International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-8 Issue-8, June, 2019

Comparison of Different Dispersion Compensation Techniques at 100Gbps Over 120Km Using Single Mode Fiber

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Abstract: Dispersion Is One Of The Principle Elements To Constrain The Advancement Of The Fiber Optics To Higher Capacity And Long Transmission Of Signals. This Paper Focuses On The Comparison Of Dispersion Compensation Techniques (DCF, IDCFBG And UFBG) For 120Km-100Gbps System Using Single Mode Fibers. All The Results Have Been Analysed By Simulating These Techniques In Three Configurations Of Pre, Post And Symmetrical Shapes. Experimentally We Have Proved That Post Compensation Of DCF And Post Compensation Of IDCFBG Has Exhibited The Highest Q-Factor And Least BER For The Input Powers Ranging From 1-10dbm. We Have Also Proved Post Compensation Of UFBG To Be The Best When Compared With Others. Hence, In This Paper These Three Techniques Have Finally Been Compared To Demonstrate A Best Technique For Chromatic Dispersion Compensation Over A Long Distance Of 120Km With A Bit Rate Of 100Gbps.

Keywords: Bit Error Rate (Ber); Chromatic Dispersion (Cd); Dispersion; Electronic Dispersion Compensation (Edc).

I. INTRODUCTION

The extension of transmission capacity, enhancement of the transmission rate and increase in the distance are altogether firmly related with non-linearity, loss in the fiber and other dispersion effects in optical communication systems [1]. Particularly for the long and ultra-long transmission, their impact is progressive with increase in the length of the fiber. With the initiation of EDFA, the issue of losses has received more attention. Thus, the major obstacle in increasing the transmission distance and enhancement of capacity is dispersion. Dispersion causes widening of the optical pulses when they travel along the fiber. It limits the data rate of the fiber and results in the degradation of the optical signal [2], [3]. Combating the effect of the dispersion can be done by employing two approaches. First one is the designing of the new fibers with lesser amount of dispersion and the second one is to make use of dispersion compensating modules [4]. Managing dispersion and using fibers with opposite dispersion rate is the main technique to keep the overall dispersion low while taking the most of the nonlinear effects. In case of dispersion management systems consisted of DCF and SMF, the positive dispersion of SMF can be removed by negative dispersion of DCF [5].

A. DISPERSION TYPES

Three major categories of dispersion are modal dispersion, polarization dispersion and chromatic dispersion which are discussed below in detail.

i. Modal Dispersion: This type of dispersion results from the pulse widening caused by the difference in the propagation delay between lower order modes and higher order modes of multimode fibers. Since these modes go along the channel at various propagation speeds, the width of the pulse at the output depends upon the transmission intervals of the fastest and the slowest mode. As a result, modal dispersion is more prominent in multimode fibers.

ii. Polarization Mode Dispersion: Single mode fiber can manage just one transverse mode but the polarization mode dispersion conveys this mode in two unique polarizations and slight modifications in fiber changes the propagation speeds for the two polarizations. This is known as birefringence and it directly depends upon the fiber length. This means that the pulse becomes mode broadened with the increase in the length.

iii. Chromatic Dispersion: Since the refractive index of the fiber glass depends upon the wavelength, the spectral components of a pulse containing distinct wavelengths propagate at distinct speeds. The variation in the speeds causes the different components of the pulse to reach at the output at different time intervals, thereby, resulting in pulse broadening at the yield. This widening of pulse is known as chromatic dispersion. There are two main components of chromatic dispersion: (i) material dispersion, and (ii) waveguide dispersion [6],[7],[8],[9]. In fact, this chromatic dispersion should always be accompanied by material absorption because of the Kramers-Kronig relation [10]. However, we do not go into details of the dispersive and absorptive aspects in this study.

B. DISPERSION COMPENSATION TECHNIQUES

To limit or completely mitigate the spreading of the pulses during transmission, compensation of dispersion is the most necessary part. For providing dispersion compensation, distinct techniques have been proposed. Out of them dispersion compensating fibers (DCF), Fiber Bragg Grating and Electronic Dispersion Compensation are the most efficient and reliable techniques.

i. Dispersion Compensating Fibers (DCF): DCF works on the principle of providing negative dispersion of magnitude being the same as that of the fiber. Hence, the positive dispersion of the fiber is cancelled by the equal negative dispersion of the fiber, thereby, leading to zero dispersion. It is the standard solution to remove the dispersion from the transmission system but its use has been limited by the large insertion losses occurring in it [11].

ii. Fiber Bragg Grating (FBG): It is a flexible technique for the compensation of dispersion. The main principle behind the working of FBG is Fresnel reflection. Its working principle includes reflecting a particular wavelength and transmitting all other wavelengths. Chirped fiber Bragg grating is the most effective and convenient technique for wavelength division multiplexed systems. With the change in the length of the grating, the grating period is also altered. In order to get the reflected wavelengths, Bragg's condition must be satisfied which is given below in Eq. (1).

$$\lambda_B = 2\Lambda n_g \qquad (1)$$

Here, Λ = grating period, n_g = effective refractive index, and λ_B = reflected wavelength. FBG has advantages of almost zero non linearity and lesser insertion losses which can significantly boost the overall capacity of the system [12],[13],[14].

Uniform fiber Bragg grating is another type of fiber Bragg grating. A device that enhances the intensity of the reflected or the transmitted signal when it passes through is known as grating. Modification of the intensity is done periodically. Uniform fiber Bragg grating means that the change in the refractive index and grating period remains constant over the whole length of the grating. UFBG can be further divided into two types: Reflection gratings and Transmission gratings [15],[16].

iii. Electronic Dispersion Compensation: EDC has major applications in cell phones and modems. This technique can simply remove the dispersion without any need of special type of coding at the transmitter side. This characteristic of EDC makes it more compatible for the networks with different wavelengths. EDC involves the direct detection at the receiver, thereby converting the linear distortions into nonlinear distortions after optical electronic conversion. For the cancellation of these nonlinear distortions, decision feedback equalizers and feed forward equalizers have been used. But it has a disadvantage of slowing down the system because of the slow process involved in converting the digital signals to analog ones [17],[18],[19],[20].

Table 1: Parameters for simulation

Sr.No.	Parameter	Value
1	Length of fiber (km)	120
2	Dispersion (ps/nm/km)	17
3	Attenuation (db/km)	0.2
4	Differential group delay(ps/km)	3
5	Differential slope (ps/$nm2/km$)	0.008

II. SIMULATION MODEL USING OPTISYSTEM 7.0

Simulation models are used to verify and analyze the outcomes of the dispersion compensators over 120Km transmitting distance at a rate of 100Gbps. The whole setup includes the use of pseudo random bit sequence generator, continuous wave light source along with MZ-modulator at the transmitting end. Similarly a setup is provided at the receiver end to convert optical signals back into electrical signal, and thus it consists of photodiode, low pass filter and BER analyzer. Depending upon the pre, post, or symmetrical configuration, a specific dispersion compensator is placed inside the fiber.

Experimentally it has already been proved that post scheme of DCF and IDCFBG has highest Q-factor and least BER at 100 Gbps over a long distance of 120Km. Fig.1 is showing the simulation setup of post DCF. All the iterations have been performed at distinct input powers of values 1-10dBm. The simulation parameters are shown in Table-1. Also, the parameters for DCF are shown in tabular form in Table-2.

Table 2: Parameters for DCF

Sr. No.	Parameter	Value
1	Bit Rate (Gbps)	100
2	Sample Rate (THz)	6.4
3	Frequency (THz)	193.1
4	Power (dBm)	1-10
5	Extinction Ratio	30
6	Gain (dB)	20
7	Noise (dB)	2

Table 3: Parameters for UFBG

Sr. No.	Parameter	Value
1	Length of fiber (Km)	120
2	Reference wavelength (nm)	1550
3	Length of DCF (km)	24
4	Attenuation (db/km)	0.3
5	Differential slope (ps/$nm2/km$)	0.21
6	Dispersion (ps/nm/km)	-80

Table 4: Parameters of IDCFBG

Sr. No.	Parameter	Value
1	Length of fiber (km)	120
2	Noise Threshold (dB)	-100
3	Reflectivity	0.99
4	Sample rate (GHz)	500

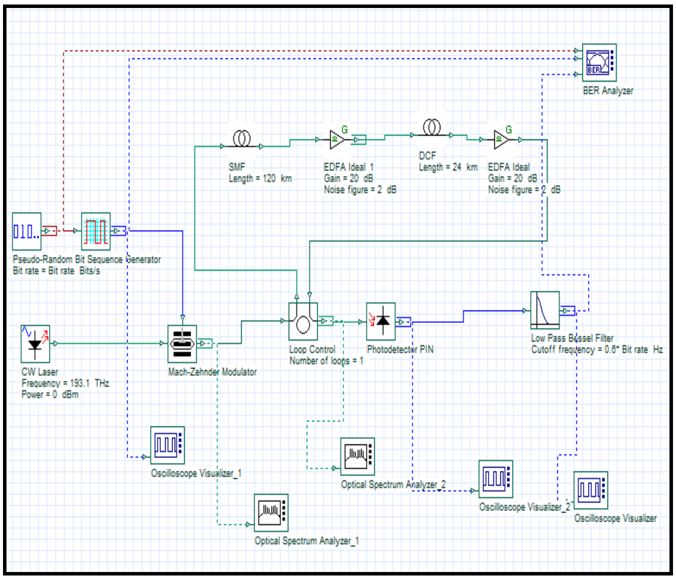

Fig.1: Simulation setup of Post compensation using DCF

Fig. 2 is showing the setup for simulating IDCFBG in post configuration at input powers from 1-10dBm. Table-3 is showing parameters of UFBG. Dispersion compensation using Uniform Fiber Bragg Grating has also been analyzed in three containing the parameters of IDCFBG for simulating the showed that post configuration has the best results when compared with pre and mix configurations of UFBG. Fig.3 is showing the best configuration of UFBG, i.e. post configuration. Besides, IDCFBG parameters used is described in Table-4.

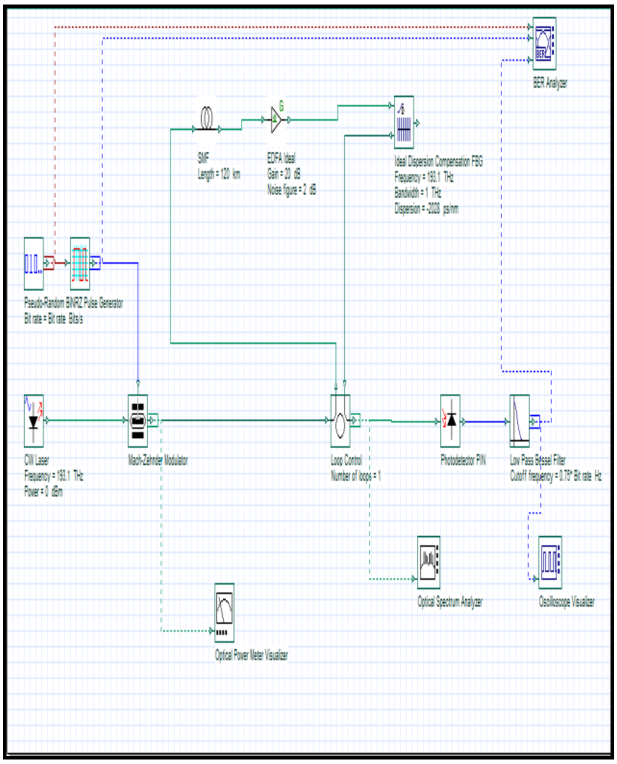

Fig.2: Simulation setup of post compensation using IDCFBG

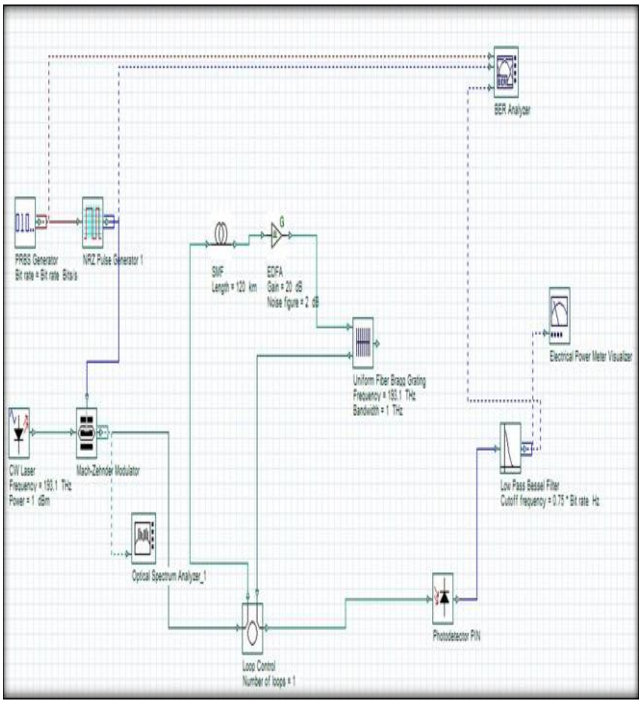

Fig.3: Simulation setup of post compensation using UFBG

Table 6: Results for post compensation of IDCFBG at inputs from 1dbm to 10dbm

Iterations	Q factor	BER	Eye Height	Power (dbm)
1	6.2989	1.48E-10	0.000226	-39.957
2	6.81376	4.73E-12	0.000304	-37.969
3	7.31658	1.27E-13	0.000404	-35.978
4	7.87031	1.77E-15	0.000534	-33.983
5	8.37922	2.66E-17	0.0007	-31.988
6	8.94922	1.78E-19	0.000915	-29.98
7	9.43164	2.01E-21	0.001186	-27.99
8	9.86961	2.18E-23	0.00153	-25.99
9	10.1927	1.06E-24	0.001962	-23.99
10	10.2168	8.32E-25	0.002486	-21.99

III. RESULTS AND DISCUSSIONS

Post configurations of DCF, IDCFBG and UFBG are executed by using Optisystem 7.0. The outcomes have been analyzed in terms of the Q-Factor, BER, received power and eye height. All the outcomes of the individual dispersion compensation techniques are then compared to extract the best technique among them. The values of Q-factor, BER, Eye height and received power of post configuration of DCF are presented in Table-5.

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Table 5: Results for the post compensation of DCF at inputs from 1dbm to 10dbm

Iterations	Q factor	BER	Eye Height	Power (dbm)
1	6.2989	1.48E-10	0.000226	-39.957
2	6.81376	4.73E-12	0.000304	-37.969
3	7.31658	1.27E-13	0.000404	-35.978
4	7.87031	1.77E-15	0.000534	-33.983
5	8.37922	2.66E-17	0.0007	-31.988
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7	9.43164	2.01E-21	0.001186	-27.99
8	9.86961	2.18E-23	0.00153	-25.99
9	10.1927	1.06E-24	0.001962	-23.99
10	10.2168	8.32E-25	0.002486	-21.99

Simulation results of IDCFBG at input powers of 1-10dBm are shown in Table-6, thus conveying the values of Q-factor, Eye height, BER and received power for the post configuration. All the corresponding values for post configuration of UFBG are offered in Table-7.

Table 7: Results for the post compensation of Uniform FBG at inputs from 1dbm to 10dbm

Iterations	Q factor	BER	Eye Height	Power(dBm)
1	10.5753	1.56E-26	0.00036	1.09E-07
2	11.913	4.04E-33	0.0004752	1.73E-07
3	13.369	3.55E-41	0.0006205	2.73E-07
4	14.9508	5.97E-51	0.0008056	4.32E-07
5	16.663	9.12E-63	0.00104	6.85E-07
6	18.512	6.11E-77	0.00133935	1.09E-06
7	20.5079	6.61E-94	0.001718	1.72E-06
8	22.6786	2.55E-11	0.002197	2.72E-06
9	25.028	1.04E-13	0.002805	4.31E-06
10	27.54	1.95E-16	0.00357	6.84E-06

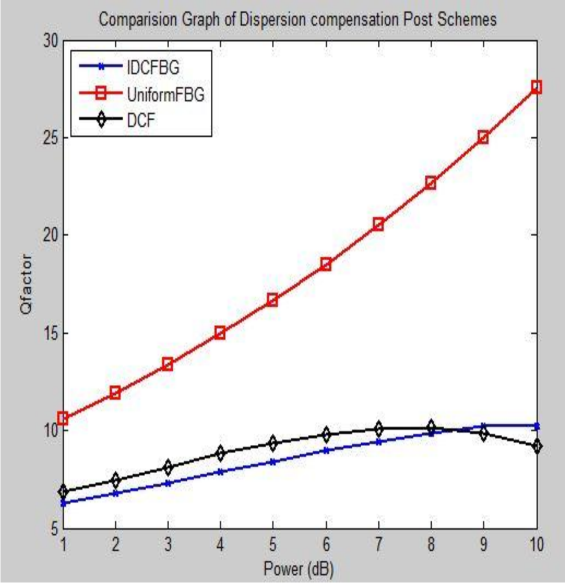

Fig.4: Input Power Vs Q- factor plot

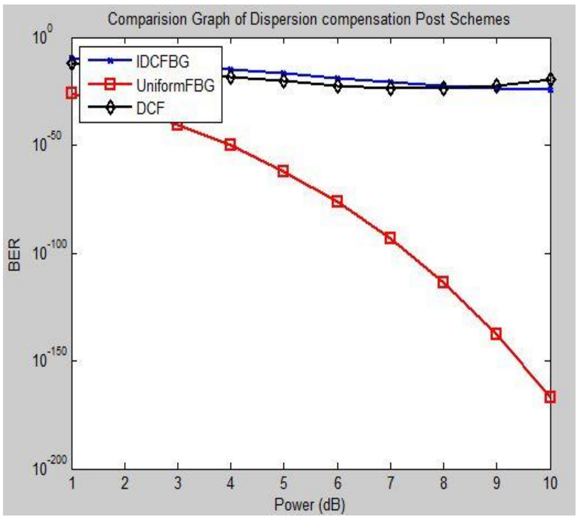

Fig.5: Power Vs BER Plot

The change in different factors with respect to the change in the input power has been shown through graphs. Graphs show the comparative analysis of the post configuration of DCF, IDCFBG and UFBG.

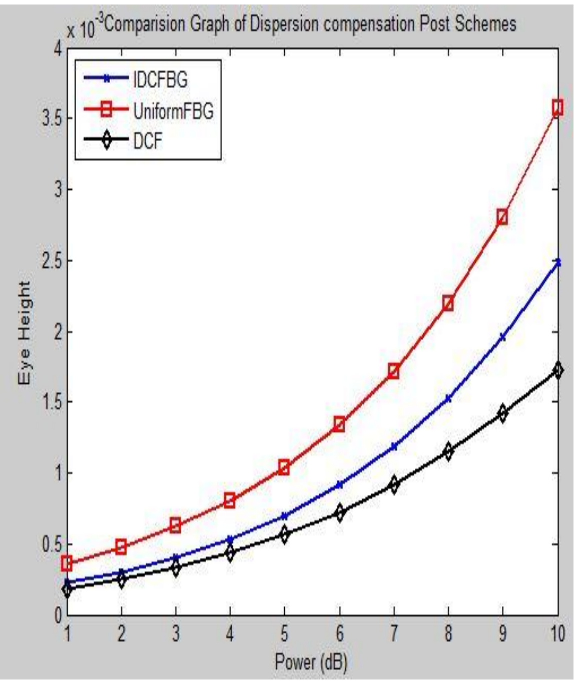

Fig.6: Eye Height Vs Received Power Plot

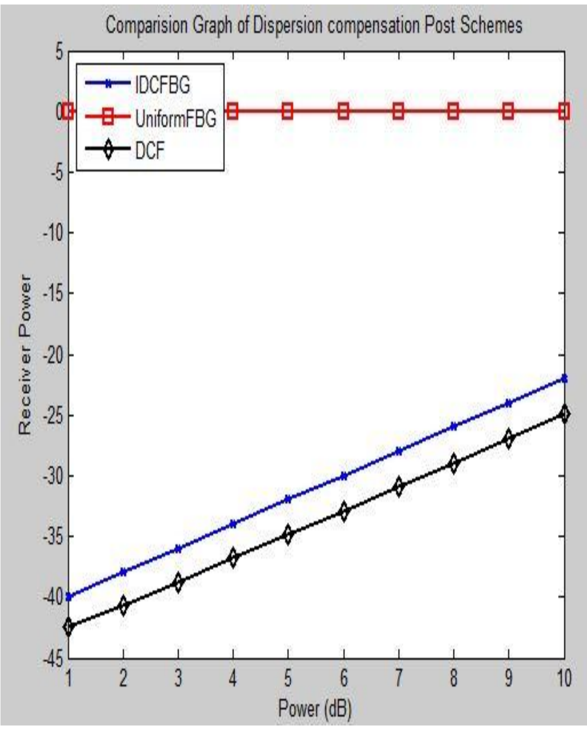

Fig.7: Power Vs Received Power Plot

Fig. 4 is representing the change in Q-factor with respect to input power whereas change in BER is indicated in Fig.5. Similar comparison results are presented in Fig. 6 and 7 for eye height and received power, respectively.

The comparison among the three configurations shows that the post configuration of UFBG is more efficient and effective at 100Gbps for 120Km of the transmittance distance than DCF and IDCFBG. Table-8 is demonstrating the comparison of all the techniques at varying input power of 1-10dBm showing post configuration of UFBG to be best.

IV. CONCLUSION

This paper is focused on identifying the best configuration among experimentally available dispersion compensation schemes. In this paper, the outstanding configurations of DCF and IDCFBG at input powers 1-10dBm have been compared with the foremost configuration of UFBG. In the previous papers, the post configuration of DCF and IDCFBG exhibited the best performance for 120Km 100 Gbps system. Similarly, our previous research has also proved that the best outcomes can be attained by utilizing UFBG in the post configuration. The research in this study includes the comparison of all the best schemes at the same bit error rate for equal transmission distance. Finally, it is concluded that UFBG has superior performance than other techniques. Although a complete mitigation of dispersion is not attainable, partial dispersion compensation can be made at least to some extent.

Table 8: Comparison of DCF and IDCFBG dispersion compensation technique with UFBG

Compensation Technique	erations	Q-Factor	BER	Received Power (dBm)	Eye Height
DCF (Post compensation)	1	6.83	1.04E-12	-42.5	0.0001
	2	7.46	3.91E-14	-40.64	0.0002
	3	8.11	2.40E-16	-38.74	0.0003
	4	8.80	6.56E-19	-36.8	0.0004
	5	9.33	5.20E-21	-34.85	0.0005
	6	9.8	5.31E-23	-32.88	0.0007
	7	10.11	2.42E-24	-30.9	0.0009
	8	10.14	1.73E-24	-28.92	0.0011
	9	9.84	3.46E-23	-26.93	0.0014
	10	9.2	1.69E-20	-24.95	0.0017
IDCFBG (Post compensation)	1	6.29	1.48E-10	-39.95	0.0002
	2	6.81	4.72E-12	-37.96	0.0003
	3	7.31	1.27E-13	-35.97	0.0004
	4	7.87	1.76E-15	-33.98	0.0005
	5	8.37	2.66E-17	-31.98	0.0006
	6	8.94	1.78E-19	-29.98	0.0009
	7	9.43	2.00E-21	-27.99	0.0011
	8	9.86	2.17E-23	-25.99	0.0015
	9	10.19	1.06E-24	-23.99	0.0019
	10	10.21	8.31E-25	-21.99	0.0024
UFBG (Post	1	10.57	1.56E-26	-39.61	0.0003
	2	11.91	4.04E-33	-37.63	0.0004
	3	13.36	3.54E-41	-35.63	0.0006
	4	14.95	5.96E-51	-33.64	0.0008
	5	16.66	9.12E-63	-31.64	0.0010

ompensation)	6	18.51	6.11E-77	-29.64	0.0013
	7	20.50	6.61E-94	-27.64	0.0017
	8	22.67	.54E-114	-25.64	0.0021
	9	25.02	.04E-138	-23.64	0.0028
	10	27.54	.95E-167	-21.64	0.0035

REFERENCES

1. W. Liu, S. Guo et. al, " The Research on 10Gbps Optical Communication Dispersion Compensation Systems without Electric Regenerator," 3rd International Congress on Image and Signal Processing, pp. 4480-4483, 2010.
2. S. Anand, P. K. Raghav et. al," Analysis on dispersion compensation using Post FBG with EDFA," International Journal of Scientific & Engineering Research, vol. 04, issue no. 09, pp. 1809-1813, September, 2013.
3. A. B. Dar and R. K. Jha, "Chromatic Dispersion Compensation Techniques and Characterization of Fiber Bragg Grating for Dispersion Compensation," Opt Quant Electron (Springer), February, 2017.
4. V. Dilendorfs, S. Spolitis et. al, "Effectiveness evaluation of Dispersion Compensation Methods for Fiber Optical Transmission Systems," Progress in Electromagnetic Research Symposium(PIERS), pp. 3759-3763, August 8-11, 2016.
5. A. Sheetal, A. K. Sharma et. al, " Simulation of high capacity 40 Gb/s long haul DWDM system using different modulation formats and dispersion compensation schemes in the presence of Kerr’s effect, "Optik Optics (Elseveir), pp. 739-749, 2010.
6. P. Shukla and Prof. S. Tiwari , " A Review of Dispersion Compensation using Fiber Bragg Grating (FBG) in Optical Communication," International Advanced Research Journal in Science, Engineering and Technology, vol. 4, issue no. 6, pp. no. 66-69, June, 2017.
7. Garima and Dr. A. K. Garg, " A Review Paper on Dispersion Compensation Technique in WDM Optical Networks," International Journal of Electronics, Electrical and Computational System, vol. 06, issue no. 05, pp. no. 480-484, May, 2017.
8. R. Kaur and Dr. M. Singh, " A Review Paper on Dispersion Compensation Methods," International Research Journal of Engineering and Technology, vol. 04, issue no. 6, pp.1991-1994, June, 2017.
9. N. Dalal and Dr. A. K. Garg," A Comprehensive Study of Various Compensation Techniques in High Speed Single Mode Optical Fiber Communication," International Journal of Recent Trends In Engineering and Research, vol. 02, issue no. 05, pp. 275-278, 2016.
10. Huttner B and Barnett S M, “Quantization of the electromagnetic field in dielectrics”, Phys. Rev. A 46 4306 (1992)
11. N. K. Kahlon and G. Kaur, "Various Dispersion Compensation Techniques For Optical System: A Survey, "Open Journal of Communications And Software, vol. 1, issue no.1, pp. 64-73, May, 2014.
12. A. Sangeetha and I. Srinivasa Rao, "Performance Analysis Of Dispersion Compensation Techniques in a 100Gbps Coherent Optical System," International Journal of Engineering and Technology, vol. 5, issue no. 3, pp. 2292-2296, July 2013.
13. A. Sharma, I. Singh et. al, " Simulation and Analysis of dispersion compensation using proposed model at 100Gbps over 120Km using SMF, " International Journal of Mechanical Engineering and Technology (IJMET), vol. 08, issue no. 12, pp. 600-607, December, 2017.
14. F. M. Kabonzo and Y. Peng, " Adaptive Performance Improvement of Fiber Bragg Grating in Radio Over Fiber System," Journal of Computer and Communications,, vol. 04, pp.1-6, March, 2016.
15. J. R. Mahapatra and M. Chattopadhyay, "Spectral Characteristic of Uniform Fiber Bragg Grating using Couple Mode Theory," International Journal of Electrical, Electronics and Data Communication, vol. 01, pp. 40-44, July, 2013.
16. A. Sharma and I. Singh et. al, " Analyzing Dispersion Compensation using UFBG at 100Gbps over 120Km using Single Mode Fiber, " International Journal of Mechanical Engineering and Technology (IJMET), vol. 08, issue no. 12, pp. 1075-1082, December, 2017.
17. S. Devra and G. Kaur, "Different Compensation Techniques To Compensate Chromatic Dispersion In Fiber Optics," International Journal of Engineering and Information Technology, vol. 3, issue no. 1, pp. 1-4, 2011.
18. G. Kaur and G. Kaur," Mitigation of Chromatic Dispersion using Different Compensation Methods in Optical Fiber Communication: A Review," International Journal of Engineering and Management Research, vol. 4, issue no. 3, June, 2014.
19. K. Kaur and B. Kaur, " Dispersion Compensation Techniques: A Review," Second International Conference On Innovative Trends In Electronics Engineering, vol. 20, pp. no. 58-61, November, 2016.
20. R. Rout, S. Pradhan et. al, "Role of DCF technique for enhancing optical fiber communication System utility," International Research Journal of Engineering and Technology (IRJET), vol. 2, issue no. 7, October, 2015.

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