IJITKM Volume 6 • Number 2 • July-December 2013 pp. 109-112

PERFORMANCE ANALYSIS OF WDM SYSTEMS WITH FBG AND DCF AS DISPERSION COMPENSATORS

Hardeep Singh[1] and Abhishek Pal[2]

ABSTRACT: We have evaluates the chromatic dispersion compensation for a long-haul WDM transmission. A 4 channel optical network was modeled, simulated and analyzed at a 100km distance using two chromatic dispersion compensators i.e. Fiber Bragg Grating (FBG) and Dispersion Compensated Fiber (DCF) . This analysis concludes that the DCF device seems to be the better compensating solution for the long haul narrowband transmission

Keywords: Dispersion Compensation , Dispersion Compensated fibers , Fiber Bragg Gratings Wavelength Division Multiplexing

1. INTRODUCTION

Fibre Optic communication system has an important advantage of exploiting the large bandwidth (THz) of an optical fiber. However, it is extremely difficult to exploit all of the huge bandwidth of a fiber using a single high-capacity wavelength channel due to optical-electronic bandwidth mismatch. The transmission capacity of WDM system can be increased by raising the signal bit rate per channel and/or the number of signal channel. Optical communication provides a higher bandwidth capacity, lower bit error rates, longer distance between repeaters, better resistance to electromagnetic interference and higher information security in comparison to other modes of communication i.e. copper cable and microwave [1] - [3]. The number of signal channels depends on the available optical pass band width of the system as well as the channel spacing, so that increasing the available optical pass band width is essential for increasing the transmission capacity of WDM sysmtems. This is mainly determined by the optical fibre charactics such as dispersion and nonlinearity as well as the gain bandwidth of optical amplifiers.

A channel rate of 2.5 gigabit per second (Gb/s) is now widely used, and soon 40Gb/s will be extensively deployed [4]. However, dispersion poses a serious problem in WDM optical communication, thus, limiting either the bit-rate or the transmission distance severely. Dispersion is a phenomenon where the light pulse broadens as it travels along the fiber cable. This broadening of pulse has a destructive effect on sequential pulses.

2. DISPERSION

Chromatic dispersion is dominant in the single mode fiber.Therefore the chromatic dispersion D, in ps/nm/km, can be defined as [1]-[2] Chromatic dispersion (CD) is caused by the fact that singlemode glass fibers transmit light of different wavelengths at different speeds. The ratio of the speed of light in a medium to the speed in a vacuum defines the index of refraction or refractive index of the material. For optical fiber, the effective index of refraction is about 1.45, so the speed of light in glass is about 2/3 the speed of light in a vacuum. But the index of refraction, and thereby the speed of light in the fiber, is a function of the wavelength of light, the principle we all know from seeing a prism break light into a spectrum. Most sources used in long distance fiber optic links are lasers which have very little spectral width. And fibers are optimized for the wavelength of use. Both these factors minimize the effects of chromatic dispersion but cannot totally stop it. As the pulse proceeds down the fiber, the light of longer wavelength travels slightly faster and spreads the pulse out as shown here.

3. CHROMATIC DISPERSION COMPENSATION TECHNIQUES

Chromatic dispersion (CD) is caused by the fact that single mode glass fibers transmit light of different wavelengths at different speeds. The ratio of the speed of light in a medium to the speed in a vacuum defines the index of refraction or refractive index of the material. Two chromatic dispersion compensating techniques are considered hereafter with regards to its properties and operations.

3.1. Fiber Bragg Grating Dispersion Compensation (FBG)

In Fiber Bragg Grating dispersion (FBG) compensation, there are two fiber gratings to do dispersion compensation, which are chirp fiber grating and uniform fiber grating. We use chirp fiber grating dispersion compensation more. The basic principles of Chirped fiber grating dispersion compensation are as follows.

[1] Department of Electrical & Instrumentation Engineering, Thapar University, Patiala, India *E-mail: hardeep@thapar.edu*

[2] Department of Electrical & Instrumentation Engineering, Thapar University, Patiala, India *E-mail: abhishekrjp@gmail.com*

The FBG device is able to compensate chromatic dispersion at multiple variations of the wavelength. Therefore, it is the preferred solution for chromatic dispersion compensation. FBG is a dynamic dispersion compensator. This chirped FBG are based on the principle of diffraction gratings. Bragg gratings actually have a periodic variation of refractive index within the propagating medium. This chirped FBG enables the grating to reflect the various wavelengths at different points along its grating length. Therefore it sets off different delays for all the different frequencies or wavelengths. The shorter wavelength which travels faster will arrive at the FBG and get reflected further up the FBG where its Bragg condition is met. Hence, a longer delay is introduced for the shorter wavelength. The longer wavelength which travels slower, will encounter a shorter delay. Thus, at the circulator the pulse will be un-dispersed.[5]-[7]

3.2. Dispersion compensation fiber (DCF)

Changing the sectional structure of fiber, we can design fiber which has a negative optical waveguide dispersion value. That is dispersion compensation fiber. When it is used together with conventional fiber, the two would cancel each other out. Deep research for it and finding the appropriate compensation technologies, will be of great significance in improving the level of optical communication and meeting the growing demand for communication services. The DCF introduces a negative dispersion coefficient. Postcompensation is achieved by adding the DCF onto an existing fiber. The fiber's dispersion can be manipulated by varying the refractive index profile and the relative index value. Very high negative dispersion is achieve by methods like depressed cladding or decreasing the core radius [8]. However these could induce other penalties such as non-linear effects and insertion loss. A 5 km SMF which has a dispersion of 16ps/nm/km would encounter a total of (5 × 16) 80ps/nm of dispersion. Assuming the DCF has a negative dispersion of -80 ps/nm/km, and then 1km (80ps/nm ÷ 80ps/nm/km) of DCF is needed for the compensation. In a WDM system, multiple wavelengths are used to transmit information. DCF provides an "un-tunable" fixed negative dispersion for all the different channels in the WDM system. DCF is a good compensating device for its reference wavelength but it will leave residual dispersion at other wavelengths in a multi-channel transmission [9]. In other words, it will only correct the center wavelength of a pulse causing shorter wavelength to be overcompensated and longer wavelength to be under-compensated. The magnitude of accumulated residual dispersion is dependent on the degree of DCF slope matching and the length of the transmission fiber link [10].

4. FIGURES AND TABLES

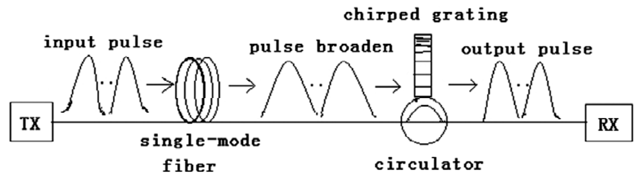

Figure 1: The Basic Principles of Chirped Fiber Grating Dispersion Compensation

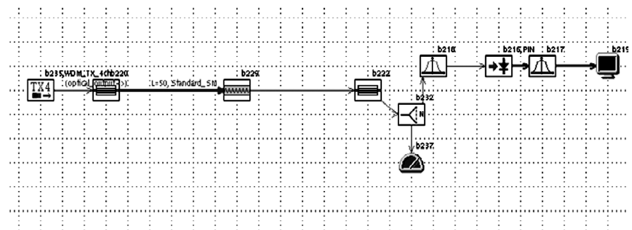

Figure 2: FBG as Dispersion Compensator

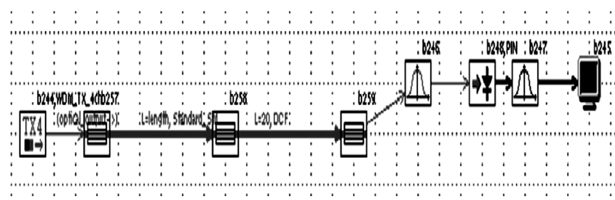

Figure 3: DCF as Dispersion Compensator

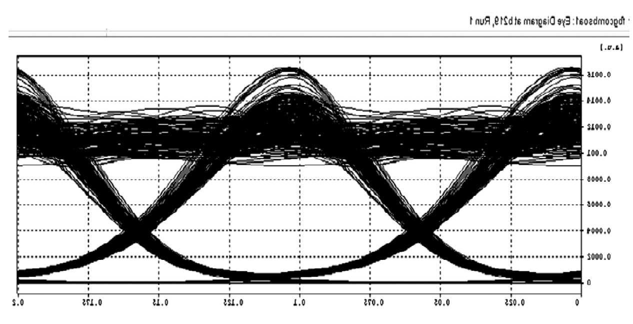

Figure 4 : 20 Km Transmission Distance(FBG)

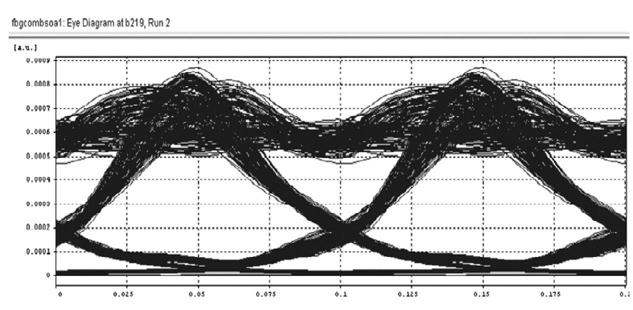

Figure 5: 40 Km Transmission Distance(FBG)

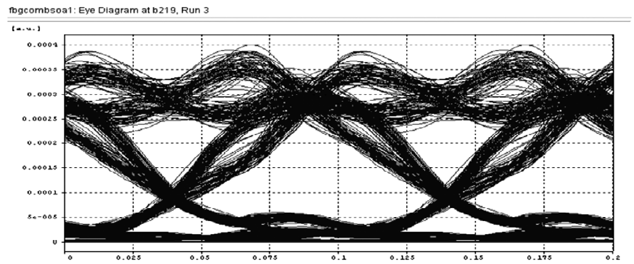

Figure 6: 60 Km Transmission Distance(FBG)

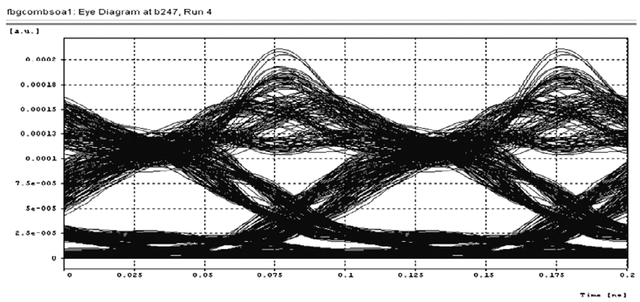

Figure 7: 80 Km Transmission Distance(FBG)

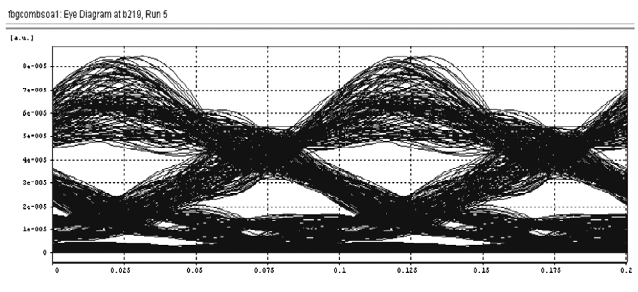

Figure 8: 100 Km Transmission Distance(FBG)

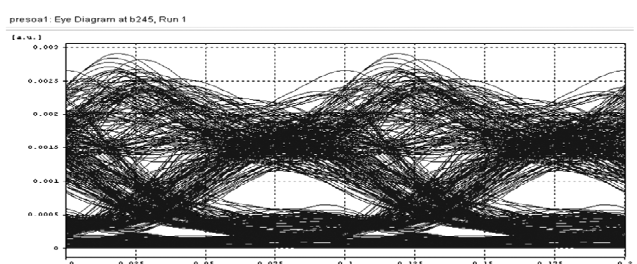

Figure 9: 20 km Transmission Distance(DCF)

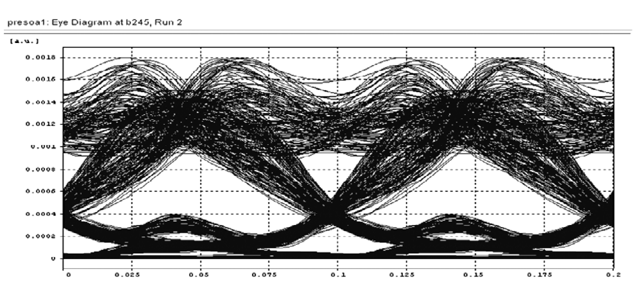

Figure 10: 40 Km Transmission Distance(DCF)

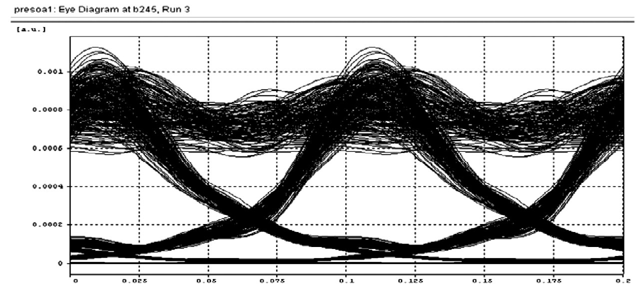

Figure 11: 60 km Transmission Distance(DCF)

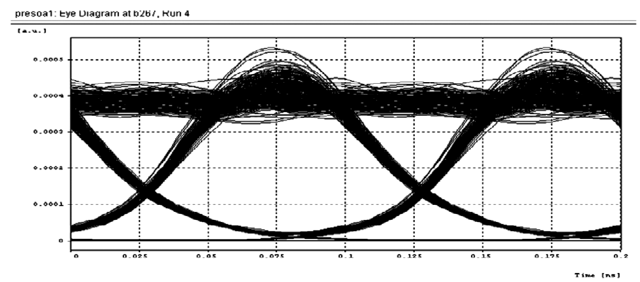

Figure 12: 80 km Transmission Distance(DCF)

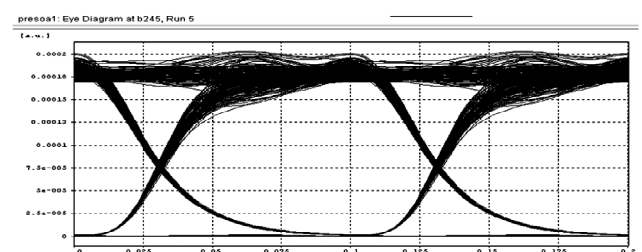

Figure 13: 100 Km Transmission Distance(DCF)

5. SIMULATION MODELS AND RESULTS

Simulation models are used to verify the compensators used for this analysis whereby 4 channels separated by 0.1THz are modeled over 100 km and simulated alternately with both the compensators i.e. the DCF and the FBG. The performances of these models are monitored by comparing the bit error rate, the eye diagram and the Q-factor at the receiving end. Simultaneously, the received power level is also varied over range by varying the input power levels at steps of 0.5dBm in order to make comparisons on the performance of the link. The non-linear effect which is inherent in long haul systems is activated within all the simulation models to ensure realistic simulations.

5.1. Simulation for FBG as Dispersion Compensator

In order to illustrate how FBG as dispersion compensation can be studied, the system is simulated with block diagram shown in figure In this case, the transmitter section consists of data source, electrical driver (NRZ), laser source

(CW_ Lorentzian) and amplitude modulator (sin^2_MZ) is connected. Two SOA and one FBG are connected through two SSMF. Here, FBG used as a dispersion compensator. The output of last SOA is given to optical raised cosine filter which is connected to receiver section. In receiver section PIN is connected to an electrical Bessel filter and the final result is shown through electrical scope, Q estimator and bit error rate estimator.

5.2. Simulation for DCF as Dispersion Compensator

In order to illustrate how DCF as dispersion compensation can be studied, the system is simulated with block diagram shown in figure. In this case, the transmitter section consists of data source, electrical driver (NRZ), laser source (CW_ Lorentzian) and amplitude modulator (sin^2_MZ) is connected. Three SOA are connected to SSMF and DCF. Here, DCF is used as a dispersion compensator. The output of last SOA is given to optical raised cosine filter which is connected to receiver section. In receiver section PIN is connected to an electrical Bessel filter and the final result is shown through electrical scope, Q estimator and bit error rate estimator.

6. CONCLUSION

We analyzed the effect of FBG and DCF as compensator. We have been discussed the performance of wavelength division multiplexed (WDM) system with fiber bragg grating (FBG) and dispersion compensator fiber (DCF) as compensator by varying the length of single mode fiber. In the case of fiber bragg grating (FBG) we analysis from the eye diagrams, bit error rate (BER) and the Q-factor characteristics, it is clear that as we changing the length of single mode fiber from 20km-100 km the performance of wavelength division multiplexed (WDM) on length of 20 km is the best. We have also discussed the bit error rate (BER) and the Q-factor characteristics at 20km to 100km.In the case of dispersion compensator fiber (DCF) it is clear that as we changing the length of single mode fiber from 20km-100 km the performance of wavelength division multiplexed (WDM) on length of 100 km is the best.

REFRENCES

[1] Bigo, S., et al. (OFC 2001). 10.92-Tb/s (273 × 40-Gb/s) Triple Band/ Ultra-Dense WDM Optical-Repeater Transmission Experiment. Proc. 26th Optical Fiber Communications Conference, Anaheim, California, Paper PD24. *Institute of Electrical and Electronics Engineers, Inc. (IEEE)*.

[2] Nagasawa, Y., Aikawa, K., Shamoto, N., Wada, A., Sugimasa, Y., Suzuki,I. and Kikuchi,Y. (2001). *High Performance Dispersion Compensating Fiber Module. Fujikura Technical Review*.

[3] Duthel, T., Jansen, S.L., Krummrich, P.M, Otto, M. & Schaffer, C.G. (2005) Multi Channel Residual Dispersion Compensation in 40Gb/sWDM System Utilizing a Single all Fiber Dalay Line Filter. *Optical Society of America* 060.2330

[4] Ghatak, A. and Thyagarajan, K. (1998). Introduction to Fiber Optics. Cambridge University Press.

[5] Gnanam Gnanagurunathan, Faidz Abd. Rahman. "Comparing FBG and DCF as Dispersion Compensators in the Long Haul Narrowband WDM Systems", *Photonics Technology Letters, IEEE*, **8,** No. 11, May. 2010.

[6] Misha Brodsky, Elizabeth C. George, Cristian Antonelli, Mark Shtaif "Higher-Order Polarization Mode Dispersion New Expressions Induced Pulse Broadening and its Compensation", *Optics Communications*, pp. 331-339, October 1986.

[7] Wei ZHAO, "Polarization Mode Dispersion Induced Pulse Broadening in Optical Fibers", **Opt. Lett.**, **3,** pp. 688-690, 2001.

[8] Agrawal, Govind P. (1998) "Fiber Optics Communication Systems", 3rd Ed. Wiley Inter science Publication.

[9] Bass, M and Van Stryland, E.W. (2002). "Fiber Optics Handbook: Fiber, Devices and Systems for Optical Communications". Mc.Graw Hill.

[10] Bayvel, P. and Killey, I.K. (2002). "Optical Transmission Systems Design Techniques an Computer Aided Design Tools". *Business Briefings: Global Optical Communication*, pp. 84-88.