ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 2, February 2015

Simulation of Optical Transmission System to Compensate Dispersion Using Chirped Fiber Bragg Grating (FBG)

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Abstract: Fiber Bragg Grating (FBG) is one of the applicable and important components in optical communication system. In this paper, chirped FBG has been studied as a dispersion compensator in an optical communication system for the different lengths of grating and apodization functions. All the simulations are done in OPTISYSTEM 7.0 simulation software at 10 Gbits/sec and 210 km of transmission fiber. The simulated transmission system has been analyzed on the basic of different parameters, which are BER, Q-factor, Output power and Eye height.

Keywords: Fiber Bragg Grating (FBG), eye diagram, BER and Q-factor.

I. Introduction

Optical communication is a system transmitting information in form of light through an optical fiber. The light acts as 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. 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 and non-linear effects, 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 in optical communication systems that lead to performance enhancement of the transmission system. [1]

The optical amplifiers (EDFA, SOA etc) has resolved the problem of optical fiber losses and made the long distance transmission possible without electronic regenerators. But the dispersion and other non-linearities of optical fibers hindered ultra-long distance transmission and high bit rate transmission. 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. 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. [2]

In order to improve the overall system performance affected by dispersion, several dispersion compensation techniques are proposed and analyzed. Among the various techniques proposed in literature, the most suitable techniques are: Dispersion compensating fibers (FBG), Fiber bragg gratings (FBG), Electronic dispersion compensation (EDC), Digital filters and Higher order mode (HOM) fibers.

In this paper, the FBG is used as the dispersion compensator. The rest of the paper is organized as followed: In section II the FBG operation principle is described. In section III, simulation of transmission system is presented. Section IV presents the results and analysis and section V concludes the paper.

II. 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. The reflected wavelength changes with grating period. Thus, FBG is very simple and low cost filter for wavelength selection that improves the quality and diminishes the costs in optical networks. [3] The equation relating the grating periodicity, Bragg wavelength and effective refractive index of the transmission medium is given by:

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

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Vol. 4, Issue 2, February 2015

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

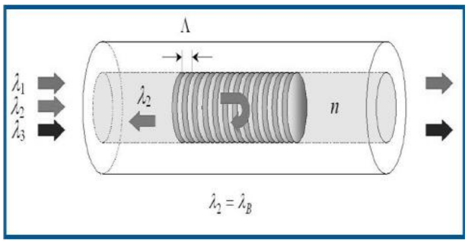


Fig. 1: Principle of FBG [4]

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. [4]

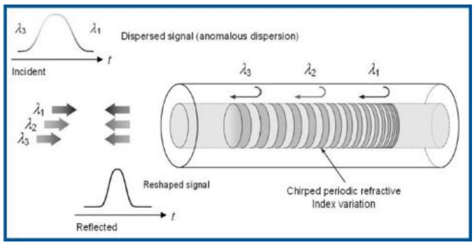


Fig. 2: A chirped FBG principle [4]

III. METHODOLOGY

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. [4]

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. And FBG is used as the dispersion compensator. At the receiver side, the PIN diode is used as a photo detector, 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
Dispersion (ps/nm.km)	17.25
Dispersion slope (ps/nm^2/km)	0.085
Attenuation (db/km)	0.2
Fiber length (km)	210

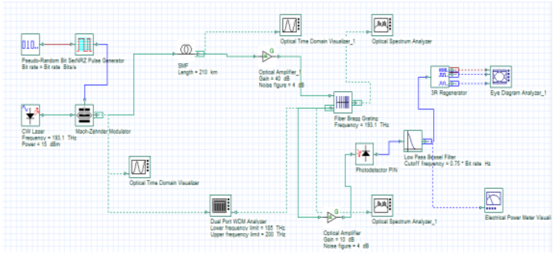
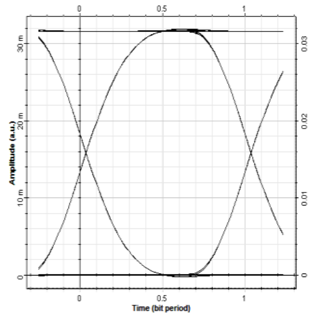


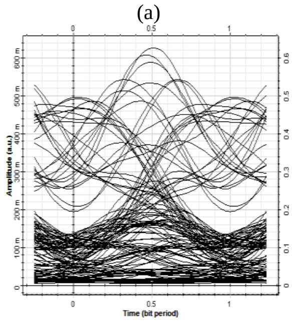
Fig. 3: Model of simulated system

IV. RESULTS AND DISCUSSION

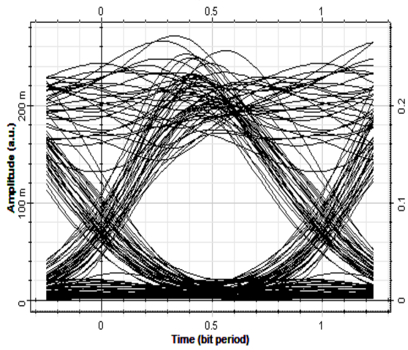
Fig. 4(a) shows the eye diagram of modulator output that is the main information shape in fiber input. Fig. 4(b) shows the eye diagram of the fiber output that is affected by dispersion. We can see that the data before entering to fiber and after exit from the fiber are not same; this is the main disadvantage of communication system. Therefore, we use the FBG as the dispersion compensator after the optical fiber. Fig. 4(c) shows the eye diagram of the signal at the receiver end with dispersion compensation. The FBG parameters used are shown in Table 2.



(a)



(b)



(c)

Fig. 4: (a) Eye diagram of the signal from M-Z modulator; (b) Eye diagram of the signal after propagating over 210 km without dispersion compensation and (c) Eye diagram with FBG as the dispersion compensator

 DOI 10.17148/IJARCCE.2015.4281

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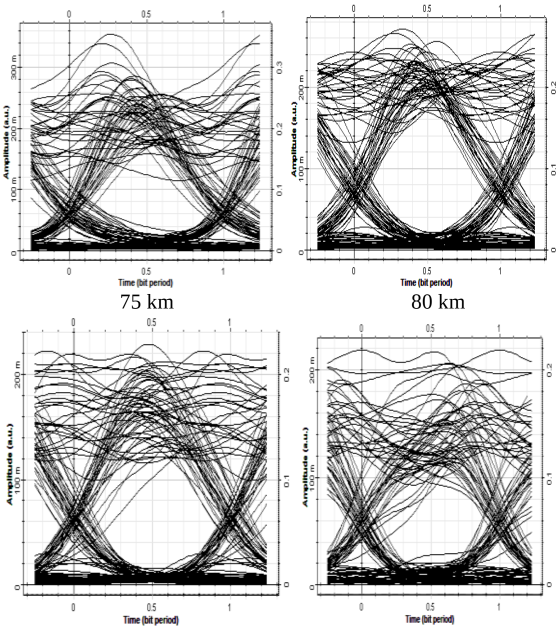
Table 2. FBG parameters

Parameters	Value
Frequency (THz)	193.1
Effective refractive index	1.45
Length of grating (mm)	80
Apodization function	Tanh
Chirp function	Linear

We achieved the most proper grating length for the proposed model of 80 mm by try and error method. Eye diagrams for the different lengths of grating are shown in Fig.5 and the values of Q-factor and BER for the different lengths of grating are tabulated into Table 3.



75 km 80 km

85 km 90 km

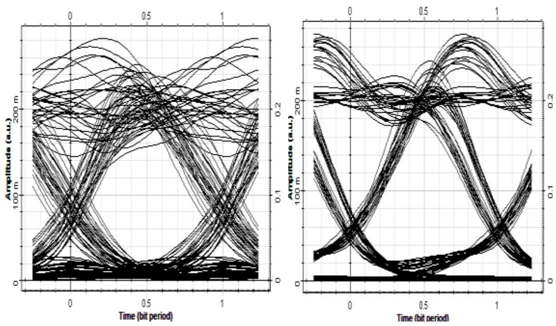
Fig. 5: Eye diagrams for the different grating lengths

Table 3. : Comparison of different FBG lengths

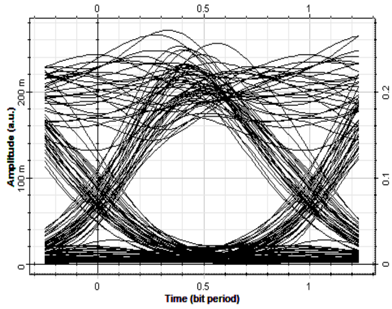
FBG length (mm)	Q-factor (db)	BER
75	5.2124	7.16442e-008
80	8.65973	1.94706e-018
85	5.37153	2.53473e-008
90	3.84116	4.51004e-005

By comparing the values in Table 3, we found that the 80 mm grating length is better for 210 km of optical fiber.

In Fig.6, the eye diagrams for different profiles of apodization depicted that Tanh and Gaussian give better results as compared to Uniform apodization function. The Q-factor and BER for the different apodization functions are tabulated into Table 4.



(a) (b)



(c)

Fig. 6: Eye diagrams for different apodization functions: (a) Uniform (b) Gaussian and (c) Tanh

Table 4. Comparison of apodization functions

Apodization function	Q-factor (db)	BER
Uniform	8.27338	5.38347e-017
Gaussian	10.5922	1.5591e-026
Tanh	8.65973	1.94706e-018

VI. 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.

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 DOI 10.17148/IJARCCE.2015.4281