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PERFORMANCE EVALUATION OF DCF AND FBG IN A WDM SYSTEM WITH EIGHT CHANNELS IN TERM OF QUALITY FACTOR

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ABSTRACT

Dispersion Compensation is an essential feature of a wave division multiplexed (WDM) system. In this paper, we are going to demonstrate dispersion compensation using Fiber Bragg Grating and Dispersion Compensating Fiber for WDM System. The basic principles for use of DCF and FBG are reviewed, including definition of figure, merit and condition for dispersion compensation. In multiple channels dispersion can be compensated with number of techniques such as FBG, DCF, EDC and Digital Filters. In this paper the design technique and implementation of FBG and DCF has been discussed. The simulation of the system is analyzed by using different parameters.

Keywords: Wave Division multiplexed (WDM) System, Dispersion Compensating fiber (DCF), Fiber Bragg Grating (FBG), Electronic Dispersion Compensation (EDC)

INTRODUCTION

In an optical communication transmission the information is transmitted back and forth by sending light pulses. Although it provides user with large bandwidth but due to increase in the bandwidth and the distance of the fiber cable, the optical transmission faces many problems such as dispersion, attenuation and other losses. [1] These limitations can be overcome by different techniques. All Optical Signal processing is a new and emerging technology which is used to overcome the limitation caused by slow operating speed of the electronic signal processing circuits. All optical half-adder and half-subtractor can be served as building block for All optical Arithmetic Logical Unit.[2] Interferometric architectures such as Sagnac Interferometers, Ultrafast Non-Linear Interferometer (UNI) and Mach–Zehnder Interferometer (MZI) are All-Optical logic design methods.[3]

Dispersion is the main problem which affects the performance of optical transmission at high bit rate. It is the pulse broadening which may be caused by different elements such as core diameter, refractive index profile, wavelength, numerical aperture, and laser line width of a fiber cable. It may lead the signal to distortion and overlapping of pulse which is also known as Inter Symbol Interference (ISI). [4] Dispersion is mainly of two different types:

(a) Non linear Dispersion
(b) Chromatic Dispersion
(c)

Chromatic Dispersion occurs when wavelength may travel at different speeds through a fiber cable. An optical source emits a specific wave length within a range of a Dense Wave Division Multiplexing System and when these wavelengths travel through a fiber, each signal wavelength arrives at different time and speed, which leads to the signal distortion as shown in Fig 1.

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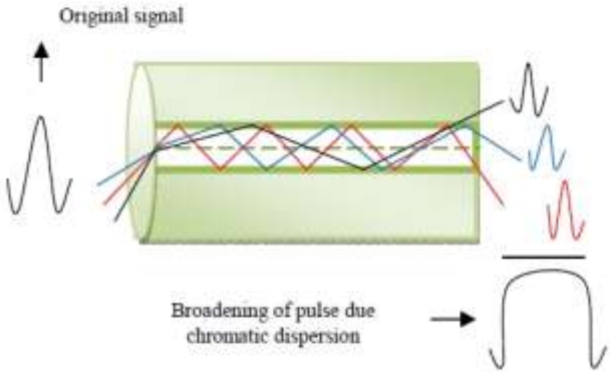

Fig 1: Broadening of pulse due to chromatic dispersion.[5]

The Rest of paper is organized in following manner:
In Section II we will discuss the literatures of various authors.
Section III will through ample light on the dispersion compensation techniques.
Section IV will shows the methodology and Simulation Setup of the techniques which are used.
In Section V the results of the experiments which are simulate by us are discuss.
Section VI will discuss on the conclusion of the paper.

LITERATURE SURVEY

H. M. Foisel et al [6] in 1999 investigated that RZ versus NRZ Modulation Format for Dispersion Compensation SMF based 10 GB/s Transmission. They discover that by independently varying the power at the different types of fiber input and compensation ratio, the post compensation performs better than pre compensation. They also show that by introducing pre distortion the performance of both pre compensation and post compensation schemes can be significantly improved.

Zhou Zhi Qiang et al[7] in 2000 investigated in his paper " Optimum scheme of dispersion compensation transmission system using dispersion compensation fibers laser technology" . He found that a device itself requires only a Bragg Grating and a taped thin metal film coating to shift and chirp the FBG wavelength by changing the applied current throught the film which optimize time varying dispersion maps and can reduce power penalty associated with non-linear transmission impairments and other variation.

S. Devra et al [8] in 2011 discussed in his paper "Different Compensation Techniques To Compensate Chromatic Dispersion In Fiber Optics" that dispersion compensation is most challenging as well as important aspect to maintain signal to noise ratio in an optical communication. He discussed that Dispersion Compensation Fiber (DCF) is a reliable technology but it also gives high insertion loss as well as introduce some nonlinear distortion when there is high input power. Other dispersion techniques such as electronics dispersion Compensation (EDC), Fiber Bragg Grating (FBG) and Digital Filters are discussed by him.

S. Devra et al [9] in 2011 in his paper "Dispersion compensation using all pass filters in optical fibers" discussed that All Pass Filter (APF) is leading requirement for dispersion compensation in an optical fiber transmission system. Any order dispersion can be compensated with the All Pass Filters by designing multistage APF and also used in WDM systems.

S. Devra et al [10] in 2011 investigated in his paper "Dispersion Compensation using Raised Cosine Filter in Optical Fibers" that Raised Cosine Filter is one of the APF which is used in a WDM system to compensate dispersion in an optical link.

Zhang Hongb et al [11] in 2001 demonstrated on the basis of analyzed the three system simulation result. The attenuation of Dispersion compensation fiber is not null. Therefore the attenuation of DCF will produce impairment to signal quality as well as that of SMF. Mix compensation scheme can greatly reduce the fiber nonlinear effect.

M. Weiming demonstrated dispersion compensation over 50 km of standard single mode fiber using chirped fiber grating [12]. Chirped fiber grating is a passive device with low insertion loss that is compatible with the transmission system and CFG dispersion can be easily adjusted. For optimum results CFG should be located in-line [13].

Y. Aiying concluded that, the increased interaction of SPM and anomalous dispersion in CFG can be used to extend the transmission distance in point-to-point system [14].

M. J. Islam analyzed that FBG can also be used to compensate GVD, based on BER. The numerical results indicated that the BER performance can be improved significantly depending on the fiber length [15].
Cascaded grating was implemented in WDM system to compensate GVD [16]. Chirped FBG (CFBG) is more preferred technique over LDF and DCF because of its advantages including small footprints and dispersion slope compensation and negligible non-linear effects over others [17].

DISPERSION COMPENSATION TECHNIQUES:

In order to reduce the spreading of light pulses, Dispersion Compensation is the most important feature in optical communication system. The most commonly utilized techniques for the compensation of dispersion are as follows:

i. Dispersion Compensation Fiber (DCF)
ii. Fiber Bragg Grating (FBG)
iii. Electronics Dispersion Compensation (EDC)
iv. Digital Filters

In this paper we briefly discuss the working and principle of DCF and FBG.

Dispersion Compensation Fiber (DCF)

The basic principle of using a dispersion compensation fiber in an optical link is that, by inserting a piece of fiber with an opposite dispersion as that of original fiber in the link. DCF has 3 methods which are as follows:
1. Pre-compensation: the DCF of negative dispersion is placed before the fiber as shown in fig.2 (a)
2. Post-compensation: the DCF of negative dispersion is placed after the fiber as shown in fig.2 (b)
3. Symmetrical or mixed compensation: the DCF of negative dispersion is once placed before fiber and then placed after fiber as shown in fig.2(c) [7, 8].

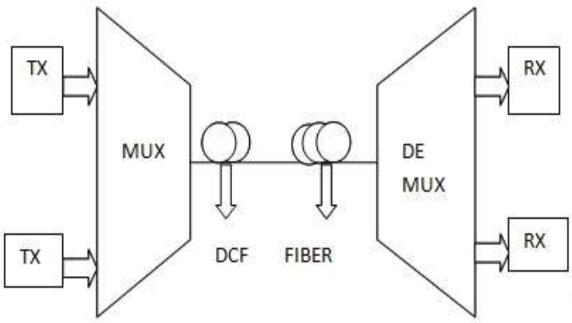

Fig.2 (a) Pre Compensation

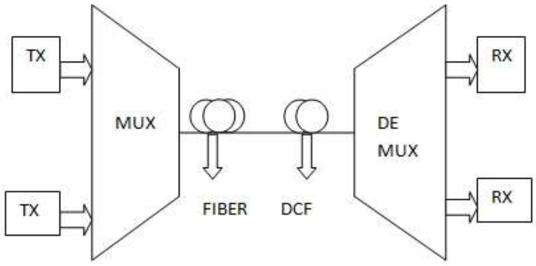

Fig.2 (b) Post Compensation

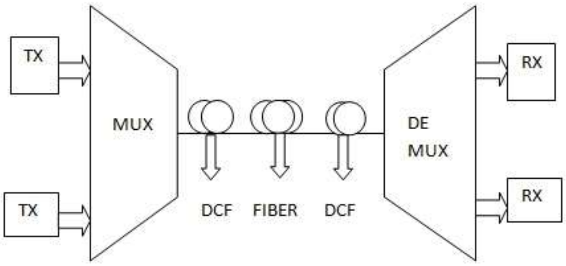

Fig.2(c) Symmetrical or mixed compensation

Fig. 2: Different Compensation techniques by DCF [8]

Fiber Bragg Grating (FBG)

Is lately found and very effective in compensation of dispersion-broadening in long haul communication. The basic principle behind the operation of FBG is Fresnel Reflection, in which light travelling between media of different refraction indices may refract as well as reflect at interface. It is used as an optical filter to block certain wavelengths. [22]

The Reflected index will be possible over a particular wavelength. The reflected wavelength (λ_B), called as Bragg wavelength, given by:

$$\lambda_B = 2n_e\Lambda$$

Here $n_e$is the effective refractive index

Λ is grating period

n_eDepends on wavelengths as well as on the mode of propagated light. So that it is also known as modal index.

The wavelength spacing between minima or bandwidth is given by:

$$\Delta\lambda = [\frac{2\delta n_0 \eta}{\pi}]\lambda_B$$

Where δn_0 is a variation in refractive index.

η fraction of power in core.

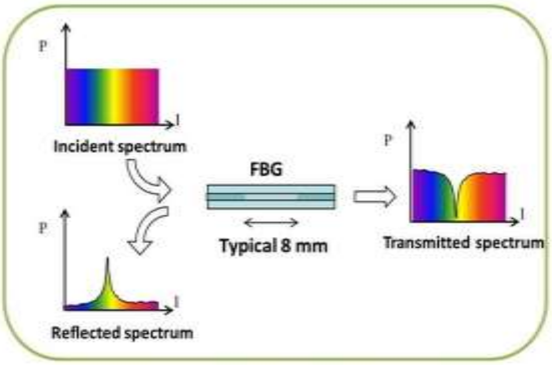

Fig.3 working principle of FBG [18]

Electronic Dispersion Compensation (EDC)

Electronic Compensation techniques are widely used in many applications such as use in mobile phones [8]. There are various methods in which EDC can be used to compensate dispersion. One of the methods to compensate the first order PMD in the fiber by cancelling it out with a compatible PMD vector produced at the receiver. By using equalization circuit for the dispersion compensation in the most common technique used to compensate dispersion by EDC. Optical transmission system had many limitations; most of them are related to increasing in bit rates. Dispersion included penalty which is given by [19]:

$$\text{Penalty (db)} = A.\ (\Delta\tau/t)^2\ \gamma\ (1-\gamma)$$

Digital Filters

Digital Filters when used with Digital Signal Processing (DCF) can compensate the chromatic dispersion. They have provided fix as well as tunable dispersion compensation for WDM system [20]. Most effective way for dispersion compensation using digital filter is All Pass Filters. All Pass filters are lossless filters which are flexibly tuned to a desired phase response [9]. Some other filters which are used as band pass, Gaussian, Super Gaussian, Butterworth and Micro Photonic Filters [21].

METHODOLOGY AND SIMULATION SETUP

In this section we briefly discuss the description of the simulation setup. We use a setup of 8 channels Wavelength Division Multiplex (WDM) System,

This will compensate the dispersion using DCF and FBG. Both the techniques are shown in different setups. Both the techniques have 8 channels WDM system, each channel having a separate transmitting channel which is connected with 8X1 multiplexer to an optical fiber cable. In DCF we uses Post compensation technique and use a DCF after the fiber cable with negative dispersion as shown in fig.4.

For FBG setup, the optical fiber cable directly connected to the 1X8 demultiplexer and then in at receiver side a FBG is connected with 1X8 demultiplexer each channel output. Now in both the setups the optical signal is detected at receiver side by APDs and low pass filter is used to pass desired signal and get the desired output. A BER visual analyzer is used at the output to check the Q-factor, BER and eye diagram.

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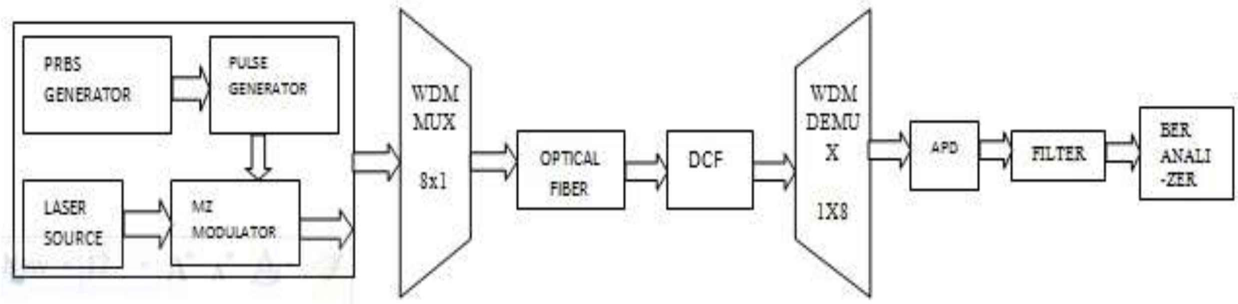

Fig. 4: Simulation setup with DCF

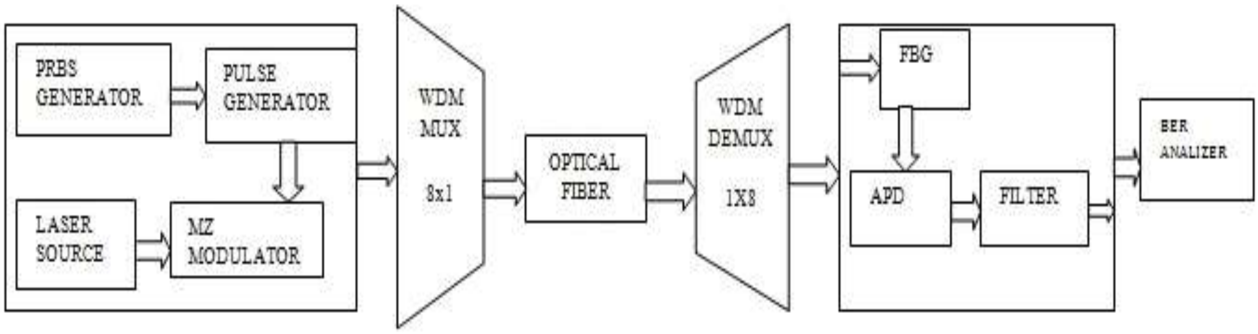

Fig. 5: Simulation setup with FBG

We have use different parameter of fiber cable, CW laser Source, DCF, and FBG which are given below:

Fiber Parameter	Value
Reference wavelength	1550 nm
Length	10-100 km
Attenuation	0.2 db/km
Dispersion	16.75 ps/nm/km
Dispersion slope	0.075 ps/nm^2/km
PMD coefficient	0.5 ps/km
Differential group delay	0.2 ps/km

Table 1: Parameters of optical fiber

CW Laser	value
Power	0db
Frequency	1550-1557nm

Table 2: Parameters of CW laser Source

DCF Parameters	Value
Reference wavelength	1550 nm
Length	10 km
Attenuation	0.2 db/km
Dispersion	-80 ps/nm/km
Dispersion slope	0.075 ps/nm^2/km

PMD coefficient	0.5 ps/km
Differential group delay	0.2 ps/km

Table 3: Parameters of DCF

FBG Parameters	**Value**
Frequency	1550-1557 nm
Effective index	3.45
length	6mm

Table 4: Parameters of FBG

RESULTS

In this section we analyze the results of outputs to check the better dispersion compensation. First we check the results of DCF using the output readings in a Mat Lab graph of one channel which will show in fig. 4.

Now we see the results of in below figures

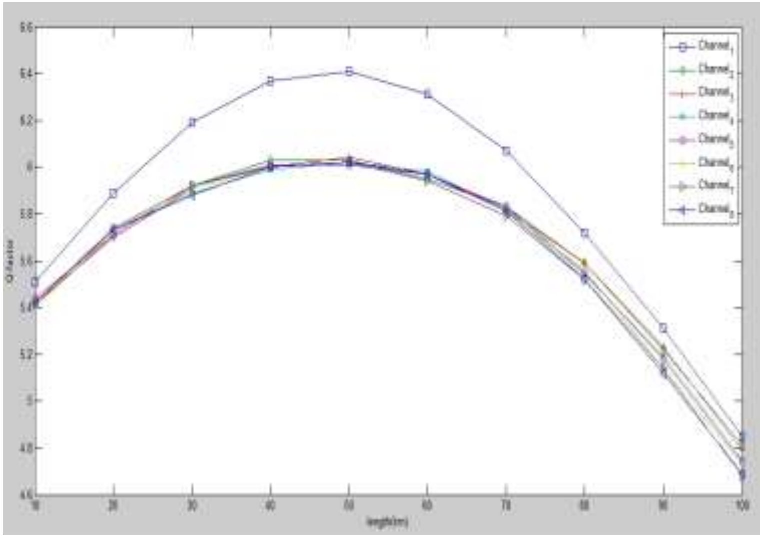

Fig 4 (a): Mat Lab graph using DCF

	Q-Factor	BER
Without DCF	5.51	$1.56x10^{-7}$
With DCF	3.24	0.0005

Table 5: Result of channel 1 at 10 km with and without FBG

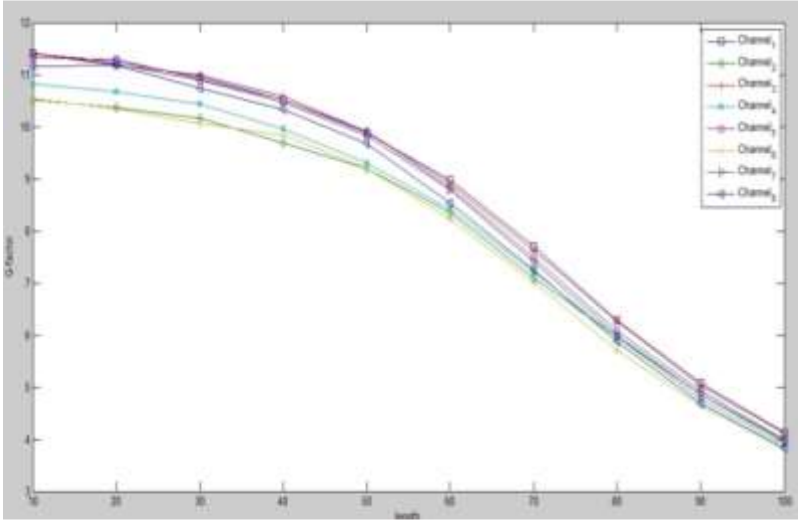

Fig 5(a): Mat Lab Graph Using FBG

	Q-Factor	BER
Without FBG	6.00	$6.11x10^{-10}$
with FBG	11.40	$2.10x10^{-30}$

Table 6: Result of channel 1 at 10 km with and without FBG

\CONCLUSION

We have analyzed the dispersion compensation with DCF and FBG at 10 Gb/s from 10 km to 100 km. we use a 10 km DCF with -80ps/nm/km in post compensation technique and use FBG at the receiving channels by varying frequencies from 1550 nm to 1557 nm to match with that of frequencies of 1X8 demultiplexer with an effective index of 3.45. After simulating both the experiments it is observed that the results of both the experiments are satisfactory but FBG gives the better results than that of DCF as it almost doubles the Quality Factor for proper reception of signals in optical communication.

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