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Analysis of Dispersion Compensation Using FBG in a 12 GBPS Optical System with RZ Modulation

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Abstract: Dispersion is the main barrier in achieving an efficient Optical Communication system. In this paper we simulate an optical communication system which involves FIBRE BRAGG GRATING (FBG) as a mean of compensating dispersion in the system. RETURN TO ZERO (RZ) modulation format is used to analyze the simulated transmission system for different parameters using OPTISYSTEM Simulator. We have taken different values for parameters like Fiber length (Km), Input power (dBm), and Attenuation coefficient (dB/Km) and analyzed the effect on Quality factor, Gain (dB), output power (dBm), Noise Figure (dB) and Min BER. The system is simulated and all the results are analyzed using OPTISYSTEM 14.0 at 12 GBPS.

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

1. INTRODUCTION

Optical communication is a way of sending information from one place to another place through an optical fiber. The basic optical communication system consists of three parts which are optical fiber (transmission media), light source as the transmitter (converts electric signal into light signal) and a light detector as the receiver (converts light energy into electric signal). In this modern era of technology the use of optical fiber in order to transmit data at high rates in transmission windows having low loss has seen great importance [1], [2]. But in achieving high data rate, dispersion is the main obstacle which degrades the overall system performance. When the signal is transmitted through fiber at transmitter, some losses are observed in receiver end and as a result data from original signal is lost. Dispersion is the time domain spreading or broadening of the transmission signal light pulses as they travel through the fiber. At high data rate, these broaden pulses may overlap with each other causing crosstalk and inter symbolic interference (ISI) which causes errors during reception of the signal at the receiver side of optical link [3]. The use of erbium doped fiber amplifiers (EDFAs) and dispersion compensated fibres (DCF) can compensate dispersion but their use lead to total loses nonlinear effects and the cost of optical transmission systems [4]. Fiber Bragg Gratings (FBG) is a key component to compensate dispersion in a optical communication system. In the transmission section, the gratings are placed in the line with the fiber. It will help to achieve the maximum compression ratio [5]. Fiber bragg gratings (FBG) has an advantage that it is cost effective and has a low insertion loss and is easily compatible with single mode fibres [6]. The FBG post compensation scheme gives better results than DCF's pre, post and symmetrical compensation schemes [7].

2. FIBER BRAGG GRATING (FBG)

The idea of Fiber Bragg Grating (FBG) was first came into existence in 1980 and from then it has many applications and widely researched [8].

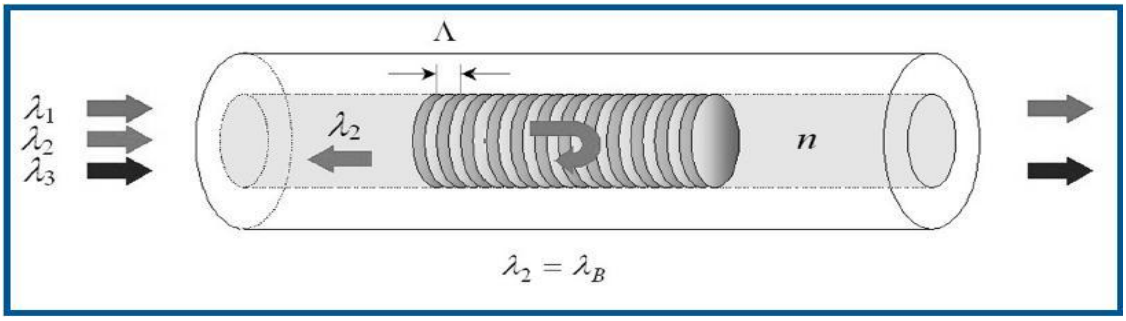

Figure 1 Principle of Fiber Bragg Grating [4]

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A FBG acts as an optical filter because of thr existence of a stop band, the frequency region in which most of the incident light is reflected back [9]. The stop band is centered at Bragg wavelength given by:

$$\lambda_b = 2n\Lambda,$$

where Λ is the grating period and n is the average mode index.

The periodic nature of index variations couple the forward and backward propagating waves at wavelength close to Bragg wavelength, as a result provides frequency-dependent reflectivity to the incident signal over a bandwidth determined by the grating length.

3. DESCRIPTION OF COMPONENETS

The return to zero (RZ) pulse generator is used to produce the electrical data signal. The 12 Gbps system performs better using RZ modulation format because nonlinearity dominates [10]. Pseudo-random bit sequence generator is used to generate a binary sequence with a deterministic algorithm and is difficult to predict. The mach-Zehnder (MZ) modulator is used for controlling the amplitude of an optical wave. It has two inputs (electrical signal and optical signal) and one output (optical signal) [11]. The continuous wave CW LASER is used to produce the optical signal and its output is externally modulated with RZ binary sequence in mach-Zehnder modulator. The output of MZ modulator is allowed to propagate in single mode fiber (SMF). The FBG is used as the dispersion compensator. Photodetector (PIN) diode coverts the optical signal into electrical signal. One photon yields one electron [12].

4. DESIGN CONSIDERATION

The simulated system as shown in Figure 2, consists of a transmitter, transmitter link and a receiver. The input consists of combinations of 0's and 1's is generated by pseudo-random bit sequence generator. The RZ pulse generator generates the electrical signal corresponding to the output of PRBS generator. The CW LASER supplies optical signal with 1550 nm wavelength which is then externally modulated at 12 Gbps with a return to zero (RZ) binary sequence in a Mach- Zehnder modulator with 30 dB of extinction ratio. Single mode fiber is used as it yield higher data rate and has less dispersion. The length of FBG used for dispersion compensation is 6 mm. After compensation the signal will pass through PIN photodetector of responsivity 1 A/W.

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

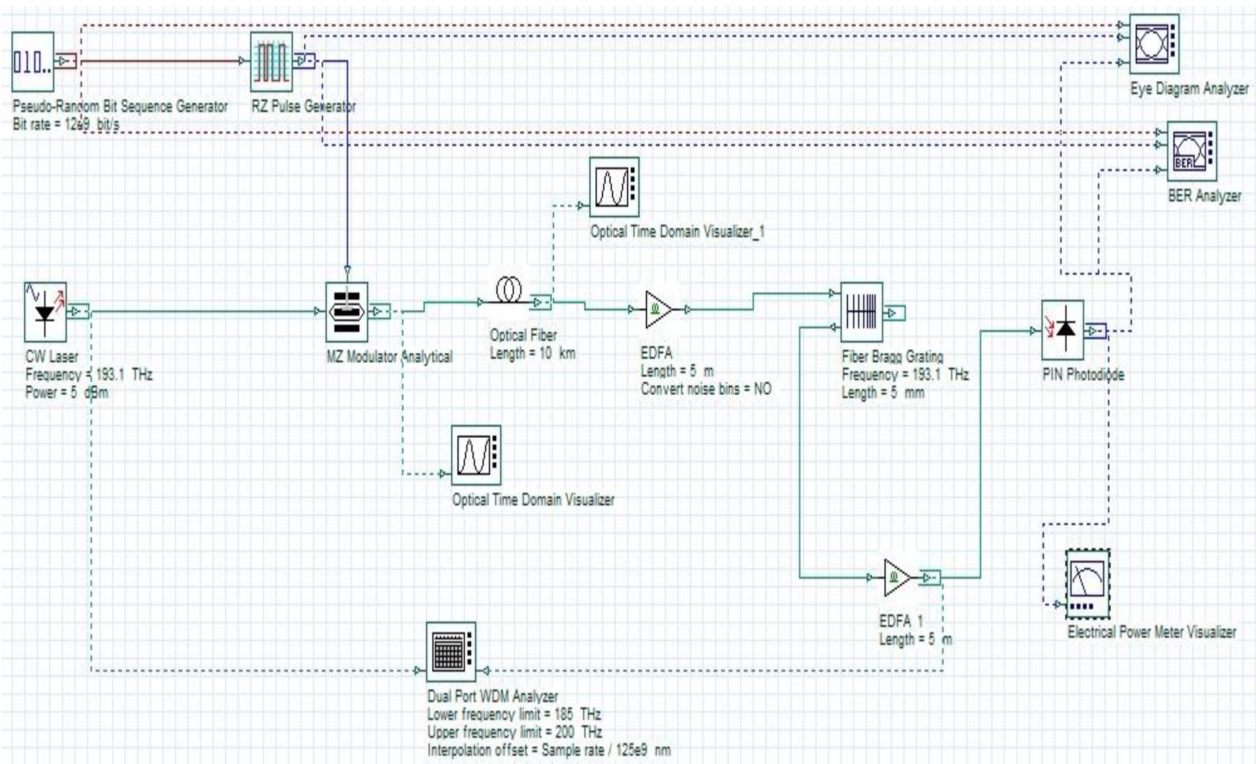

Figure 2. Simulated model of 12 GBPS optical transmission system on Opti system software

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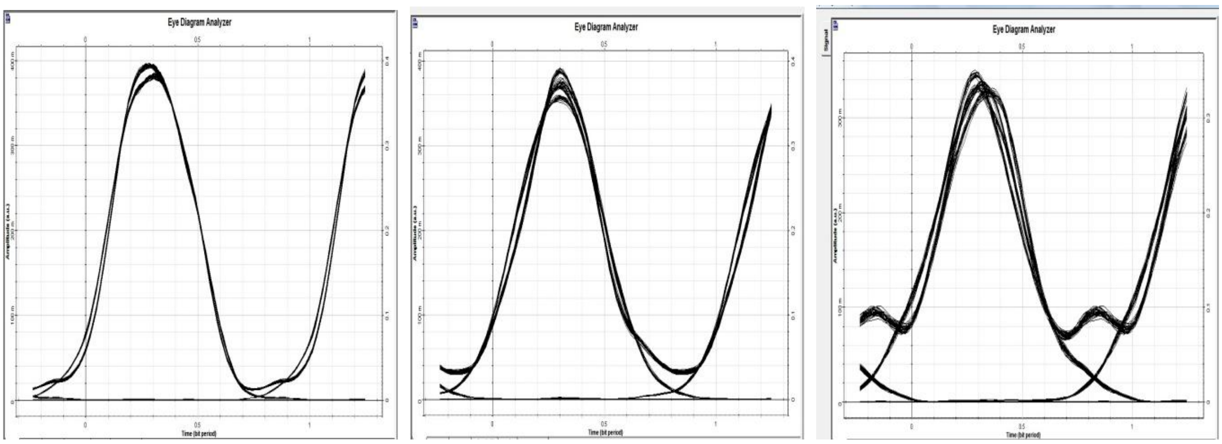
5. RESULTS AND DISCUSSIONS

The design and simulation of the optical dispersion compensation scheme is done by Optisystem 14.0 software. The eye diagrams and graph of quality factor, output power (dBm), gain (dB) and noise figure (dB) are shown in the subsequent tables and figures by varying the fiber length (km), input power (dBm) and attenuation coefficient (dB/km).

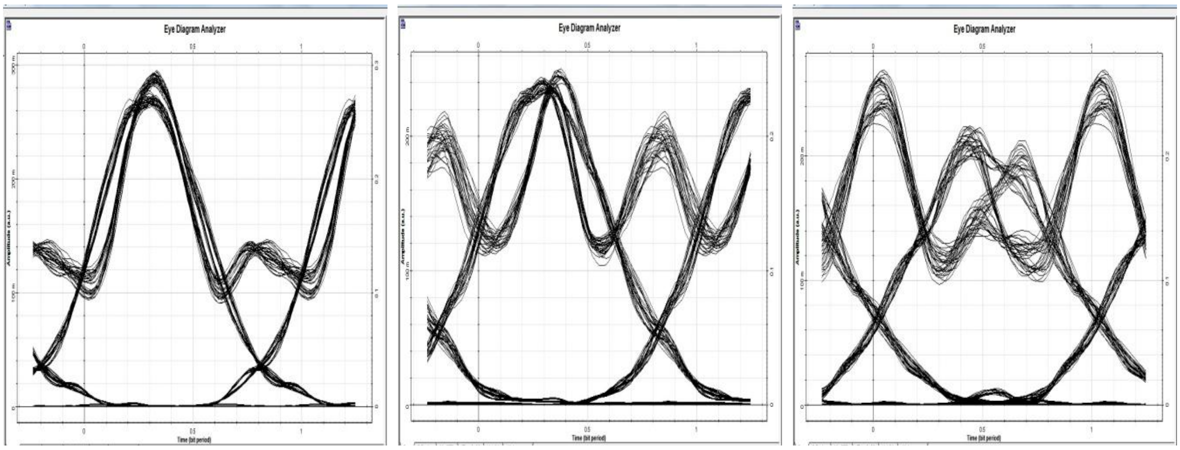
(a). **Fiber length**:

Table 1. Output readings are measured by varying the fiber length.

LENGTH (Km)	QUALITY FACTOR	GAIN(dB)	O/P POWER (dBm)	NOISE FIGURE(dB)	MIN BER
5	255.615	13.350301	13.763	11.457489	0
10	93.6458	13.345381	13.273	12.367143	0
15	53.9588	13.339717	12.641	13.295517	0
20	43.9564	13.328936	11.942	14.245024	0
25	44.34	13.312192	11.420	15.21385	0
30	6.75343	13.290268	11.152	16.199697	5.56948e-012



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



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

Figure 3. Eye diagrams at different fiber length.

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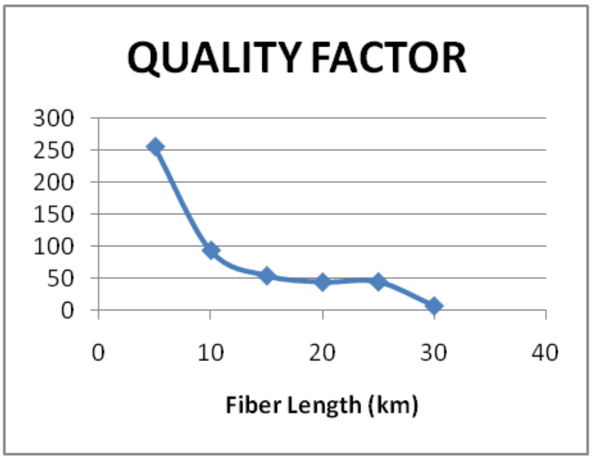
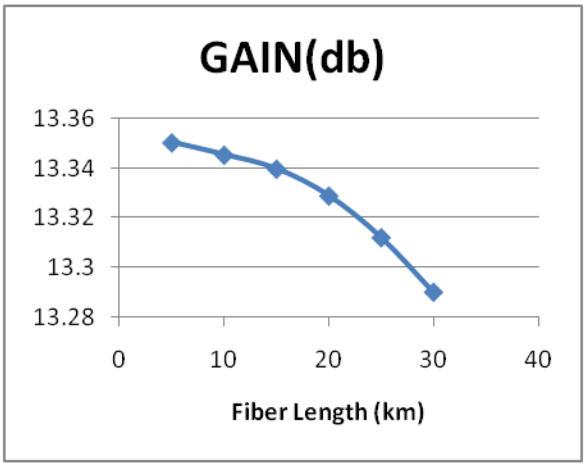
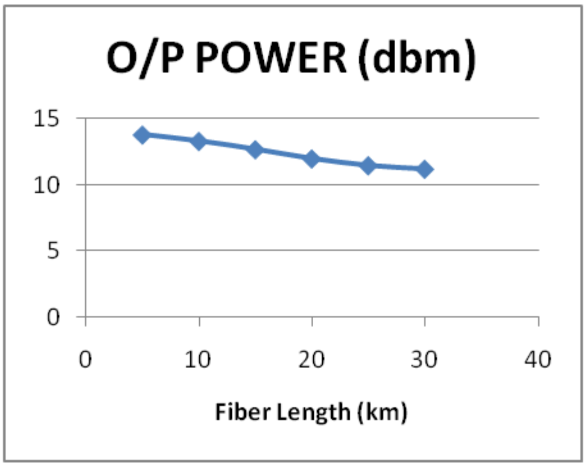


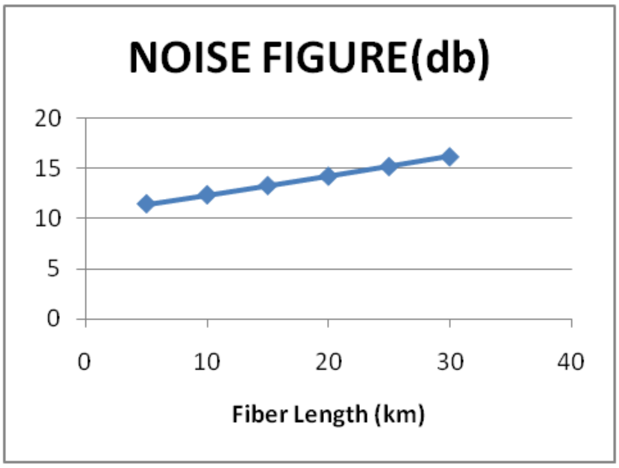
(a). Fibre length vs. Quality factor



(b) Fibre length vs. Gain



(c) Fibre length vs. Output power



(d) Fibre 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). Input Power:

Table 2. Output readings are measured by varying the Input power.

POWER(dBm)	QUALITY FACTOR	GAIN(dB)	O/P POWER (dBm)	NOISE FIGURE (dB)	MIN BER
-5	55.2135	22.952139	11.891	13.442915	0
0	57.1041	18.209556	12.398	13.241997	0
1	56.8607	17.241831	12.462	13.230374	0
5	53.9588	13.339717	12.641	13.295517	0
10	44.6226	8.4571388	12.820	13.736301	0
15	29.5022	3.6832326	13.138	14.867529	$1.01715e^{-191}$
20	41.7129	-1.0322832	13.903	17.219619	0

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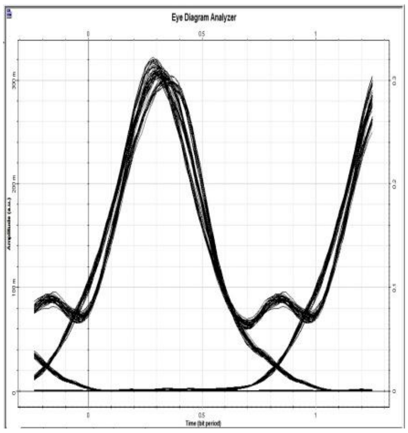
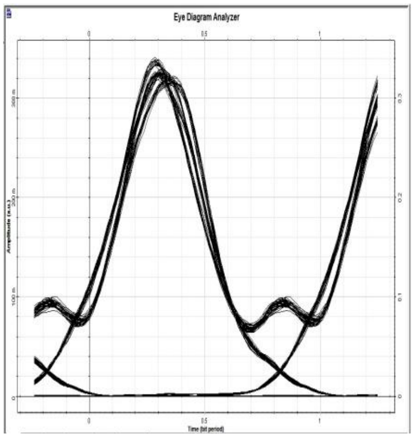
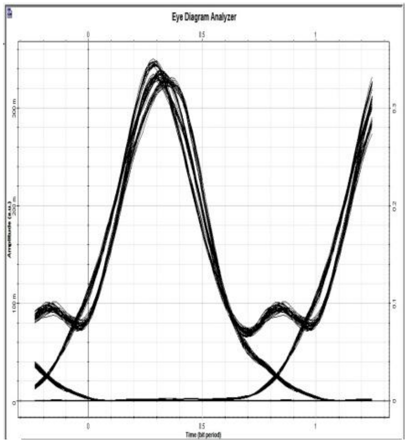


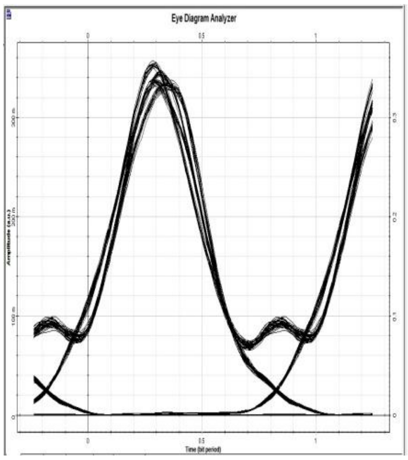
(a) 5 dBm



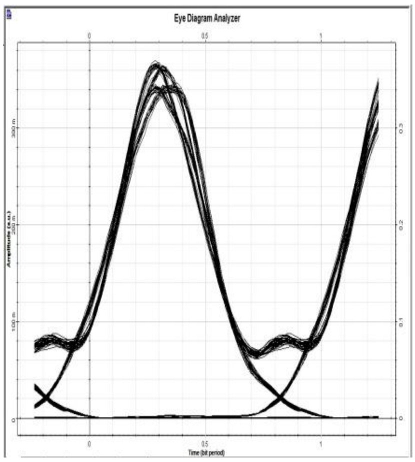
(b) 0 dBm



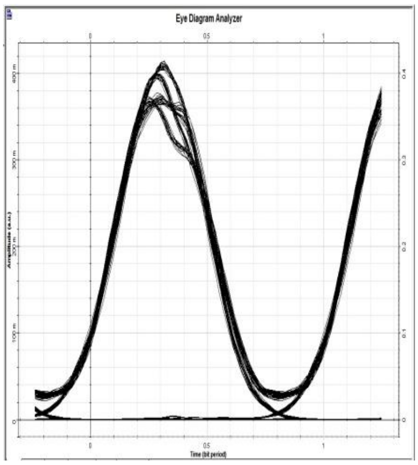
(c) 1 dBm



(d) 5 dBm

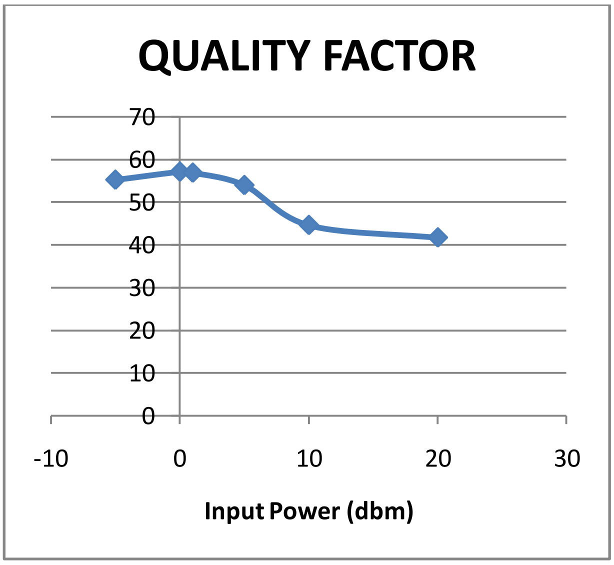


(e) 10 dBm

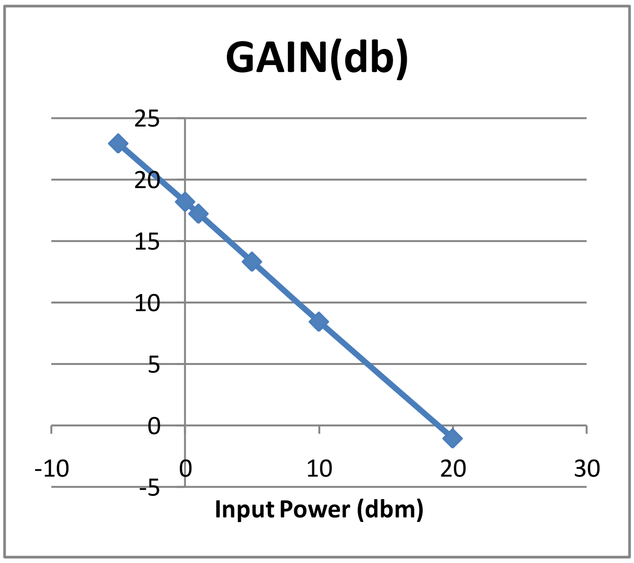


(f) 20 dBm

Figure 5. Eye diagram at different input power



(a) Input power vs. Quality factor



(b) Input power vs. Gain

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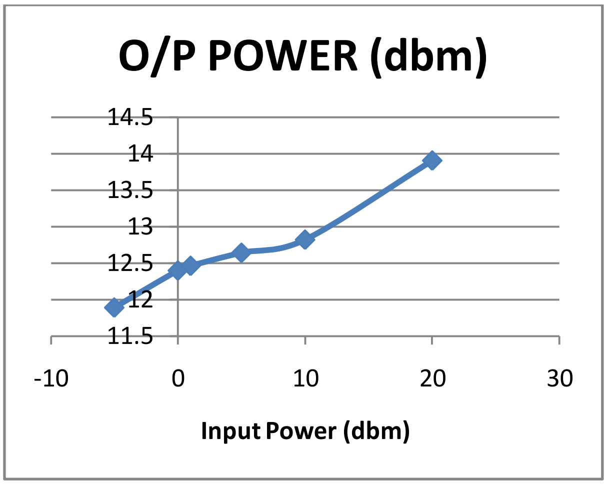
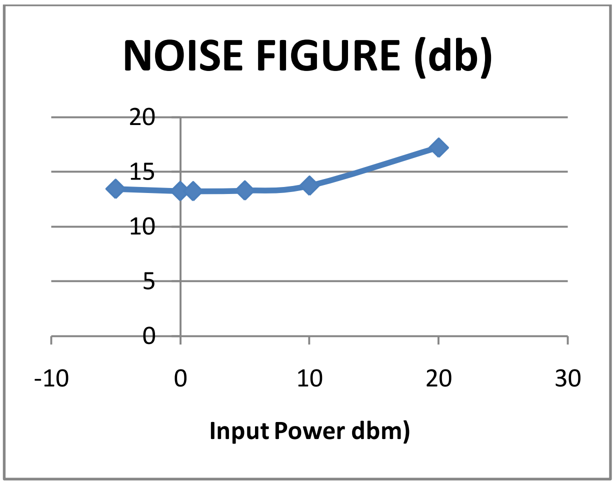




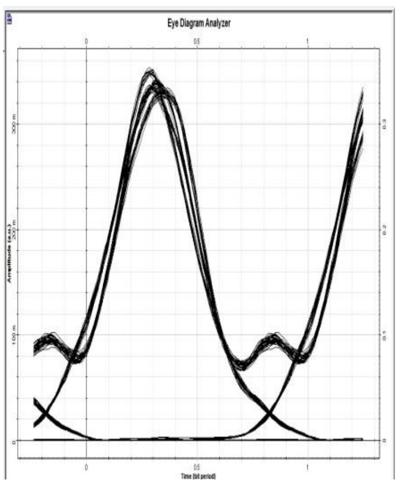
(c) Input power vs. Output power (d) Input power vs. Noise figure

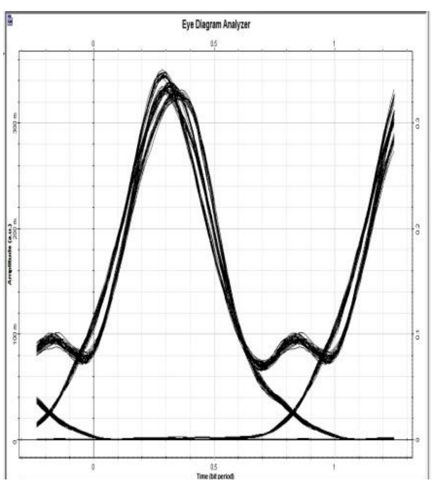
Figure 6. Graphs showing variation in (a) Quality factor, (b) Gain, (c) Output power and (d) noise figure as a function of Input power.

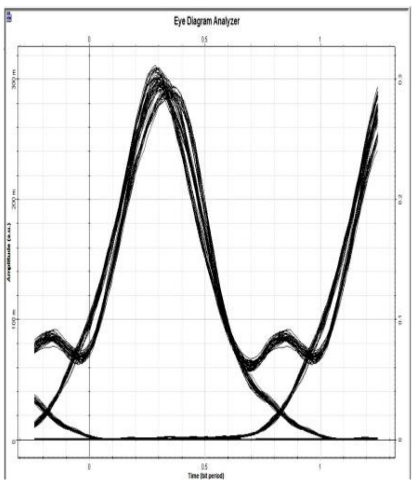
(c) Attenuation coefficient:

Table 3. Output readings are measured by varying the Attenuation coefficient.

ATTENUATION COFFECIENT (dB/Km)	QUALITY FACTOR	GAIN (dB)	O/P POWER (dBm)	NOISE FIGURE (dB)	MIN BER
0	52.2241	13.394197	12.731	10.511867	0
0.2	53.9588	13.339717	12.641	13.295517	0
1	51.3733	12.800283	11.588	25.56558	0
2	15.4996	11.595483	9.296	41.194998	1.14139e-054
3	2.40601	7.0407248	4.716	57.974617	0.00658346
5	0	-1.#INDe+2147 483648	0.046	100	1







(a) 0 dB/Km (b) 0.2 dB/Km (c) 1 dB/Km

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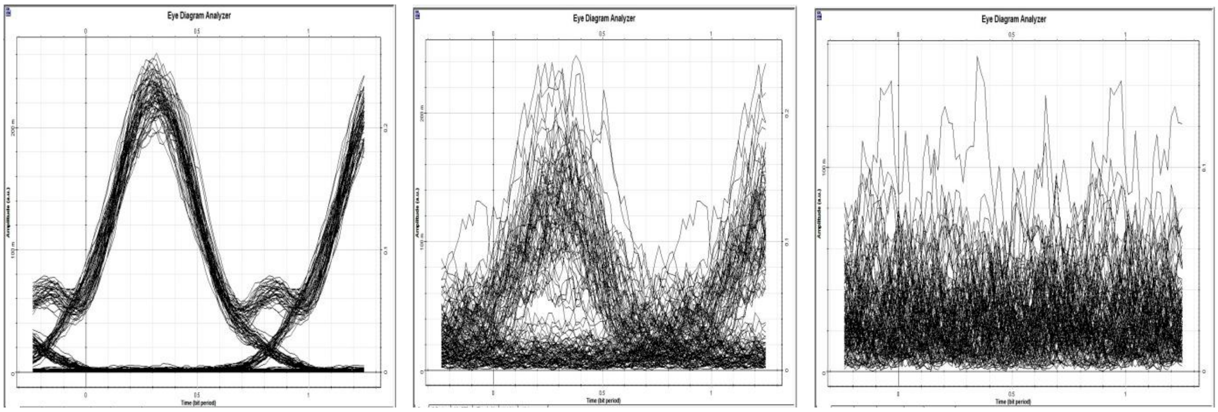
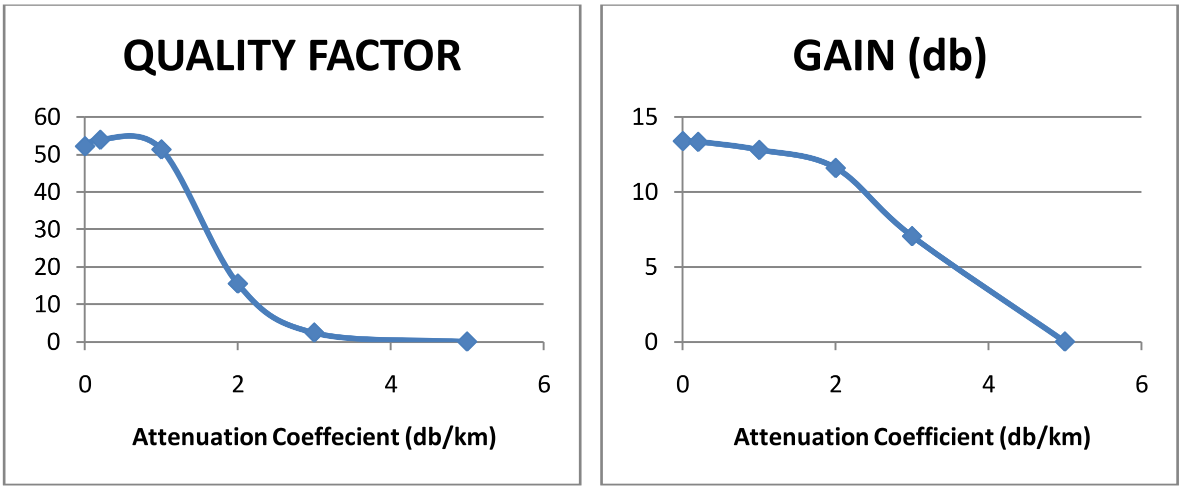
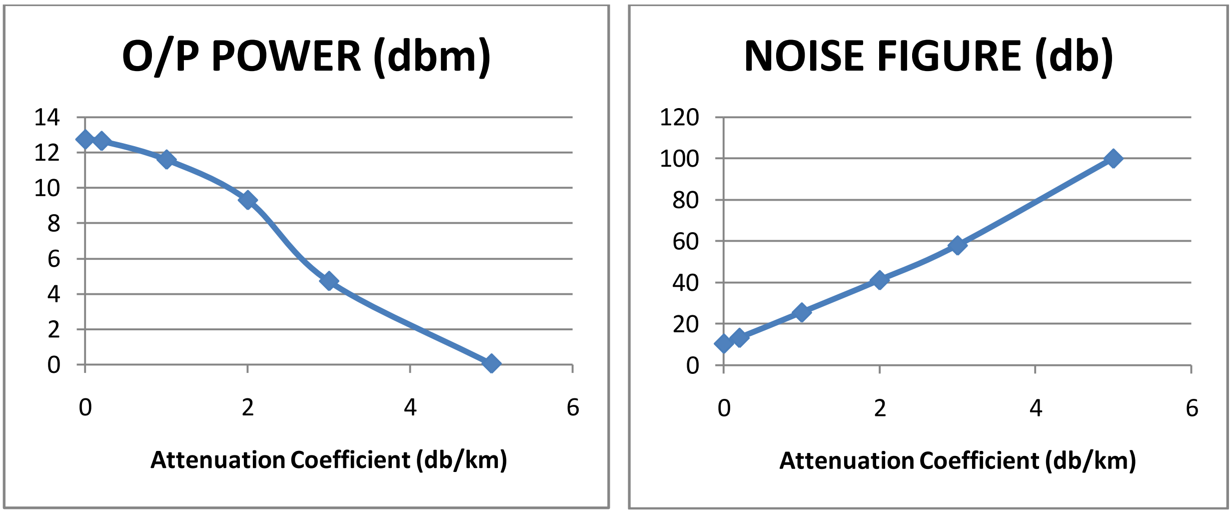


(d) 2 dB/Km (e) 3 dB/Km (f) 5 dB/Km

Figure 7. Eye diagram at different Attenuation coefficient.



(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.

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7. CONCLUSION

We have analyzed the dispersion compensation using FBG and concluded that:

1. On increasing the fiber length (km), the quality factor, gain (dB) and output power decreases while the noise figure (dB) increases.
2. On increasing the input power (dBm), the quality factor first increases and show maximum at 0 dBm input power then it continuously decreases with increasing input power. The gain (dB) decreases with increasing input power. The other two parameters output power (dBm) and noise figure (dB) both increases with increasing input power (dBm).
3. On increasing the attenuation coefficient (dB/Km), the quality factor, gain (dB) and output power (dBm) decreases while the noise figure (dB) increases.

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