ABHIYANTRIKI
An International Journal of Engineering & Technology
(A Peer Reviewed & Indexed Journal)
Vol. 4, No. 4 (April, 2017) http://www.aijet.in/ eISSN: 2394-627X

Dispersion Compensation Analysis in an Optical Fiber by using Chirped Fiber Bragg Gratings

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Abstract
Dispersion is the most important factor which determines the data rate and the maximum repeater distance spacing in a fiber optical link. In this paper, the use of chirped FBG has been studied as a dispersion compensator in a 38 km long fiber optic link using NRZ modulation format. For the given optical communication system, it was observed that NRZ modulation format gives a maximum value of Q- factor of 18.3881. The simulation model of the chirp grating is based on the Optisystem 7.0 and is presented according to the above principle.

Keywords*: Fiber Bragg Grating, RZ, NRZ, Q-factor, Power levels.*

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1. Introduction

In recent times, the use of single mode fiber (SMF) in order to transmit data at high bit rates in transmission windows having low loss has seen great importance. But dispersion is a matter of great concern which degrades the overall performance of fiber optic communication link. As the bit rate is increased dispersion cause the pulse to broaden at the output of the optical fiber. At high data rate, these broaden pulses may overlap with each other causing crosstalk and inter symbolic interference (ISI) which causes errors during reception of the signal at the receiver side of optical link. Using erbium doped fiber amplifiers (EDFAs) in an optical fiber communication system is an offer to compensate loses. By the use of Erbium Doped Fiber Amplifier (EDFA) in 1550 nm wavelength window in order to increase the distance of fiber optic link which has been limited by loss caused due to dispersion. But EDFA induces nonlinear effects in the optical fiber which limits the data rate of fiber optical channel and also reduces the maximum repeater distance spacing in fiber optic link. The combined effect of chromatic dispersion and nonlinear effect are very disastrous for data transmission in a very high data rate optical fiber link which induces overall loss in optical data transmission system. To overcome this problem, dispersion compensation fibers (DCFs) are extensively used to compensate chromatic dispersion. This method required to use DCFs negative dispersion coefficient in a communication link in order to disable the effect of positive dispersion in fibers. Now days, FBG are suggested to compensate chromatic dispersion in fibers. In Fiber Bragg Grating different wavelength are reflected inside of grating at different distance. The larger wavelength travels a larger distance before reflection and the shorter wavelength travels a comparatively lesser distance inside the fiber. As a result the pulse which was expanded by dispersion has now been compressed by use of Fiber Bragg Grating. In this paper, we discussed the use of FBG to compensate dispersion in a 38 km long fiber optical link.

2. Fiber Bragg Grating (FBG)

The concept of Fiber Bragg Grating was first introduced in 1980 and has been used in several applications and widely researched. A FBG is a type of distributed Bragg reflector constructed in a small segment of an optical fiber that reflects particular wavelengths of light and transmits all other. This is achieved by producing a periodic variation in the refractive index of the fiber core. Transmitted light in an FBG core which satisfies the Bragg conditions is resonated by grating structure and reflected. The FBG consists of a linear reflective device whose reflective index profile changes linearly with respect to length of the fiber. The grating reflects the light depending upon the wavelength of the light entered in the grating. The light with larger wavelength travels a greater distance in the grating before getting reflected; on the other hand, ray with smaller wavelength travels a shorter distance inside the grating before getting reflected. As a result, the ray which is expanded by the chromatic dispersion in an SMF is compressed by passing through a Fiber Bragg Grating. A FBG can therefore be used as an optical filter to block certain wavelengths. This filter has various applications which improve the quality and reduce the cost of an optical network. The refractive index profile of the grating may be varied to add some features, such as a linear variation in the grating period, called a chirp. The reflected wavelength changes with the grating period, broadening the reflected spectrum. The most important inclination of chirp FBG than other recommended types are small internal lose and cost efficiency.

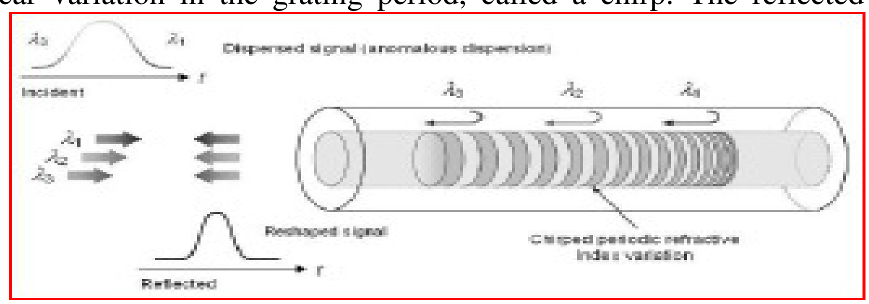

Fig. 1: A chirped FBG compensate for dispersion by reflecting different wavelengths at different locations along the grating lengths

3. FBG Operation Principles

FBG is the addition of another modulation of refractive index which acts like a wavelength selective mirror. FBGs were firstly seen as a result of strong argon ion laser radiation to a fiber with germanium dope. Later, various methods were employed in order to map grating in optical fiber in which wide-ranging types of pulsed and continuous lasers were used in visible and ultraviolet region. Subsequent gratings selectively reflect transmitted light in fiber according to Bragg wavelength which is given as follows:

$$\Lambda_b = 2n\Lambda \quad (1)$$

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:

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

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

The main advantage of using Fiber Bragg Grating as a dispersion compensation technique is that it is very cost effective and has a low insertion loss and they are passive components compatible with single mode fiber. FBG also find its application in different a field such as WDM add/drop filters, pump lasers and wavelength stabilizers. Fig below shows the basic principle of FBG. The functioning of FBG depends upon the reflection of light from gratings and coupling of modes [6]. Forward and backward propagating fields of the same mode causes coupling and they show strong coupling if they satisfy following condition:

$$\beta 1 - \beta 2 = 2m\pi/\Lambda \qquad (3)$$

where β1 and β2 are phase constants of two modes. Now if we consider two modes which are counter propagating we have:

$$\beta 2 = -\beta 1 \qquad (4)$$

and hence the Bragg Diffraction condition is given by:

$$2\beta = 2m\pi/\Lambda \qquad (5)$$

If effective modal index is given by Neff then:

$$\beta 1 = 2\pi n_{eff}/\lambda \qquad (6)$$

Thus, the Bragg wavelength which is strongly reflected by grating is given by:

$$\lambda_b = 2n_{eff}\Lambda \qquad (7)$$

This is the final condition of the wave to be reflected inside of a Fiber Bragg Grating.

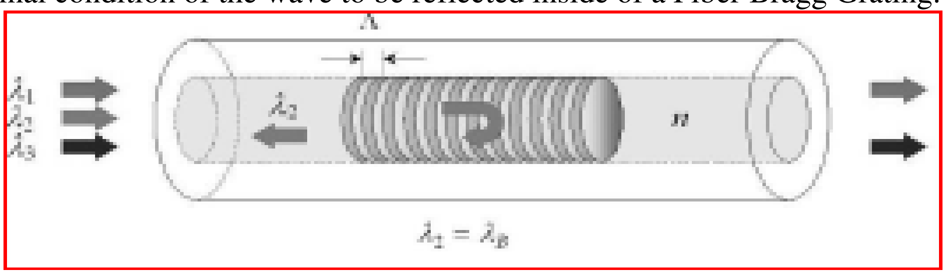

Fig. 2: Principle of operation of a FBG

4. Chirp FBGs and Dispersion Compensate

A chirp is where variations in grating period are formed along the grating. As shown in figure below, when a signal arrives into chirp, different wavelengths are reflected from different parts of grating. Thus, a delay subjected to wavelength of signal is created by grating. Some wavelengths have more expansion than others. This feature is used for dispersion compensating in communication links.

5. Simulation of Transmission System

In this paper, simulations have been performed using NRZ modulation format. Various simulations parameters utilized in this analysis work are given in table 1 and various fiber parameters used in this simulation are given in table 2.

Table 1: FBG Parameters

PARAMETERS	**VALUE**	**PARAMETERS**	**VALUE**
Frequency(THz)	193.1	Tanh parameter	0.5
Effective refractive index	1.45	Chirp function	Linear
Length of grating(mm)	6	Linear parameter(μm)	0.0001
Apodization function	Tanh		

Table 2: Fiber Parameters

PARAMETERS	SMF	PARAMETERS	SMF
Length (Km)	38	Dispersion (ps/nm/Km)	16.75
Attenuation (db/Km)	0.2	Dispersion Slop (ps/nm^2/Km)	0.075

At first we have used a pseudo-random bit generator which transmits a sequence of 0's and 1's which are fed into the input stage of NRZ modulators. This string of 0's and 1's is converted into electrical pulses which are fed to input of Mach-Zender modulator which modulates the signal with a continuous wave centered at frequency 193.1 THz. The signal is then fed to an SMF of length 38 km. An Optical Amplifier is used to compensate loss due to large span of single mode fiber. Then the signal is passed through the FBG for compensation. The optical information signal is then retrieved by PIN photo diode which converted optical signal to electrical signal. The signal is finally analyzed by BER which determines various performance parameters such as BER, Q-factor, and Eye height.

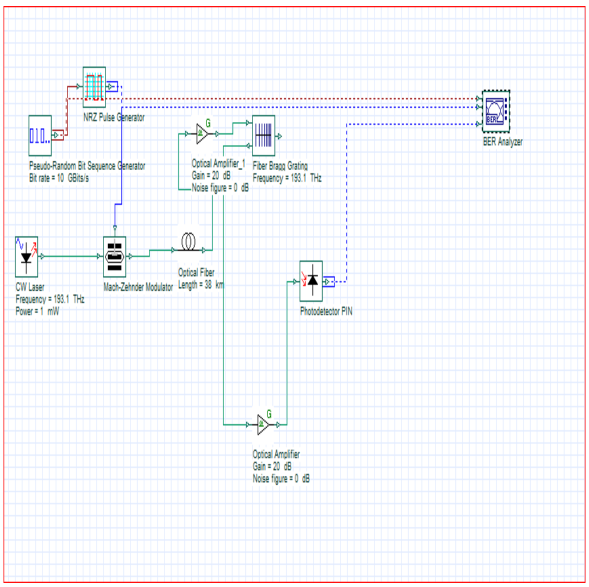

Fig. 3: Simulation setup for NRZ modulation format

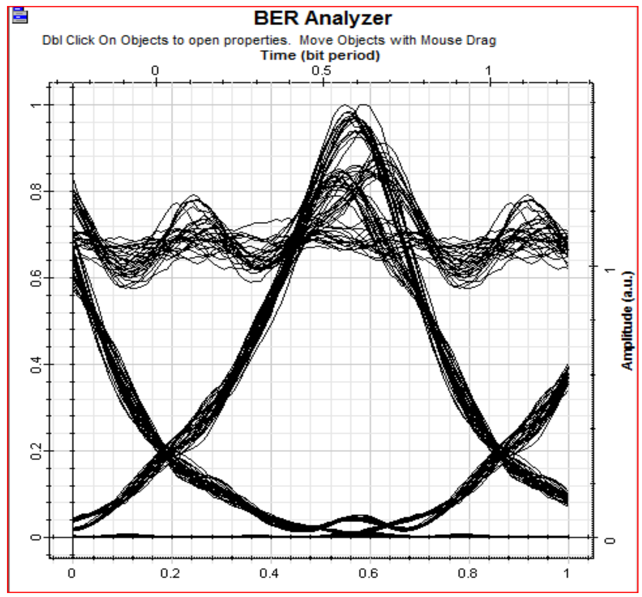

Fig. 4: Eye Diagram for NRZ modulation format at 193.1 THz

6. Conclusion

In this paper, we simulated an optical communication system in an information transmission. As soon as we saw dispersion, we decided to compensate it in mandate to receive data at receiver. For this purpose, we used 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 power. By seeing the power of the output spectrum of modulator and the pulse shape in that point, the most appropriate length which equals to 6 mm can be followed. Apodization function is not very effective in FBG reflected spectrum, although the favorable shape is Tanh function due to its grating length. Lastly, it can be understood that the pulse was broadened and its power is increased as a result of the increase in the chirp parameter which is the best volume.

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