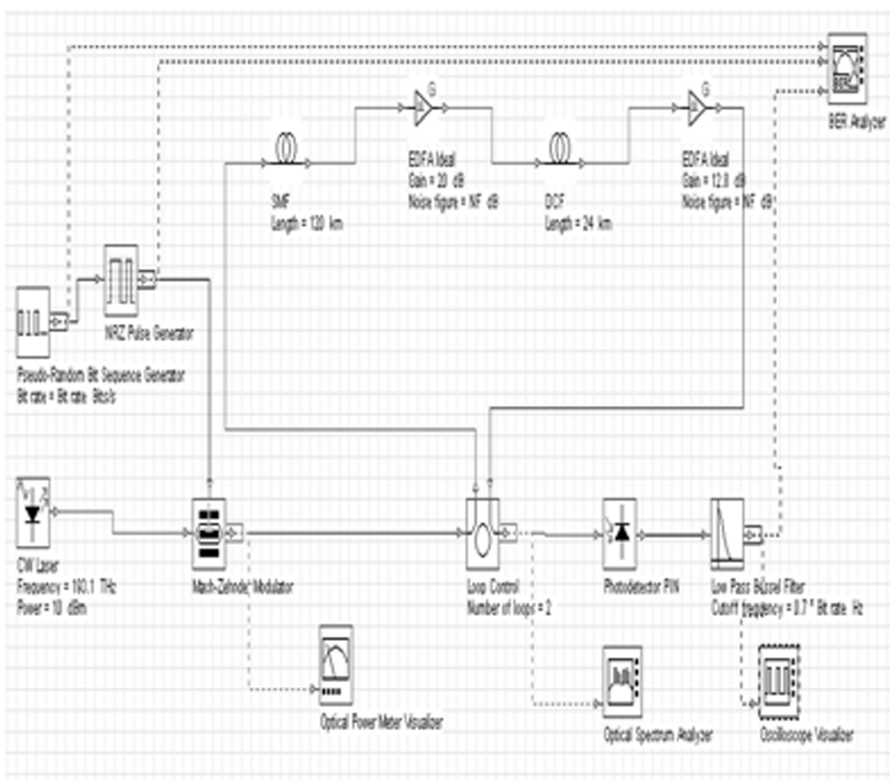


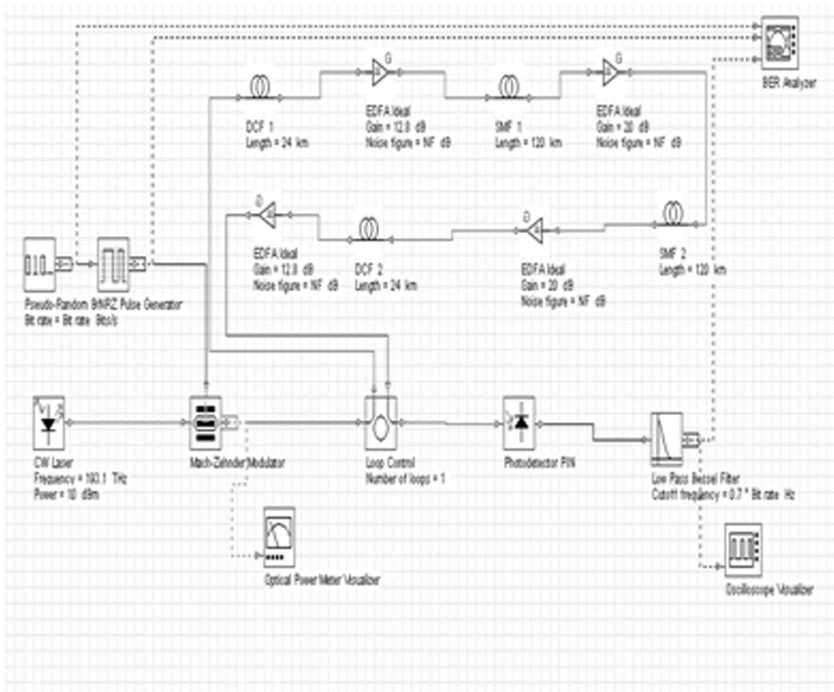
Figure 2: Post Dispersion Compensation System Setup

negative dispersion to pulses when they are transmitted from transmitter and before they enter the SMF channel.In post dispersion compensation system the DCF is placed after SMF which provides pulses to pass through negetive dispersion fiber after they have already undergone pulse broadening.In simulations, we have used optical amplifiers after each fiber to compensate dispersion and signal amplification. The dispersion parameter of SMF is 120 km long and 16 ps/nm-km. Therefore, total accumulated dispersion is

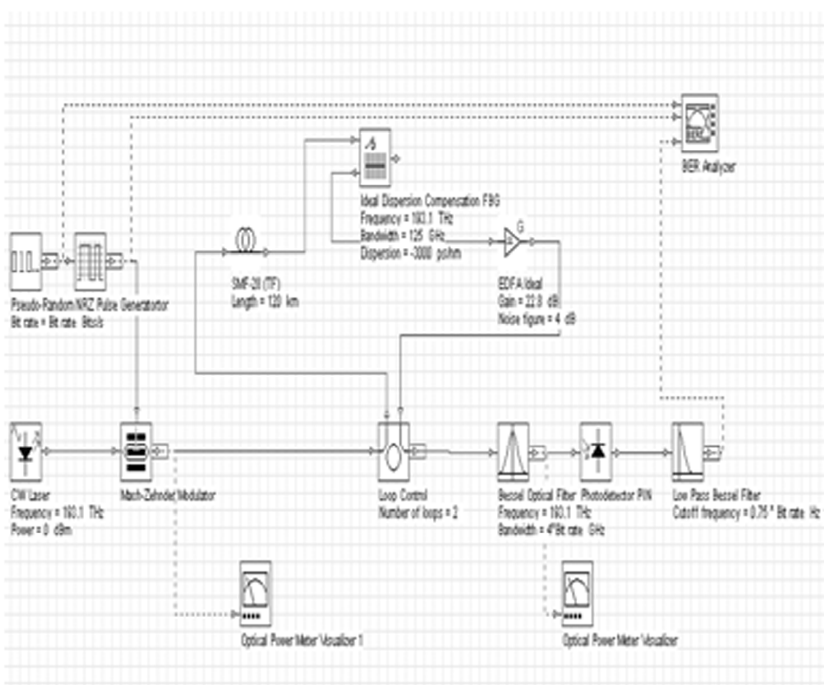
16 × 120 = 1920 ps/nm. This dispersion can be compensated by using a 24 km long DCF with -80 ps/km-nm dispersion. Total transmission distance is 120 × 2 = 240 km for each [17].

2.2. Dispersion Symmetrical compensation and Dispersion Compensation Module- FBG

Fiber placement follows the sequence of SMF, DCF, DCF, and SMF in symmetrical compensation scheme and we also used FBG as the dispersion compensation module. In this case, we selected a post-compensation



(a)



(b)

Figure 3: Dispersion symmetrical compensation system setup and Dispersion Compensation Component with FBG (a) and (b) respectively

scheme because it is simple compared to the symmetrical compensation scheme. All dispersion compensation techniques operate in low power region. Dispersion symmetrical compensation system setup andDispersion Compensation Component with FBG are shown in figure 4 (a) and (b) respectively.

3. RESULTS AND DISCUSSION

Simulation results are shown in Table 1. Table shows Q-factor of received signal versus transmitted signal power for these three different compensation schemes at 2.5 Gbps, 5Gbps and 10 Gbps bit rate. For simulation parameter bit rate 10 Gbps need to set and from the simulation outputs we can conclude that symmetrical dispersion compensation gives best performance. Pre-compensation scheme is the worst case out of all three schemes. This can also be seen from the eye diagrams given in Table 2.

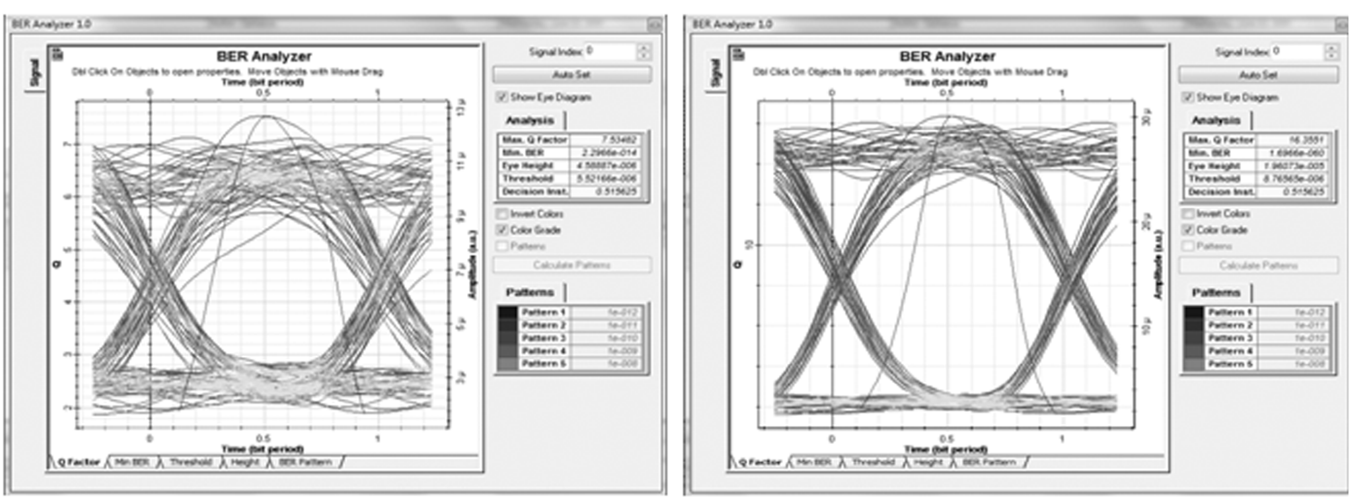
Table 1
Comparison of results obtained from Simulation

Bit rate	*Parameter*	*Pre*	*Post*	*Symmetric*	*Power*
2.5 Gbps	Q-Factor	7.534	8.3925	8.190	-10dBm
	Min. BER	$2.296*10^{-14}$	$2.243*10^{-17}$	$1.223*10^{-16}$	
	Q-Factor	16.355	18.176	17.746	-5 dBm
	Min. BER	$1.696*10^{-60}$	$3.388*10^{-74}$	$8.620*10^{-71}$	
5 Gbps	Q-Factor	19.820	21.381	21.380	0 dBm
	Min. BER	$7.781*10^{-88}$	$7.674*10^{-102}$	$7.979*10^{-102}$	
10 Gbps	Q-Factor	22.757	27.043	25.901	5 dBm
	Min. BER	$4.3839*10^{-115}$	$1.641*10^{-161}$	$2.348*10^{-148}$	
	Q-Factor	17.051	19.283	22.488	10 dBm
	Min. BER	$1.095*10^{-65}$	$2.385*10^{-83}$	$1.786*10^{-112}$	

3.1. Various Eye Diagrams obtained after Compensation

This section shows the various Eye diagrams achieved at output end at BER analyzer. In this Eye diagrams at different power for dispersion compensation techniques like pre compensation scheme, post compensation scheme and dispersion symmetric compensation scheme are observed.

3.1.1. Dispersion Pre compensation Scheme



(a) (b)

Figure 4: Eye Diagram Obtained at 2.5 Gbps with (a) -10dBm Power (b) -5dBm Power

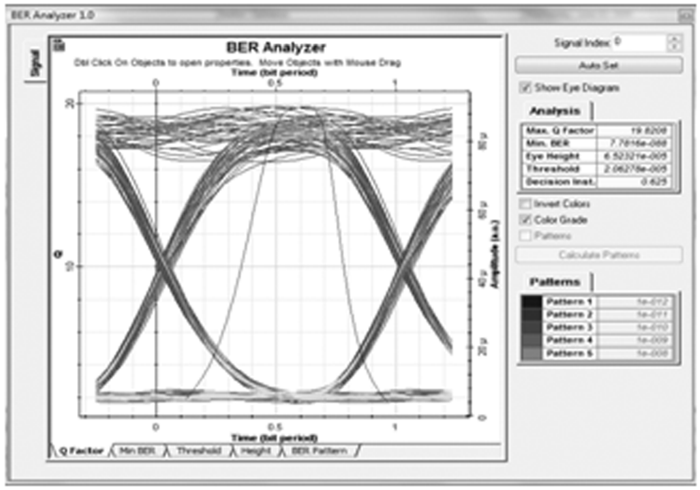
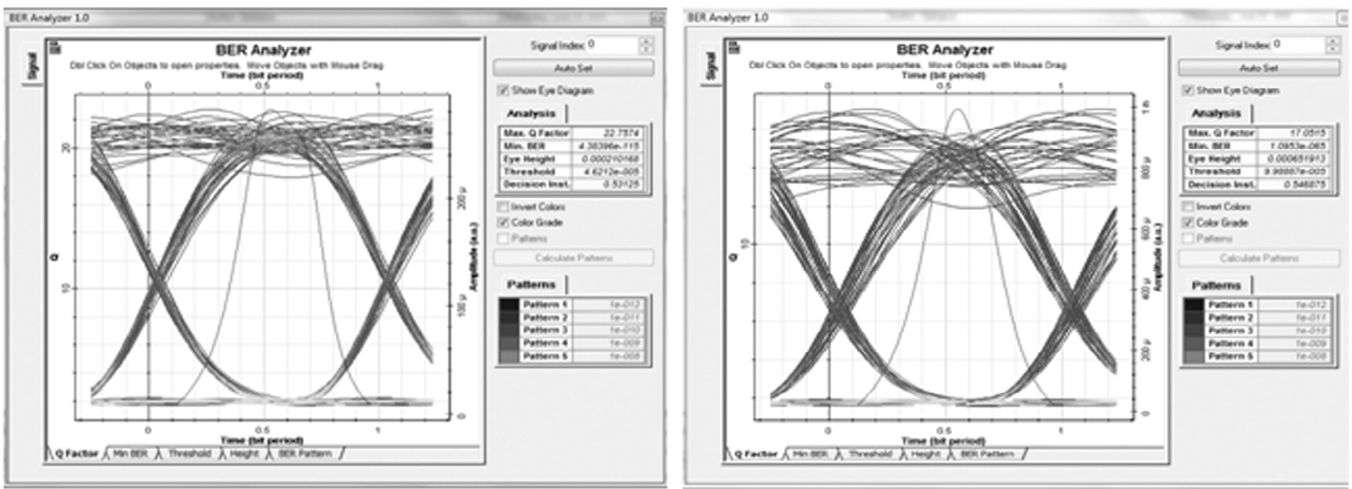


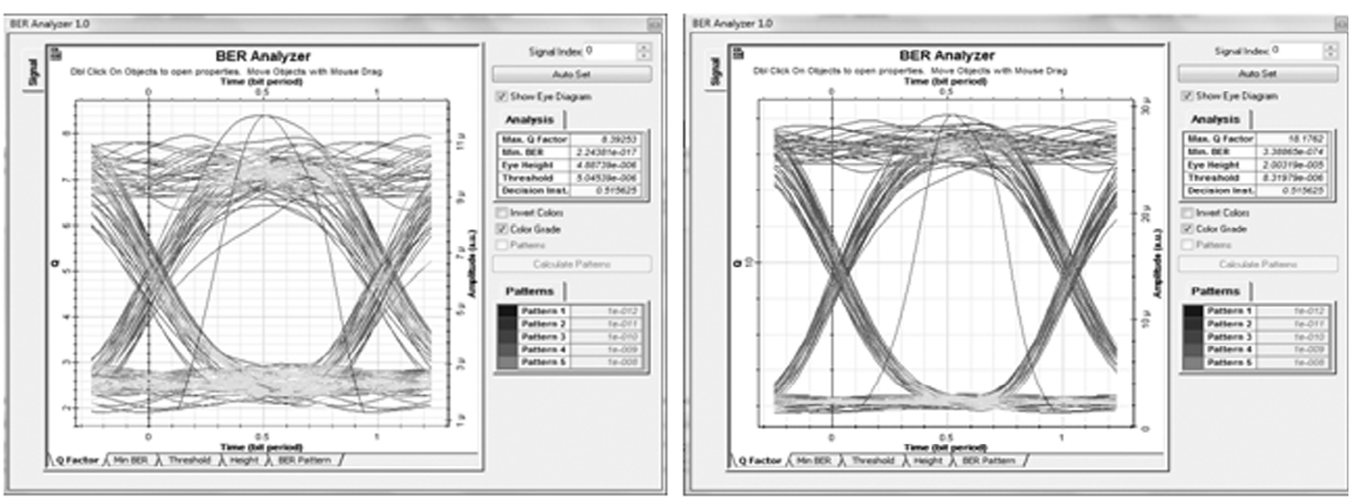
Figure 5: Eye Diagram Obtained at 5 Gbps and 0 dBm Power



(a) (b)

Figure 6: Eye Diagram Obtained at 10 Gbps with (a) 5dBm Power (b) 10 dBm Power

3.1.2. Dispersion Post Compensation Scheme



(a) (b)

Figure 7: Eye Diagram Obtained at 2.5Gbps with (a) -10dBm Power (b) -5dBm Power

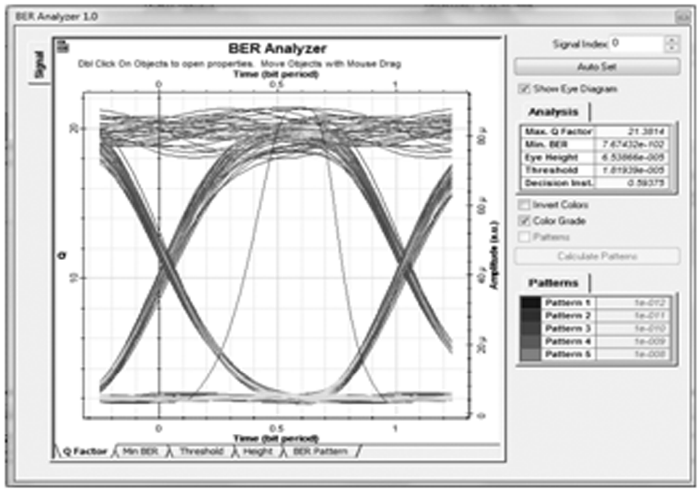
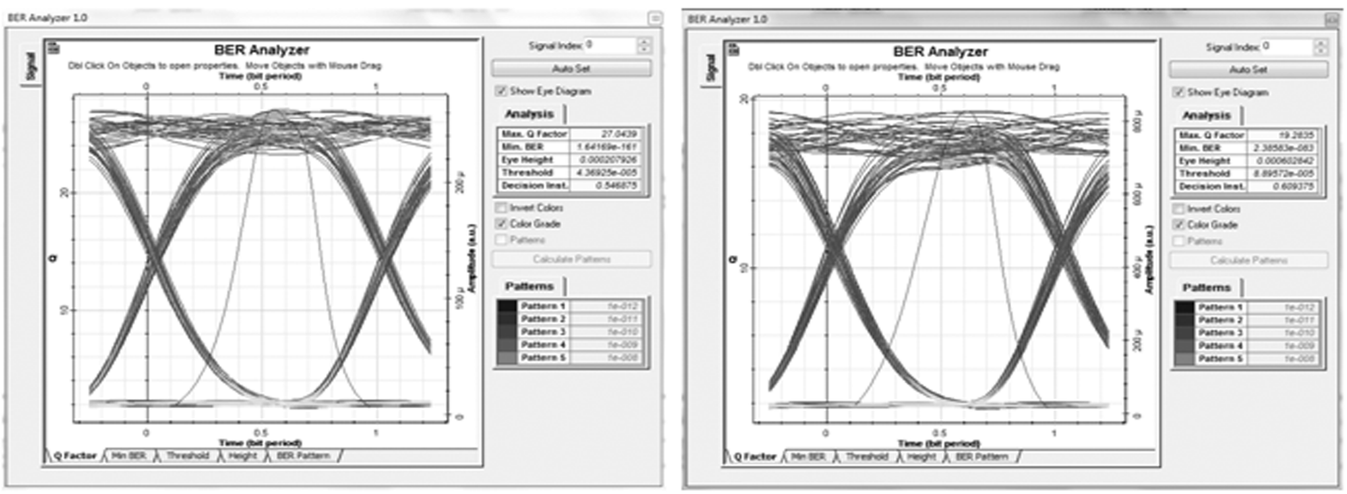


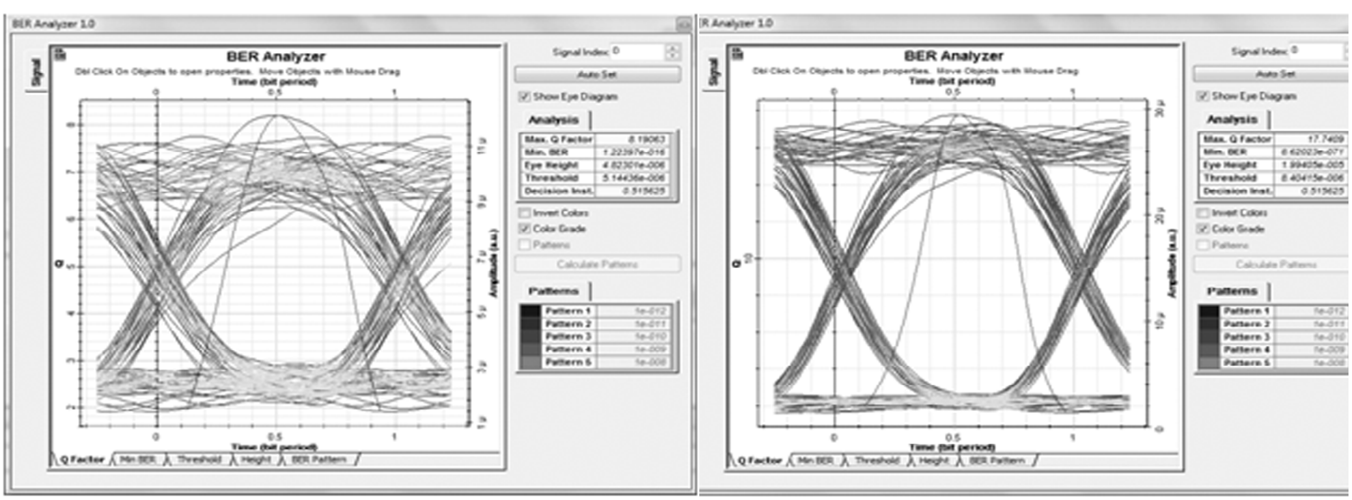
Figure 8: Eye Diagram Obtained at 5Gbps and 0dBm Power



(a) (b)

Figure 9: Eye Diagram Obtained at 10Gbps with (a) 5dBm Power (b) 10dBm Power

3.1.3. Dispersion Symmetric Compensation Scheme



(a) (b)

Figure 10: Eye Diagram Obtained at 2.5Gbps with (a) -10 dBm Power (b) -5dBm Power

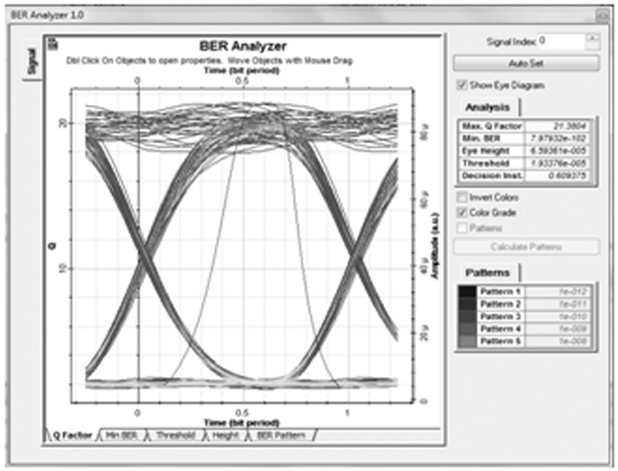
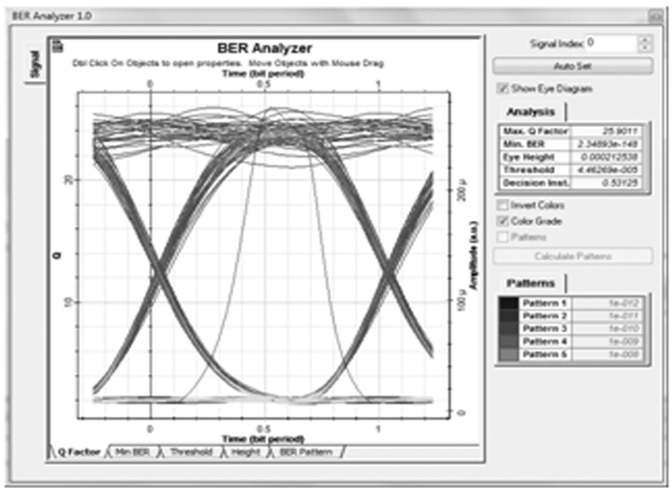
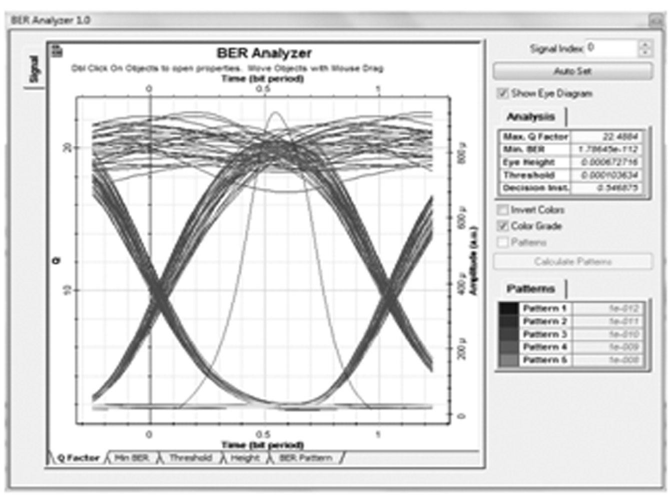


Figure 11: Eye Diagram Obtained at 5 Gbps and 0 dBm Power



(a)



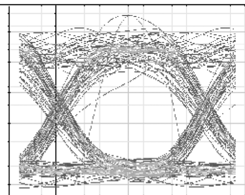
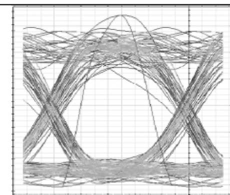
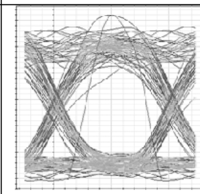
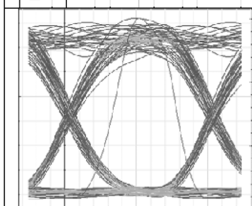
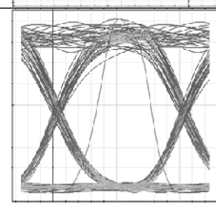
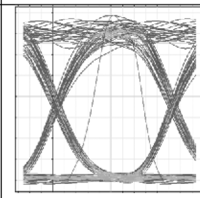
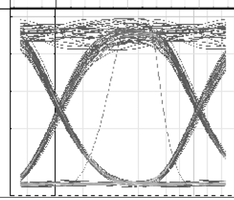
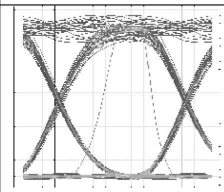
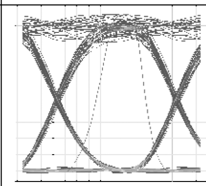
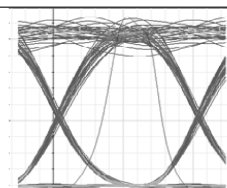
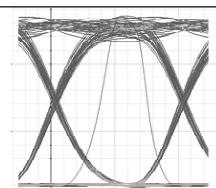
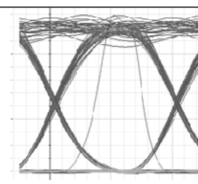
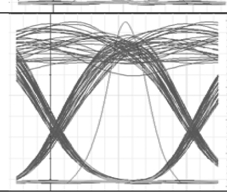
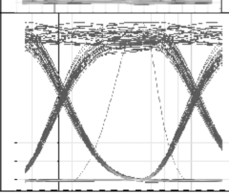
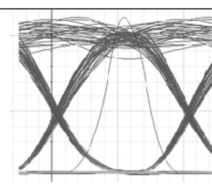
(b)

Figure 12: Eye Diagram Obtained at 10 Gbps with (a) 5 dBm Power (b) 10 dBm Power

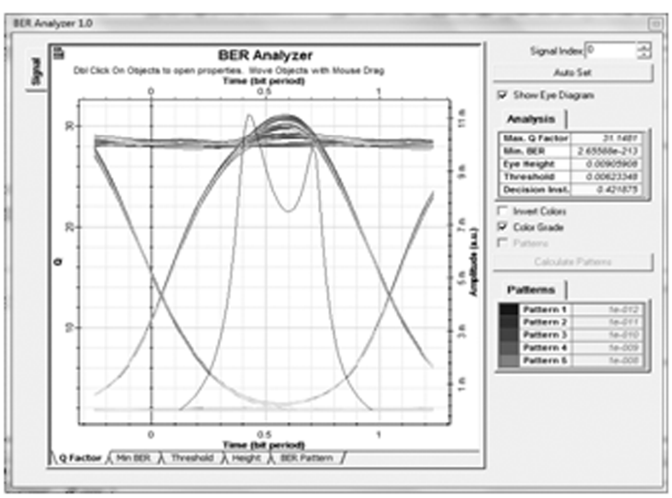
Figure 4, figure 5 and figure 6 shows the Eye Diagram Obtained at 2.5 Gbps, 5Gbps and 10 Gbps bit rate respectively for the Pre compensation Dispersion Scheme. Figure 7, figure 8 and figure 9 shows the Eye diagram obtained at same bit rate 2.5 Gbps, 5 Gbps and 10 Gbps respectively for post compensation dispersion scheme. Figure 10, figure 11 and figure 12 shows the Eye diagram for Dispersion Symmetric Compensation Scheme.

3.2. Comparison of eye diagrams obtained from pre-, post and symmetric dispersion compensation techniques

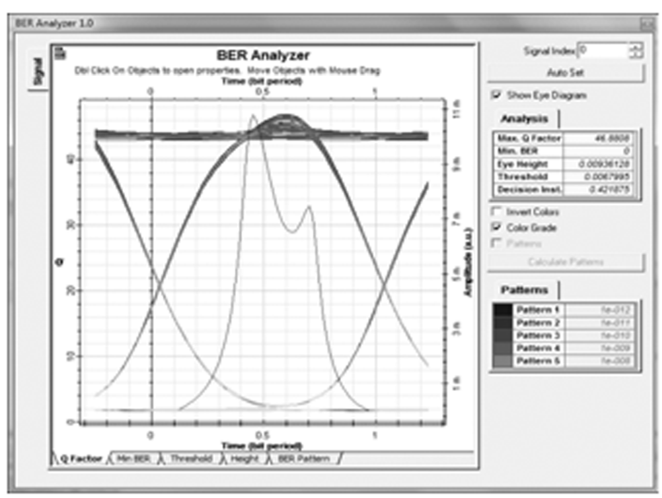
Table 4
Comparison from eye diagrams of pre, post & Symmetric compensation

Bitrate	Pre	Post	Symmetric	Power
2.5 Gbps				-10dBm
				-5dBm
5Gbps				0dBm
10Gbps				5dBm
				10dBm

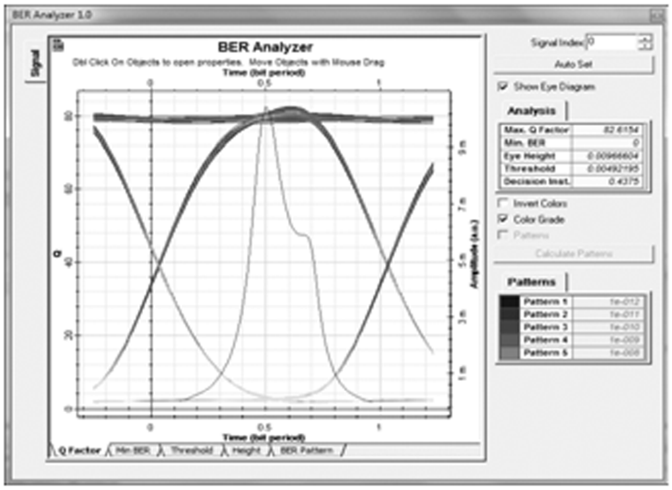
3.3. Dispersion compensation by FBG



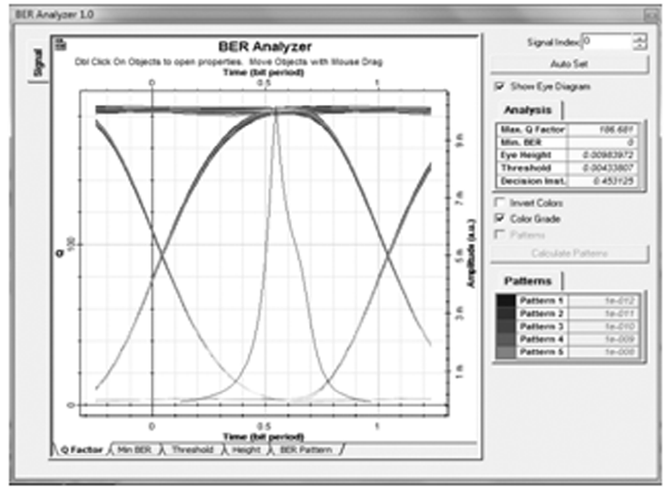
(a)



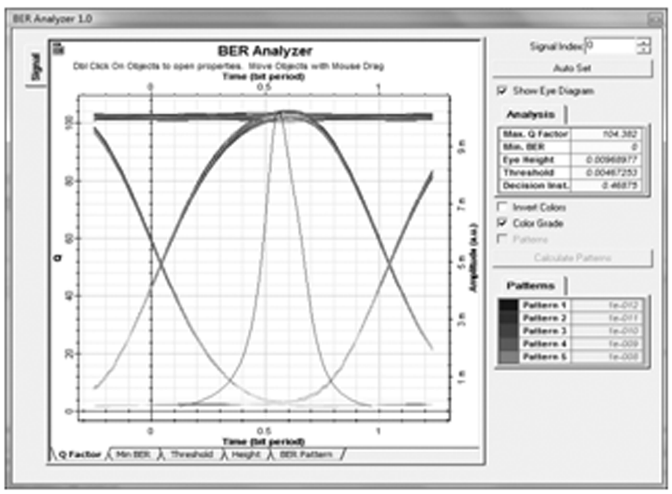
(b)



(c)



(d)

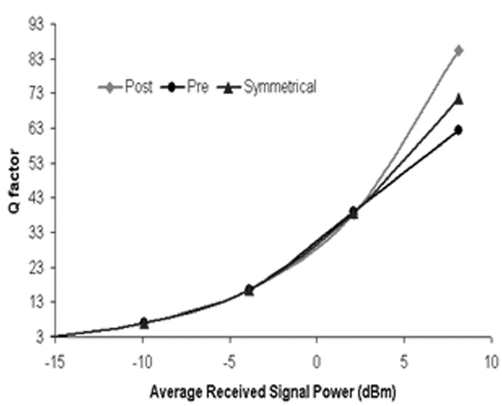


(e)

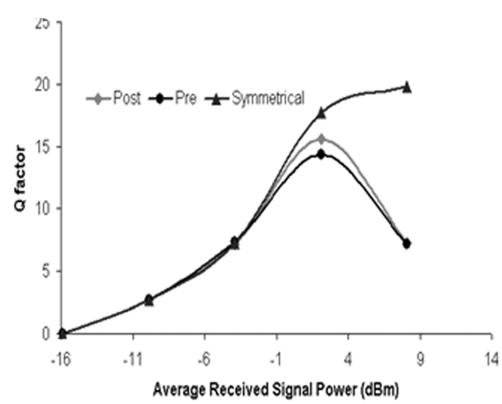
Figure13:Eye Diagram Obtained with 10 dBm Power at (a) 0 Gbps (b) -500 Gbps (c) -1000 Gbps (d) -1500 Gbps (e) -2000 Gbps

Figure 13 shows Eye Diagram Obtained with 10 dBm Power at 0 Gbps, -500 Gbps, -1000 Gbps, -1500 Gbps and -2000 Gbps in (a), (b), (c), (d) and (e) respectively for dispersion compensation by FBG.

3.4. Graphs Comparing Performance Compensation Schemes



(a)



(b)

Figure14: Q factor verses signal power for pre-, post-, and symmetrical dispersion Compensations at (a) 2.5Gbps (b) 10 Gbps

4. CONCLUSION & FUTURE SCOPE

The results of the simulation for pre, post & Symmetric dispersion compensation systems are presented and discussed in this research paper. The performance of the system was analyzed by varying several parameters of the system. In this firstly we compare and analyze the performance of pre, post and Symmetric dispersion compensation system is accomplished successfully. The design and model of pre, post and Symmetric dispersion compensation systems are presented and also model of the systems using OptiSystem software are explained in this research work. We observed the effect of power on dispersion compensation systems. As the power of system is increased at 2.5 Gbps, the performance of system increases and best can observed results are of post dispersion compensation scheme. When the Bitrate is increased to 10 Gbps and power to 10 dBm the system is observed to give best results for symmetric compensation scheme.The Quality factor observed is in range of 10^{-100} for symmetric compensation scheme. From this, it can be concluded that link distance can be increased to greater extents using symmetric compensation techniques as compared to pre and post dispersion compensation techniques.From the simulated results it is concluded that best performance is achieved by dispersion compensation by FBG and pre-compensation is worst scheme.In this research paper, the schemes including placement of dispersion compensation fiber in optical link are discussed. There more topics and areas that we can be improved.

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