

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Design and optimization of WDM PON system using Spectrum Sliced Technique

Sukhwinder Kaur¹, Neena Gupta²

P.G. Student, Department of Electronics and Communication Engineering, PEC University of Technology,
Chandigarh, India¹

Professor, Department of Electronics and Communication Engineering, PEC University of Technology,
Chandigarh, India²

ABSTRACT: In today's scenario, demand for high speed internet and data services increase which require more systems with more capacity and reach improvement. To fulfil this need, the concept of Wavelength Division Multiplexed Passive Optical Network (WDM PON) was developed in optical fiber communication. But chromatic dispersion (CD) causes the broadening of pulses which is the major problem of signal degradation in WDM PON system. CD is a term which defines that the signals get scattered or distorted due to the inconsistency in the frequency of the signals and modes of the light pulse in Single mode fiber (SMF). In this paper, an effort is made to improve the performance of WDM PON system cost effectively and efficiently for long distance communication. Two channel Spectrum Sliced-WDM PON system is designed using a single broadband ASE light source with bit rate (BR) of 10 Gbps per channel. For effective dispersion compensation in multichannel WDM PON system, a hybrid compensation (electrical and optical) technique using Dispersion Compensating Fiber (DCF) is suggested and compared with optical compensation techniques.

KEYWORDS: Chromatic Dispersion (CD), Wavelength Division Multiplexed Passive Optical Network (WDM PON), Dispersion compensating fiber (DCF), Hybrid compensation, Single Mode Fiber (SMF).

I. INTRODUCTION

In the field of optical communication systems, evolution of technology has contributed a major role. To satisfy the world wide growing demand for transmission capacity, the use of WDM-PON is an attractive solution. Speed of the signal transmission down the optical fiber is limited by transmission impairments such as dispersion and other non linearities[1]. Dispersion is the main problem in the emerging system which degrades the performance of the system. As the input optical pulse travels through the fiber, it broadens due to dispersion effects. The various frequency components of input optical pulse reach the destination at different times due to different propagation speeds[2]. This effect is called inter-symbolic interference (ISI). Modal Dispersion can be mitigated by using the SMF instead of Multi mode fiber (MMF). But in SMF, CD is the major degrading factor. The EDFA is the gigantic change that was developed to amplify the optical signals. Since EDFA works in 1550 nm wave band, the average SMF dispersion value in this wave band is very big, about 15-20ps / (nm.km-1)[3]. Hence it can be said that the dispersion become the major degrading factor that restricts the long distance fiber optic communication system. To improve the performance of WDM-PON, CD compensation is very important because it has an important role on the quality of transmitted optical signal, amount of data provided to the users. Few parameters such as BR, transmitted power, length of the fiber and dispersion effects should be considered while designing the WDM system because they will affect the performance of the system[4].

In this paper, performance of two channel WDM PON system with single broadband ASE light employing is investigated. Optical and hybrid compensation schemes are compared. In optical compensation, DCF is employed and

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

in hybrid compensation scheme, combination of DCF and electronics equalizer is used. This paper is organised as follows. Section II gives the theoretical overview of different dispersion compensation techniques. Section III describes the spectrum slicing technique and compares the optical and hybrid compensation schemes in 10Gbps two channel WDM PON system. Section IV presents simulation results and comparative analysis of conventional two channel WDM PON and SS-WDM PON system. Section V compares the optical and hybrid compensation schemes with DCF in mix configuration. Finally, section VI gives the conclusion of the paper.

II. DISPERSION COMPENSATION TECHNIQUES

The main reason for presence of CD is that the velocity of light carrying the information signal is dependent upon the reflective index of the core which in return is dependent on wavelength of the light used to carry information. There are many ways to compensate dispersion such as use of Electronic dispersion compensation (EDC), DCF, FBG and digital filters[5]. The different methods of CD compensation are discussed below:

1. DISPERSION SHIFTED FIBER (DSF)

In the 1300nm wavelength region, standard SMF exhibits zero CD. But performance of the system is best at 1550 nm because fiber losses are low here and EDFAs work well in this wavelength region. But CD is major problem at this wavelength region. To reduce the effect of CD, the first technique developed was the DSF. These are the type of SMFs with the tailored index profile of core-cladding to shift the zero dispersion wavelength at 1300 nm to 1500 nm. DSF is not suitable compensation scheme for WDM PON systems due to phenomena known as four wave mixing (FWM).

2. NON ZERO DISPERSION SHIFTED FIBER (NZDSF)

NZDSF was designed to overcome the problem of DSF in WDM systems. It is a type of SMF specified in ITU-T G.655 that reduces CD at 1550 nm wavelength region but not to the extent that would encourage the FWM like DSF do. This is called NZDSF because it has small non zero dispersion at 1550nm. According to the requirement, a careful combination of NZDSF and SMF is required so that benefits of local non-zero dispersion for WDM are realized.

3. DISPERSION COMPENSATING FIBER (DCF)

DCF is a special type of fiber which has a large negative dispersion. DCF supports the negative dispersion value ranging from -70 to -90 ps/nm/km. It is used as a technique for updating the installed links which are created by using SMF for operations at 1550 nm [5]. It can also be used for compensating the positive dispersion of transmission fiber. The performance of WDM PON is decreased because of group velocity dispersion in the network. The smaller size of the DCF is suitable for most cases. Smaller length of DCF will be required if DCF has large dispersion coefficient. The net dispersion will be zero if one DCF with negative dispersion is placed after SMF having positive dispersion[5]:

$$D_{SMF} \times L_{SMF} = - D_{DCF} \times L_{DCF}$$

Where D = dispersion and
 L = Length

DCF supports three configurations as follows[5]:

1. Pre compensation refers when the DCF with negative dispersion is placed before SMF so that the positive dispersion of standard fiber can be compensated
2. Post compensation refers when the DCF of dispersion is placed after SMF so that the positive dispersion of standard fiber can be compensated
3. Mix compensation refers to placing of DCF before as well as after the SMF to achieve the dispersion compensation. It is also called symmetrical compensation.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

4.FIBER BRAGG GRATING (FBG)

FBG is a technique used for dispersion compensation in Wavelength Division Multiplexing Passive optical network. It is a distributed Bragg reflector. Bragg reflector reflects a specific pulse or wavelength. When an input wavelength becomes equal to half the grating period, then the bragg diffraction effect occurs. Each variation in the refractive index acts like a reflecting mirror in the grating region and only those beams are reflected which have the bragg wavelength and all these reflected wavelengths are added together in phase with each other[6]. The equation used for Bragg wavelength is as follow:

$$\lambda_B \equiv 2\bar{n}\Lambda$$

Where, $\bar{n}$ = average mode index,
 Λ = grating period

5. ELECTRONIC DISPERSION COMPENSATION (EDC)

Electronic compensation technique makes use of electronics in conjunction with optics in order to compensate dispersion. At electrical part of receiver or transmitter,optical compensation can't compensate dispersion. In case of electronic compensation, there is no need of any changes in optical transmitting or receiving system. It doesn't have considerable losses like optical compensation schemes[7]. There are several techniques for electronic dispersion compensation, such as Feed Forward Equalizer (FFE), Feed Forward-Decision Feedback Equalizer (FFE-DFE), Nonlinear Feed forward-Decision Feedback Equalizer (NL-FFE-DFE) etc.

5.1 DECISION FEEDBACK EQUALIZER (DFE)

In case of DFE, if the value of the current transmitted symbol is determined, the ISI contribution of that symbol to future received symbols can be easily compensated. In DFE, there is a decision device which finds out the actually transmitted symbol of a set of discrete levels and this decision device causes the non linearities.The working of DFE is such that its filter structure calculates the effect of ISI on subsequent received symbols after deciding the current symbol and it compensates the effect of ISI on the future samples. DFE is a type of filter that uses feedback of detected symbols to produce an estimate of the channel output.

5.2 FEED FORWARD EQUALIZER (FFE)

In case of FFE, the actual waveform equalization is performed and it only concerns with correcting the voltage levels in the waveform. FFE consists of taps and a delay line filter. In order to correct the voltage levels, taps are the unit less correction factors applied to them. By forming a sum of the taps and voltage levels of the previous two tap delayed locations as well as the location of interest before being equalized,FFE obtains the corrected (or equalized) voltage level at the location of interest on the waveform. In FFE, the coefficients of filter weight the present and the past values of detected signal [7]. The coefficients of delay line filter are adaptively updated with channel variations. In the present work, DFE-FFE has been used in conjunction for better performance as electronic dispersion compensation.

III. SPECTRUM SLICING TECHNIQUE

In order to decrease the cost of components and to simplify the architecture of WDM passive network, spectrum slicing technique is one of basic techniques for WDM PON systems. In this technique, a broadband light source (BLS) is sliced and it generates equally spaced multi wavelength signals for different users. The main purpose of spectrum slicing is to use a single BLS instead of multiple laser sources for multiple number of channels[8].

Broadband light sources such as LED, SLED (superluminescent diode) or ASE can be used for transmitting data in multi channels spectrum sliced PON systems. Slice width is the main factor for determining the transmission power for each separate optical channel. The size of slice should be considered carefully as the total channel power increases with larger sliceand it will increase the total channel power and hence increase the effect of dispersion[9]. In this work, ASE is chosen as BLS as a spectrum slicing techniques as it has the highest optical output power out of all other mentioned light sources.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

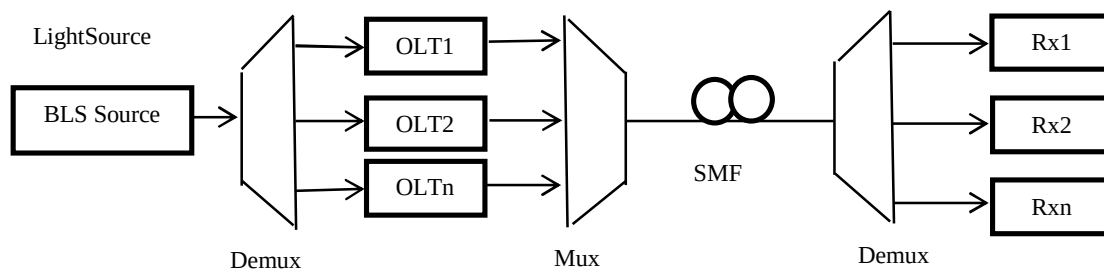


Figure 1: Operational principle of spectrum sliced multi-channel fiber optical transmission system

Design and Realization of spectrally uniform ASE light source

If no signal is there to be amplified, EDFA emits high power amplified spontaneous emission (ASE) noise in C band (wavelength from 1530 to 1565 nm) and L band (wavelength from 1565 to 1625 nm). This effect of ASE noise generation can be very useful in designing a broadband ASE light source. This noise generation is dependent on the emission of the erbium ions and along all EDFA fiber length, gain occurs[8]. There are different ways to realize the Broadband ASE light source such as: by employing one EDFA or connecting more than one EDFA in cascade mode (one after another). The cascaded EDFAs method results in obtaining almost flat ASE output spectrum and because of better Er^{3+} ions usage along cascaded amplifiers, higher output power can be achieved at the output. In this work, the broadband ASE light source has been designed by employing two EDFAs in cascaded mode. It has been observed that if 100mW power is used for two lasers, the smoothest ASE output spectrum with high output power can be obtained. The first EDFA amplifier is pumped on 980 nm in co-propagating direction, and second EDFA is pumped in same direction on 1480 nm as shown in figure 2(a).

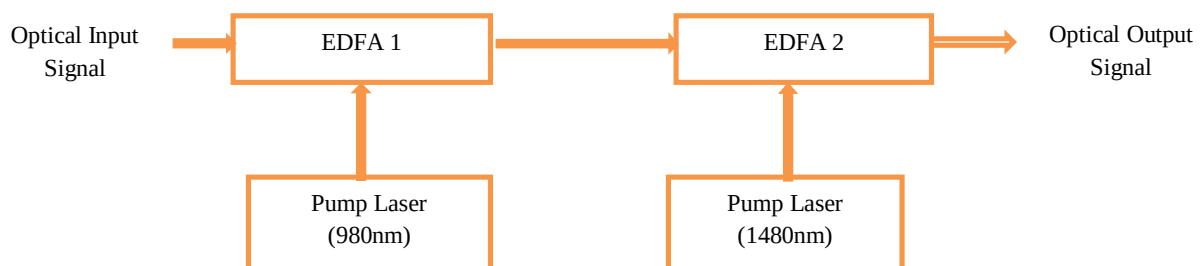


Figure 2 (a): Block diagram of ASE light source with cascaded EDFA

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

ASE Source

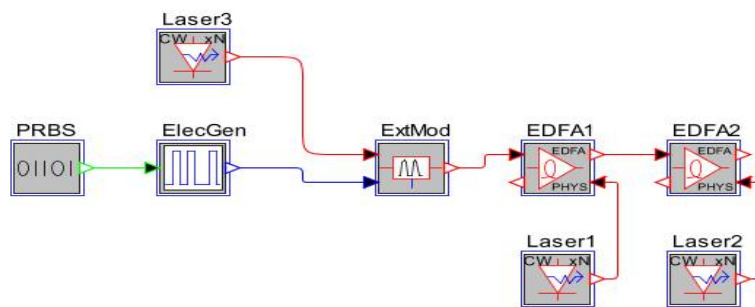


Figure 2 (b): Simulation setup of Broadband ASE light source in OptSim

For first EDFA, fiber span with length of 9 m has been used and for second EDFA, 12 m long fiberspan has been used. In this way, a broadband ASE light source with almost flat spectrum has been designed and at the output of this cascaded EDFA system, output power of about +23 dBm (approx.200 mW) has been achieved as shown in figure 2(b). The following are the parameters used for the realisation of ASE source.

Table 1: Simulation parameters of broadband ASE light source

Component	Parameter	Value
PRBS Generator	Bit Rate	10 Gbps
Laser 3	Wavelength	1550 nm
	Peak Power	100 mW
Laser1	Wavelength	980 nm
	Peak power	100 mW
Laser 2	Wavelength	1480 nm
	Peak power	100 mW
ElecGen	Modulation format	NRZ
	Start bits	3
	Stop Bits	2
EDFA1	Length	9 m
EDFA2	Length	12 m

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

IV. DESIGN AND COMPARATIVE ANALYSIS OF CONVENTIONAL TWO CHANNEL WDM PON AND SS-WDM PON SYSTEM

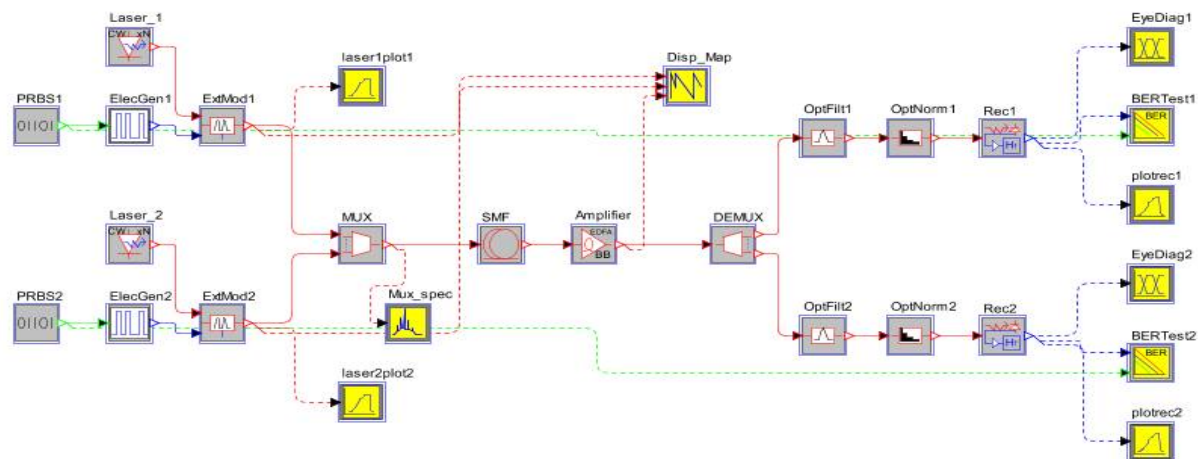


Figure 3: Simulation Setup of conventional two channel WDM system

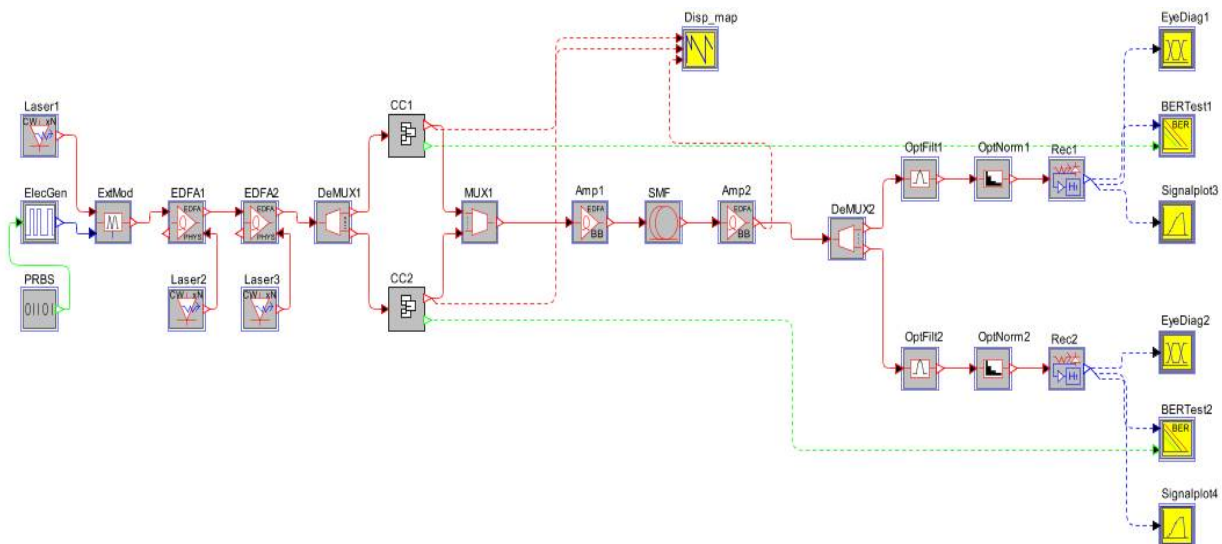


Figure 4 (a): Simulation Setup of two channel SS-WDM PON

Figure 3 describes the simulation scheme of two channel WDM PON system with two different laser sources and figure 4(a) shows the WDM system with single ASE light source, realized in the previous section. In the figure 4(a), CC1 & CC2 are the compound components representing the ONT 1 and ONT 2 at the transmitter side. Compound component 1 and 2 i.e. CC1 & CC2 is shown in figure 4(b).

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

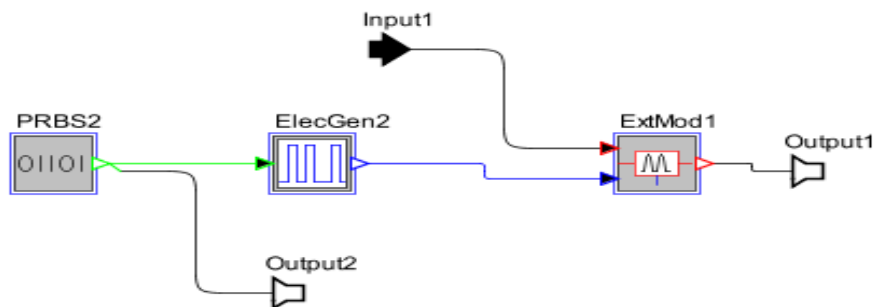


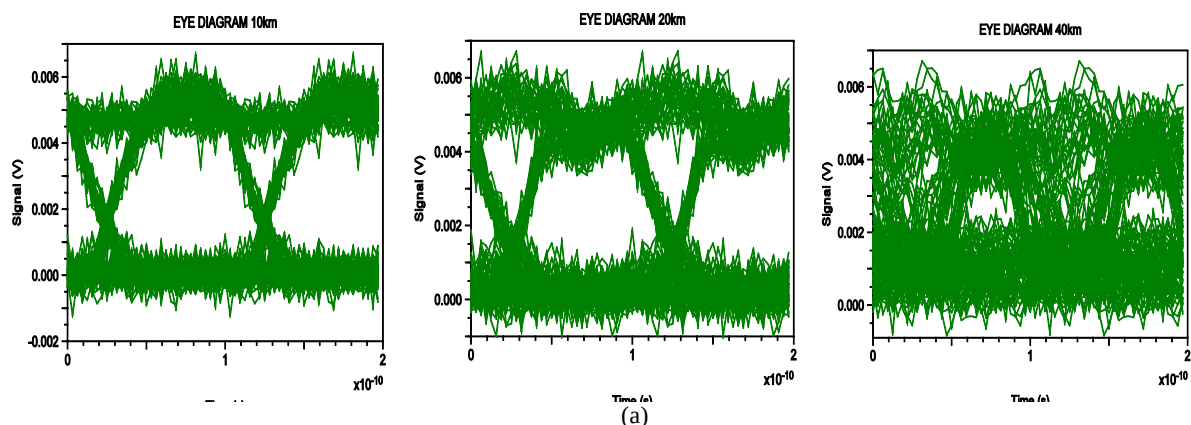
Figure 4 (b): Inside setup of compound component CC1 and CC2

The signal generated from ASE light source is sliced through first optical de-multiplexer (DeMUX1) with channel spacing of 0.8 nm. Then the sliced signals are sent to CC1 and CC2. Each OLT (CC1 and CC2) consists of PRBS data generator, one NRZ driver, and an external Mach-Zehnder modulator (MZM). Next, generated bit sequence from PRBS data source is sent to electrical generator (ElecGen2) where electrical NRZ pulses are formed. These electrical NRZ pulses are then sent towards MZM (ExtMod1) which modulates the optical slices received from DeMUX1 and forms optical signal according to electrical drive signal. These formed optical pulses from two OLTs are coupled by Optical multiplexer (Mux1) and sent into standard optical SMF.

An EDFA (Amp1) has been used as pre-amplifier as it saturates the system with high power that leads to a low noise figure. In the end of fiber optical link, two optical channels are separated using second de-multiplexer (DeMUX2). Receiver section consists of two ONT units. Each ONT has an Optical filter, Optical power normalizer, sensitivity receiver with PIN photodiode. For the performance analysis, BER Tester, Eye Diagram Analyser, Signal Analyser has been used.

Results and discussion

The performance of both the systems shown in figure 3 and figure 4 (a) has been compared using different parameters such as Q-factor, Laser peak power, BR and BER at different transmission distances. The eye diagram comparison is shown in figure 5.



International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

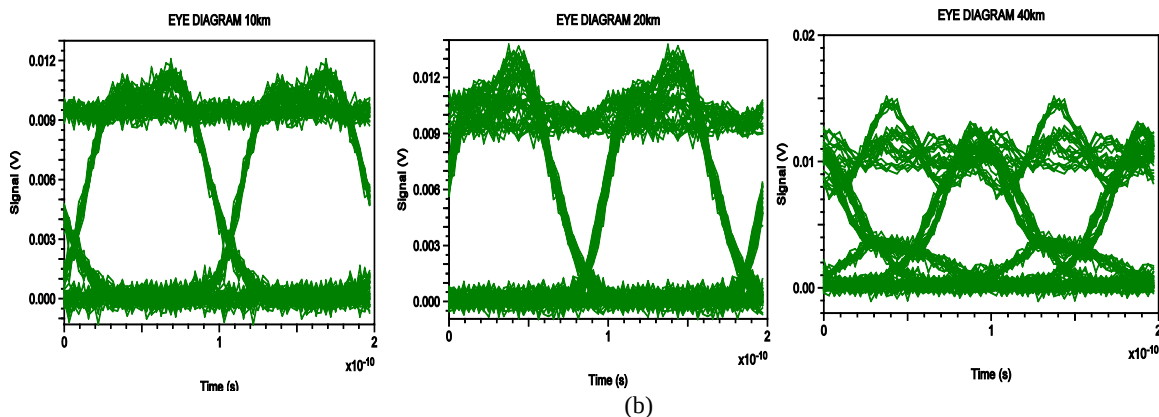
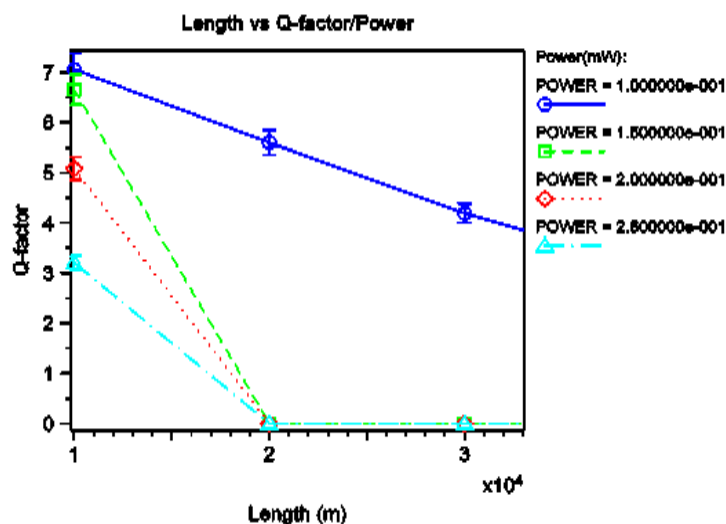


Figure 5: Eye diagrams at transmission distance of 10km, 20km and 40km for
(a) conventional WDM system (b) SS-WDM system

The figure 5 depicts that the effect of distortion and noise is lesser in SS-WDM system at all the transmission distances as compared to conventional WDM system. As the distance increases, the closed eye pattern is observed for conventional WDM system. Closed eye pattern means effect of dispersion and noise is more. From the eye diagram comparison, it is clear that system with single light source helps in improving the reach and in decreasing the effect of noise and dispersion to a great extent.



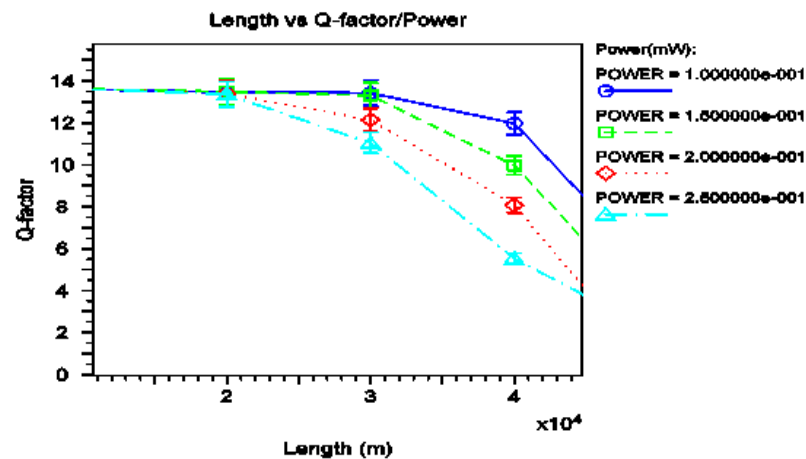
(a)

International Journal of Innovative Research in Science, Engineering and Technology

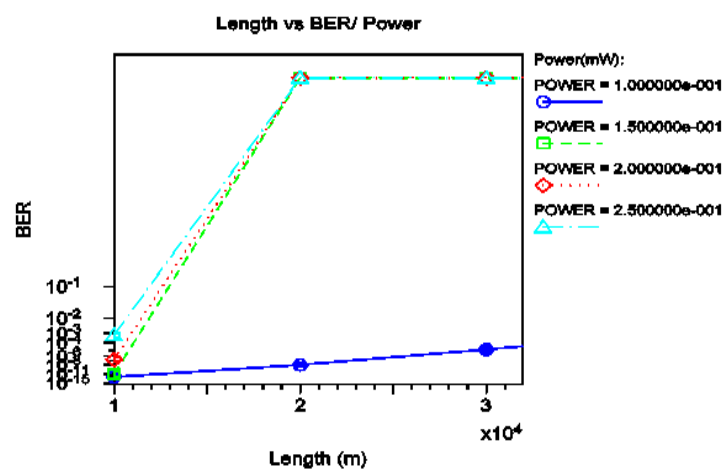
(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017



(b)
Figure 6: Variation of Q-factor with Laser peak power at various transmission distances for (a) conventional WDM PON system (b) SS-WDM PON system.



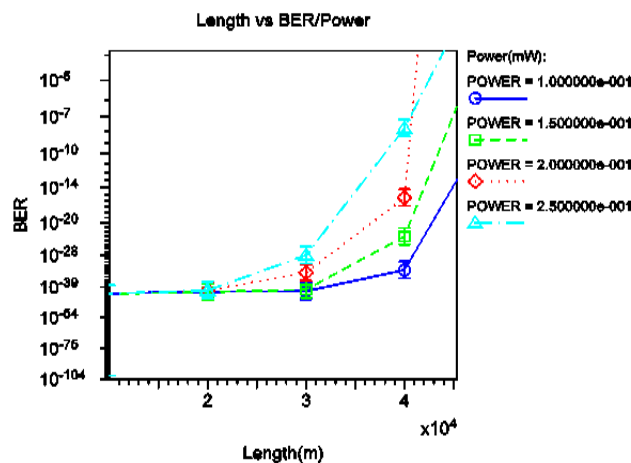
(a)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017



(b)

Figure 7: Variation of BER with Laser peak power at various transmission distances for (a) conventional WDM PON system (b) SS-WDM PON system.

The figure 6 and 7 shows the comparison of performance of SS-WDM PON system with the conventional WDM PON system. The X-axis is the length of SMF used in the system. In figure 6, it is clear that SS-WDM PON system has better Q-value as compared to conventional WDM system even higher laser peak power and greater transmission distances. In conventional WDM system, the Q-factor at 10km is nearly 3 at 250 mW laser peak power. For the same parameters, the Q-factor obtained in SS-WDM PON system is 13. The performance of the conventional system degrades suddenly when the distance has been increased from 10 to 20km with increasing peak power. But SS-WDM system improves the performance to great extent as it has high Q-factor and acceptable BER even at 40km distance. After 40km distance the performance starts degrading.

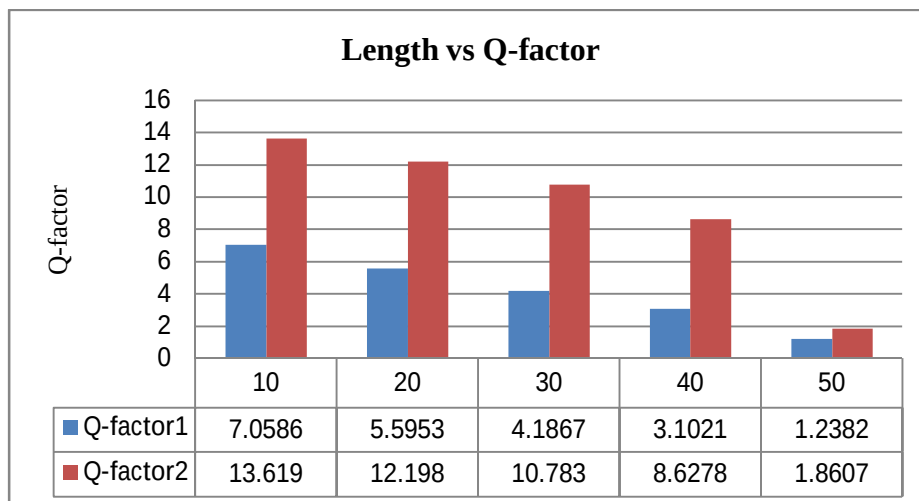


Figure 8: Variation of Q-factor of two channel SS-WDM and conventional WDM at various transmission distances (10 to 50km) where Q-factor 1 is for Conventional WDM & Q-factor 2 is for SS-WDM

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

The figure 8 shows the comparison of Q-factor values for the systems shown in figure 3 and figure 4(a). The analysis has been done at various transmission distances from 10km to 50km at data rate of 10Gbps and 100mW laser peak power. At 10km, Q-factor obtained with SS-WDM system is 13.619 and its value is just half, i.e. 7, for conventional WDM system. At greater distances the Q-factor obtained is higher for SS-WDM system as compared to the other system. It can be concluded that SS-WDM PON system has been proved to be better in terms of reach improvement.

V. COMPARISON OF DCF MIX & DCF MIX-HYBRID DISPERSION COMPENSATION SCHEME

DCF mix Compensation

Here DCF has been placed before and after the SMF as shown below:

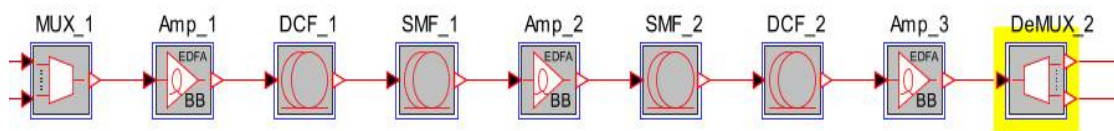


Figure 9: Simulation setup of two channel SS-WDM PON with DCF mix Compensation

DCF mix-hybrid compensation

Here DCF has been used in mix configuration as optical compensation and DFE-FFE has been used as electrical compensation.

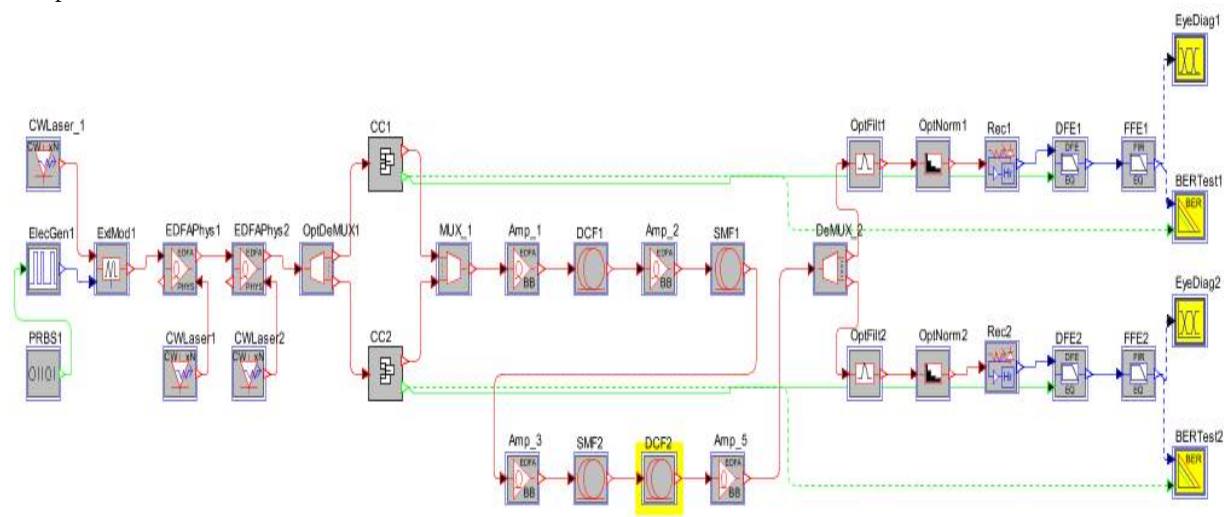


Figure 10: Simulation setup of two channel SS-WDM PON with DCF mix-hybrid compensation

Results and discussion

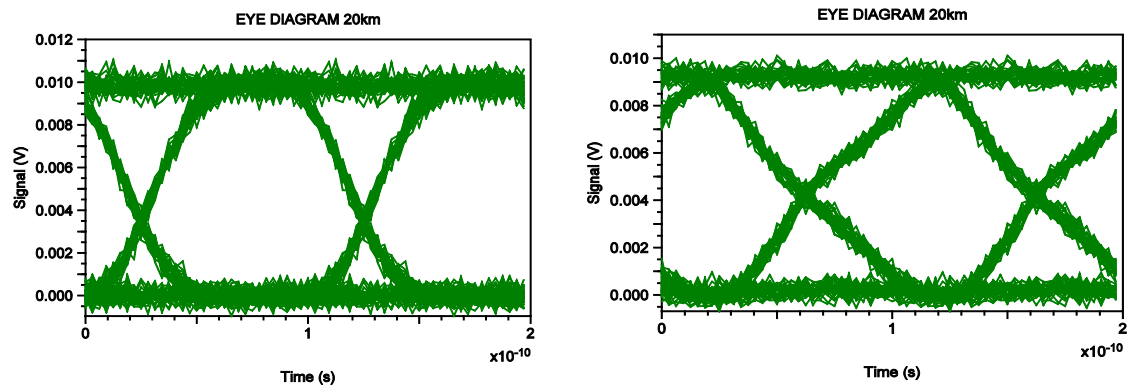
The performance of the systems shown in figure 9 and figure 10 is compared in terms of Q-factor, BER and eye diagrams. The eye diagram comparison at various distances is shown:

International Journal of Innovative Research in Science, Engineering and Technology

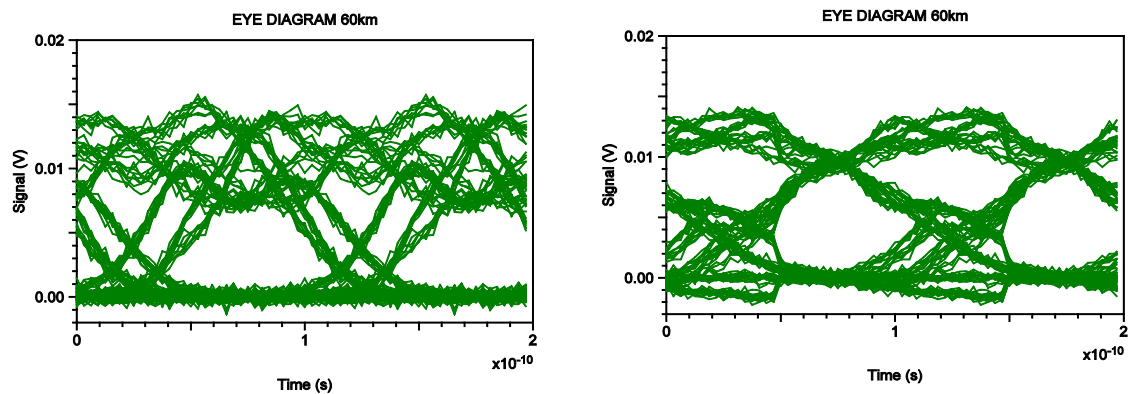
(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017



(a)



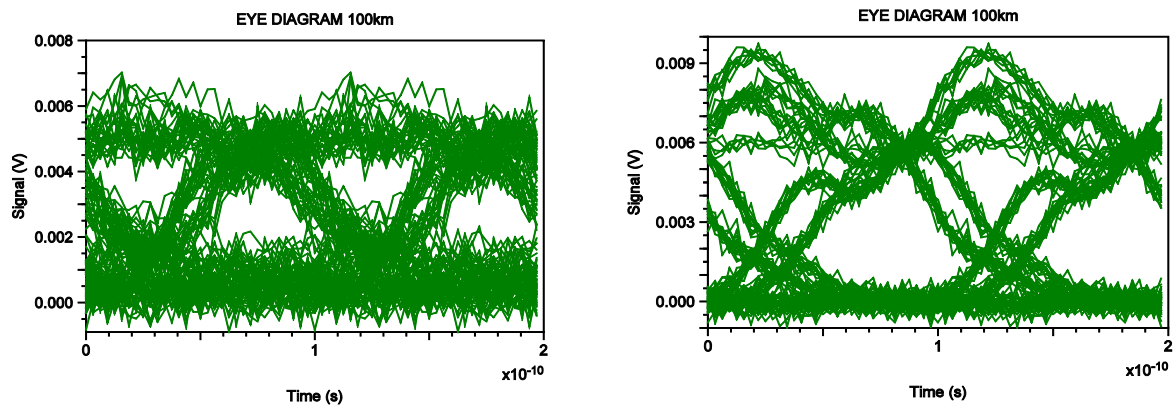
(b)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017



(c)

Figure 11: Eye diagrams of two channel SS-WDM PON with DCF mix & DCF mix-hybrid compensation at (a) 20km (b) 60km (c) 100km

Table 2: Q-factor and BER values obtained with DCF mix and mix-hybrid compensation in 2 channel SS-WDM PON system

Length(km)	DCF mixCompensation		DCF mix-hybrid compensation	
	Q-factor	BER	Q-factor	BER
20	14.442	1.4142e-47	18.069	2.8018e-73
40	11.445	4.3714e-31	16.426	6.1851e-61
60	10.360	1.8792e-25	11.972	2.4977e-33
80	5.678	6.8007e-09	8.3143	4.6132e-17
100	4.000	5.9710e-06	8.000	3.8837e-16

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

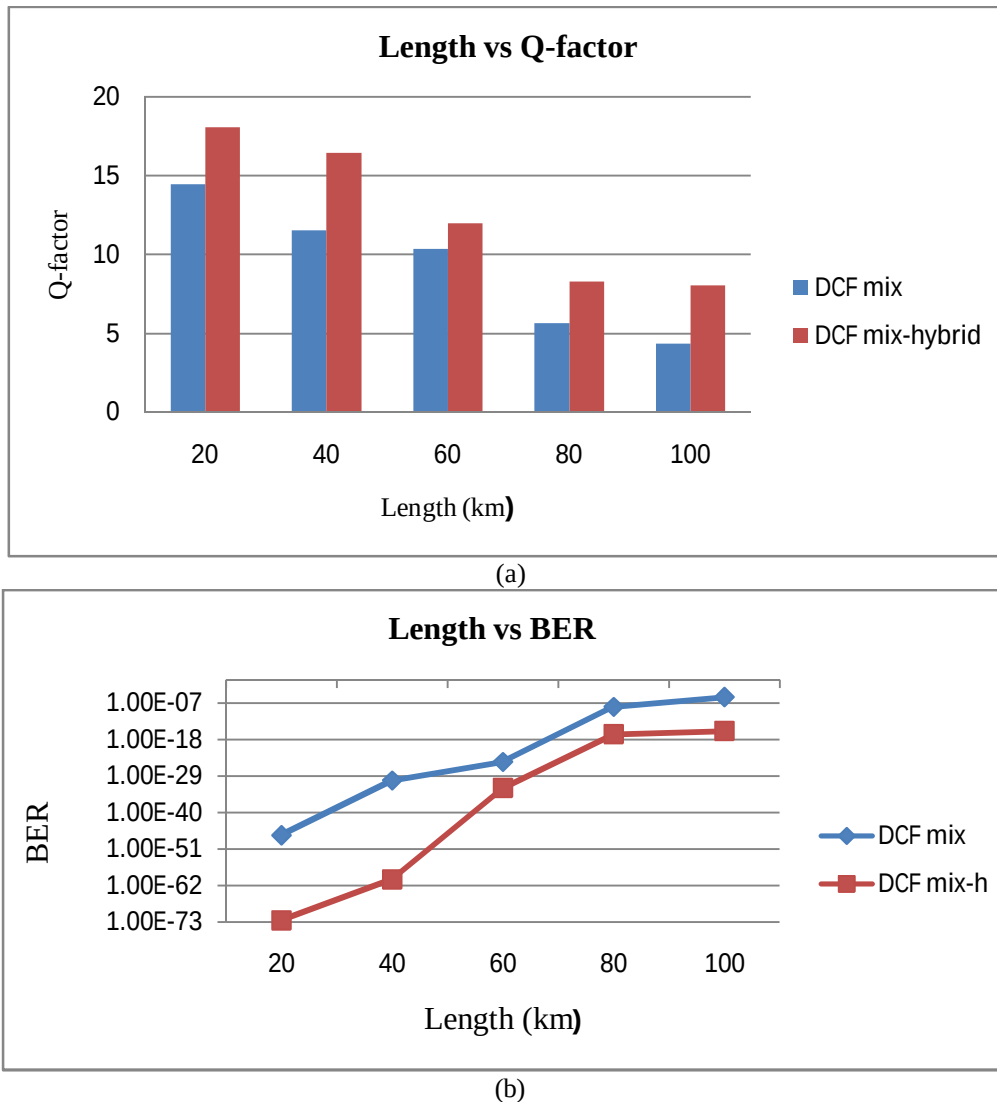


Figure 12: Comparison of 2 channel SS-WDM PON system with DCF mix and DCF mix-hybrid scheme at various distances (a) Q-factor (b) BER

From the figure 11, figure 12 and table 2, it can be concluded that DCF mix-hybrid has the higher Q-factor value and acceptable BER as compared to the DCF mix. From the above comparison graphs and eye diagrams, it is concluded DCF mix-hybrid compensation gives much better performance than DCF mix compensation.

VI. CONCLUSION

The design and analysis of SS-WDM PON system with optical and hybrid dispersion compensation configurations is presented in this chapter. The performance analysis shows that SS-WDM PON system gives the better performance at all the transmission distances in terms of Q-factor and BER than conventional WDM PON system. Then optical and hybrid dispersion compensation schemes have been compared with Spectrum Sliced technique. It is found that hybrid

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

compensation technique gives better results as compared to optical technique. Q-factor obtained with hybrid compensation technique is double at all transmission distances as compared to optical compensation techniques.

REFERENCES

- [1] S. Spolitis, V. Bobrovs, P. Gavars, and G. Ivanovs, "Comparison of passive chromatic dispersion compensation techniques for long reach dense WDM-PON system," *Elektron. ir Elektrotehnika*, vol. 122, no. 6, pp. 65–70, 2012.
- [2] B. Badar and A. P. Anisha, "Performance Analysis of Dispersion Compensation in WDM Optical Communication Systems," vol. 4, no. 2, pp. 155–159, 2015.
- [3] R. Rout, S. Pradhan, and S. Patnaik, "Role of DCF technique for enhancing optical fiber communication System utility," pp. 691–696, 2015.
- [4] A. Mohan, N. P. Saranya, S. B. Johnson, and A. Sangeetha, "Compensation of dispersion in 5 Gbps WDM system by using DCF," *Proceeding IEEE Int. Conf. Green Comput. Commun. Electr. Eng. ICGCCCE 2014*, 2014.
- [5] G. Singh and J. Saxena, "Dispersion Compensation Using FBG and DCF in 120 Gbps WDM System," vol. 3, no. 6, pp. 514–519, 2014.
- [6] R. Rao and M. T. Scholar, "Performance Analysis of Dispersion Compensation using FBG and DCF in WDM Systems," no. October, pp. 170–174, 2016.
- [7] R. B. Patel and D. K. Kothari, "Hybrid Dispersion Compensation Approach for Performance Enhancement of 10 Gb / s Optical System for Long Distance Communication," pp. 1–6, 2013.
- [8] V. Bobrovs, S. Spolitis, I. Trifonovs, and G. Ivanovs, "Spectrum Sliced WDM-PON System as Energy Efficient Solution for Optical Access Systems," no. Dcm, pp. 6–11, 2013.
- [9] B. Sankar, G. Pillai, B. Sedighi, W. Shieh, and R. S. Tucker, "Chromatic Dispersion Compensation - An Energy Consumption Perspective," no. 1, pp. 3–5, 2012.