

DISPERSION COMPENSATION IN OFC USING FBG

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Abstract: The process of communicating using fiber optics involves the following basic steps: The optical signal is created using a transmitter, the signal is relayed along the fiber, the signal is ensured that it does not become too distorted or weak, the optical signal is received and converting it into an electrical signal. The chromatic dispersion in optical fiber is a phenomenon caused by the different wavelengths which depends on its group refractive index which causes Pulse broadening as they propagate in OFC. Though EDFAs (Erbium doped fiber amplifiers) compensate the transmission losses, Chromatic dispersion is not compensated using EDFAs. One of the applicable and important components in optical communication system is Fiber Bragg Grating (FBG). For different lengths of grating, Chirped FBG is studied as a dispersion compensator in any optical communication system. The simulator used is OPTISYSTEM 7.0 simulation software. All the simulations are done in OPTISYSTEM 7.0 at 10 Gbits/sec and 210 km of transmission fiber. The simulated transmission system has been analyzed on the basis of different parameters such as BER, Q-factor, Output power, Gain, Noise Figure and Eye height.

Keywords: Fiber Bragg Grating (FBG), BER, eye diagram, Q-factor, EDFA, Dispersion, Gain, ISI.

1. INTRODUCTION:

Fiber optic communication is a method of transmitting information from one place to another by sending light through an optical fiber. The optical fiber is always used in telecommunication system because of its characteristics which include small size or dimension, low loss and low interferences from outside environment. The light forms an electromagnetic carrier wave that is modulated to carry information. The basic optical communication system consists of three elements which are light source that convert electrical signal into optical signal, optical fiber which acts as a transmission medium and photo detector or light detector that converts the optical signal into electrical signal at the receiver side[1]. The goal of every communication system is to increase the transmission distance and speed. Like other communication systems the optical communication systems also faces problems such as dispersion, attenuation, losses which degrade its performance. Among them the dispersion affects the system most and it is difficult to overcome as compared to other losses. Thus it is important to incorporate an effective dispersion compensation technique[4] in optical communication systems that lead to performance enhancement of the transmission system.

The optical amplifiers (EDFA) have resolved the problem of optical fiber losses and made the long distance transmission possible without electronic regenerators but the dispersion is not compensated. Dispersion is defined as the pulse spreading in an optical fiber. When different wavelengths of light pulses are launched into the optical fiber, these pulses travelled with different speeds due to the variation of refractive index with wavelengths. The light pulses tend to spread out in time domain after travelling some distance in fiber and this is continued throughout the fiber length. This phenomenon is known as dispersion. Since each pulse spreads and overlap with its neighbouring pulse, becoming indistinguishable at the receiver end[7]. This effect is known as inter symbol interference (ISI). Dispersion limits the information carrying capacity at high transmission speeds, reduces the effective bandwidth and increases the bit error rate (BER). In single mode fiber (SMF), the performance is primarily limited by chromatic dispersion (CD) and polarization mode dispersion (PMD). CD occurs because of the wavelength dependency of refractive index of fiber and the fiber has some inherent properties like birefringence that lead to PMD. In order to improve the overall system performance affected by dispersion, FBG dispersion compensation technique is proposed and analyzed[8].

2. FIBER BRAGG GRATING (FBG) OPERATION

Principle: One of the most advanced techniques being used in the dispersion compensation methods is FBG. FBG is a piece of optical fiber with the periodic variation of refractive index along the fiber axis. This phase grating acts like a band rejection filter reflecting wavelengths that satisfy the Bragg condition and transmitting the other wavelengths[2]. The reflected wavelength changes with grating period. Thus, FBG is very simple and low cost filter for wavelength selection that improves the quality and reduces the costs in optical networks. The equation relating the grating periodicity, Bragg wavelength and effective refractive index of the transmission medium is given by:

$$\lambda_B = 2n\gamma \quad \text{----- (1)}$$

In this equation, λ_B , n and Λ are the bragg wavelength, refractive index of core and grating period respectively.

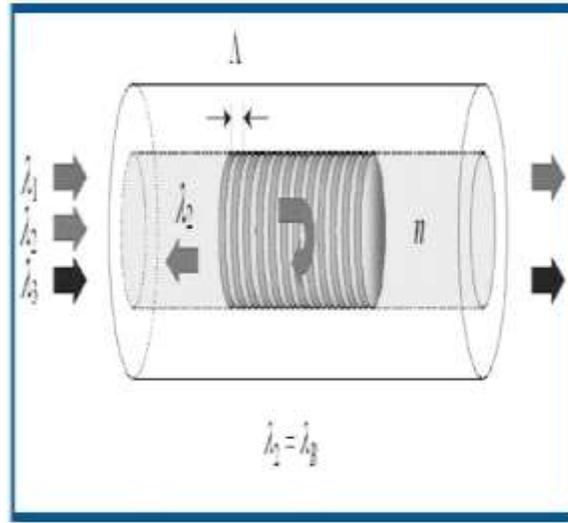


Fig 1: Principle of Uniform FBG

A chirp is variations in the grating period created along the FBG. As shown in Fig.2 when a signal enters into chirp, different wavelengths are reflected from different parts of grating. Thus, a delay related to the wavelength of the signal is produced by grating[3].

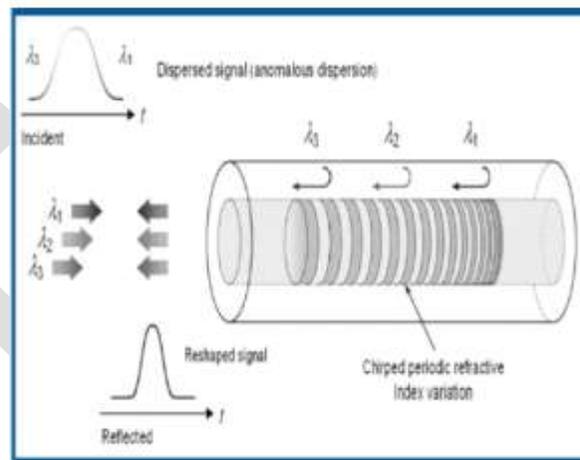


Fig2: A chirped FBG principle

3. DESCRIBING THE COMPONENTS AND SIMULATOR

3.1 Components Description:

All the simulations are done in OPTISYSTEM 7.0 simulator software. It is an advanced, innovative and powerful software simulator tool used for design, testing and optimization of virtually any type of optical link. We use the parameters in Table 1 in order to simulate the optical transmission system. The model of the simulated system is as shown in Fig.3. In the simulation, the transmitter section consists of data source, modulator driver (NRZ), laser source and Mach-Zehnder (M-Z) modulator. We use the continuous wave (CW) laser with frequency 193.1 THz and output power of 15 dbm, which is externally modulated at 10 Gbits/sec with a non-return to zero (NRZ) pseudo random binary sequence in a M-Z modulator with 30 db extinction ratio. Two EDFAs are used as optical amplifiers in the system with gain of 40 db and 10 db with noise figure 4 db. The single mode fiber (SMF) of length 210 km is used as the transmission medium. The FBG is used as the dispersion compensator[9]. At the receiver side, the PIN diode is used as a

photodetector, which converts the optical signals into electrical, having 1 A/W responsivity and 10 nA of dark current. Then the electrical signal is filtered by low pass Bessel filter and 3R regenerator is used for regeneration.

Table 1: Simulation parameters

Parameters	Value
Fiber Length	210Km
Bit Error Rate	$10e^{-9}$
Frequency of CW Laser	193THz
Input Power	15dB
Attenuation	0.2dB

3.2. Optisystem simulator

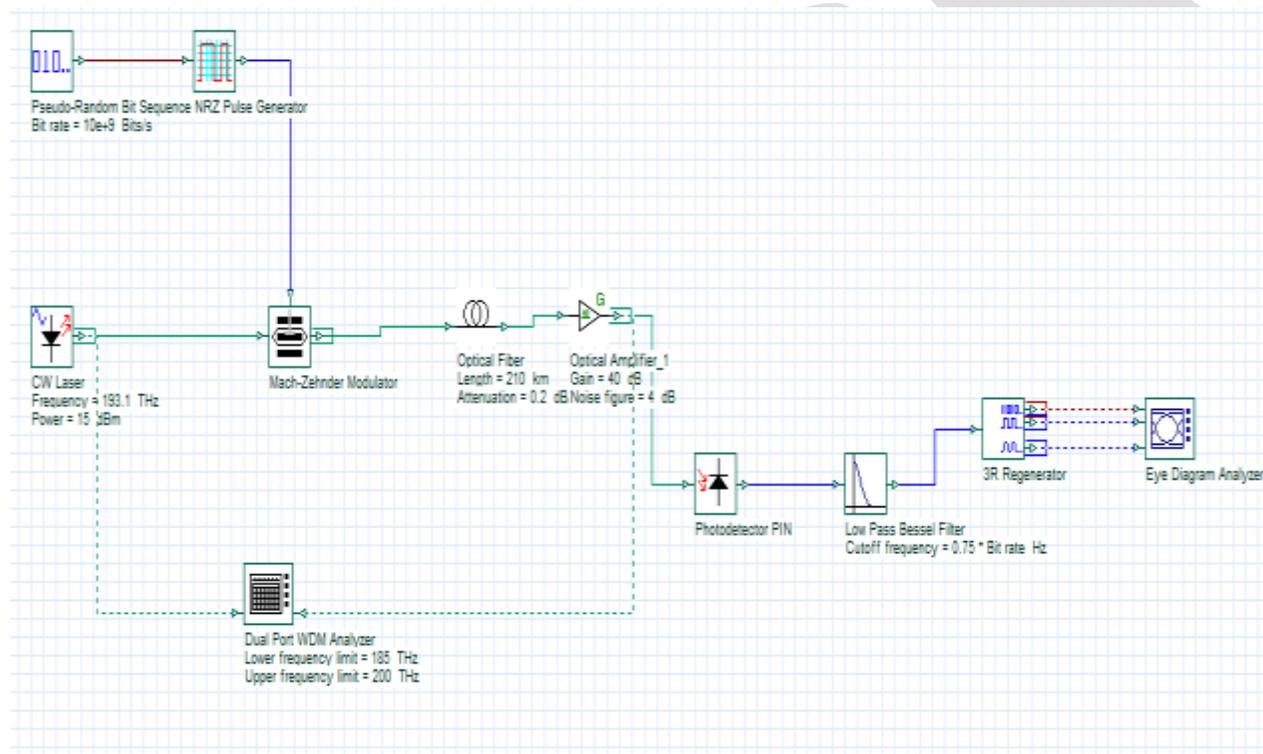


Fig 3: Model of Simulation using OptiSystem

Optisystem is an innovative optical communication system simulation package or the design, testing and optimization of virtually any type of optical link in the physical layer of the broad spectrum of optical networks, from long-haul systems to local area networks (LANs) and metropolitan area networks (MANs). A system level simulator is based on the realistic modeling of fiber optical communication systems.

4. SIMULATED RESULTS:

The simulation and optimization of the design is done by Optisystem 7 simulation software. The eye diagrams and results of output power, Signal power (dBm) at receiver, Q-Factor, Gain, noise Figure by using different values of input power (dBm) and variable length of FBG (mm).

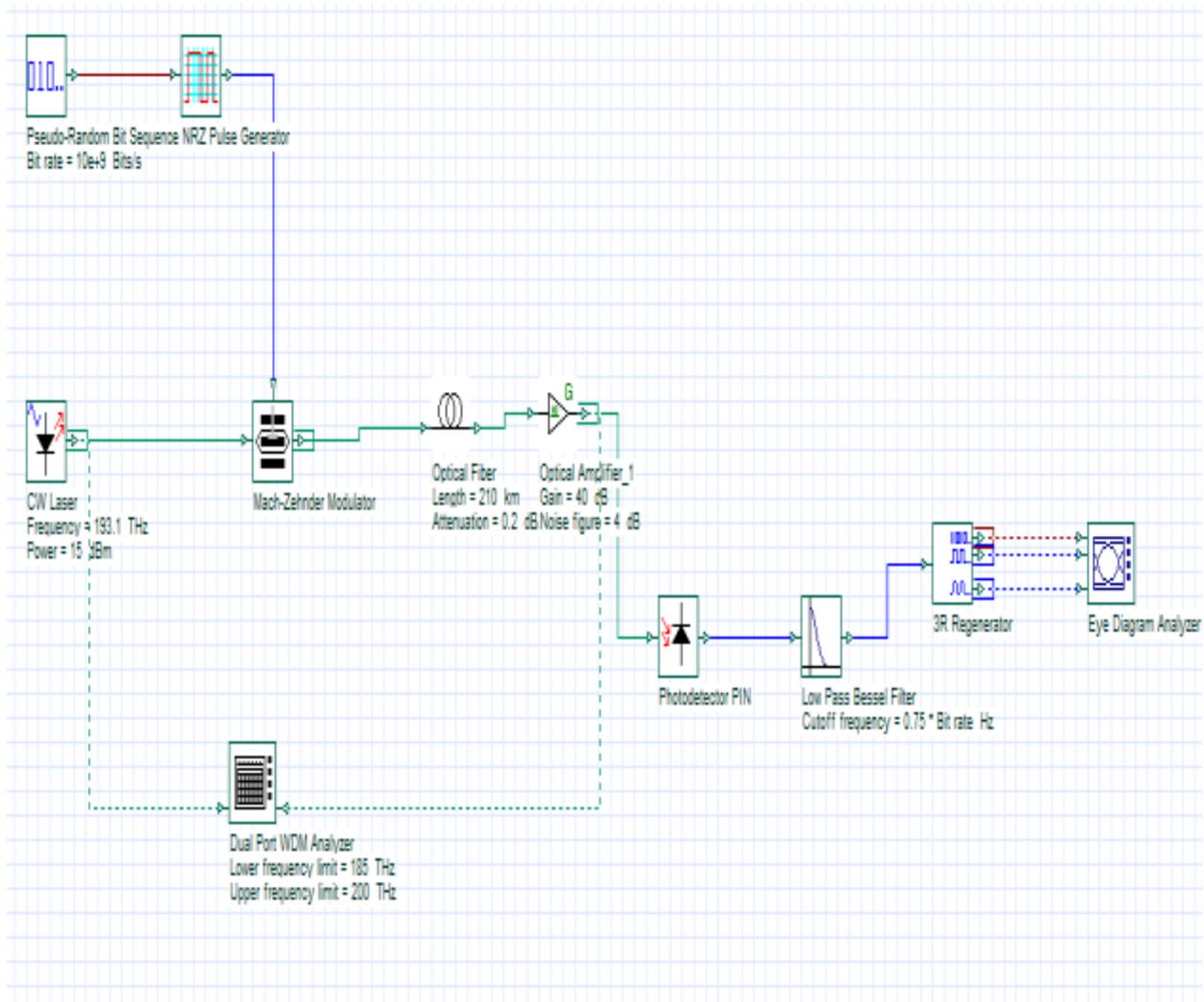


Fig 4: Layout of optical system without Dispersion compensator

4.1 Observations:

Table 2: Observations without FBG

Input power (dBm)	Output power (dBm)	Gain	Noise figure	Q-Factor	BER
15	5.09	9.9	53.9	2.68	0.003

In the eye diagram the eye opening is less and the interference between pulses is more. So the Q-factor is low and the bit error rate is high.

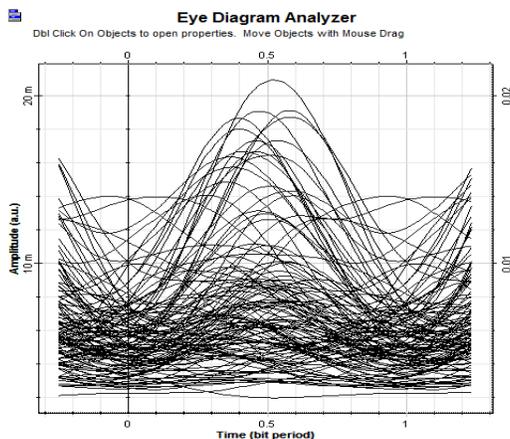


Fig 6: Eye diagram for optical system without FBG

4.2 Optical system with chirped FBG:

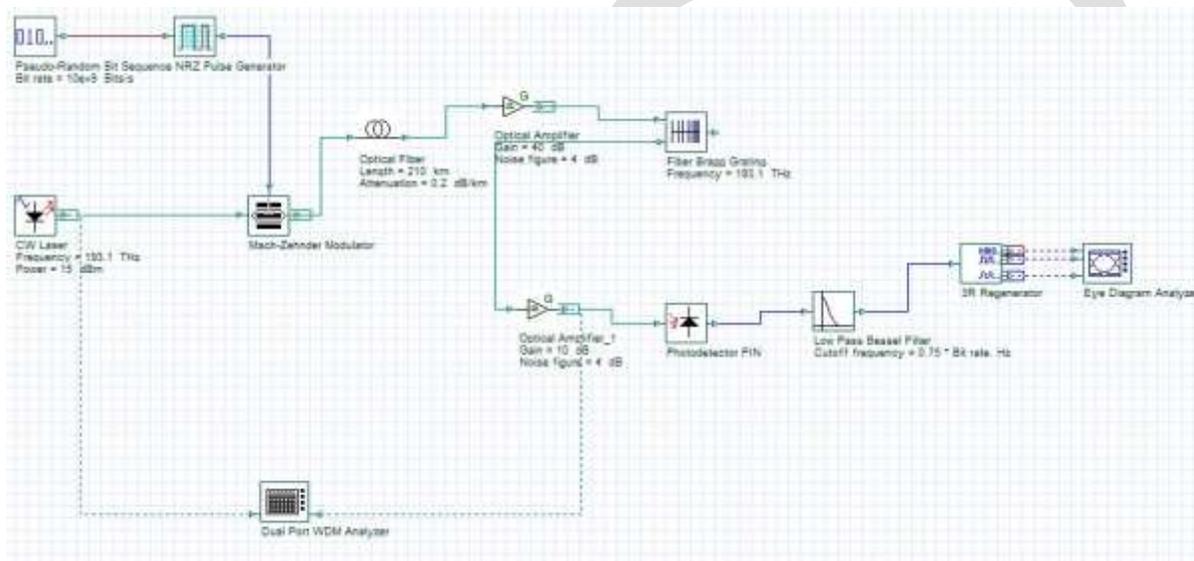


Fig 5: Layout of optical system with chirped FBG

4.2.1 Observations with varying input power:

Here we can observe that the gain is constant even the input power increases but change in the output power. The noise figure is constant because the noise will occur in fiber in this case the fiber length is made constant[6]. The Q-factor and bit error rates are improved by change in input power.

Table 3: Observations by varying input power

Input power (dBm)	Output power (dBm)	Gain	Noise figure	Q-Factor	BER
5	9.52	4.53	49.82	4.54	2.24E-06
10	14.34	4.536	49.82	6.21	1.94E-10
15	19.48	4.489	49.87	7.40	5.14E-14

4.2.2 Observations with varying Fiberbragg length (Chirped FBG):

Table 4: Observations by varying Fiber bragg length.

FBG length (km)	Output power (dBm)	Gain	Noise figure	Q-Factor	BER
70	19.48	4.48	50.51	3.71	9.06E-05
75	19.56	4.56	49.74	4.79	6.17E-07
80	19.48	4.48	49.87	7.40	5.18E-14

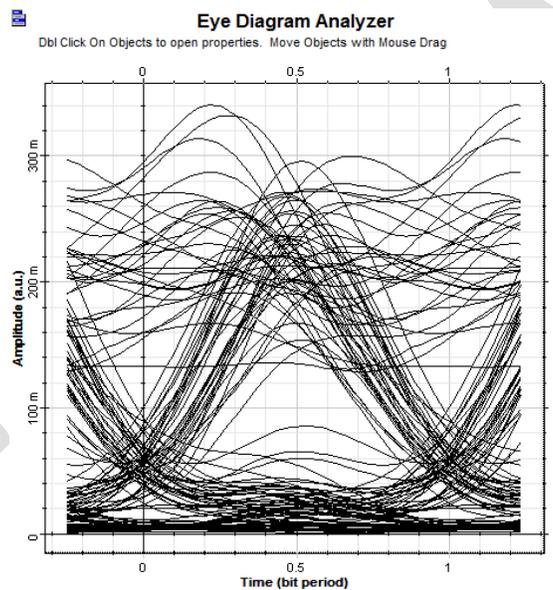


Fig 7: Eye diagram for optical system with chirped FBG of length 70mm

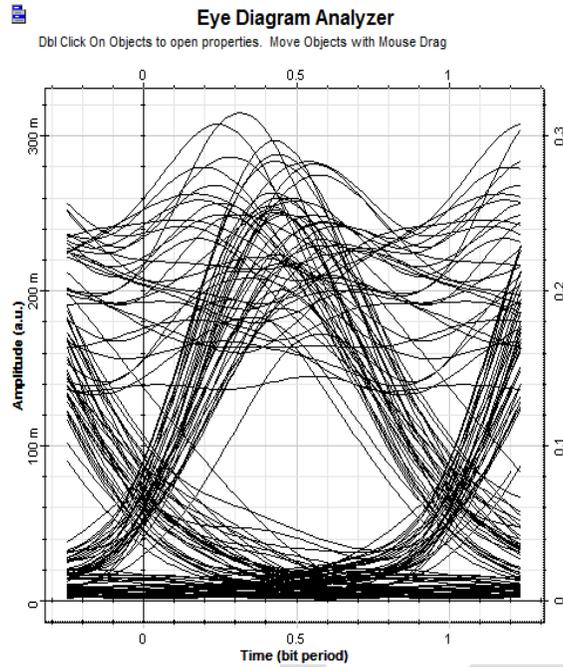


Fig 8: Eye diagram for optical system with chirped FBG of length 75mm

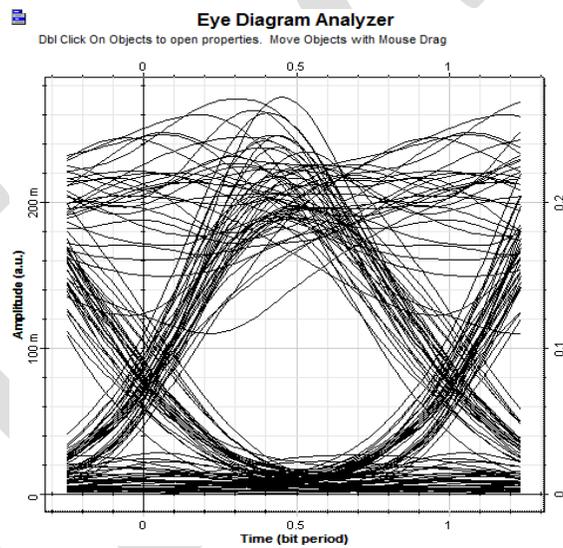
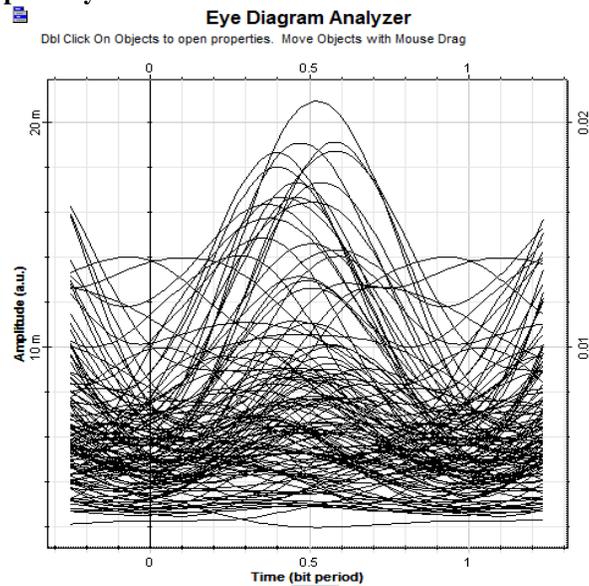


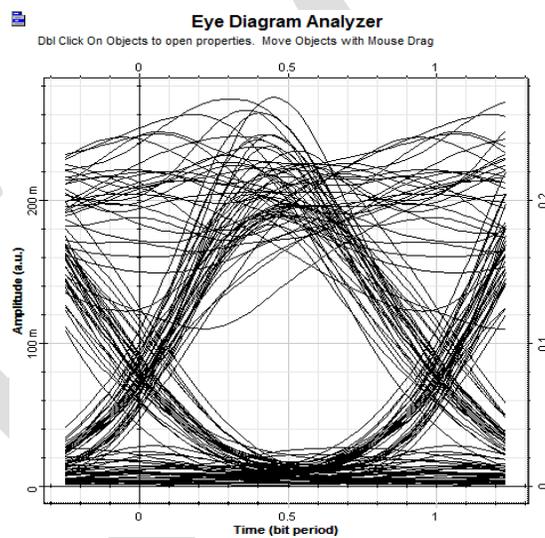
Fig 9: Eye diagram for optical system with chirped FBG of length 80m

From the above three eye patterns for different lengths of FBG as the length increase the better the eye opening and interference is also less. So the Q-factor is increases and the bit error rate is decreases.

4.3 Comparison of eye diagrams of optical systems:



(a) Without FBG



(b) With chirped FBG

Fig 10: Comparison of eye diagrams

On comparing these eye diagrams we can observe that the eye opening is large in the case of chirped FBG[5] which denotes the high Q-factor and results low bit error rate. It also seems that the interference of pulse is more in without FBG and with uniform FBG. In the eye diagram

5. CONCLUSION

In this paper, we have simulated an optical transmission system. As soon as we observed dispersion, we decide to compensate it. For this purpose, we employed chirped FBG and simulate it. The system has been studied for the different lengths of grating and apodization functions. We have analyzed that the 80 mm grating length gives better results for 210 km of optical fiber at 10 Gbits/sec. For a long distance optical communication system the dispersion in optical fiber limits the performance. By the use of fiberbragg grating the dispersion is compensated. The use of fiberbragg grating enhances the bit error rate and the Q-factor. We can conclude that

the chirped fiberbragg grating gives better Q-factor and Bit error rate than the uniform fiberbragg grating. In future this can be used for long distance optical communication with high data rates and low loss.

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