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Implementation of Dense Wavelength Division Multiplexing Network with FBG

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ABSTRACT

In today's technology, optical fibers are becoming more and more fundamental to basic transmission media in the communication world. Optical system is to improve the quality factor and use to optimize noise reduction. This paper presents the idea of improving Quality Factor (QF) and noise reduction in a Passive Optical Network (PON) network by building a Wavelength Division Multiplexing (WDM) system and implements the Dense Wavelength Division Multiplexing (DWDM) network with Fiber Bragg Grating (FBG). A laser beam is used as source. The input is allocated to 16 channels at different wavelength. For modulation, Phase Modulation (PM) technique is used. The modulated signal is transmitted to the destination through a Single Mode Fiber (SMF).The distance between the source and destination is 50km. The signal is amplified using Erbium Doped Fiber Amplifier (EDFA). The amplified signal is forwarded to demultiplexer. 16 FBG are placed in de-multiplexer subsystem. The FBG reflects a particular signal and transmits it to the photo detector. The refracted signals from the FBG will be forwarded to other FBGs. The signals from the photo detector is analyzed for various parameters like Bit Error Rate (BER), Quality factor and eye diagram. The simulation software used in this paper is Optisystem version 7.0.

INTRODUCTION

This paper presents the idea of implementing the DWDM network with FBG in WDM based on software simulation (Aulakh, N.S. and R.S. Kaler, 2000). Optisystem software is used to simulate the system and various performance parameters such as BER, quality factor and eye diagram is analyzed. WDM based PON give higher capacity compared to previous TDM standard. UDWDM scheme increases the networks capacity and it meet the ever increasing demand for high capacity optical links. In this paper the application of a FBG based demultiplexer in UDWDM PON (Erdogen, T., 1997) is implemented. The theoretical design and simulation of a FBG DEMUX of each wavelength channel and is demultiplexed using the reflection of a single FBG. The proposed design is simpler, compact and more cost effective than the previously proposed FBG DEMUX designs. In the UDWDM based PONs, the FBGs are used to simulate the data rates of 40Gbps in wavelength spacing of 30GHz and 10km to 50km length of optical fiber (Giles, C.R., 1996). The quality factor and spectral responses of the DEMUX ports are analyzed. The 16 port Continuous Wave (CW) laser array with starting frequency of 193.1THz with a frequency spacing of 30GHz is considered as source. In the 50km of SMF, the multiplexed wavelengths are launched.

The successive wavelength is reflects by each FBG in the DEMUX from the multiplexed signal and it is given to the output port (Jung, D.K. *et al*., 1996). This eliminates the need to fabricate a series of gratings for each channel which is shown in fig.1

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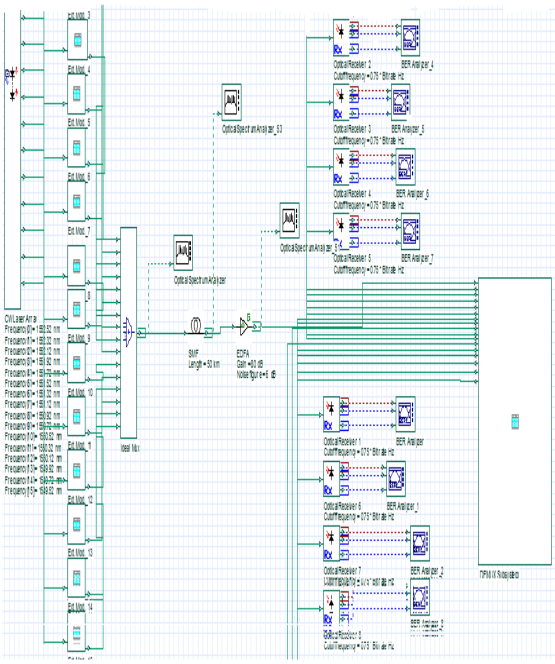

Fig. 1: System design

The Pseudo Random Binary Sequence generator (PRBS) generates a binary sequence which is coded by the NRZ pulse generator and modulators the incoming wavelength using a MZM with a extinction ratio of 40dB.The wavelength is then superimposed by the sinusoidal carrier wave of frequency 40GHz. The phase angle of -90 degrees using another MZM with an extinction ratio of 40dB. The FBGs used in the demultiplexer are of length 95mm. The modulation is done using PM with a phase deviation of 90 degrees. The output from each of these subsystems is fed into a WDM MUX. After this the signal is allowed pass through SMF which is designed to carry light only in the uniform direction without any losses in the signal. This signal is passed through EDFA where it gets amplified. The amplified signal is passed through DEMUX. It has 16 subsystems and each subsystem has separate FBG with the separate frequency. When the signals pass through FBG it reflects particular frequency and transmits the remaining signals to another subsystem. The reflected signal is forwarded to photo detectors which are used in the receiver side to detect the incoming signals. These signals are then analyzed and their characteristics such as the BER, Q factor, and also eye diagram properties which is shown in Fig.2

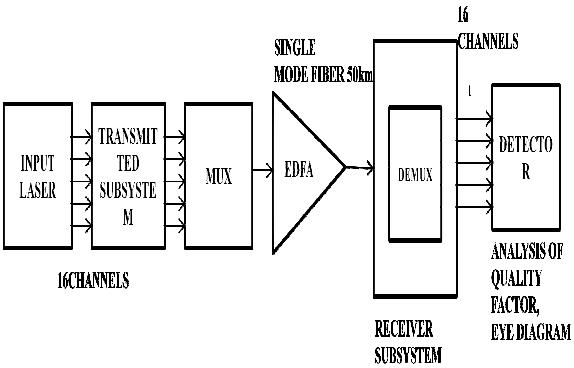

Fig. 2: Block diagram of proposed system

Methodology:

In the NRZ modulation format, the intensity of the carrier signal pulse is modulated by the applied electrical signal having a varying voltage. The MZM modulator is driven at the quadrature point and the transfer function of modulator power with an electrical NRZ signal. In general, due to the on-off switches the NRZ signal retains a narrow optical spectrum

There are opposite effect in low parameters of Inter-Symbol Interference (ISI) and dispersion on this narrow spectrum. The binary sequence generated by the PRBS and it is coded by the NRZ pulse generator and modulates the incoming wavelength with an extinction data rate of 40dB using a MZM which is shown in Fig.3

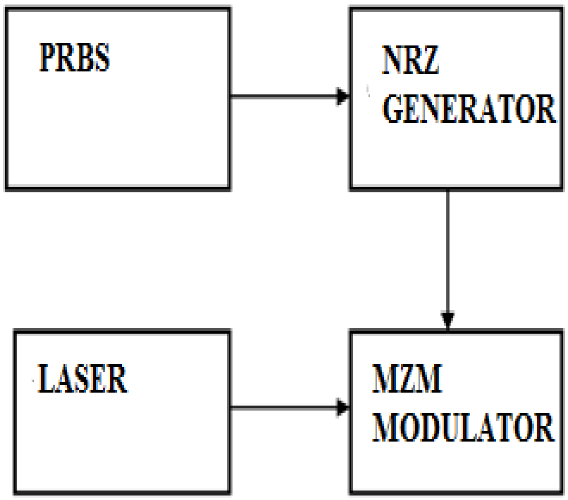

Fig. 3: Block diagram of transmitter subsystem

A. Transmitter Components:

The transmitter system contains important components such as the modulation and signal pattern generating. The transforming of digital data stream into sequence of light pulses known as modulation. The modulators are used to convert the data into sequence of pulses. A bit sequence is generated by the PRBS in an order mode and it is coded by the NRZ pulse generator. The incoming wavelength is modulates using MZM with an extinction ratio of 40db.

The sinusoidal carrier wave of frequency 40GHz and phase angle of -90 degrees is superimposed the wavelength using another MZM with same extinction ratio. The PM with a phase deviation of 90 degrees is used for the modulation. The optical time domain visualization is analyzed the output as shown in Fig.4

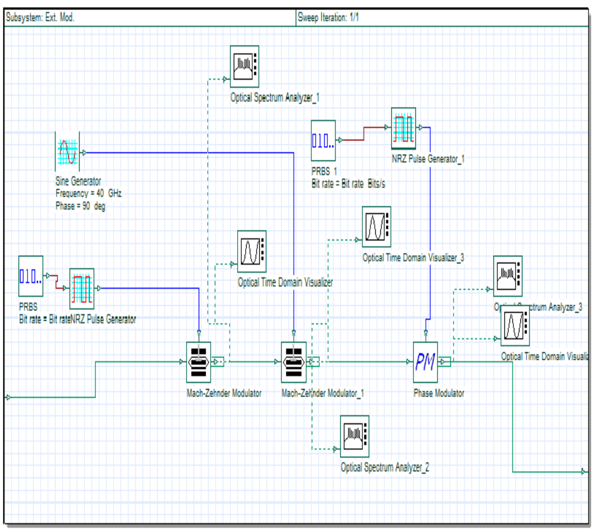

Fig. 4: Transmitter subsystem design

In the two modulation techniques, the data rate is kept constant and each modulation format effect is separately analyzed. The above figure illustrates the diagram of the two modulation format global parameters declared throughout the transmitter.

The various components used in the system of WDM network ther are:

- CW laser
- RBS
- Pulse generator
- MZM

Australian Journal of Basic and Applied Sciences, 10(1) January 2016, Pages: 302-313

The continous laser source is produce from the CW laser and the binary sequence is randomly generate using the pseudo random binary sequence. The pulse generator is used to generate the line coding of NRZ pulse.The electrical signal which is produced from the PRBS is modulated using the MZM. The signal coming from the binary sequence generator is then passed to NRZ generator, from this generator it passes through MZM and modulates the signal.

B. CW Laser:

The system of PONs WDM basically consists of the following main parts. The first part is the light source of the whole system to provide energy in order to transmit light through the optical fiber. In optical fibers, one of the key components for the communication to take place is the monochromatic light source. There are few characteristics which govern the use of the optical light sources for the optical fibers.

Among these characteristics include the duration of the use of certain light source its stability, compactness and the monochromatic feature. It is usually hard to get merely monochromatic light source in practical. The stability issue in the light source is to maintain constant intensity level regardless of the variations of the temperature and time and steady wavelength as well.

There are mainly two types of light source:

- CW light source
- Modulated light source

In this paper CW light source is used. The continuous light source continuously emits light and it usually needs external modulator at its outputs. The second type which is the modulated light source emits modulated light that does not need external modulator as shown in fig.5

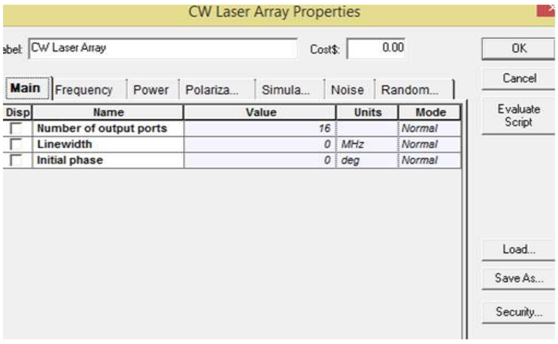

Fig. 5: CW laser properties

Fig.6 shows the laser properties of the system. The laser source is splitted into 16 output ports for 16 channels. The various parameters of the laser array are frequency, power and wavelength.

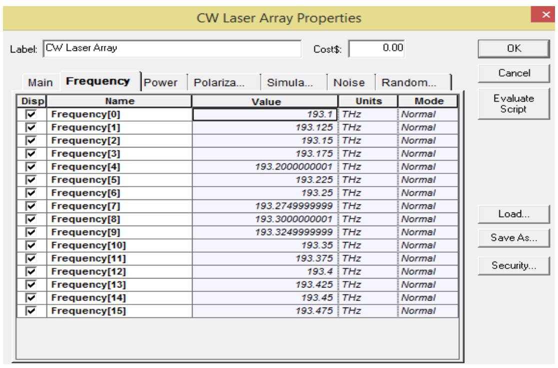

Fig. 6: CW laser properties - Frequency

The frequency for each receiver subsystem starts with 193.1THz.The frequency range used for the system between 193.1THz to 193.475THz and this frequency range is splitted into 16 channels can be dealt with different frequency range. Fig.7 shows the wavelength property of the CW laser. The range of the wavelength used in the system is 1549-1552 nm. The wavelength is divided into 16 parts for all the channels.

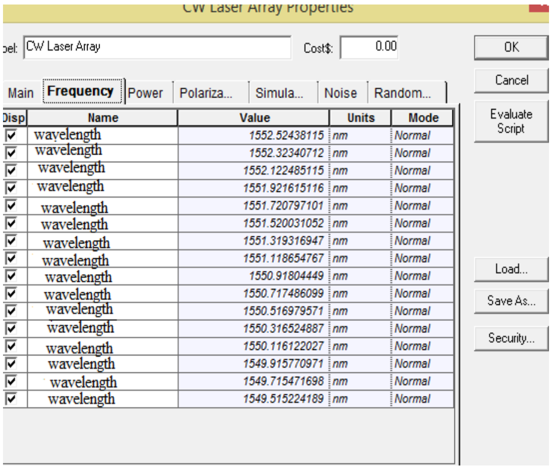

Fig. 7: CW laser properties - Wavelength

Another important parameter of the laser property is power. Power is shared for all the output parts. The power used for the system is 0.0001W for all 16 channels. Fig.8 explains the power measurement property of the laser system.

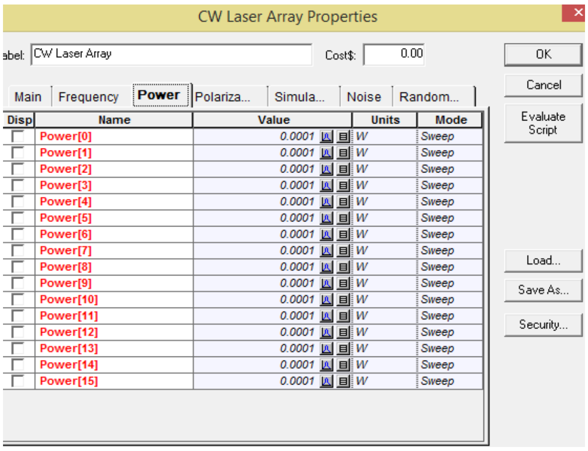

Fig. 8: CW laser properties – Power

C. NRZ Generator:

The signal coming from the binary sequence generator is passed to NRZ generator. Fig.9 represents the NZR parameters of the system

The parameters of NRZ of the system are

- Bit rate
- Sampling rate
- Sequence length
- Number of samples

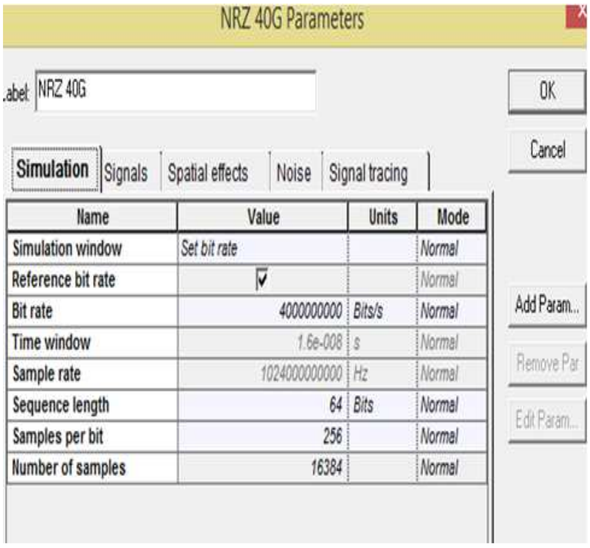

Fig. 9: NRZ parameters

The modulation components undergo various stages of modulation. At first, the data rate is generated by the binary sequence generator. The type of binary sequence generator used in this system is PRBS generator. Fig.9 represents the parameters of NRZ produce by PRBS generator.

The parameters are bit rate, sampling rate, sequence length and number of samples. The bit rate used is 40GBPS.sampling rate of the generated signal is 1024GHz. The sequence length of the signal is 64 bits.

D. Receiver:

The WDM demultiplexer receiver receives the signal from EDFA and each demultiplexer has separate 16 channels. The major components of receiver are

- DEMUX
- Photo detector
- BER analyzer

E. Demux:

Each channel receiver's subsystem has demultiplexer. The amplified signal is given to the demultiplexer. The DEMUX is internally design with FBG. The FBG receives the signal and it reflects selected frequency, refracts the remaining signal to another FBG.

$$\lambda_B=\pi_B 2n_{eff}\Delta \qquad (1)$$

where,

π_B is the Bragg equation reflected by the grating

n_{eff} is the effective refractive index of the optical fiber core

Δ is the period of the grating

The FBGs described in this method by Gaussian and quadratic equation.

$$A(Z)=\exp\{-4[(Z-L/2)]\} \qquad (2)$$

$$\Delta(Z)=\Delta_0-\frac{Z-\frac{L}{2}}{L}\Delta;\Delta\ll \Delta_0 \qquad (3)$$

where,

z is the Gaussian function which is used to measure the distance along the fiber axis

L is the grating length

Δ is the quadratic parameter

Δ_0 is the grating period at the centre (Z=0) of the grating.

The insertion loss of this demultiplexer is assumed to be 2 dB. This is chooses the same reason as the one in transmitter side. The output of this demultiplexer is 16 channels with the different frequencies.16 FBGs are placed in de-multiplexer subsystem.

The FBG reflects the particular signal and transmits to the photo detector. The refracted signal from the FBG will be forwarded to other FBG and the 16 signal are selected by reflection of the FBGs. Each of the 16 channels is connected to specific spectrum analyzer to compare the transmission of these channels in receiver as shown in Fig.10

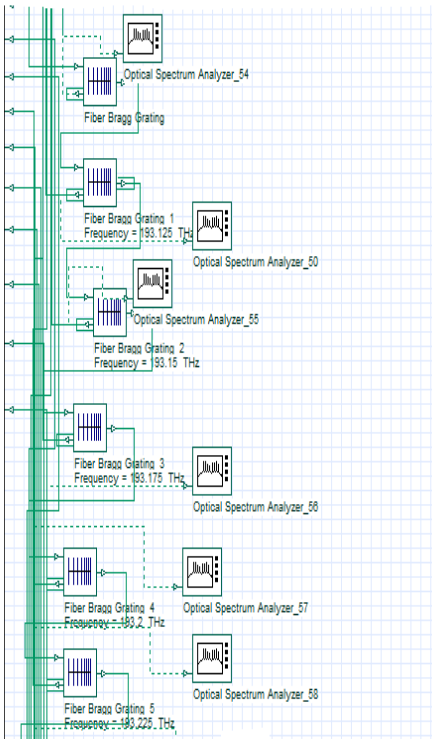

Fig. 10: Subsystem of DEMUX at receiver side

The Fig.10 represents the subsystem of DEMUX. In DEMUX, FBG is used to extract the particular signal and the selected signal is forwarded to photo detector. At first the photo detector is used to detect the incoming signal. Each of the 16 channels are connected to spectrum analyzer individually to compare the successful transmission of all channels.

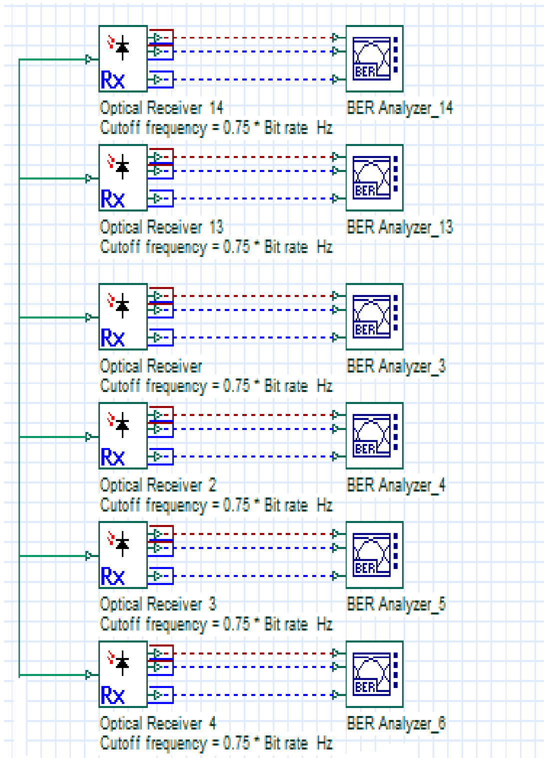

Fig. 11: Photo detector with BER analyzer

The cut-off frequency at the receiver for each channel is 0.75 bit rate in Hz. The BER analyzer has minimum effects on the system simulation but the quality factor as improved. Fig.11 shows the photo detector of the system and BER analyzer.

F. Optical Transmission Using SMF:

A 50 km of SMF is used in this system. In this distance, without the need of amplifiers and repeaters the fiber optic link can be used directly. The main objective is to analyze the performance of the single channel system of input power for different modulation formats. To achieve this, it needs to sweep a range of input power levels and, simultaneously, a range of lengths for the transmission fibers. This is done by using the sweep mode for the lengths of both transmission fibers in the cell and for the amplifier gains. This number can be increased if a finer grid is needed. However the total computation time will be increased. The lengths of the transmission fiber SMF are chosen in such a way that the dispersion compensation scheme ranges from pre-compensation to post- compensation.

Various parameters of SMF for the distance of 50 km is analyzed. The different properties are

- Dispersion
- Polarization Mode Dispersion (PMD)
- Nonlinearity
- Numerical aperture
- Noise

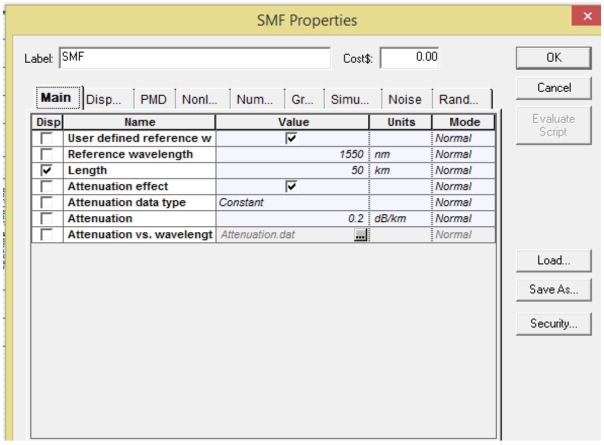

Fig. 12: SMF properties for 50 km

G. EDFA:

This EDFA amplifies the weak signal after 50km. The EDFA used has a gain of 80dB. The power and saturation power of the system is 10dBm.

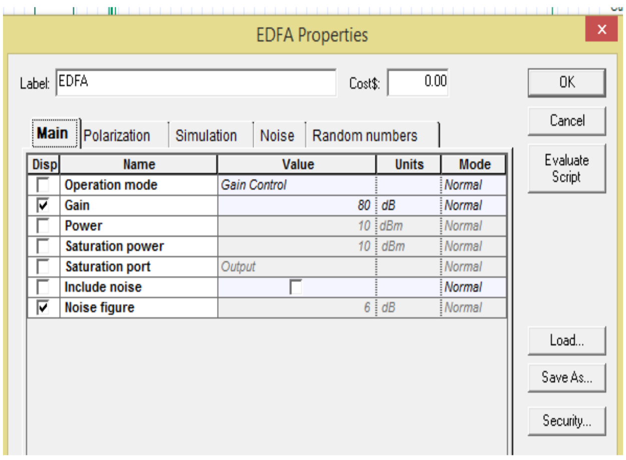

Fig. 13: shows the EDFA properties of the system.

Simulation And Result Analysis:

In general, the WDM based passive optical networks gives higher capacity than time division multiplexed (Kaneko, S., 2006). For this reason, certain dispersion solution must be taken in order to scope with the negative effect to the system performance. In this paper FBG has been introduced as the main solution to overcome dispersion. Erbium doped fiber amplifier EDFA was also proposed and also increases the data rate up to 40Gbps (Kogelnik, H., 1976). Compactly, the simulation setup contains transmitter, fiber and receiver. The WDM transmitter encompasses a CW laser source, signal modulators and optical demultiplexer. The output of the CW laser is connected to the demultiplexer. 16 channels are coming out from this demultiplexer and each channels is going to separate modulator. The transmission channel is designed by using SMF having the length of 50km has been proposed and frequency spacing is 30GHz.The signal is transmitted through 16 channels each channel as separate transmitter subsystem and signal is modulated pass through multiplexer, From MUX the signal can be analyse by spectrum analyser and again signal pass through optical SMF having length of 50km once again the signal can be analyse in another spectrum analyzer. The signal get loss sometime so boost up the signal only EDFA is added before demultiplexer. In the receiver side, a demultiplexer receives the signal and each receiver as separate subsystem the signal passes to the photo detector. This analyzer visualizes and generates graphs is taken on eye diagram, quality factor.

The overall system design which contains all components and links of WDM network with FBG. The modulators are used to convert the data in to sequence of pulses. The PRBS generates a binary sequence which is coded by the NRZ pulse generator and modulates the incoming wavelength using a MZM with an data rate of 40db.The wavelength is then superimposed by the sinusoidal carrier wave of frequency 40GHz and phase angle of -90 degrees using another MZM with an data rate of 40db.The modulation is done using a PM with a phase deviation of 90 degree. The WDM demultiplexer receiver receives the signal from EDFA and each demultiplexer has separate 16 channels. Each channel receiver’s subsystem is internally design with FBG (Mizrahi, V. *et al*., 1994). The FBG receives the signal and it reflects selected frequency, refracts the remaining signal to another FBG .The WDM demultiplexer at receiver side is almost similar to the demultiplexer at the transmitter side. The insertion loss of this demultiplexer is assumed to be 2 dB (Romero, R., 2003). This is chooses the same reason as the one in transmitter side. The output of this demultiplexer is 16 channels with the frequencies is used. Finally, spectrum analyzer is connected on each channel to detect the signal properties mainly the BER, the Q-factor and the also eye diagram (Stern, J.R., 1988). Each of the 16 channels is connected to specific spectrum analyzer to compare the transmission of these channels. The output signal is from multiplexer and the peak represents number of channels and the power is -20dBm

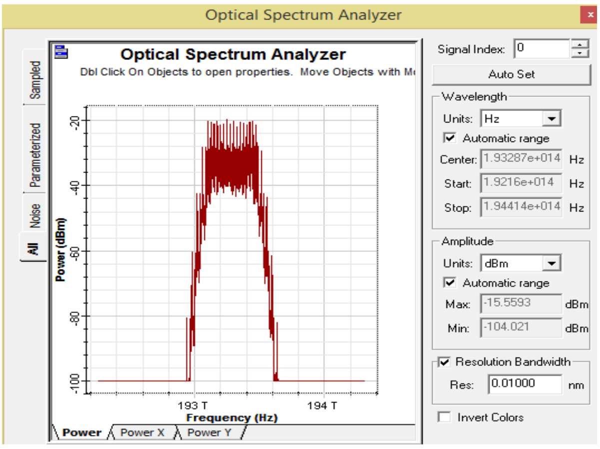

Fig. 14: Signal from multiplexer

The output signal is from single mode fiber after 50km and analysis the power in -40 dBm

Australian Journal of Basic and Applied Sciences, 10(1) January 2016, Pages: 302-313

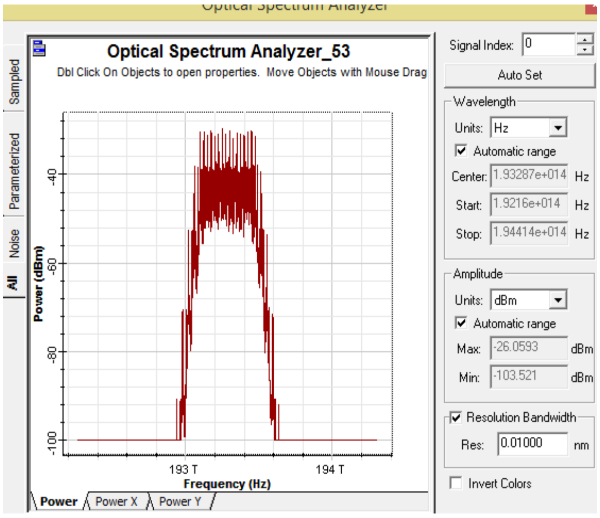

Fig. 15: Signal from SMF

The signal is from EDFA and it used to amplify the incoming signals and gain of the output signal is 80dB.

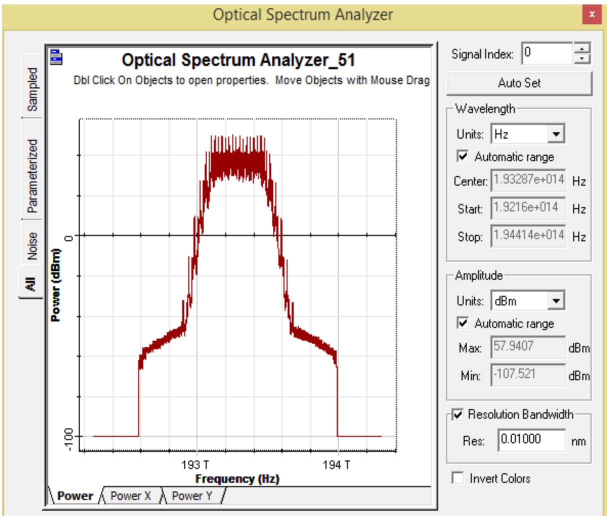

Fig. 16: Signal from EDFA

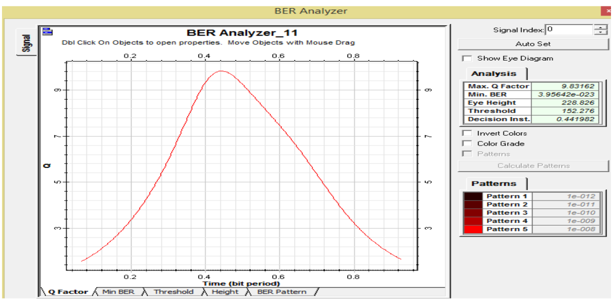

Fig. 17: Quality factor analysis for 11th channel

The maximum quality factor obtained for channel 11th is 9.83162. The minimum BER is also calculated for channel 3 is 3.95642e-023. Thus BER and quality factor is calculated.

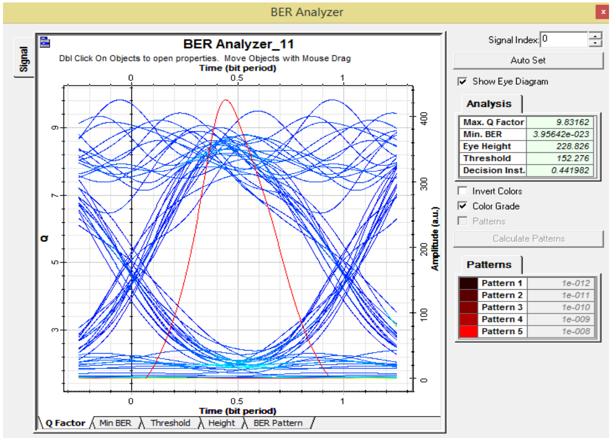

Fig. 18: Eye diagram analysis for 11th channel

The Fig.18 represents the eye diagram of channel 11th and it is used to analyse the height of the received signal is 228.826. The eye diagram can be calculated between time period and quality factor.

Table 1: Analysis of different parameters

Sl.No	Channels	Qualiy factor	BER	Eye Diagram
1	11	9.83162	$3.956x10^{-23}$ (bps)	228.8 (a.u)
2	9	12.1447	$2.789x10^{-34}$ (bps)	245.8 (a.u)
3	3	13.7587	$2.011x10^{-43}$ (bps)	271.5 (a.u)

The table represents the analysis of quality factor, BER and eye diagram of channels 3,11and 13 channels. The improved quality factor is considered.

Conclusion:

In the proposed system, DWDM technique is used 16 channels are divided at a frequency between 193.1to 193.4 THz the wavelength used for the channels various between 1549.51 to 1552.52 nm. The distance between the transception of the signal has been increased to 50 km. In order to amplify the loss of the signal due to the increment in the distance will be by an amplifier. For this amplification EDFA is used. Initially the gain of the signal is 20db. After using EDFA, the gain of the amplified signal is 80dB.

The amplified signal is demultiplexed using FBG. The 16 channels that are observed using reflection of the FBG are analyzed for BER, quality factor and also eye diagram. Spectrum slicing technique at the multiplexer for the WDM system will be implemented. Also the number of channels increases up to 32. Wavelength of the signal will be spliced for the 32 different channels. Due to this process the non-linearity and dispersion will be caused. This type of dispersion will be avoided.

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