Performance Evaluation of 32 Channel DWDM System Using Dispersion Compensation Unit at Different Bit Rates

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Abstract - *Dense wavelength division multiplexing (DWDM) is a WDM technology with reduced channel spacing that can transmit multiple information streams simultaneously over the single fiber. In this paper, a 32 channel DWDM system is modeled, simulated and analyzed for 120 km and 80 km distances using dispersion compensation unit, i.e., Dispersion Compensating Fiber (DCF) and Fiber Bragg Grating (FBG). The performance of Non Return to Zero (NRZ) and Return to Zero (RZ) modulation formats with post-dispersion compensation using DCF at different bit rates (10, 20 and 40 Gbps) is investigated. The simulation is done in Optisystem simulator. The performance of the simulated system has been investigated in terms of quality (Q) factor and bit error rate (BER).*

*Key Words***: Dispersion Compensating Fiber, Fiber Bragg Grating, Dense Wavelength Division Multiplexing, Q-Factor, Bit Error Rate**

1. INTRODUCTION

1.1 Optical Fiber Communication

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information. The optical carrier frequencies are typically 200 THz, in contrast with the microwave carrier frequencies (1GHz). Optical communication systems have the potential of carrying information at bit rates 1 Tb/s [1]. The use and demand for optical fiber has grown tremendously and there are many optical-fiber applications.

Telecommunication applications are widespread, ranging from global networks to desktop computers. These involve the transmission of voice, data, or video over distances of less than a meter to hundreds of kilometers, several cable designs [2].

1.2 Advantages of Optical Communication

   a. Enormous Potential Bandwidth
   b. Small size and weight
   c. Electrical Isolation
   d. Immunity to interference and crosstalk

   e. Signal Security
   f. Low Transmission Loss
   g. Ruggedness and Flexibility
   h. System Reliability and ease of maintenance
   i. Low Potential Cost [3]

1.3 Obstacles in Fiber Optic Communication

   a. Attenuation
   b. Dispersion
   c. Non-Linearity

2. DISPERSION

Dispersion is defined as pulse spreading in an optical fiber. As a pulse of light propagates through a fiber, elements such as numerical aperture, core diameter, refractive index profile, wavelength, and laser line width cause the pulse to broaden. Dispersion increases along the fiber length. The overall effect of dispersion on the performance of a fiber optic system is known as Intersymbol Interference (ISI). Intersymbol interference occurs when the pulse spreading caused by dispersion causes the output pulses of a system to overlap, which further leads to signal degradation[2]. Dispersion is generally divided into three categories: modal dispersion, chromatic dispersion and polarization mode dispersion.

3. DISPERSION COMPENSATION TECHNIQUES

There are various methods for dispersion compensation namely, Dispersion Compensating Fiber (DCF), Optical filter, Fiber Bragg Grating (FBG), Optical Phase Conjugation, Electrical Dispersion Compensation, Digital Filters etc. Each technique has its own advantages and disadvantages. The most commonly used techniques are DCF and FBG [4].

3.1 Dispersion Compensating Fiber (DCF)

DCF is a loop of fiber having negative dispersion equal to the dispersion of the transmitting fiber. It can be inserted at either beginning (pre-compensation techniques) or end (post-compensation techniques) between two optical amplifiers. In symmetrical compensation DCF is inserted both before and after the standard mode fiber [5–7].

The positive dispersion of standard mode fiber in C and L band can be compensated by using dispersion compensating fiber having high values of negative dispersion -70 to -90 ps/nm.km.

A DCF module should have low insertion loss, low polarization mode dispersion and low optical nonlinearity. By placing one DCF with negative dispersion after a SMF with positive dispersion, the net dispersion will be zero.

$$D_{SMF} \times L_{SMF} = -D_{DCF} \times L_{DCF} \qquad (1)$$

where D and L are the dispersion and length of fiber segment respectively.

3.2 Fiber Bragg Grating (FBG)

One of the most advanced and most commonly used technique in the dispersion compensation methods is FBG. FBG is a piece of optical fiber with the periodic variation of refractive index along the fiber axis. This phase grating acts like a band rejection filter reflecting wavelengths that satisfy the Bragg condition and transmitting the other wavelengths. The reflected wavelength changes with grating period. Thus, FBG is very simple and low cost filter for wavelength selection that improves the quality and reduces the costs in optical networks [8]. The equation relating the grating periodicity, Bragg wavelength and effective refractive index of the transmission medium is given by:

$$\lambda_B = 2n\Lambda \qquad (2)$$

In this equation, λ_B, n and Λ are the Bragg wavelength, refractive index of core and grating period respectively.
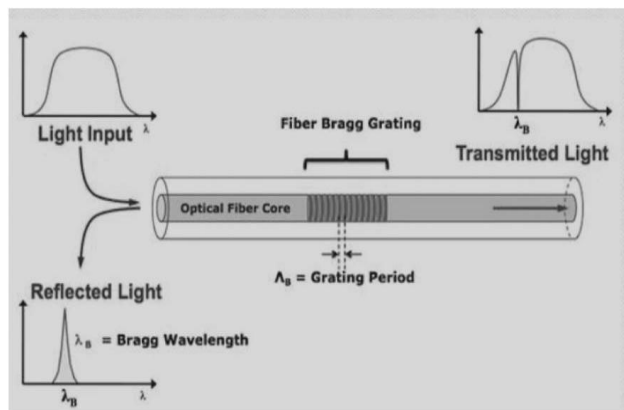

Fig-1 Principle of FBG [9]

4. SIMULATION SETUP

The 32 channel DWDM system using DCF and FBG as dispersion compensation techniques is designed and simulated in OptiSystem simulator software (Version 7). The parameters in Table 1 are used for the simulated system and Table 2 describes the fiber parameters.

Table-1: Simulation Parameters

Parameters	Value
Data rates	10, 20, 40 Gb/s
Sequence length	128 bits
Samples per bit	64
C/W Laser Frequency	193.4 THz
Reference Wavelength	1550nm
C/W Input Power	10dbm
Modulator Extinction ratio	30 dB
Channel spacing	100 GHz
Capacity	32x40 Gbps , 32x20 Gbps, 32x10 Gbps

Table-2: Fiber Parameters

Parameters	SMF	DCF
Length (km)	120	24
Length (km)	80	16
Attenuation (db/km)	0.2	0.5
Dispersion (ps/nm/km)	17	-85
Dispersion slop (ps/nm2/km)	0.075	-0.3
Differential group delay (ps/km)	0.2	0.2
PMD coefficient (ps/nm)	0.5	0.5

Fig. 2 shows simulation setup for combined DCF and FBG dispersion compensators with NRZ modulation format and fig. 3 shows simulation setup with RZ modulation format. The system is operated with the basic optical communication which consists of a transmitter, transmission link and a receiver at different data rates (10, 20, 40 Gbps). The system transmits information using optical carrier wave from transmitter to receiver via optical fiber. Each transmitter section consists of bit sequence generator, NRZ or RZ pulse generator, CW laser and Mach-Zehnder (M-Z) modulator.

Optical multiplexer that has 32 input ports is used to combine the signals and transmits over the single fiber link. For the dispersion compensator, DCF and FBG are used. After dispersion compensation the signal will pass through optical amplifier that is represented by Erbium-doped fiber amplifier (EDFA). Optical amplification is required to overcome the fiber loss and also to amplify the signal before received by Photo detector PIN at the receiver part. Optical channel consists of 120 km of SMF and 24 km of DCF. Also the system is analyzed for 80 km of SMF and 16 km of DCF.

Combined effect of DCF and FBG dispersion compensation scheme is used to compensate for the positive dispersion accumulated over the length of SMF.
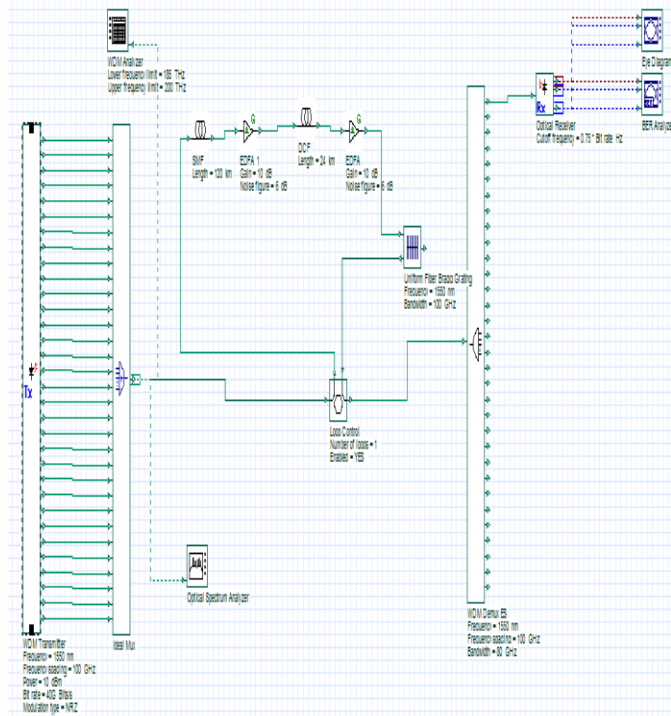

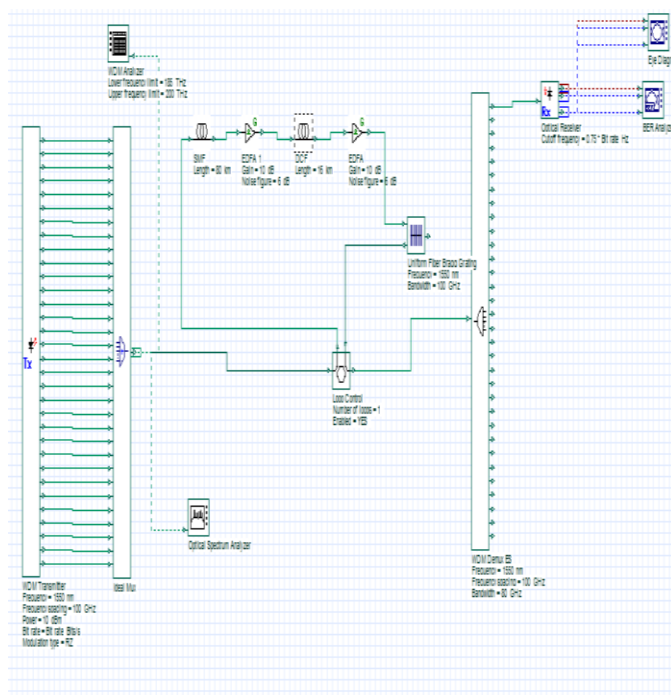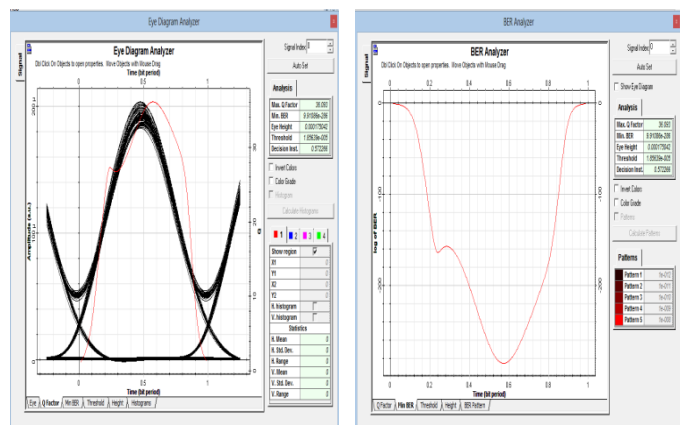**Fig-2:** Simulation Setup for NRZ Modulation Format Using DCF and FBG as Dispersion Compensators

Fig-3: Simulation Setup for RZ Modulation Format Using DCF and FBG as Dispersion Compensators
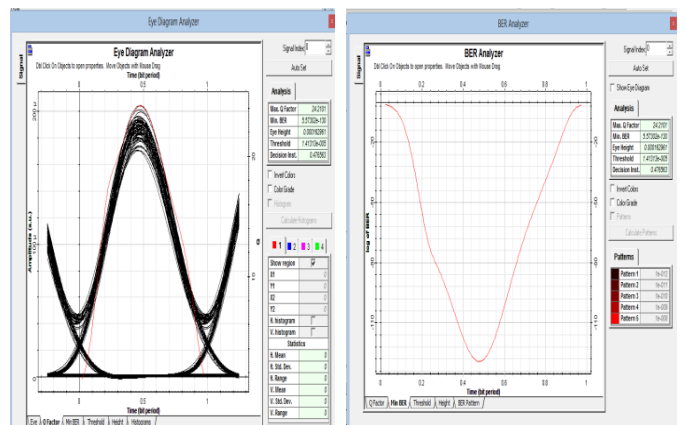
5. RESULTS AND DISCUSSION

The simulation is carried out to evaluate the performance of dispersion compensation technique using DCF and FBG on 32 channel DWDM system at different data rates (10 Gb/s, 20 Gb/s and 40 Gb/s). The performance at different data rates is investigated in terms of bit error rate (BER) and Q-factor (db) using NRZ and RZ modulation formats.

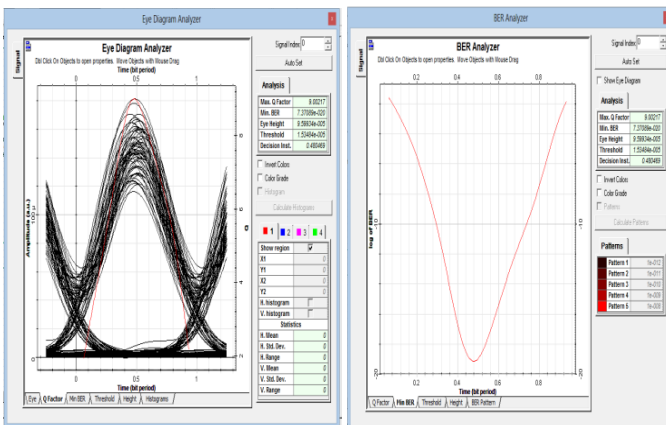**Table-3:** Simulation results with RZ Modulation format for 120 km and 80 km SMF

SMF Length	DCF Length	Bit Rate	Q factor	Minimum BER
120 km	24 km	10 Gbps	36.093	9.91086e-286
120 km	24 km	20 Gbps	24.2101	5.57302e-130
120 km	24 km	40 Gbps	9.00217	7.37089e-020
80 km	16 km	10 Gbps	53.9142	0
80 km	16 km	20 Gbps	56.9276	0
80 km	16 km	40 Gbps	10.9222	3.01707e-028

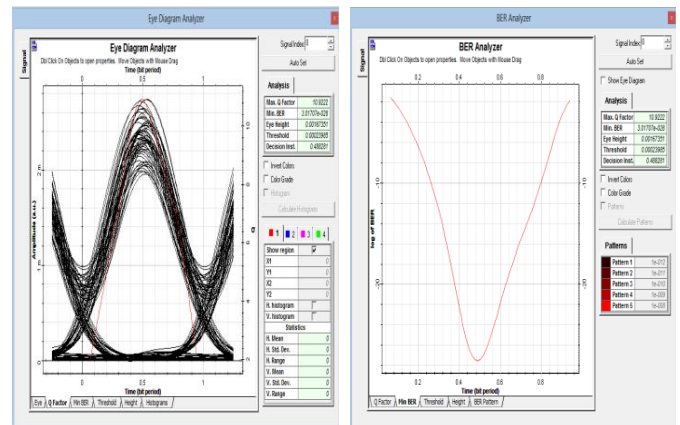
(a) Q-Factor and BER at 32X10 Gbps

(b) Q-Factor and BER at 32X20 Gbps
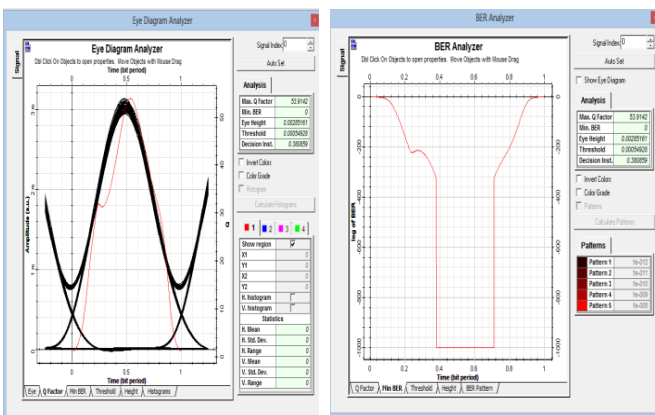
(c) Q-Factor and BER at 32X40 Gbps

Fig-4: Graphs for Q-Factor and BER at Different Bit Rates with RZ Modulation Format for 120 km SMF

From figure 4, it has been observed that Q-Factor is maximum and BER is minimum at 10 Gbps for 120 km SMF. Therefore, by using dispersion compensation unit i.e. DCF and FBG the Q-Factor value has increased.

(a) Q-Factor and BER at 32X10Gbps

(b) Q-Factor and BER at 32X20Gbps

(c) Q-Factor and BER at 32X40Gbps

Fig-5: Graphs for Q-Factor and BER at Different Bit Rates with RZ Modulation Format for 80 km SMF

From figure 5, it has been observed that Q-Factor is maximum and BER is 0 at 10 and 20 Gbps data rates for 80 km SMF. Thus, Q-factor is inversely proportional to the fiber length.
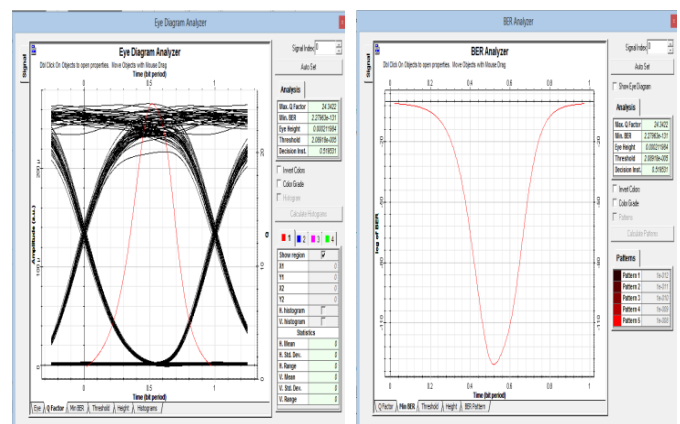
**Table-4:** Simulation results with NRZ Modulation format for 120 km and 80 km SMF

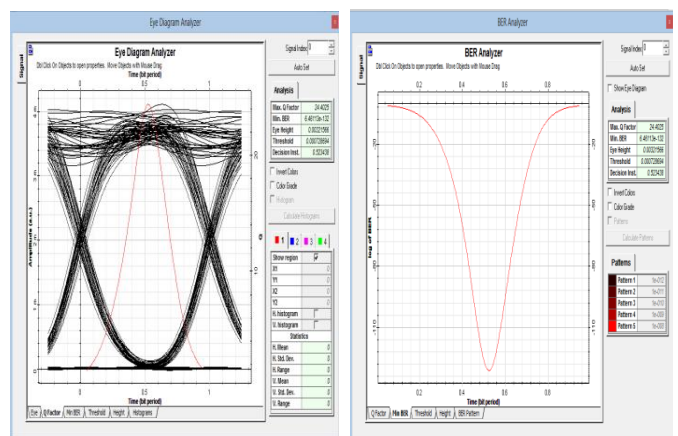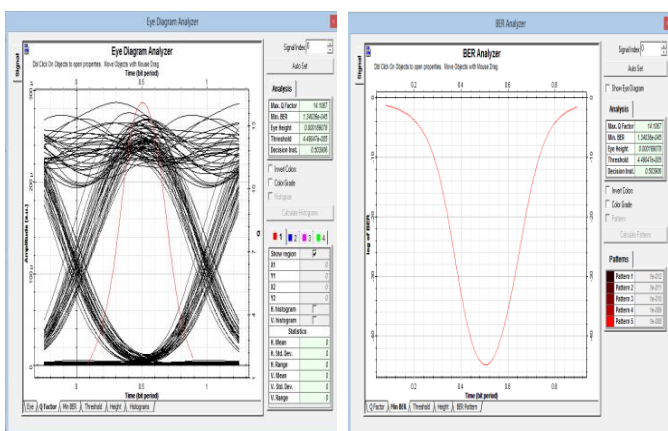| SMF Length	DCF Length	Bit Rate	Q factor	Minimum BER
120 km	24 km	10 Gbps	24.3422	2.27963e-131
120 km	24 km	20 Gbps	23.3453	5.40369e-121
120 km	24 km	40 Gbps	14.1067	1.34036e-045
80 km	16 km	10 Gbps	21.243	1.22524e-100
80 km	16 km	20 Gbps	24.4025	6.46113e-132
80 km	16 km	40 Gbps	13.0402	2.86537e-039
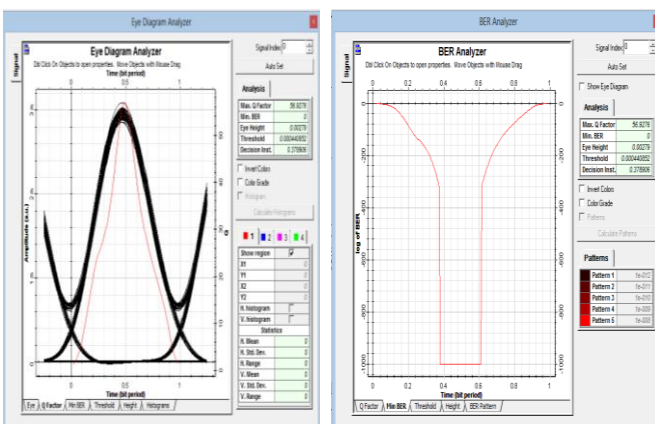
(a) Q-Factor and BER at 32X10Gbps
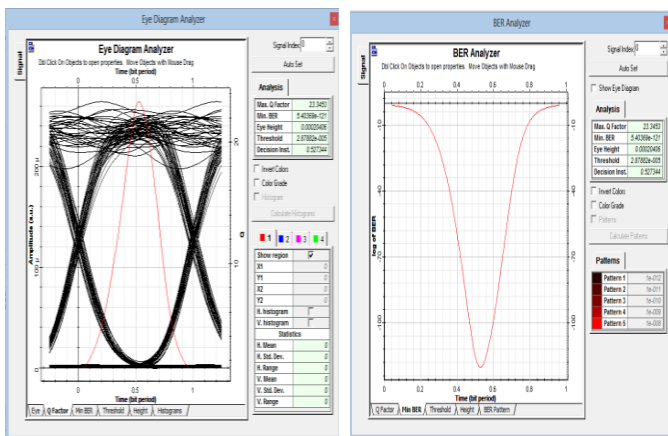
(b) Q-Factor and BER at 32X20Gbps

(b) Q-Factor and BER at 32X20Gbps

(c) Q-Factor and BER at 32X40Gbps
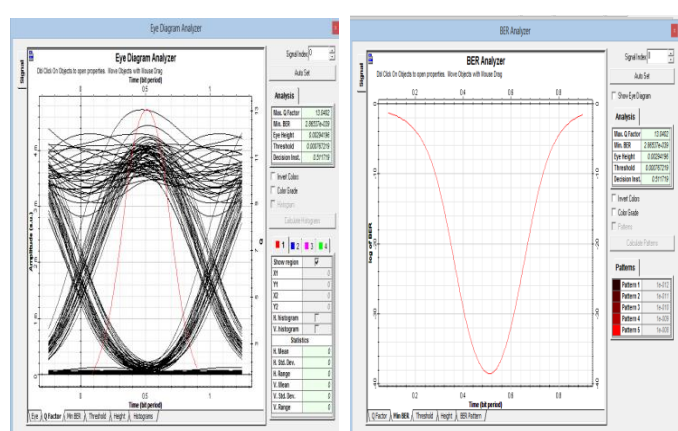
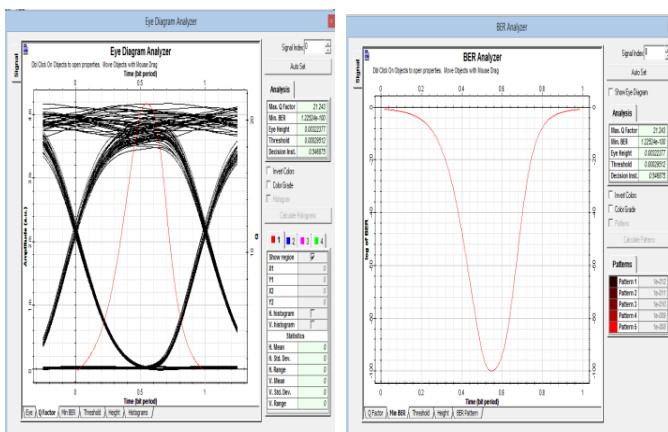(c) Q-Factor and BER at 32X40Gbps

Fig-6: Graphs for Q-Factor and BER at Different Bit Rates with NRZ Modulation Format for 120 km SMF

In figure 6, the eye diagram analyzer shows the maximum Q-Factor at 10 Gb/s for 120 km of fiber length and BER analyzer graph shows the values for BER which is minimum at 10 Gb/s.

(a) Q-Factor and BER at 32X10Gbps

Fig-7: Graphs for Q-Factor and BER at Different Bit Rates with NRZ Modulation Format for 80 km SMF

6. CONCLUSION

In this investigation, the performance of post-dispersion compensation techniques using dispersion compensating fiber (DCF) and fiber bragg grating (FBG) on 32 channel DWDM system at different bit rates (10 Gb/s, 20 Gb/s and 40 Gb/s) is evaluated. The channel spacing of 100 GHz is used in this system with the central frequency of 193.4 THz. The performance of simulated system has been investigated in terms of BER and Q-factor as shown in graphs above. From the simulation results, it has been observed that the RZ Modulation Format is more efficient for long-distance, high-bit-rate, in DWDM transmission dispersion-managed systems. The performance of the system in terms of Q-Factor and BER shows that RZ modulation format gives better result than NRZ modulation format. Thus, the simulation results show that the DWDM systems have good performance, low bit error rate and fully exploit the high speed, if the dispersion compensating fibers (DCFs) and FBG are incorporated in the system as the dispersion compensation technique.

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