Cost Effective Approch for Suppression of Four Wave Mixing in WDM System

Amrit Singh * and Dr. Baljeet Kaur **
* Research Scholar, ECE Department, GNDEC Ludhiana, Punjab
** Assistant Professor, ECE Department, GNDEC Ludhiana, Punjab

Abstract: In this article, suppression of FWM been proposed with cost effective technique of DCF and FBG.At high powers, maximum FWM power and at low powers very less nonlinearity is observed. Comparison of single tanh apodized FBG, conventional FBG and FBG+DCF module is carried out. It is concluded that DCF+FBG module is best to suppress FWM.

Keywords: FBG, FWM, DCF, WDM, Tanh,OFC.

Introduction

In recent times, there is need to fulfill the ever increasing requirement of internet in terms of data traffic. Telecommunication networking plays a significant task for the speedy boost in the high data communication [1]. So, network in optical domain have been adopted as a competent way to hold this traffic boost, particularly in the backbone as well as metro part of the network. But even then the fast grooming in communication requires having an efficient and robust optical system [2]. Wavelength-Division multiplexing (WDM) in optical communication is succeeding at an surprising rate due to the prospect of high capacity. In wavelength division multiplexing systems [3], the whole bandwidth is sliced to many channels centered at number of frequencies or wavelengths that allows many light beams of different wavelengths to be at the same time sent into the core of the fiber [4]. This indicates that if carriers are increased, ultimately capacity will also increase. To minimize the expenditure on system it is essential to plan the least usage of EDFAs or optical amplifiers. It requires because of the fact that, it increasing the transmitter power to meet signal to noise ratio (SNR). In WDM it was assumed that different carriers transmit the length of the fiber devoid of disturbing one another. This supposition is futile if the power level is augmented or high. The high optical power level makes system more prone to noises and degrading factors such as nonlinear effects, stated as fiber nonlinearity [5]. Nonlinearity in optical medium is very dominating factor and also in WDM systems. However, suppression of nonlinear effects leads to system performance improvement such as capacity and link length or system reach [6]. Numerous approaches to nullify non linear effects were completed although all those way outs and research work suppressed it to some extent [7] [8]. Consequently, fiber nonlinearity has turn out to be one of the most important limiting factors in recent transmission optical systems [9].
In wavelength division multiplexing, there are major degrading effects such as four wave mixing, cross phase modulation, cross gain modulation, stimulated Raman scattering etc. All aforementioned effects are degrading; however four wave mixing in WDM system is very prominent and degrade results to a great extent. A number of researches have been done to suppress the four wave mixing. In order to suppress FWM effects in WDM optical networks, many low power systems, unequally spaced channels, polarization allocation and pulse width managed systems are demonstrated and proposed [10] [11] [12]. All these techniques lead to the increase in overall cost of the system or make architecture complex.
In this article, suppression of Four Wave Mixing effect has been proposed with cost effective joint technique of DCF and FBG. A number of FWM suppression schemes demonstrated so far however they restricted in terms of performance and are costly. In this proposed work, a cost efficient and enhanced performance WDM system is demonstrated.

Theory

FWM takes place when light of two or more diverse wavelengths is launched in the fiber, thus generating a new wave. It is a parametric procedure in which unlike frequencies interact and by frequency mixing produce new spectral components [13]. The idler frequency f_{idler} may then be determined by:

$$f_{idler} = fp_1 + fp_2 - f_{probe}$$

where fp_1 and fp_2 are the pumping light frequencies, and f_{probe} is the frequency of the probe light [14]. This state is called the frequency phase-matching condition. When the frequencies of the two pumping waves are same, the more precise term "degenerated four-wave mixing" (DFWM) is used, and the equation for this case is written as:
$f_{idler} = 2fp - f_{probe}$

where fp is the frequency of the degenerated pumping wave. In a WDM system with angular frequencies ω1… ω_n the interaction of three signals at any frequencies ω_i, ω_j and ω_k occur due to the nonlinear polarization and produce the signals at frequencies $\omega_i \pm\omega_j \pm \omega_k$, the most bothersome is the signal equivalent to $\omega_{ijk}= \omega_i +\omega_j - \omega_k$ depending on the individual frequencies. This beat signal may be of exact frequency or may lie very near to one of the individual channels frequency resulting in considerable crosstalk to that channel.

System Setup

For the realization of WDM system, a commercial Optiwave optisystem simulation tool is used. Optisystem suit is a pioneering optical fiber communication (OFC) system simulation package to design, test and optimize virtually with any type of optical link in physical layer of broad spectrum.

Proposed system consists of 16 channel operated at 193.10 THz-193.85 THz frequencies. Starting frequency of the WDM system is 193.10 THz. Each transmitter generates data from pseudo random bit sequence generator and is modulated with external modulator and optical pulses from laser source. Total rate of binary bits 1'as and 0's per channel is 10 Gbps. WDM system is analyzed on different input power levels to evaluate four wave mixing power. To make system bandwidth efficient and ultra dense , 50 GHz channel spacing taken into consideration. It is reported that at low channel spacing's, FWM is more prominent. Multiplexer with no losses is considered to multiple all 16 channels. Here main emphasis is on exploitation of FWM and on the losses of multiplexer. Optical spectrum analyzer and optical time domain analyzer is incorporated in the system after multiplexer to depict the signals.WDM signals are fed into single mode optical fiber of length 50 Km. Attenuation of optical fiber is 0.2 dB/Km and dispersion 17ps/nm/km as per the ITU standards of SMF-28. As the signal passed through optical fiber, they experience linear and nonlinear effects. Linear effects are attenuation and dispersion. Non linear effects come into play when transmitter power increased to higher level. This is because of the reason that at high powers optical fiber experience molecule vibrations. The principle for this vibration is kerr's effect. It states that at high intensities, refracting index of the optical fiber changes and which consequently change the phase of the signal.

To suppress the effects of four wave mixing after 50 Km SMF-28, a dispersion compensation fiber (DCF) and fiber bragg grating (FBG) is incorporated. For the first analyses, only one dispersion compensation fiber is employed and evaluation has been done before and after DCF. For subsequent evaluation, FBG is used to cater the high speed requirement and to quell FWM. Finally join technique is proposed and FWM power analyzed before and after the module. After FWM compensation, channels fed to de multiplexer for direct the signal to specific port. Each receiver consists of photo detector, a low pass filter and regenerator. For final evaluation, BER analyzer is placed at the end if the system. BER analyzer provide, Q-factor, error rate, signal to noise ratio, eye closer penalty, opening penalty and received power etc.

Table 1.1 System specifications

Parameters	Values
No. of channels	16
Bit rate	10 Gbps/per channel
Transmitter power	0 dB-10 dB
Distance	50 Km
Modulation type	Non return to zero
Nonlinearity	Four wave mixing
Modulator	MZM
Amplifier	EDFA
Photo detector	PIN

Table 1.2 FBG and DCF specifications

Parameter	Values
DCF Length	5Km
Attenuation	0.6 dB/Km
Dispersion	-88 ps/nm/km
Slope	0.075 ps/nm^2/km
PMD	0.8 ps/km
Aeff	22um^2
FBG length	1mm
Apodization	Tanh
Chirping	Linear

Results and Discussion

Proposed system architecture is evaluated with the premier optical simulation tool Optiwave Optisystem. Here, the results of the proposed simulated system of WDM under the effect of four wave mixing are discussed. System consists of an EDFA optical amplifier to boost the input laser signal for long reach transmission. Here, EDFA is used to analyze the effect of high power on optical fiber and proposed FWM compensating modules. Figure 1.2 depicts the WDM signals before and after optical fiber.

In the analysis, it is observed that tanh apodized fiber bragg gratings performed better than normal FBG. Chirping of the gratings is linear and length is 1mm. So in final system we have used apodised FBG. Hence in final system use of linearly chirped uniformly apodized FBG has been done. Figure 1.3 depicts the output power spectra's at -15 dBm power for system compensated with DCF + uniformly apodized linear FBG, system compensated with DCF and system compensated with uniformly anodized linear FBG.

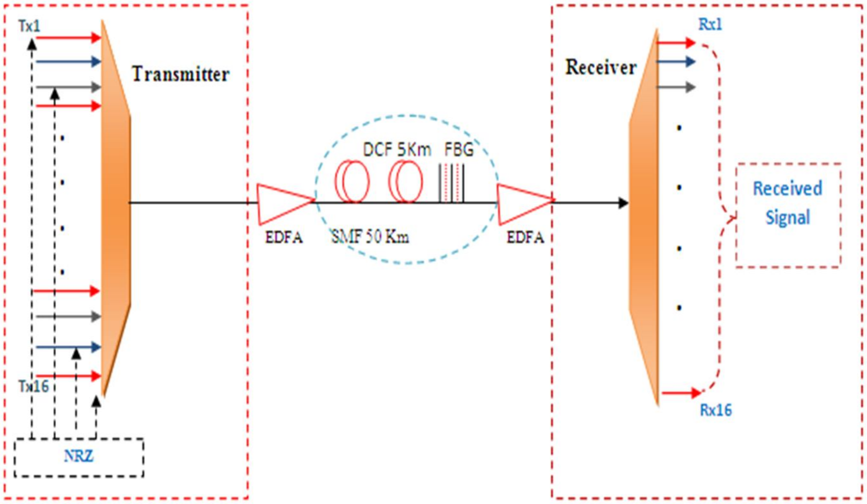

Figure 1.1 Proposed architecture of 16x10 Gbps WDM system with FWM suppression

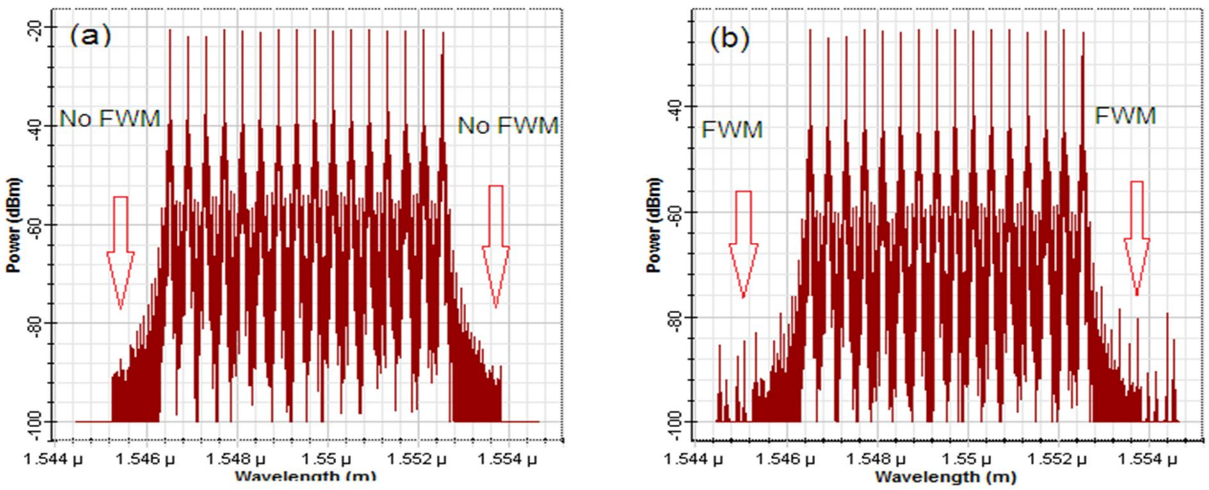

Figure 1.2 Optical spectrums (a) Before SMF (b) After SMF

By comparing the two methods, it is seen that by the use of dispersion compensation fiber method alone can decrease FWM to small extent but increase cost of the system. FBG helps in decreasing the cost of the system but do not suppress FWM to much extent when no apodization is used. The apodized fiber brag grating play very important role to suppress side lobe and maintaining the reflectivity and narrow bandwidth. Best candidate to reduce FWM is joint technique. Where DCF+FBG is used after 50 Km single mode fiber as shown in figure 1.5.

DCF + FBG is the best approach to compensate the system non-linearities and dispersion. System can be optimized by using the combination of the two dispersion compensation techniques by choosing optimal length, power, chirping profile, grating period etc. Comparison among three FWM compensation techniques has been done on the basis of suppression ability and on the basis of eye diagram. Eye diagrams give the simulation results at the first channel. As we can see from different eye diagrams, the effect of FWM suppression is very good. The signal quality is high, eye's opening is very good, and the edge neat graph is symmetrical in case of DCF+FBG join suppression method. This indicates that DCF+FBG jointly compensate different channel's four wave mixing greatly. The eye diagram shows that the time delays in the received bits are negligible and the signal distortion due to BER is tolerable. In optical communication systems, only optical signal to noise ratio (OSNR) could not accurately measure the system performance, especially in WDM systems. Typically, quality factor Q is a one of the important indicators to measure the optical performance by which to characterize the BER. Further system performance is analyzed for different launched powers in all the cases. Figure 1.5 depicts the performance of three suppression methods with the increase of power.

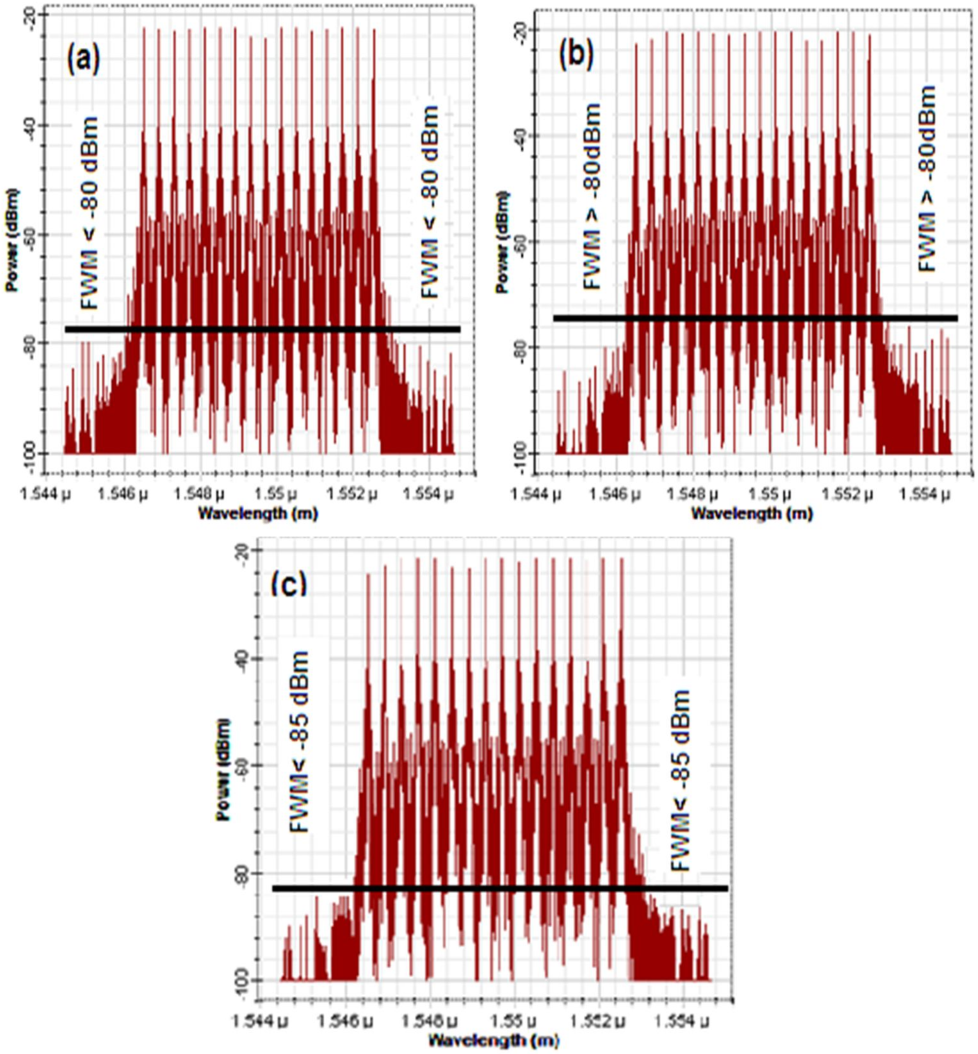

Figure 1.3 Optical spectrums after (a) Only DCF (b) Only FBG (c) DCF+FBG

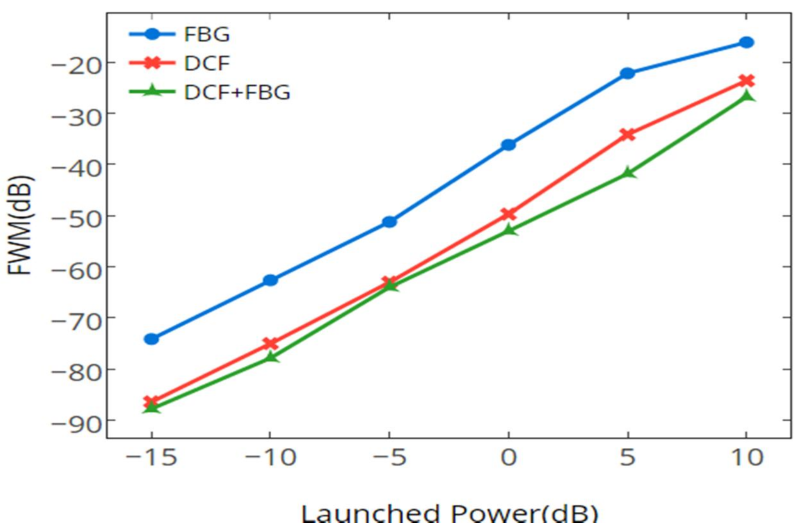

Figure 1.4 Comparison of FWM degeneration capabilities of DCF, Apodised FBG and DCF + Apodized FBG

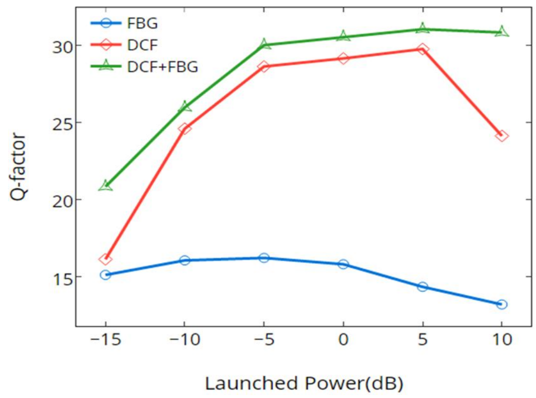

Figure.1.5 Q-factor Vs Launched power

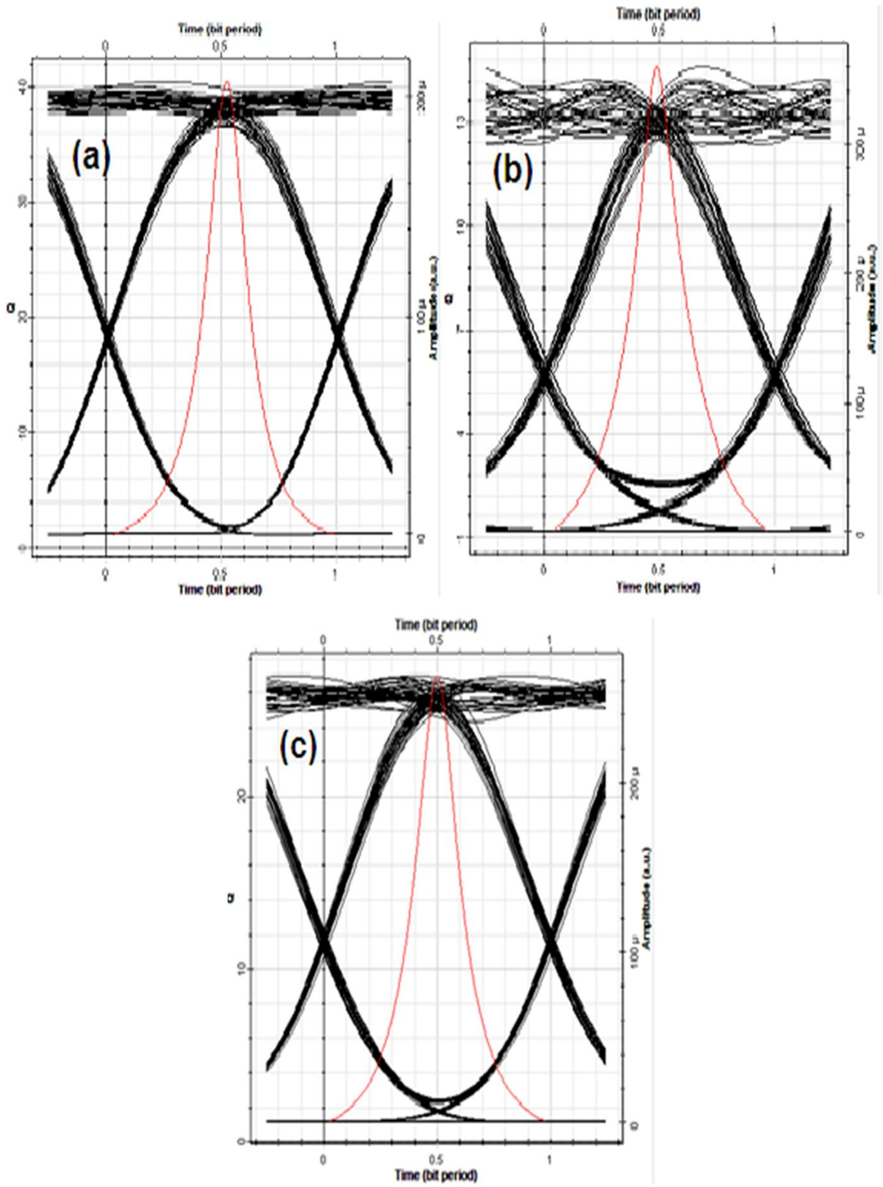

Figure.1.6 Eye diagram for (a) FBG only (b) DCF only (c) FBG+DCF joint method

This BER analyzer allows calculating and displaying the bit error rate (BER) of an electrical signal automatically. It can estimate the BER using different algorithms such as Gaussian and Chi-Squared and derive different metrics from the eye diagram, such as Q factor, eye opening, eye closure, extinction ratio, eye height, jitter, etc. It can also take in account Forward Error Correction (FEC), plot BER patterns and estimate system penalties and margins. From figure 1.6 eye diagrams for FBG system is distorted and Quality is less than alone DCF system. DCF+FBG joint method exhibit best performance in terms of Q-factor and bit error rate. Thus in this work, a cost effective and high power suppression has been proposed for future generation networks and WDM systems.

Conclusion

In this paper, work is demonstrated to suppress the four wave mixing employing a cost effective joint technique of dispersion compensation fiber and tanh apodized fiber bragg grating. Then we analyzed FWM in WDM system under different launched powers. The simulation results were compared and analyzed to get optimal FWM suppression technique. The results show that when the input power is less than 5 dBm, the FWM caused by refractive index fluctuations is very small and can be ignored. When the input power is between 5 dBm to 10 dBm per channel , the FWM is more severe. To quell this degrading effect in WDM systems, a joint technique of tanh apodized FBG and DCF is used. It is concluded that joint FBG and DCF reduce cost of the system and suppressed FWM to much extent and performs better than conventional and apodized FBG alone.

References

[1] B. K. Abd ElRazak and M. H. Aly, “Suppression of Four Wave Mixing Crosstalk in Four 10 Gbps Channels Over a 50 km Dispersion Shifted Fiber Using Unequal Channel Spacing,” ICCTA, pp. 228–233, 2009.

[2] J. Zhang, P. Shum, X.P. Cheng, N.Q. Ngo, S.Y. Li, “Analysis of linearly tapered fibre Bragg grating for dispersion slope compensation”, IEEE Photon. Technol. Lett., Vol. 15, no. 10, pp. 1389–1391, 2003.

[3] J. H. Lee, Y. M. Chang, Y. G. Han, H. Chung, S. H. Kim and S. B. Lee, "A detailed experimental study on single-pump Raman/EDFA hybrid amplifiers: static, dynamic, and system performance comparison," Journal of Lightwave Technology, vol. 23, no. 11, pp. 3484-3493, 2005.

[4] S. Jung, J. Y. Lee, and D. Y. Kim, “Novel phase-matching condition for a four wave mixing experiment in an optical fiber,” Optical Express, vol. 14, no. 1, pp. 35–43, 2006.

[5] Mohammed NA, Solaiman M, Aly MH. Design and performance evaluation of a dispersion compensation unit using several chirping functions in a tanhapodized FBG and comparison with dispersion compensation fiber. Optical Society of America, Applied Optics. Vol. 53, no. 29 pp. 239–47, 2014

[6] M. Ajmani and M. Singh, “FWM in WDM System, Effects and Techniques to Minimize: A Review,” Fifth International Conference on Advanced Computing and Communication Technologies, pp. 385–389, 2015.

[7] D. Marcuse, A. R. Chraplyvy and R. Tkach, “Effect of Fiber Nonlinearity on Long-Distance Transmission,” Journal of Lightwave Technology, Vol. 9, No. 1, pp. 121-128, 1991.

[8] I. Neokosmidis et al., “New Techniques for the Suppression of the Four Wave Mixing-Induced Distortion in Nonzero Dispersion Fiber WDM Systems,” J. Lightwave Technol., vol. 23, No. 3, pp. 1137-1144, 2005.

[9] S. Song, “The number of four-wave mixing (FWM) waves in WDM systems and its applications,” in Proc. 14th Annu. Meeting IEEE Lasers and Electro-Optics Society, vol. 1, pp. 283–284, 2001.

[10] Morteza H. Shoreh, “Compensation of Nonlinearity Impairments in Coherent Optical OFDM Systems Using Multiple Optical Phase Conjugate Modules”. IEEE journal of optical networks, vol. 6, no. 6, pp. 549-558, 2014

[11] G. Kaur and M. S. Patterh, “Suppression of four wave mixing in wavelength division multiplexed system with hybrid modules,” Optik, vol. 125, no. 15, pp. 3894–3896, 2014.

[12] E. Ip and J. M. Kahn, “Compensation of dispersion and nonlinear impairments using digital backpropagation,” J. Lightwave Technol., vol. 26, no. 20, pp. 3416–3425, 2008.