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Performance Analysis of Dispersion Compensation using FBG and DCF in WDM Systems

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Abstract: To improve overall system performance and reduce dispersion, several compensation technologies are proposed. In this paper, dispersion compensation scheme in WDM system is studied. For optical communication the widely used dispersion compensation technologies are Dispersion Compensating Fiber (DCF) and Fiber Bragg Grating (FBG). Here an 8 channel optical network is used with two dispersion compensators ie., DCF and FBG. For DCF three compensation schemes (Pre, Post and Symmetrical) are modelled and for FBG two compensation schemes (Pre and Post) are modelled. NRZ modulation format is used in transmitter. From BER and Q-factor, it is observed that FBG when used in post compensation is better than all other compensation schemes.

Keywords: Wavelength Division Multiplexing (WDM), Dispersion, Dispersion Compensating Fiber (DCF), Fiber Bragg Grating (FBG), Q-factor, BER.

I. INTRODUCTION

WDM is one of the most efficient techniques to increase the information carrying capacity of an optical fiber communication system. It has an ability to transmit multiple signals having different wavelengths simultaneously. Transmission in WDM systems is affected by attenuation, Chromatic dispersion, polarization mode dispersion and the fiber non linear effects at high bit rate and high power level. To compensate attenuation losses optical amplifiers (EDFA,SOA,Raman amplifier) are used. Dispersion compensation is a key issue in WDM optical networks. Due to dispersion, light wave travelling inside the fiber gets broadened and two consecutive pulses overlap each other causes Inter symbol interference (ISI). This leads to error in symbol detection. So it is necessary to compensate dispersion.

This paper will give an emphasis on the study of dispersion. There are various methods for dispersion compensation of optical fiber, such as Fiber Bragg grating (FBG), Electrical dispersion compensation etc. In this paper we will go through Dispersion Compensating Fiber (DCF) and Fiber Bragg grating (FBG) as these are widely used techniques.

The rest of the paper is organized as follows; in section II the Dispersion compensating Fiber (DCF) is discussed and in section III a brief description of Fiber Bragg Grating (FBG) is given. Section IV presents the simulation of communication system using DCF and FBG in which various schemes are employed. Section V includes simulation results and comparison and section VI concludes the paper.

II. DISPERSION COMPENSATING FIBER (DCF)

The dispersion compensating fiber for dispersion compensation was proposed in 1980's. The components of DCF are not easily affected by temperature and bandwidth, because DCF is more stable. The use of DCF in an efficient way to reduce the overall dispersion in WDM network. Because they have higher negative dispersion coefficient and therefore can be connected to the transmission fiber having the positive dispersion coefficient. Therefore the overall dispersion of the link is zero.

$$D_{SMF} \times L_{SMF} = -D_{DCF} \times L_{DCF}$$

Where D and L are the dispersion and length respectively.

There are three compensation schemes for dispersion compensation depending upon the position of DCF

- Pre Compensation
- Post Compensation
- Symmetrical Compensation

A. Pre Compensation

In Pre compensation scheme DCF is placed before the Standard Single Mode Fiber (SSMF) to compensate the positive dispersion of the standard fiber.

B. Post Compensation

In Post compensation scheme DCF is placed after Standard Single Mode Fiber (SSMF) to compensate the positive dispersion of the standard fiber.

C. Symmetrical Compensation

In Symmetrical compensation scheme both the schemes are used ie., DCF is placed before as well as after Standard Single Mode Fiber (SSMF) to acheive the dispersion compensation.

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III. FIBER BRAGG GRATING (FBG)

FBG is a type of distributed Bragg reflector which reflects a particular wavelength of light and transmits all others. A Fiber Bragg Grating is either used as an inline optical filter to block certain wavelength or as a wavelength specific reflector. There is a periodic variation of refractive index in Bragg grating within the propagating medium.

Fresnel reflection is the fundamental principle behind the operation of FBG, where light travelling between media having different refractive indices may reflect or refract at the interface. The refractive index will alternate over a particular length. During refraction small amount of light is reflected. These reflected light signals combine to one large reflection at a particular wavelength in which the grating period is approximately half the input lights wavelength. This is Bragg condition on the wavelength at which reflection occurs is called Bragg wavelength.

The Bragg wavelength ($\lambda_B = 2\bar{n}$) varies along the grating length, therefore the frequency component is reflected on where the Bragg condition is satisfied. The grating dispersion D_g ,

$$D_g = \frac{2\bar{n}}{C(\Delta\lambda)}$$

Where $\bar{n}$ is average mode index, $\Delta\lambda$ is grating bandwidth and C is the velocity of light.

FBG is used in two configurations,

- Pre compensation
- Post Compensation

A. Pre Compensation
In Pre compensation FBG is placed at the beginning of the optical link before the optical amplifier.

B. Post Compensation
In Post compensation FBG is placed at the end of the optical link.

IV. SYSTEM DESIGN AND SIMULATION SETUP

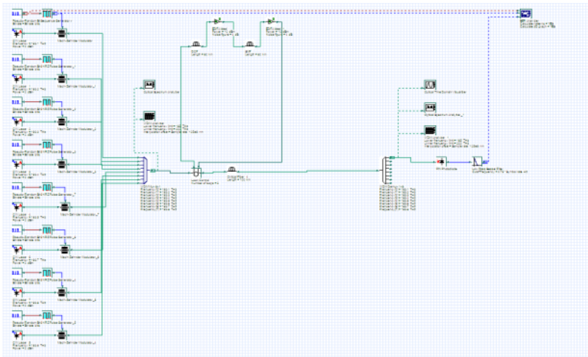
The 8 channel WDM optical network is designed using Optisystem 13.0 simulation software. This is used to compare different compensation techniques. This is an Optical Communication System simulation package.

In the transmitter module, each single channel consists of Psuedo Random Bit Sequence (PRBS) generator followed by NRZ pulse generator. The PRBS generator having 15 Gbps bit rate. The CW laser having power 0dBm is used. The laser at each channel having different frequencies ranging from 193.1 to 193.8 THz followed by Mach Zehnder modulator. An 8x1 MUX is used to multiplex the different wavelength. The optical link is made using SMF and dispersion is compensated using DCF or FBG. An EDFA (Erbium Doped Fiber Amplifier) of gain 10dBm is added after SMF and DCF and EDFA with 14dBm is used before DEMUX. TABLE I shows the fiber parameters for simulation.

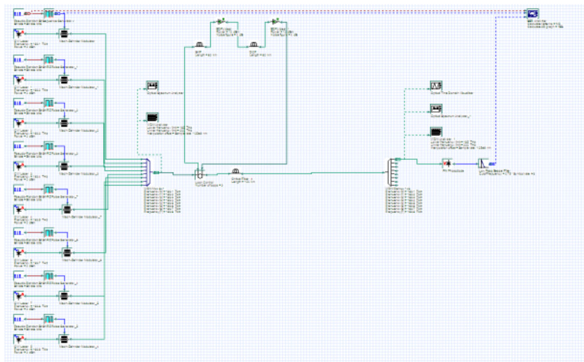
TABLE I FIBER PARAMETERS

	SMF	DCF
Length (km)	120	24
Attenuation (db/km)	0.2	0.6
Dispersion ($ps/nm/km$)	17	-80
Dispersion slop ($ps/nm^2/km$)	0.08	0.3
Differential group delay (ps/km)	0.5	0.5

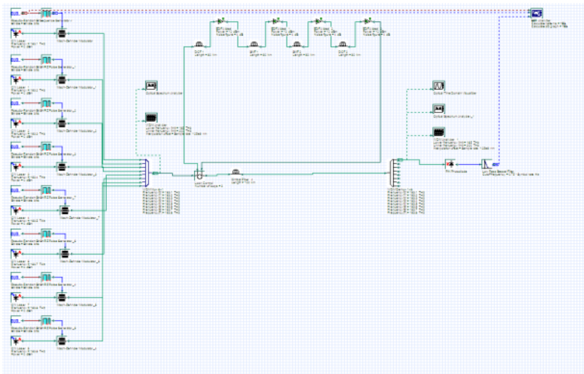
In the receiver module, 1x8 DEMUX is used followed by a Photodiode. There is a Bessel filter that is connected to the Photodiode at particular frequency, which is followed by an analyzer to get results of the Q-factor, BER and eye diagrams. Fig. 1 shows the simulation of three compensation schemes using DCF and Fig. 2 shows simulation of two compensation schemes using FBG.



(a) Pre compensation scheme



(b) Post compensation scheme



(c) Symmetrical compensation scheme

Fig. 1 Simulation of three compensation schemes using DCF

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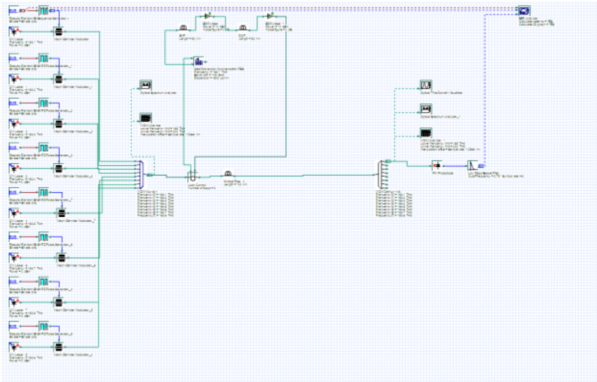
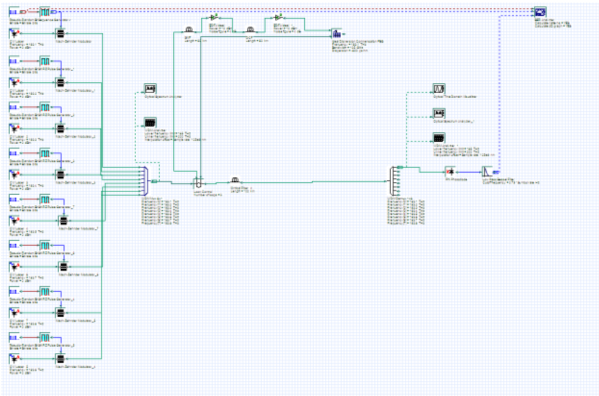


(a) Pre compensation scheme



(b) Post compensation scheme

Fig. 2 Simulation of two compensation schemes using FBG

V. SIMULATION RESULTS AND DISCUSSION

Q-factor is one of the most important factor in WDM system to measure the performance of the system. TABLE II shows the readings of Q-factor and BER at 0dBm input power for each compensation.

TABLE II READINGS OF Q-FACTOR AND BER

COMPENSATION TECHNIQUE USED	Q-FACTOR	Bit Error Rate (BER)
Pre Using DCF	12.8	2.077 e-38
Post Using DCF	15.5	6.192 e-055
Symmetrical Using DCF	15.9	1.263 e-057
Pre Using FBG	16.0	2.328 e-058
Post Using FBG	16.3	2.478 e-060

Also if we made the comparison of DCF, the Symmetrical compensation scheme performs better than any other schemes. The Q-factor of Symmetrical compensation scheme is 15.9. Fig. 3 shows the comparison graph of compensation using DCF.

FBG Post compensation is better than other techniques in NRZ modulation format. FBG post compensation having highest Q-factor of 16.4 at 0dBm and DCF Pre compensation having the least Q-factor of 12.8. Fig 4.shows the graph between Q-factor and input power

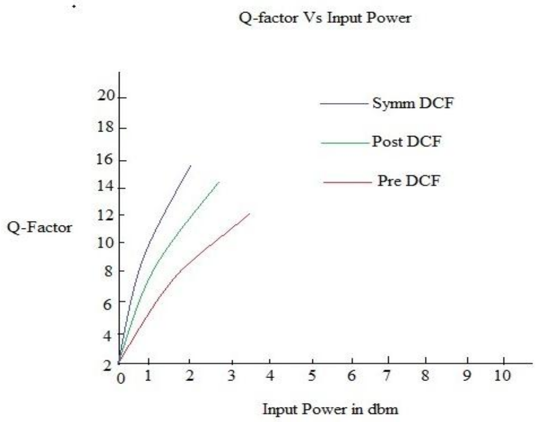


Fig. 3 Comparison graph of DCF compensation

of laser. Power varies from 0-9dBm and reading of Q-factor and BER is observed. From Fig. 4 we can also see that as the input power increases for NRZ format, the Q-factor decreases ie., the performance of the system degrades as input power increases.

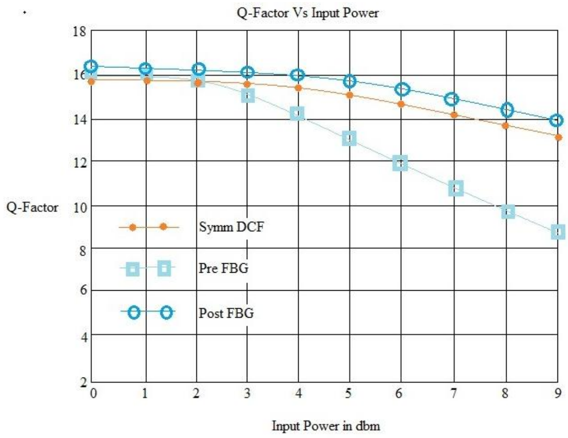
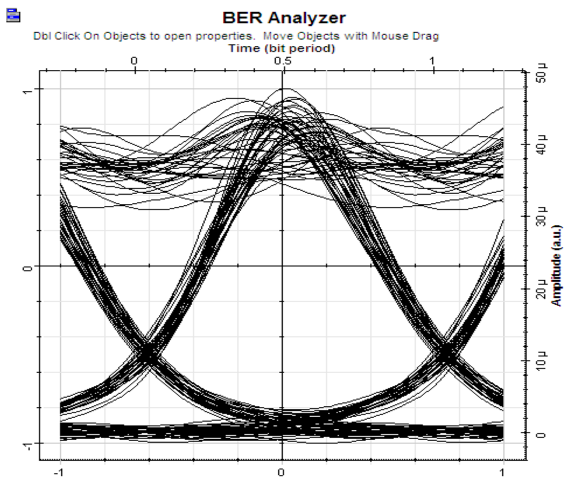


Fig. 4 Q-factor and Input power

Fig. 5 shows the eye diagram of five compensation techniques. If the opening of eye diagram is maximum the performance is better. From the results FBG is better than DCF for dispersion compensation. There is a slight difference between Q-factor of FBG and DCF.



(a) Pre Compensation using DCF

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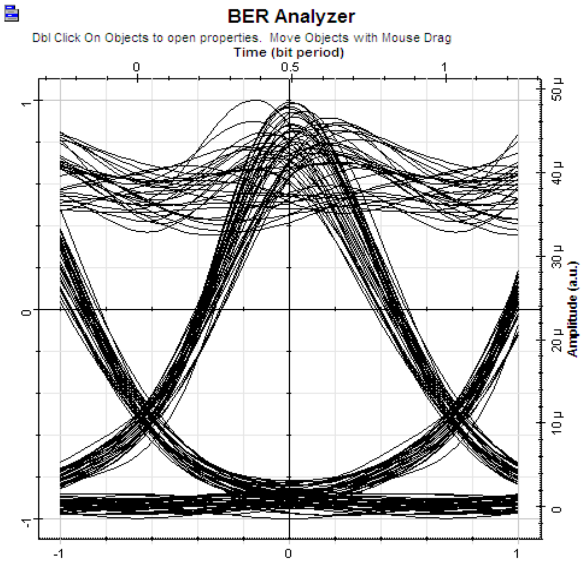
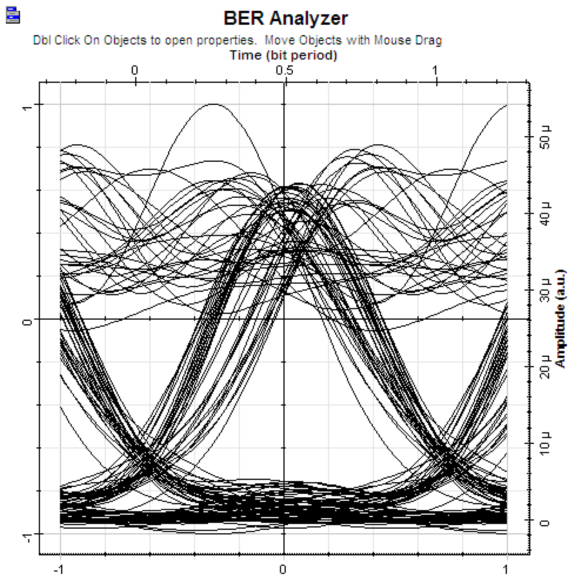
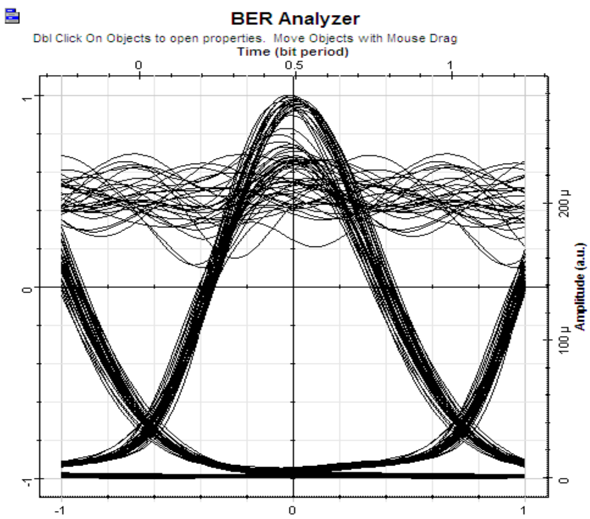


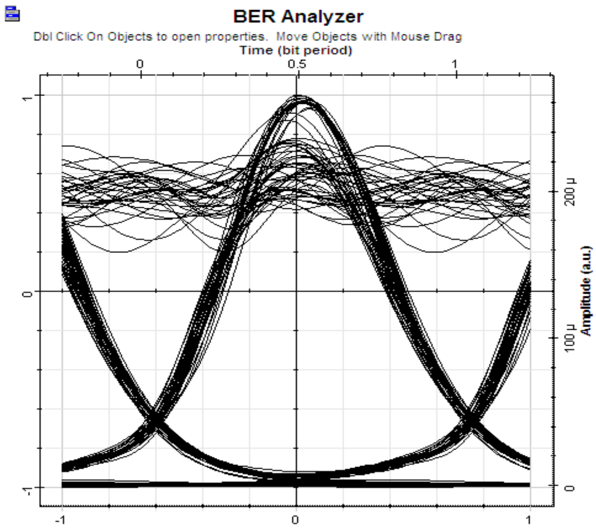
(b) Post compensation using DCF



(c) Symmetrical compensation using DCF



(d) Pre compensation using FBG



(e) Post compensation using FBG

Fig. 5 Eye diagram of Five Compensation schemes

VI. CONCLUSION

In this paper we have analysed the 8 channel WDM system at 15 Gbps for DCF and FBG. It is found that both of these two compensators, DCF as well as FBG works well. However, the FBG compensator performs better than DCF in high speed 8 channel WDM network. DCF and FBG is compared in terms of BER and Q-factor. From this we observed that FBG Post compensation scheme performs better than other compensation techniques.

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