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Performance Analysis of Effect of Fiber Length, Input Power and Attenuation Coefficient on Dispensation Compensation Using FBG

Sami Haider[1], Dr. D K Srivastava[2], Ravindra Kumar[3]

Student, M.Tech Digital Communication Department of ECE, BIET Jhansi, India[1, 3]

Associate Professor, Department of ECE, BIET Jhansi, India[2]

Abstract: The phenomenon of broadening of pulse as it travel along the optical fiber called dispersion, is the main barrier in achieving an efficient and high speed communication system. In this paper, we have analyzed the effect of fiber length (km), input power (dBm) and attenuation coefficient (dB/km) on the overall performance of an optical communication system containing Fiber Bragg Grating (FBG) as the dispersion compensator. The values of system performance parameters like Quality factor, Output power (dBm), Gain (dB), Noise figure (dB) and Minimum bit error rate (BER) have been calculated and analyzed using Eye diagram and related tables and graphs. All the simulation of the system has been done on the Optisystem 14.0 software.

Keywords: Fiber Bragg Grating, Fiber Length, Input Power, Attenuation Coefficient, Quality Factor, Output Power, Gain, Noise Figure.

1. INTRODUCTION

Speedy and secure transmission of information is a need of today. Fiber optic communication is a type of communication that provides high speed transfer of information from one place to other place. The transfer of data or information from one place to other, whether the places are separated by a few kilometers or by a large range is called communication. Information is often carried by an electromagnetic carrier wave whose frequency can vary from a few megahertz to several hundred terahertzes. Optical communication systems use high carrier frequencies (~100 THz) in the visible or near-infrared region of the electromagnetic spectrum[1]. The optical communication systems was first came into limelight in 1980's with the advent of LASER since it has a theoretical information carrying capacity exceeding that of microwave system by a factor of 10^5 [2]. But dispersion is the main obstacle in achieving these goals.There are many type of loses when the light signal propagate through fiber like material absorption loses, scattering loses and bending loses [3]. Dispersion is one such loss among these loses which is a major problem in optical system. When different wavelengths of light pulses are launched into the optical fiber, these pulses travelled with different speeds due to the variation of refractive index with wavelength. The light pulses tend to get spread out in time domain after travelling some distance in fiber and this is continued throughout the fiber length. This phenomenon of broadening of pulse width is known as dispersion [4]. There are many types of dispersion namely Intermodal dispersion, Intramural or Chromatic dispersion and Polarization mode dispersion [5]. There are many dispersion compensating techniques like using Erbium Doped fiber Amplifier (EDFA's), Dispersion Compensation Fibers (DCF's). But the use of EDFA's introduce nonlinear effects in the optical fiber which limits the data rate and also reduces the maximum repeater distance spacing in fiber optic link [6]. Moreover using dispersion compensation fibers (DCF's) increases the total loses nonlinear effects and the cost of optical transmission systems. Their compensation depends on the wavelength and they can perfectly act only in a narrow band of frequency [7].So using Fiber Bragg Grating (FBG) is an alternative to compensate dispersion. FBG is a key component in optical communication system as, dispersion compensators, filters and flatteners gain. FBG are very attractive components because as well as being passive, linear and compact, retain strong dispersion in both reflection and transmission [8]. Also the FBG post compensation scheme gives better compensation results than DCF's pre, post and symmetrical schemes [9]. OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks.

In this paper, the effect of optical fiber length, input power and attenuation coefficient on the dispersion compensation using FBG with NRZ modulation format is analyzed using optisystem 14.0 software. The value of quality factor, gain, output power, noise figure and minimum bit error rate (BER) is calculated for each and every value case. Fiber Bragg Grating (FBG) is discussed in detail in section 2. Parameters of system design are presented in section 3. The results and conclusion are given in section 4 and 5 respectively.

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2. DISPERSION COMPENSATION TECHNIQUE- FBG

The FBG device can compensate dispersion at multiple variations of the wavelength unlike DCF.

Therefore it is a suitable solution for dispersion compensation [10]. A Fiber Bragg Grating (FBG) is a periodic perturbation of the refractive index along the fiber length which is formed by exposure of the core to an intense optical interference pattern. This exposure leads to increase in the refractive index. A fixed index modulation pattern is formed due to exposure called grating [11]. The Bragg wavelength given by:

$\lambda_b = 2n\Lambda$,where Λ is the grating period and n is the average mode index.

In this, propagated light which satisfies the Bragg condition is resonated by grating structure and reflected and thus we get only a small part of the signal and rest all goes out of the fiber. Spacing decreases along fiber means bragg wavelength decreases along the grating length.

Shorter wavelength components travel farther, experience more delay than longer wavelength components and relative delay introduced by grating is opposite to delay caused by fiber. This results in dispersion compensation since the grating compress the pulse [12]. So in this way a FBG works as a dispersion compensator.

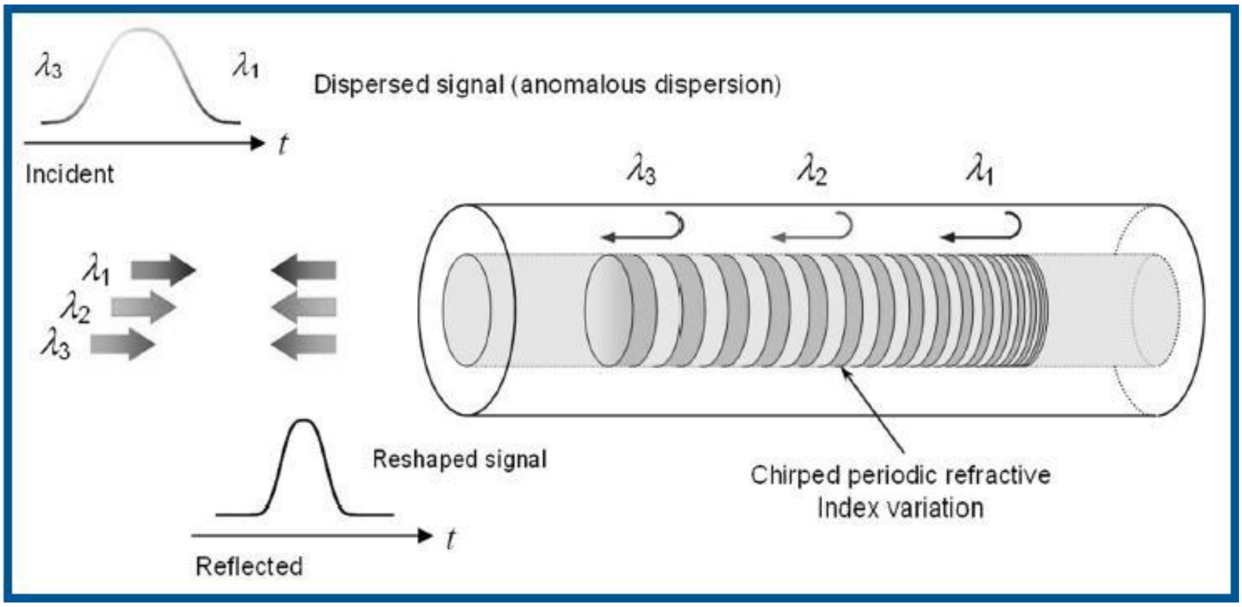

Figure 1. A FBG compensates dispersion by reflecting different wavelengths at different locations along the length [7].

3. SYSTEM DESIGN

In this simulation design, the Non return to zero (NRZ) modulation format is used to produce the electrical signal from the output of Pseudo Random Bit Sequence (PRBS) generator.An advantage of the NRZ format is that the bandwidth associated with the bit stream is smaller than that of the RZ format by about a factor of 2 simply because on–off transitions occur fewer times. The NRZ format is often used in practice because of a smaller signal bandwidth associated with it [1]. A continuous wave CW LASER with frequency 193.1 THz is used to produce the optical signal. The Mach-Zehnder modulator has three ports, two inputs (one electrical signal and other optical signal) and one output port (optical signal).

The output of continuous wave CW LASER is externally modulated with NRZ binary sequence in Mach-Zehnder modulator which is externally modulated at 12 Gbps with an extinction ratio of 30 dB. The fiber used is single mode fiber with dispersion of 16.75 ps/nm/km. Employed EDFA in this model has the gain amount of 6 dB which is independent of wavelength and ignorable noise that is only used for dispersion compensating and nonlinear effects in transmission system. A PIN photo detector is used at the receiver to convert the optical signal back into the electrical signal has responsivity of 1 A/W. The FBG of 5 mm is used before the PIN photo detector to compensate the dispersion. The simulated circuit diagram of the system is shown in figure 2.

The initial values of various components are as follows:

- CW Input Power: 5 dBm
- CW LASER frequency: 193.21 Thz
- Fiber length: 15 Km
- Reference wavelength: 1550 nm
- Mach-Zehnder modulator extinction ratio: 30 dB
- Attenuation coefficient: 0.2 dB/Km
- EDFA length: 5m
- FBG length: 5mm
- Bit rate: 12 Gbps
- PIN photodiode responsivity: 1A/W
- PIN photodiode dark current: 10 nA

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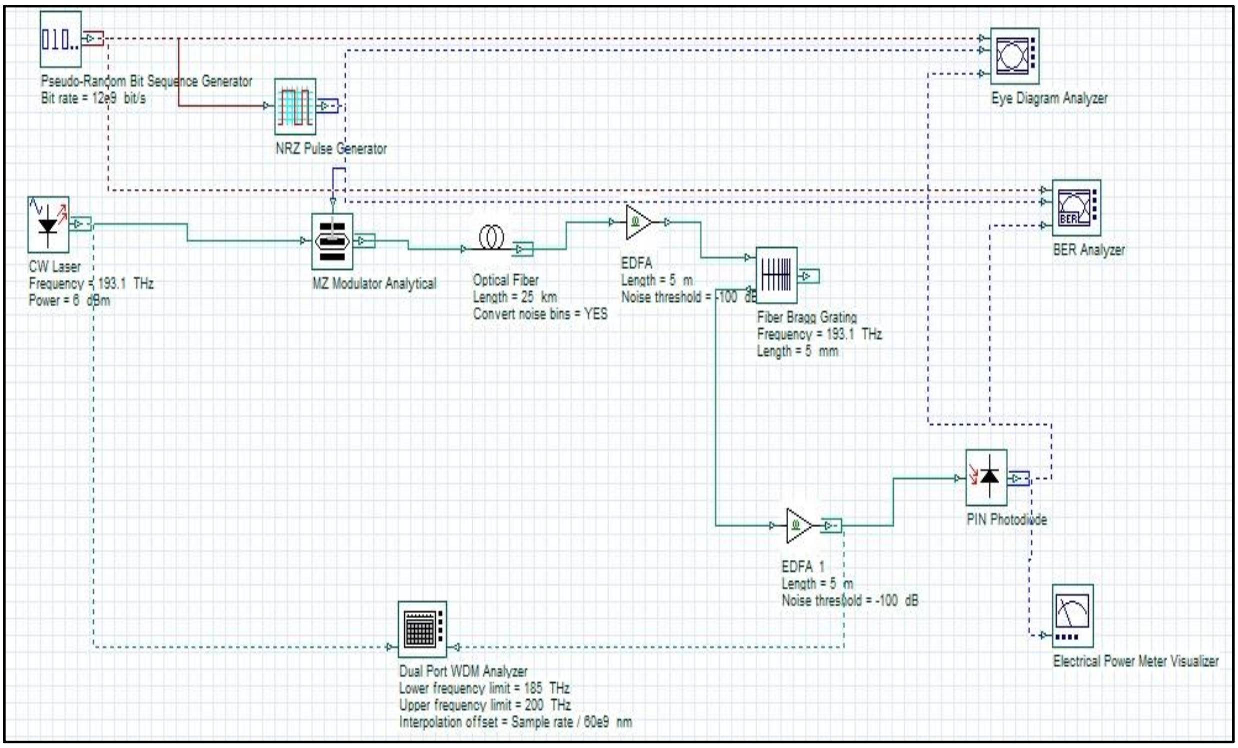


Figure 2. A model of simulated system at 12 Gbps.

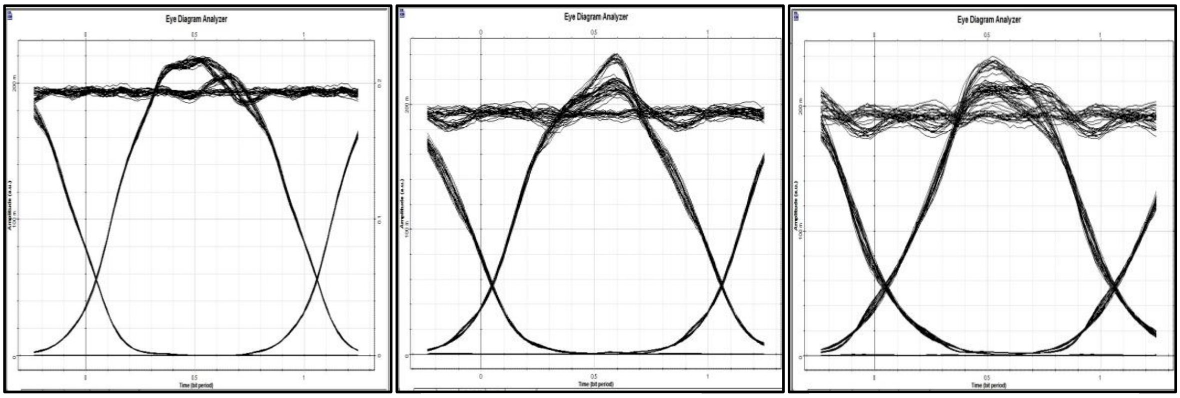
4. RESULTS AND DISCUSSION

(A) Effect of Fiber Length: In this case the following parameters are taken to see the effect of fiber length.

- FBG length: 5mm
- Input power: 5 dBm
- Attenuation coefficient: 0.2 dB/km

LENGTH (Km)	QUQLITY FACTOR	GAIN(dB)	O/P POWER (dBm)	NOISE FIGURE(dB)	MIN BER
5	85.9818	14.532058	12.151	7.1235709	0
10	39.9253	14.516543	12.106	7.9656132	0
15	24.7774	14.501854	12.066	8.8372598	7.4536e-136
20	16.5193	14.486182	12.028	9.7351718	1.09059e-061
25	10.7401	14.469868	11.986	10.655083	2.775e-027
30	8.57637	14.452663	11.928	11.594192	4.54887e-018

Table 1 Performance parameters at different values of fiber length



(c) 5 km (b) 10 km (a) 15 km

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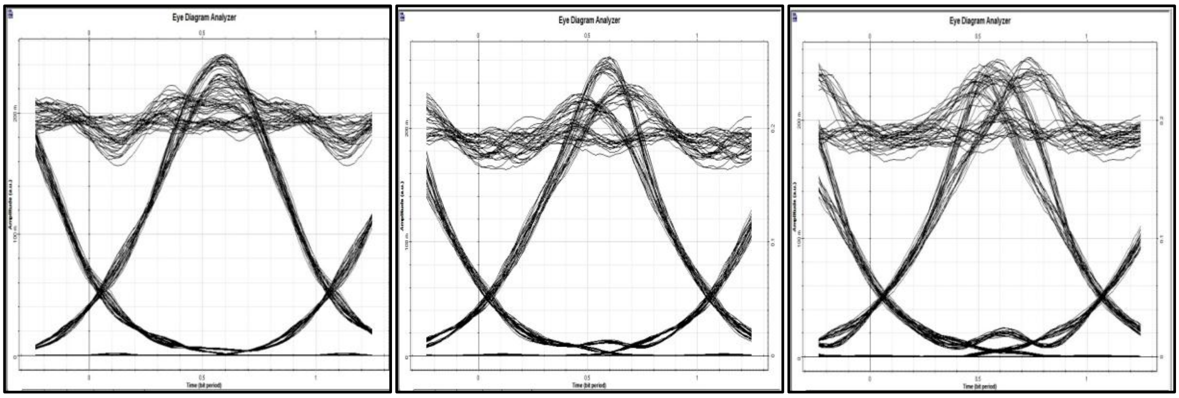
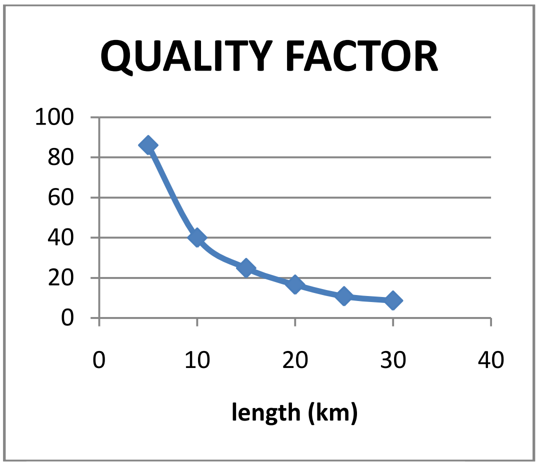
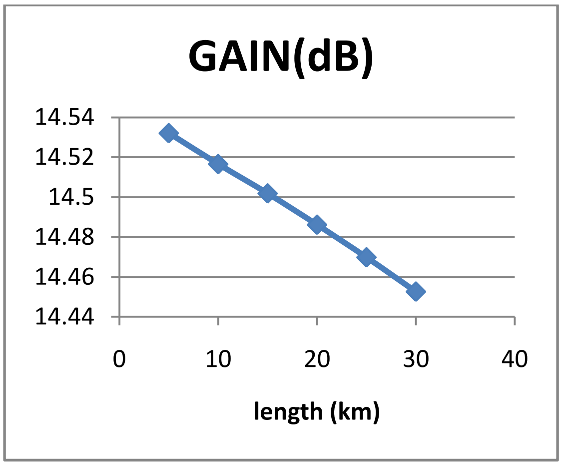


(d) 20 km (e) 25 km (f) 30 km

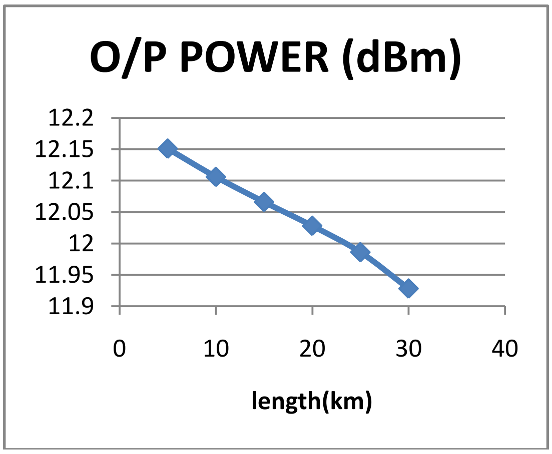
Figure 3. Eye diagram at different values of fiber length.



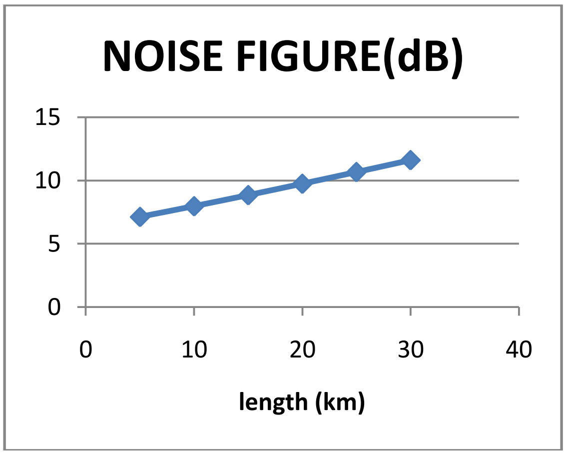
(a) Fiber length vs. Quality factor



(b) Fiber length vs. Gain



(c) Fiber length vs. Output power



(d) Fiber length vs. Noise figure

Figure 4 Graphs showing variation in (a) Quality factor, (b) Gain, (c) Output power and (d) noise figure as a function of Fiber length

(B)Effect of Input Power: In this case the following parameters are taken to see the effect of fiber length.

- FBG length: 5mm
- Fiber length: 15 km
- Attenuation coefficient: 0.2 dB/km

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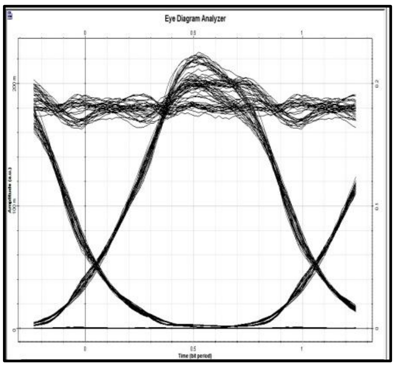
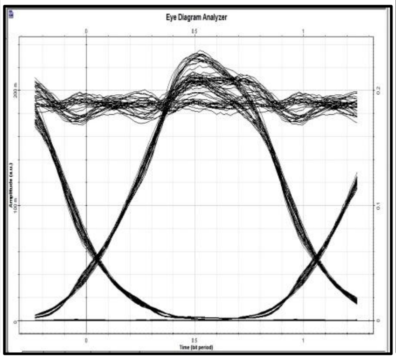
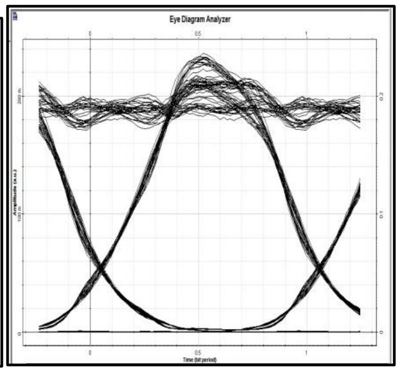
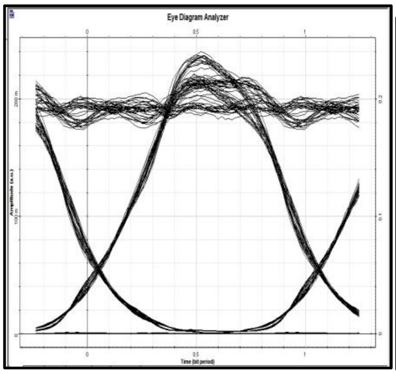
POWER(dBm)	QUALITY FACTOR	GAIN(dB)	O/P POWER (dBm)	NOISE FIGURE (dB)	MIN BER
-5	24.0053	24.23164	11.523	8.5572553	1.10154e-127
0	24.2578	19.411598	11.884	8.5209446	2.59507e-130
1	24.3277	18.433637	11.928	8.5499541	4.7325e-131
5	24.7774	14.501854	12.066	8.8372598	7.4536e-136
10	26.3439	9.5867413	12.242	9.806631	2.85353e-153
15	30.0306	4.7477556	12.596	11.780516	1.80919e-198

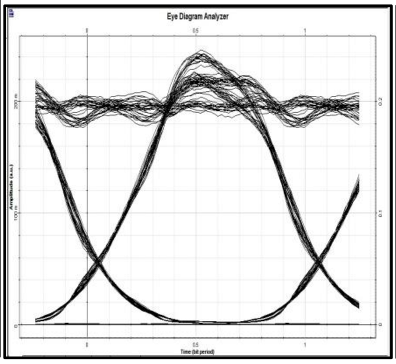
Table 2 Performance parameters at different values of input power


(a). -5 dBm


(b). 0 dBm


(c). 1 dBm


(d). 5 dBm


(e). 10 dBm

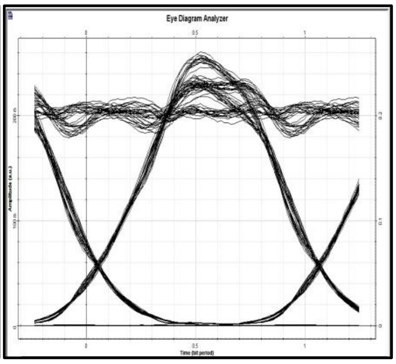
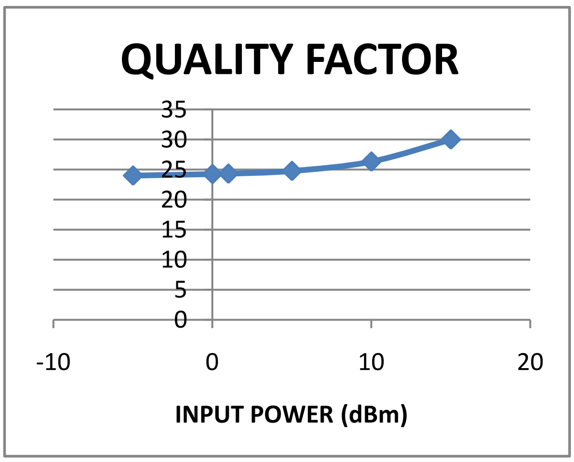
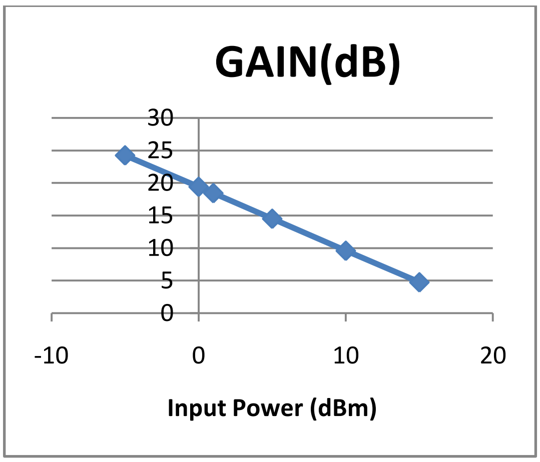

(f). 15 dBm

Figure 5. Eye diagram at different values of Input power



(a). Input power vs. Quality factor



(b). Input power vs. Gain

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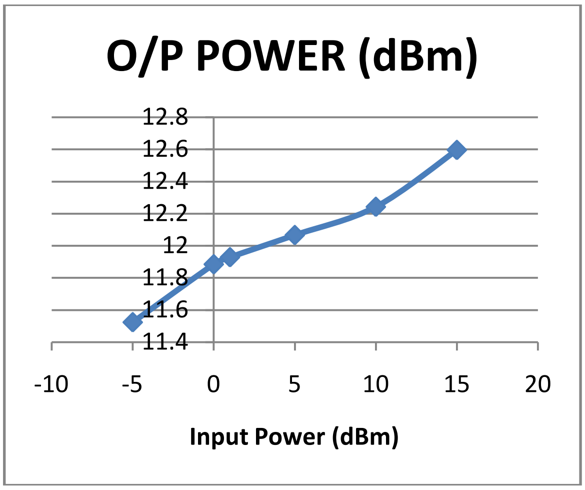
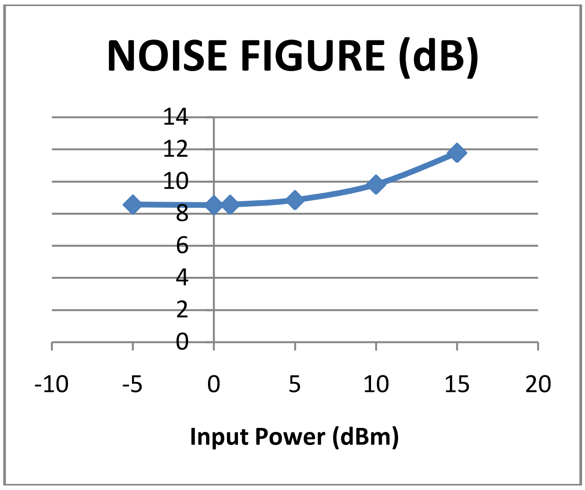


(c). Input power vs. Output power



(d). Input power vs. Noise figure

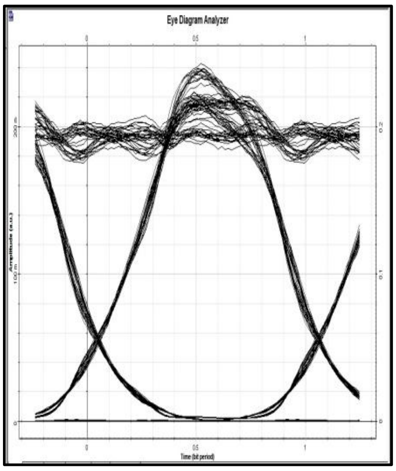
Figure 6. Graphs showing variation in (a) Quality factor, (b) Gain, (c) Output power and (d) noise figure as a function of Input power

c) Effect of Attenuation Coefficient: Similarly the following values are made fixed to analyze the effect of attenuation coefficient (dB/km). :

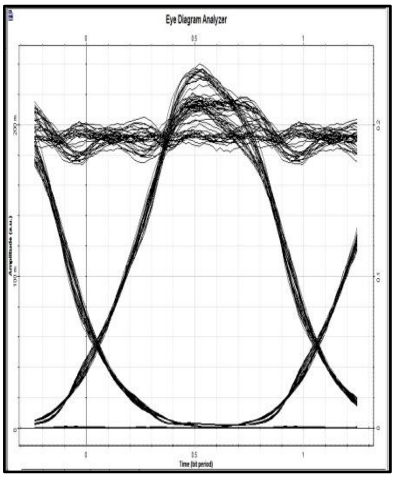
- FBG length: 5mm
- Input power: 5 dBm
- Fiber length: 15 km

ATTENUATION COFFECIENT (dB/Km)	QUALITY FACTOR	GAIN (dB)	O/P POWER (dBm)	NOISE FIGURE (dB)	MIN BER
0	24.986	14.548575	12.160	6.313825	4.10742e-138
0.2	24.7774	14.501854	12.066	8.8372598	7.4536e-136
1	23.9553	14.1077	11.277	20.64395	3.65521e-127
2	13.7101	12.694933	8.493	36.384101	3.53057e-043
3	2.88398	10.603128	5.790	51.963288	0.00142035
5	0	-1.#INDe+2147483648	0.056	100	1

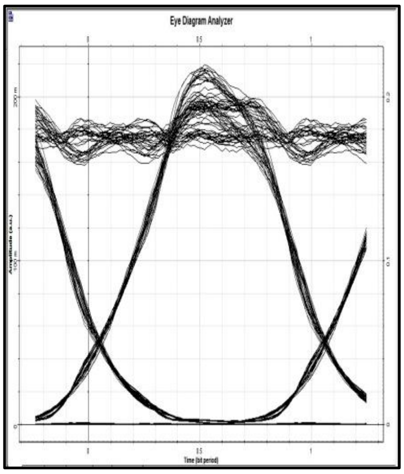
Table 3. Performance parameters at different values of attenuation coefficient



(a). 0 dB/km



(b). 0.2dB/km



(c). 1dB/km

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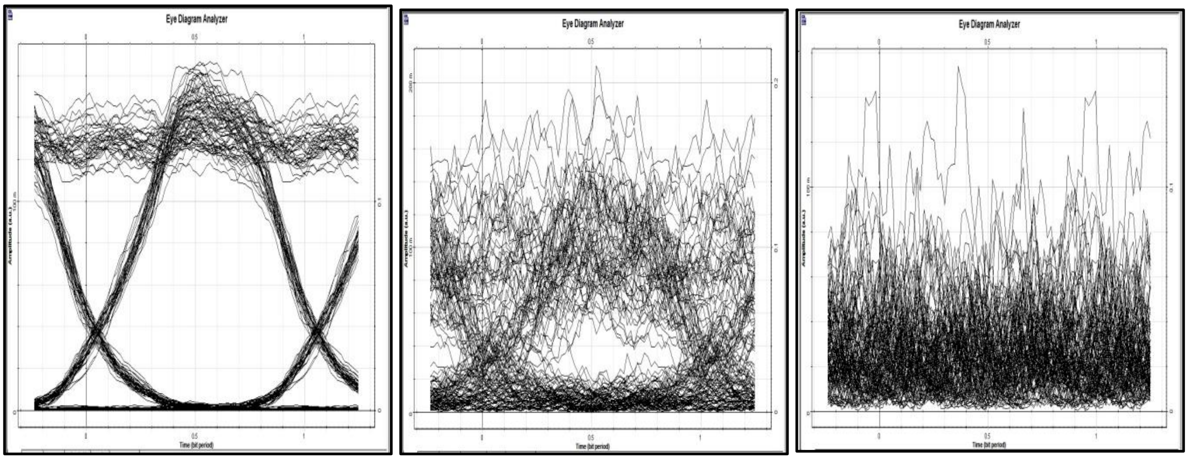
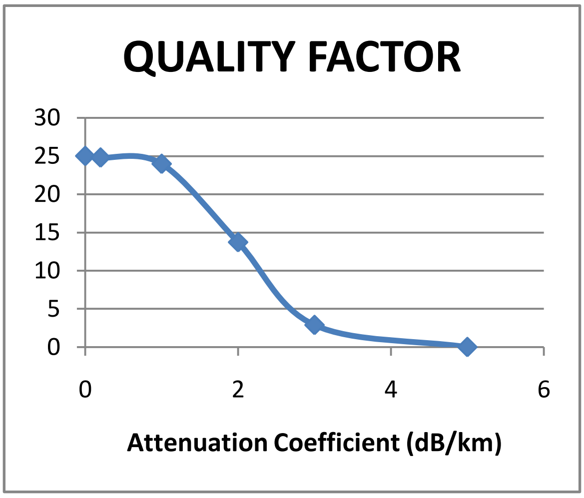
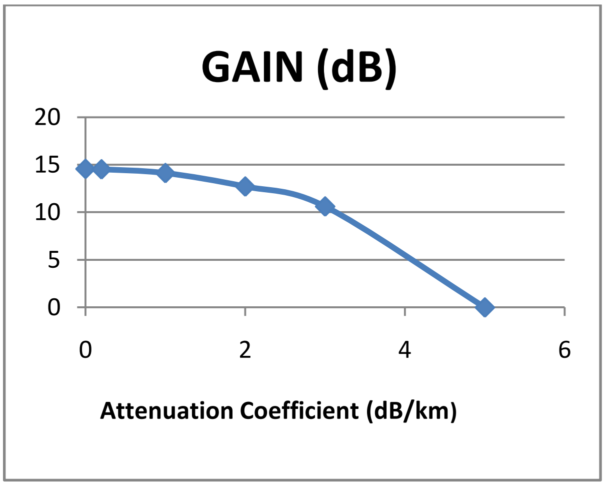


(d). 2dB/km (e). 3dB/km (f). 5dB/km

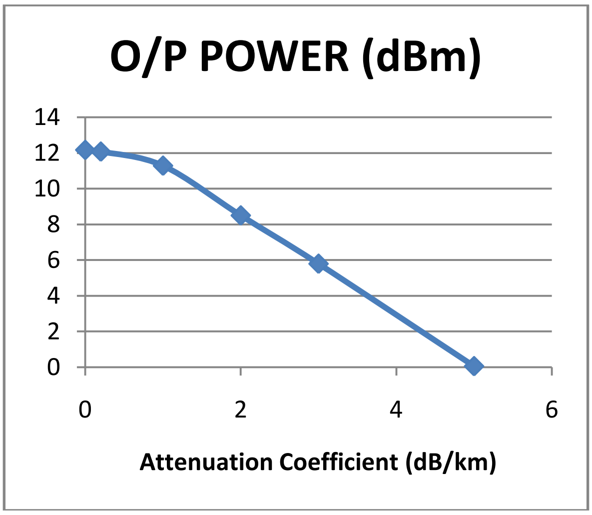
Figure 7. Eye diagram at different values of Input power



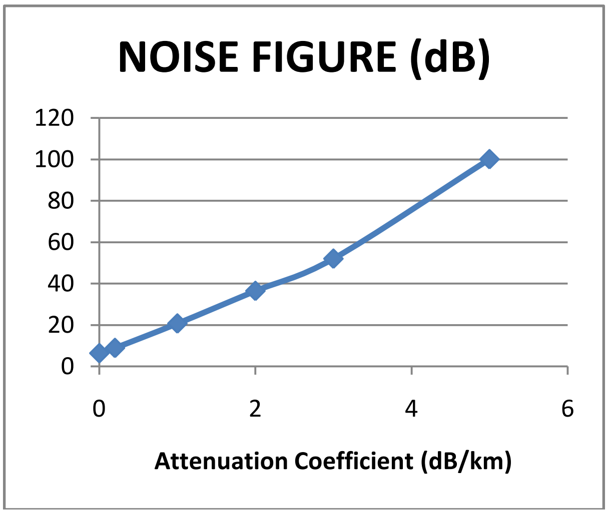
(a). Attenuation coefficient vs. Quality factor



(b). Attenuation coefficient vs. Gain



(c). Attenuation coefficient vs. Output power



(d). Attenuation coefficient vs. Noise figure

Figure 8. Graphs showing variation in (a) Quality factor, (b) Gain, (c) Output power and (d) noise figure as a function of Attenuation coefficient.

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 9, September 2016

5. CONCLUSION

We have analyzed all the three factors that is fiber length, input power and attenuation coefficient at the 12 Gbps with FBG length of 5mm. From the above results, it can be concluded that-

1. The Quality factor decreases with fiber length (km) and Attenuation coefficient (dB/km), whereas it increases with Input power (dBm).
2. The Gain (dB) of the system is inversely proportion to all three factors means the gain (dB) of the system decreases with increase in the value of fiber length (km), Attenuation coefficient (dB/km) and Input power (dBm).
3. The output power (dB) show an increase in the value with increasing Input power (dB) and decreases with Fiber length (km) and Attenuation coefficient (dB/km).
4. The Noise figure (dB) increases with all the three factors namely Fiber length (km), Attenuation coefficient (dB/km) and Input power (dBm).

So in the last we can make the conclusion that the simulated system performance parameters like quality factor, Gain (dB), Output power (dBm) and Noise figure (dB) gets affected by the Fiber length (km), Input power (dBm) and Attenuation coefficient (dB/km). So in order to compensate dispersion, these performance parameters must be optimized according to Fiber length (km), Input power (dBm) and Attenuation coefficient (dB/km).

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