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Full Length Research Paper

Simulation of a transmission system to compensate dispersion in an optical fiber by chirp gratings

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Fiber Bragg Grating (FBG) is one of the applicable and important components in optical communication system, and it first emerged in 1980. In this article, the application of chirped FBG was studied as a dispersion compensator in optical communication systems. By simulating a model of communication system and finding the best amounts of parameters, we investigated the effect of this component in data receivers.

Key words: Fiber Bragg Grating (FBG), dispersion compensation, optical communication.

INTRODUCTION

Chromatic dispersion is a phenomenon in optical fiber which is created because of dependence of group index (N_g) to wavelength. Dependence of N_g to wavelength in optical fiber creates a time extension in propagated pulses. Extension of pulses, after a specific distance, leads to remarkable errors in receiver which leads to missing data (Luis and Rui, 2004). Using erbium doped fiber amplifiers (EDFAs) is an offer to compensate loses in optical communication systems. Moreover, dispersion compensation fibers (DCFs) and bulk type dispersion compensators were extensively used to compensate chromatic dispersion. This method needs to use DCFs with negative dispersion coefficient in certain distances in a communication link in order to disable the effects of positive dispersion of common fibers. However, using these fibers increases the total loses nonlinear effects and the cost of optical transmission systems. Their compensation depends on the wavelength and they can perfectly act only in a narrow band of frequency. Recently, FBGs are suggested to compensate chromatic dispersion of common fibers. FBG is a part of common single mode fiber that is like a grating. Fiber Bragg gratings are simply inclusion of alternative modulation of refractive index in the core of optical fiber. Propagated light in a FBG core which satisfies the Bragg conditions is resonated by grating structure and reflected. The distance between gratings specify the reflected wavelength, so that, reflected light in Bragg wavelength is removed from transmission spectra. The most important feature of FBGs is that resonant wavelengths reflect to resource and others transmit through the device without any attenuation. A fiber Bragg is a very simple and low cost filter for wavelength selection. This filter has various applications which improve the quality and diminish the costs in optical networks. This instrument executes some operations like reflection and filtering with high efficiency and low loses. FBGs made a mutation in communication and optical fiber sensors. In a chirp FBG, some changes are created in period of gratings (as a result changes in response to different wavelength) along the grating. As the period of grating changes along the axis, different wavelengths are reflected by different parts of grating, and therefore are delayed with different time intervals. Final effect is compression in incident pulse and can be appropriate to compensate chromatic dispersion in a communication link. Most important preferences of chirp FBGs than other suggested types are low internal lose nonlinear effects and cost efficiency (Isa and Ahmet, 2005). The Idea of dispersion compensating was proposed firstly by Qulette, and then Williams and their colleagues proved it experimentally.

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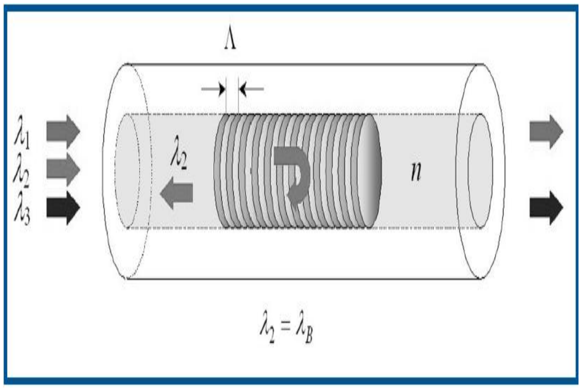

Figure 1. Principle of operation of a FBG.

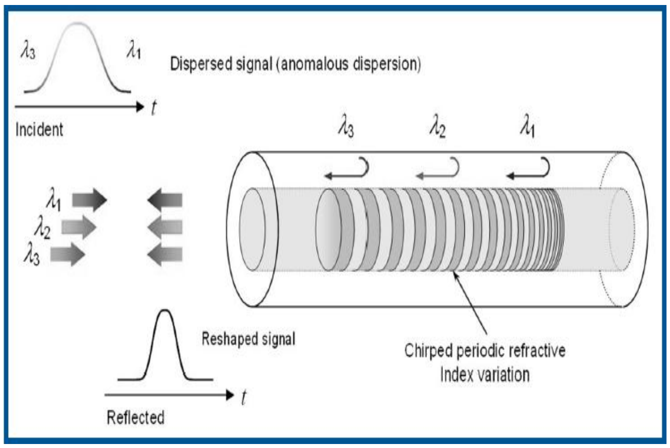

Figure 2. A chirped FBG compensate for dispersion by reflecting different wavelengths at different locations along the grating lengths.

FBG OPERATION PRINCIPLES

FBG is the inclusion of alternative modulation of refractive index which acts like a wavelength selective mirror as Shown in Figure 1.

FBGs were firstly observed as a result of strong argon ion laser radiation to a fiber with germanium dope. Afterwards, various methods were employed in order to map grating in optical fiber in which extensive types of pulsed and continuous lasers were used in visible and ultraviolet region (Raman, 1999; Othonos and Kyriacos, 1999; Marcuse, 1994). Resulted gratings selectively reflect the propagated light in fiber according to Bragg wavelength which is given as follow:

$$\lambda_B=2n\Lambda \qquad (1)$$

In this equation, n and Λ are refractive index of core and grating period in fiber, respectively. A uniform grating can be expressed as sinusoidal modulation of fiber core refractive index (Martin, 2004):

$$n(z)= n_{core}+\delta n\,[1 + \cos(2\pi z/\Lambda +\varphi(z))] \qquad (2)$$

In which n_{core} is the core refractive index when it is not radiated and δn is amplitude of induced refractive index variations.

Chirp FBGs and dispersion compensate

A chirp is where variations in grating period (and as a result changes in reaction to different wavelengths) are created along the grating. As shown in Figure 2, when a signal enters into chirp, different wavelengths are reflected from different parts of grating. Thus, a delay related to wavelength of signal is produced by grating. Some wavelengths have more dilation than others. This feature is used for dispersion compensating in communication links.

OPTISYSTEM SIMULATOR

Optisystem is an innovative optical communication system simulation package for 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 optic communication systems, new simulation environment and a truly hierarchical definition of components and systems. Its capabilities can be easily expanded with the addition of user components and seamless interfaces to a range of widely used tools.

SIMULATION OF TRANSMISSION SYSTEM

We use the parameters in Table 1 in order to simulate the system. The model of this simulated system is as shown in Figure 3.

In this simulation, we apply a continuous wave (CW) laser with frequency of 193.1 THz and output power of 1 MW which is externally modulated at 10 Gbits/s with a nonreturn-to-zero (NRZ) pseudorandom binary sequence in a Mach-Zehnder modulator with 30 dB of extinction ratio. Employed EDFA in this model has the gain amount of 6 dB which is independent of wavelength and ignoreable noise that is only used for dispersion compensating and nonlinear effects in transmission system.

Figure 4a shows the eye diagram of modulator output which is the main information shape in fiber input. Figure4b is the eye diagram of fiber output that has dispersion in comparison with Figure 4a. As a result, the

Table 1. Fiber parameters.

Parameter	
Dispersion (ps/km/nm)	17
Dispersion slope (ps/nm^2/km)	0.050
Attenuation index (dB/km)	0.20
Length of fiber (km)	10

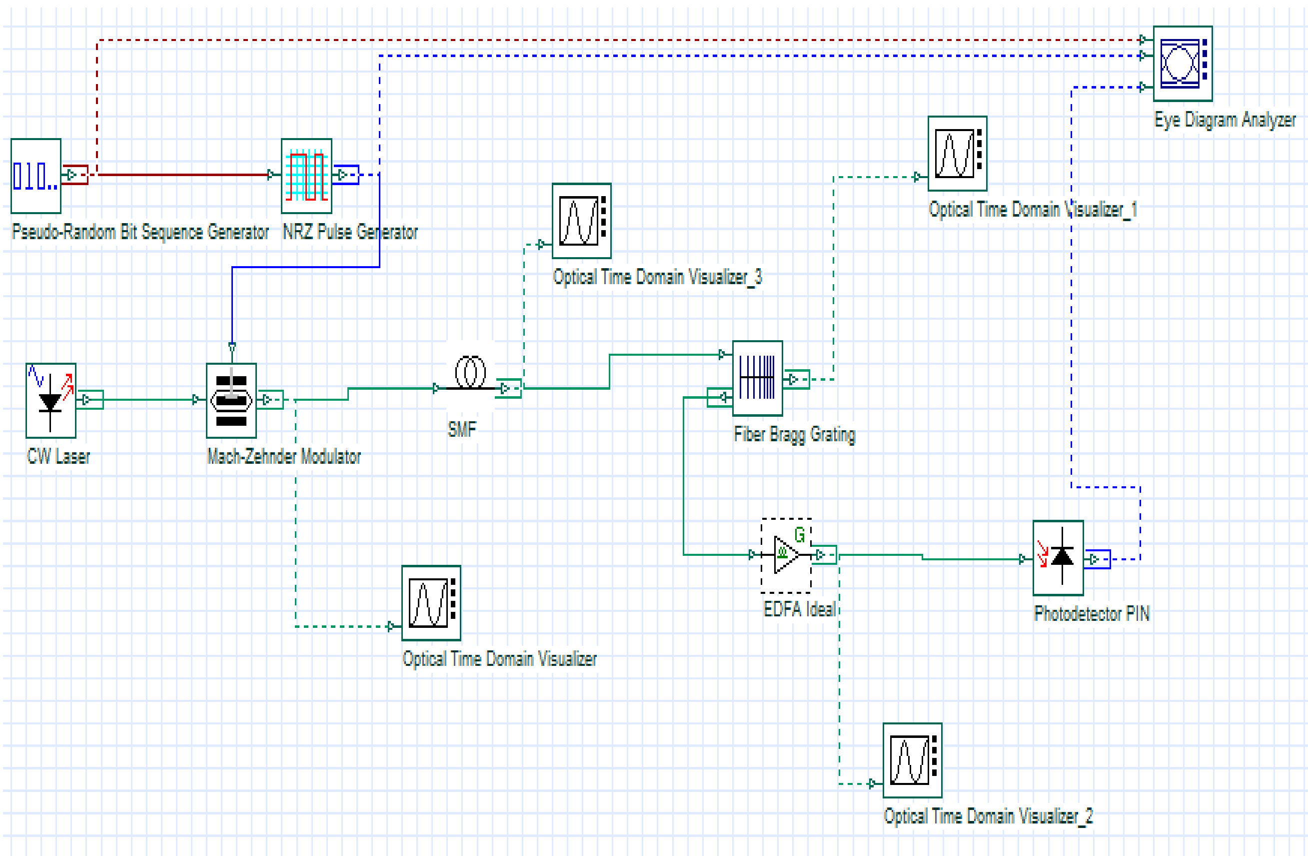

Figure 3. A model of simulated system with Optisystem software.

data before entering to fiber and after exit from the fiber are not the same; this is the main disadvantage of communication systems. Therefore, after fiber, we use a compensator to produce a dispersion index equal but with opposite sign to that produced in fiber, of which the former will finally inactive the latter one. This effect is clearly shown in Figure 4c that is related to reflected spectra of FBG after dispersion compensating. FBGs have following parameters as shown in Table 2 and in the figures.

We achieved the most proper length for proposed model equal to l = 6 mm by try and error method. Diagrams respect to different length of grating is as shown in Figure 6. In these diagrams, we randomly selected 3 points at eye diagram of the signal that is reflected from FBG as shown in Figure 5, and with changing the length of grating, the results were observed. The coordinates of these points are shown in Table 3. The color of diagrams in Figure 6 corresponds to the color of the selected point in Figure 5. Also, it is shown in Figure 6 that the power increases with increasing the grating length.

The nearest values to this amount are the best parameter for grating length and chirp parameter that will be investigated later. We can see that the increase in grating length increased power, and by comparison with the values in Table 3, we can find that l = 6 mm is the best value.

In Figure 7, the eye diagrams of different profiles of apodization depicted that Tanh was the most appropriate one. In Figure 8, diagrams of different parameters for

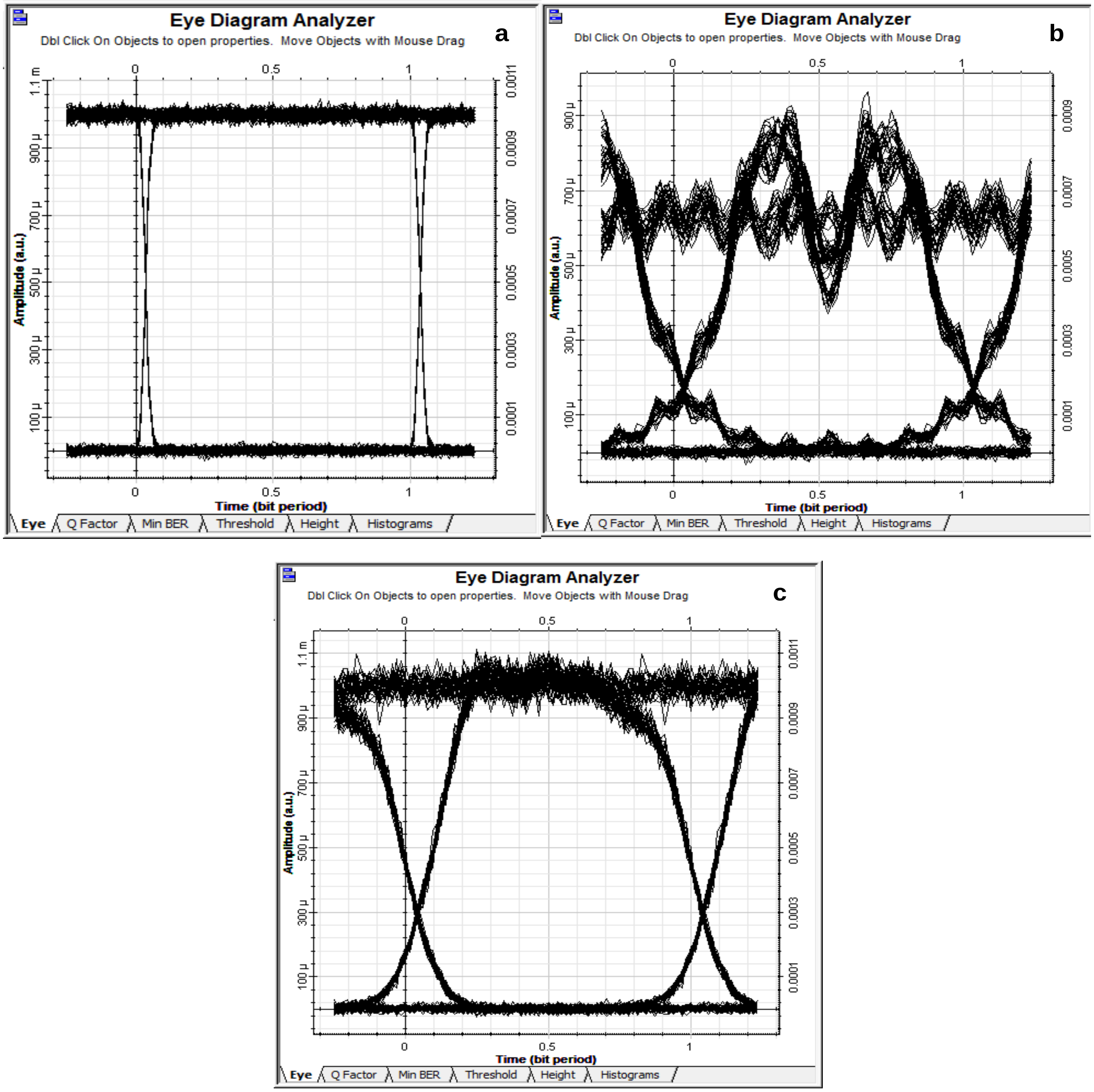

Figure 4. (a) The eye diagram of the signal from M-Z modulator; (b) The eye diagram of the signal propagating over 10 km without dispersion compensation; (c) The eye diagram of the signal reflected from the FBG.

Table 2. FBG parameters.

Parameter	
Frequency (THz)	193.1
Effective refractive index	1.45
Length of grating (mm)	6
Apodization function	Tanh
Tanh parameter	4
Chirp function	Linear
Linear parameter (μm)	0.0001

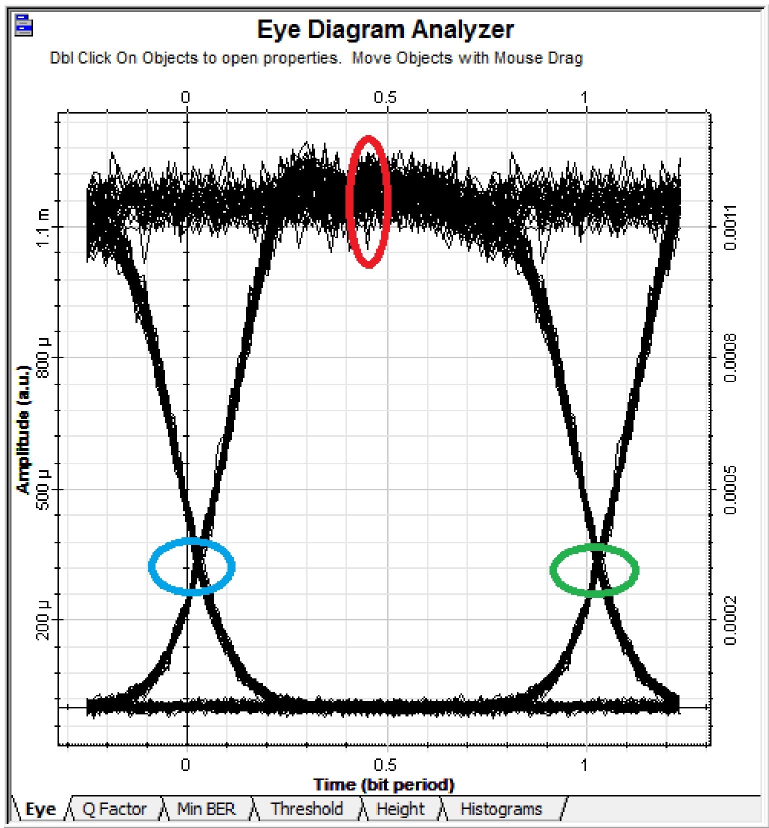

Figure 5. Three points selected for investigation.

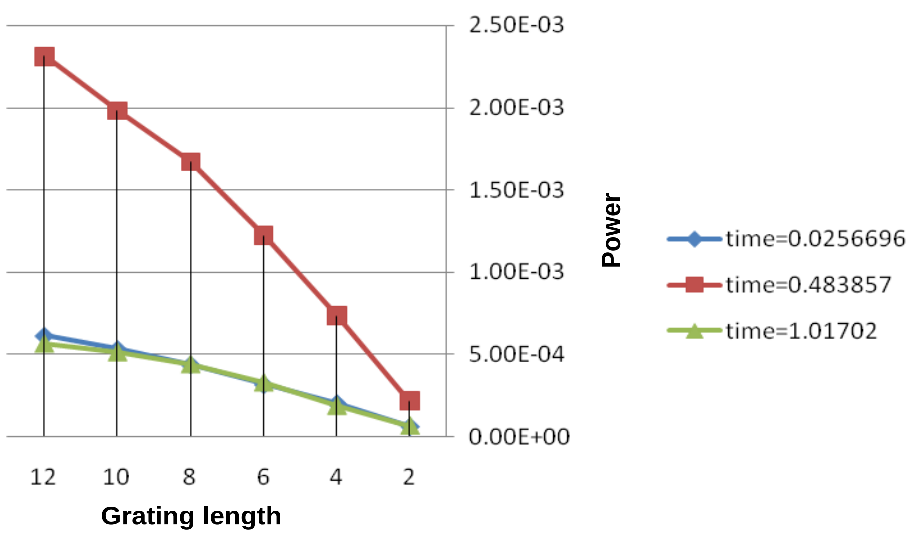

Figure 6. Investigation of grating length.

Table 3. Selected points coordinate.

	Blue	Red	Green
Power	0.000309866	0.00102719	0.000307042
Time	0.0256696	0.483857	1.01702

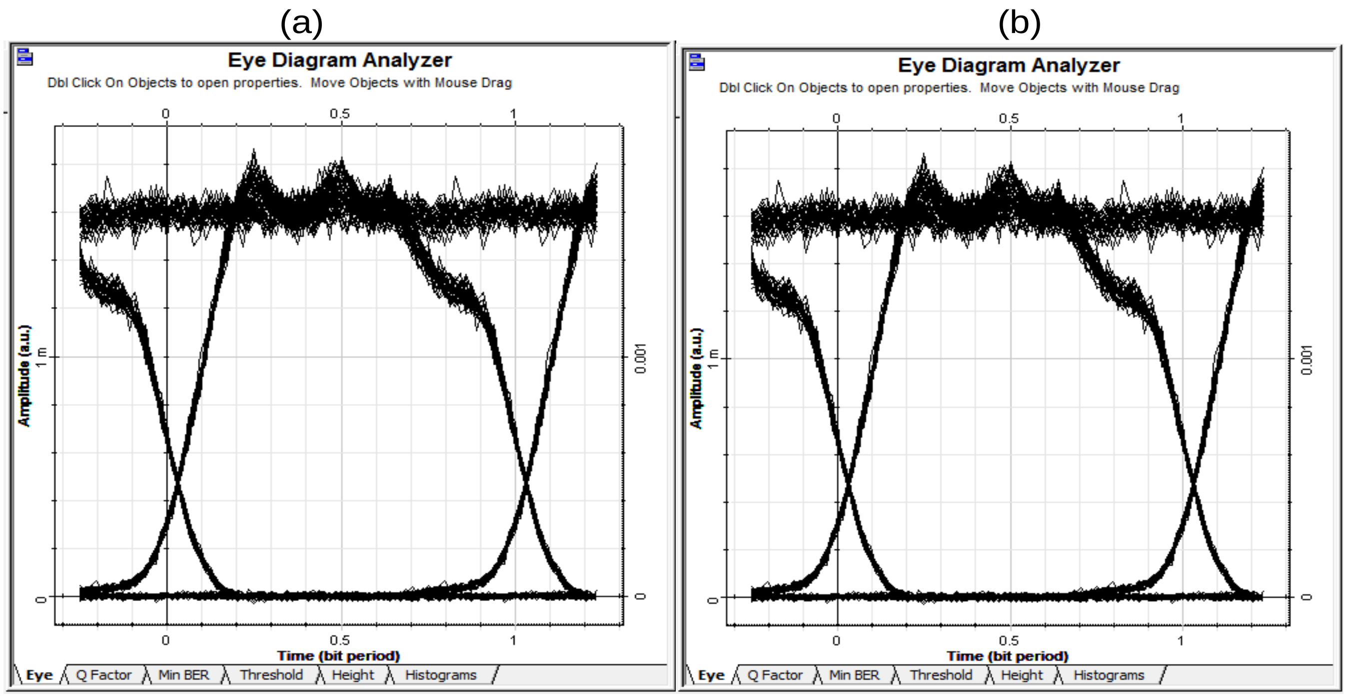

Figure 7. Eye diagram from different apodization function: (a) uniform function and (b) Gaussian function.

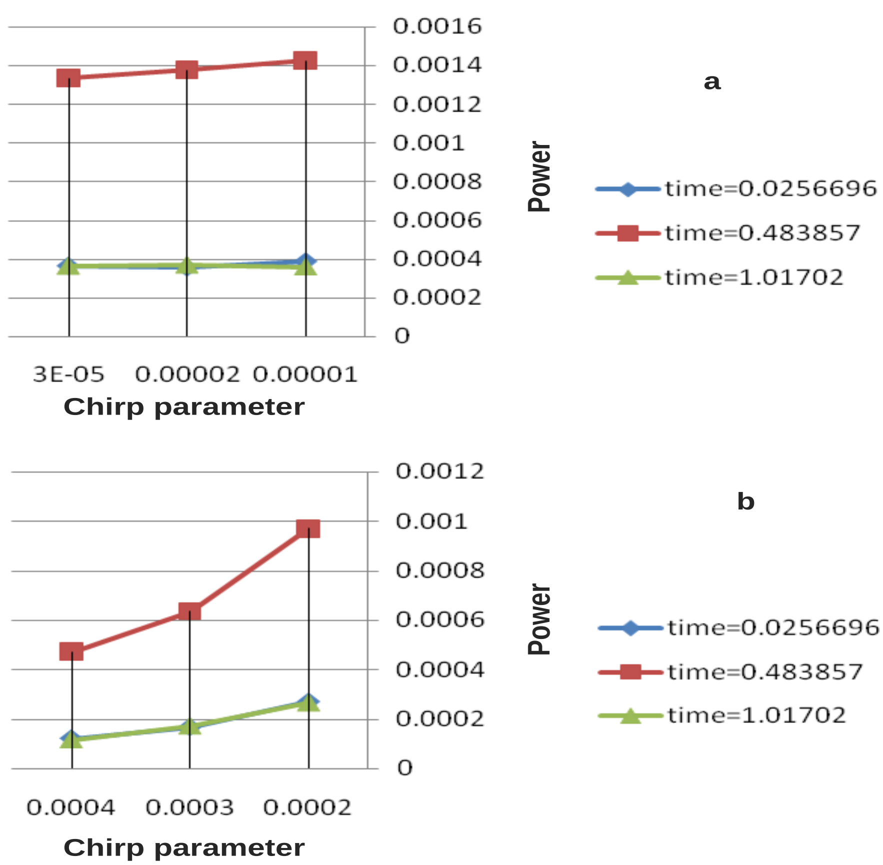

Figure 8. The effect of changing chirp parameter: (a) decreasing the chirp parameter toward ideal amount and (b) increasing the chirp parameter toward the ideal amount.

chirp are shown. As shown in Figure 8a, power decreased by decreasing the chirp parameter toward the ideal amount, while in Figure 8b, power increased by increasing the chirp parameter. By comparing these figures with Table 3, we find that decreasing the chirp parameter toward the ideal amount (0.0001) is adaptable for achieving the best output.

Conclusion

In this work, we simulated a communication system in information transmission. As soon as we observed dispersion, we decided to compensate it in order to receive data in receivers as they are. To this purpose, we employed chirp FBG and simulated it.

Also, it can be obtained that increase in grating length leads to decrease in pulse extension, and also increase in its power. By considering the power of the output spectrum of modulator and the pulse shape in that point, the most suitable length which equals to 6 mm can be resulted. Apodization function is not very effective in FBG reflected spectrum, although the best shape is Tanh function because of its grating length. Finally, it can be understood that the pulse was broadened and its power increased as a result of the increase in chirp parameter which is the best amount.

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