

Performance Analysis of Single Channel and Multiple Channel in Optical Link Using DWDM

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Abstract: In this paper the architecture of optical communication networks is analyzed for a Wavelength division multiplexing techniques in Gigabit and Terabit speed of communication using different parameters such as BER and Q-Factor. Dense wavelength division multiplexing (DWDM) is used in C band (1530 nm-1565 nm) communication for multiple inputs. Using DWDM, multiple channels of information can be transmitted on a single fiber. Here we first analyze a single channel at carrier frequency of THz and then use multiple channels implementing DWDM technique. Comparative analysis is done for bits per second to Gigabit per second range using single channel and in GHz range input using DWDM. The Q factor and BER of linear systems are compared with Nonlinear DWDM systems in which self-phase modulation (SPM) and cross-phase modulation (CPM) are present.

Keywords : BER, NRZ, Q factor, DWDM, SPM, CPM.

1.INTRODUCTION

WDM offers a better solution for increasing the capacity of high-speed networks. The IP based WDM network and its access network architecture support for IPv4, Ipv6, and interoperability WiMAX based internet access concepts design. Many passive optical components including Arrayed Waveguide Gratings (AWG) consume power in signal paths during the multiplexing / demultiplexing process of WDM. WDM systems are categorized as (WDM), coarse (CWDM) and dense (DWDM). Normal WDM (sometimes called BWDM) uses the two normal wavelengths 1310 and 1550 on one fiber. Dense WDM (DWDM) uses the C-Band (1530 nm-1565 nm) . Typical DWDM system uses 40 channels at 100 GHz spacing or 80 channels with 50 GHz spacing. Recent innovations in DWDM transport systems include pluggable and software-tunable transceiver modules capable of operating on 40 or 80 channels. Dense WDM (DWDM) Transceivers: Channel 17 to Channel 61 according to ITU-T .An optical fiber system

consists of transmitter, connecting optical fiber and receiver with a decision circuit Fig 1. The input is transmitted by a data-source. Here the optical signal is generated by a laser at a fixed wavelength. The data source and the optical signals are sent to the modulator and the resulting signal propagates through the fiber [3]. An optical sensor or a photodetector detects the incoming optical signal at the receiver end. The received signal is passed through the demodulator to get the required output signal. In standard form ITU transponders are used at the transmitter and receiver end which converts signals from electrical to an optical wavelength and from a wavelength to an electrical output.

1.1 Methodology:

Input sequences are generated by user defined bit sequence generator. It generates a predefined sequence. Then NRZ Coding is used which Generates pulse according to a defined sequence. Laser Generates a continuous wave optical signal which is modulated by bit sequence. Here the Mach-Zehnder Modulator is connected which uses an electro-optic effect, bit sequence is applied externally to vary the refractive indexes. Then intensity modulation takes place by applying voltage. At the detector side APD Diode filters the optical signal obtained from fiber and converts it to an electrical signal. Opti System is used for the design, testing, and optimization of this WDM optical network.

1.2 Channel capacity:

Using Shannon-Hartley equation maximum capacity (transmission bit rate) that can be calculated for a given channel with certain noise characteristics and bandwidth. For an AWGN the maximum capacity is given by:

$$C = B \log_2 \left(1 + \frac{S}{N} \right)$$

Here C is the maximum capacity of the channel in bits/second, B is the bandwidth of the channel, S is the signal power and N is the noise power. The ratio S/N is Signal to Noise Ratio (SNR). A unit bandwidth can carry a maximum of two pieces of information per second [5]. Optical communication has approximately 30 Thz bandwidth [4].

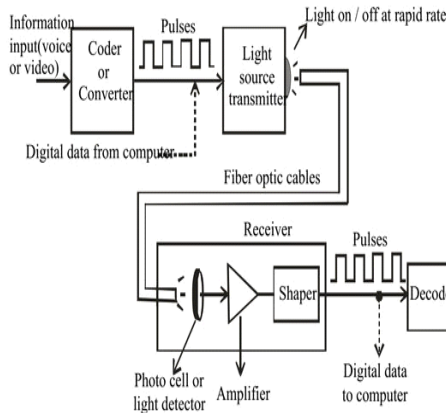


Fig. 1. Communication link

2.CIRCUIT AND PERFORMANCE

2.1Circuit Designing

First single input (from bps to Gbps) with transmitter is simulated with carrier frequency at 193.1Terahertz and then multiple inputs (at 10 Gbps) for multiple channels are simulated at a wavelength spacing of 100GHz at carrier frequency 193.1 Terahertz. Optical Spectrum Analyzer and the BER Analyzer is used to check the performance of circuits. Single input and multiple input channels are compared using an eye diagram and Q factor.

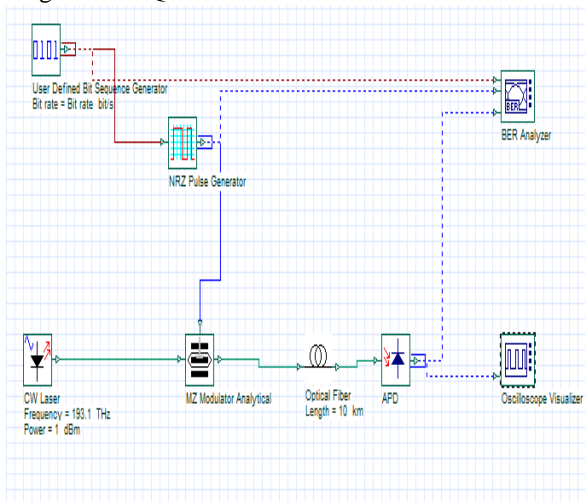


Fig. 2. Single channel at carrier frequency 193.1 THz

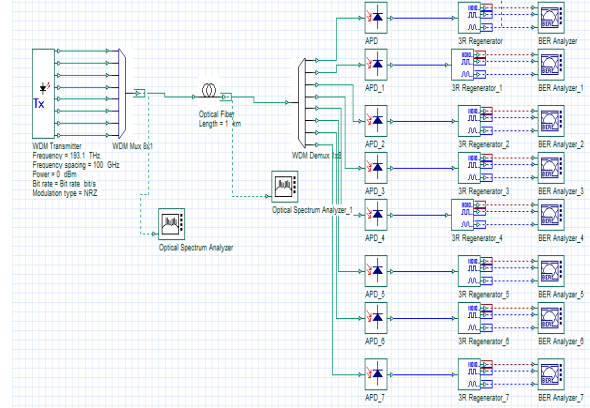


Fig. 3. Multiple channels at spacing of 100 Ghz

In single channel communication we give a predefined bit sequence and then vary data rate and at the receiver side observe the bit sequence and compare it with the transmitting side bit sequence.

2.2 Performance Analysis

EYE DIAGRAM: If the signal is an ideal one and zero appears in rectangular pulses, then the eye will appear fully open. As the pulses are distorted in phase and amplitude the eye will be no more fully open it begins to close.

However, the most important issue is the eye lines passing under the decision threshold it tells about the bits in error. So, we count the total number of bits N , and the part of that which lies in the decision threshold N_e , it gives the number of bits in errors. Then the bit error rate BER will be $= N_e/N$. And $BER = 10^{(-9)}$ corresponds to Q factor = 6 which means there is a one-bit error in one billionth bits at the receiver.

Table 1 and Figure 5 shows results for a single channel. As the data rate is increased from bps to Gbps the Q factor decreases for a single channel design.

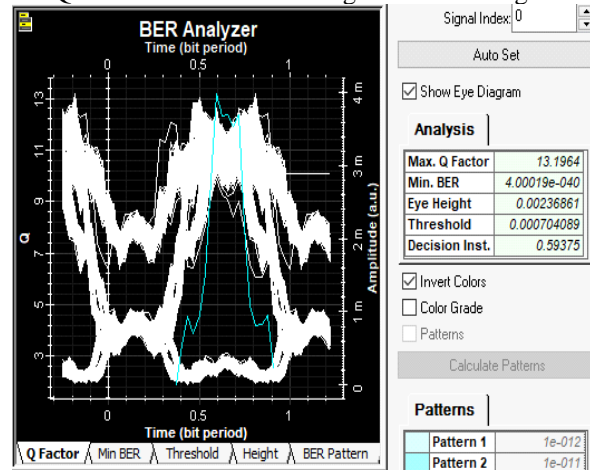


Fig. 4. EYE Diagram

TABLE 1 For a single channel

Bit rate	Q Factor
10 bps	1361770
1000 bps	30586.5
1000 mbps	45.45
19 Gbps	13.19

TABLE 2.For multiple channel inputs in a DWDM network at carrier frequency 193.1 THz and frequency spacing of 100GHz ref(Fig3)

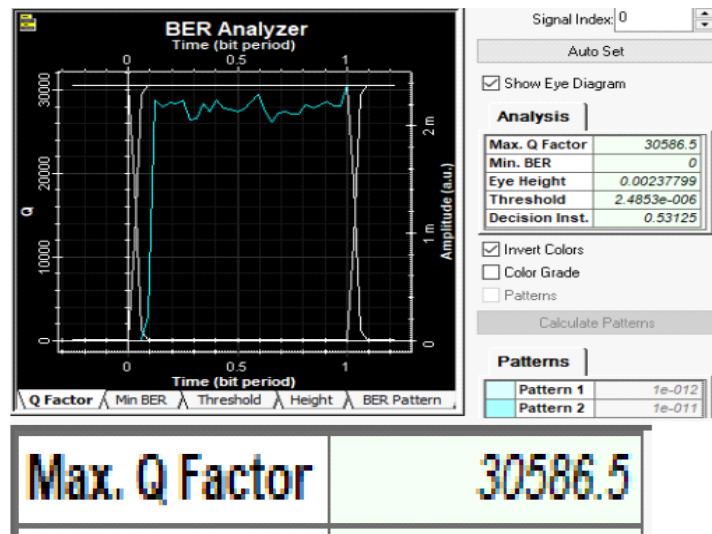
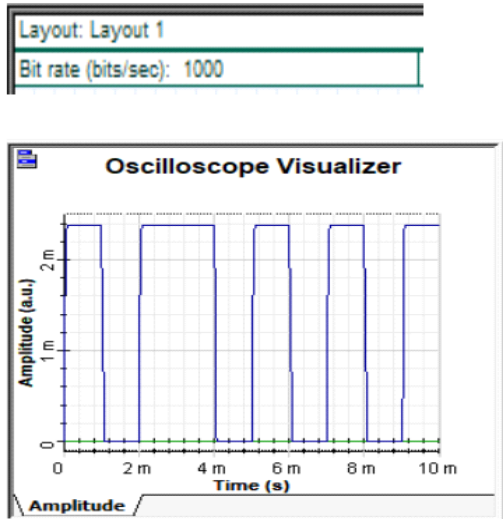
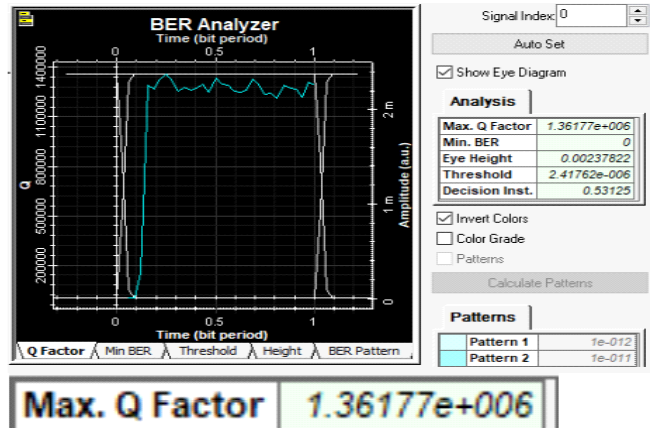
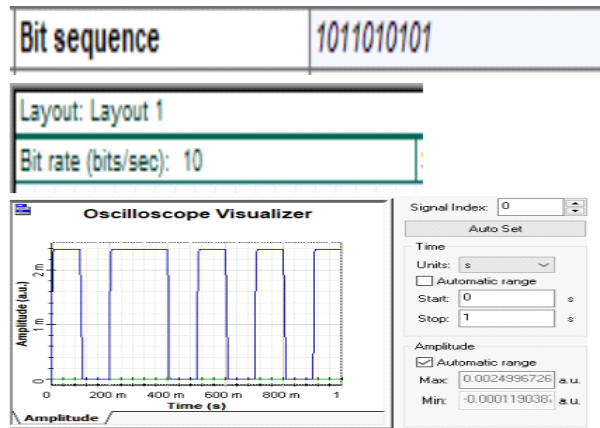
No. of channels	Q-Factor	Optisim specifications: Data rate =10Gbps Transmitted power -0dbm Fiber length=1km Fiber loss =0.2dbm/km Frequency Spacing =100GHz Modulation type=NRZ
2	6.20	
4	6.11	
8	6.92	
16	6.43	
32	5.66	
64	5.69	
128	5.55	

TABLE 3. BER and Q factor at wavelength (1550-1300nm)

No. of channels	Bit Error Rate	Q-Factor
4	0.01389	2.07483
11	0.745323	1.38279
18	0.075745	1.37282
26	0.0490579	1.57407

TABLE 4. BER and Q factor for 11 input channels at THz

Frequency in (THz)	BER	Q-Factor
200	4.48794e-006	4.426
205	1.51514e-006	4.65385
210	7.04895e-007	4.80842
215	76.8091e-007	4.7915
220	8.27238e-007	4.77626
225	2.30098e-006	4.56749
230	6.88484e-006	4.33292
235	2.89344e-005	4.02401
240	9.61199e-005	3.74578
245	0.000348102	3.37853



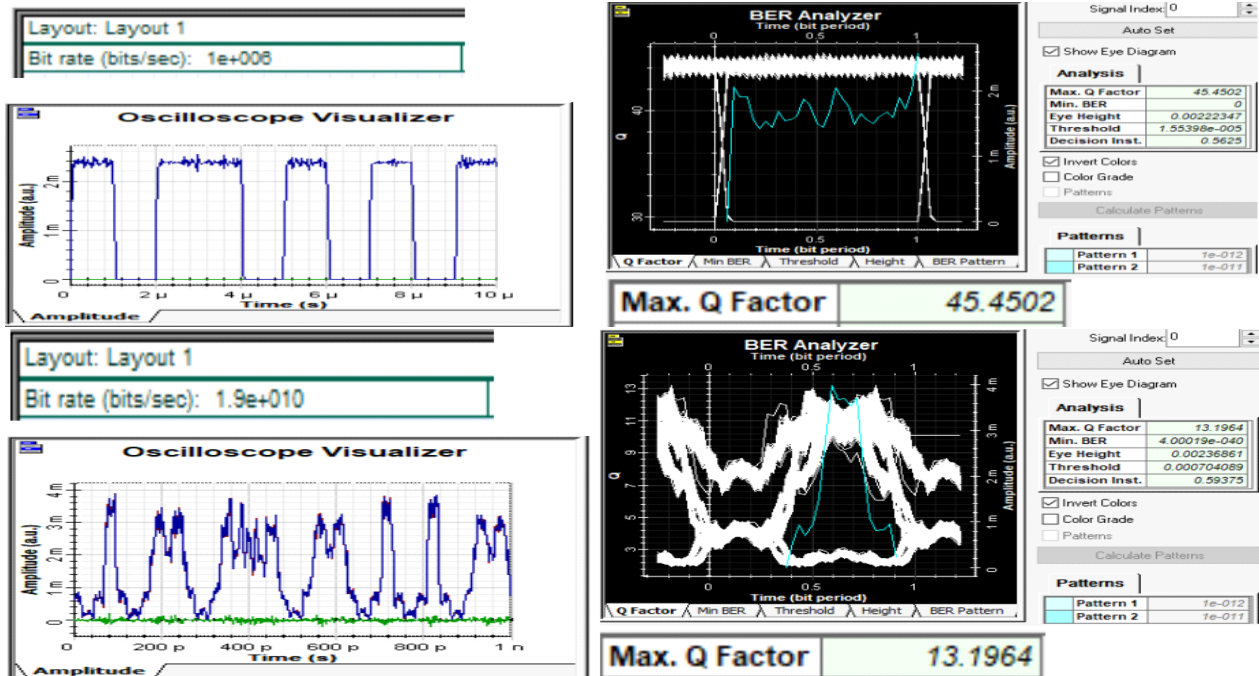
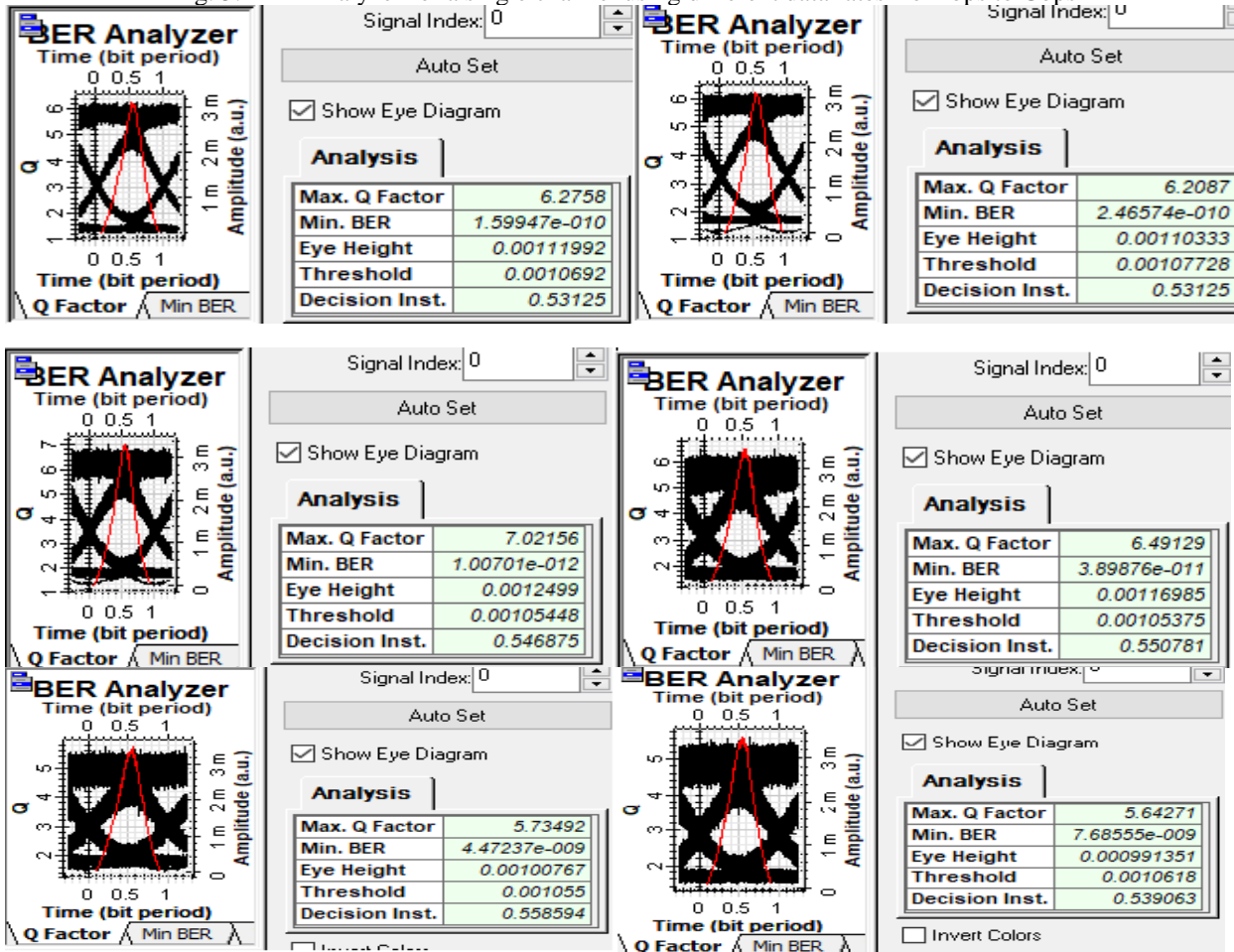


Fig. 5. BER Analyzer for a single channel using different data rates from bps to Gbps



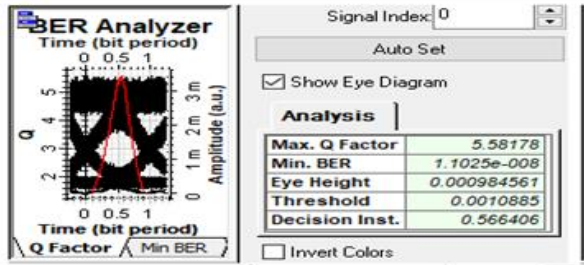


Fig. 6. BER Analyzer for WDM network for different number of input channels

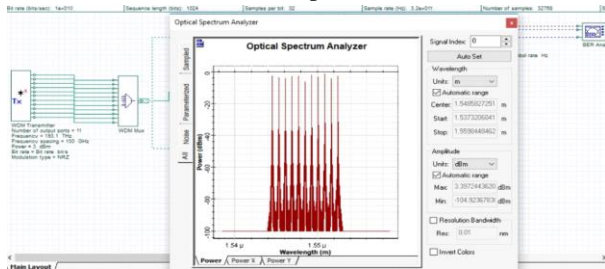


Fig. 7. DWDM for 11 numbers of channels
 Above circuit is checked for a different number of channels as shown in table 3.
 Above results are At Frequency in terahertz (THz) (Wavelength): 1550 nm – 1300nm). Quality factor reduces here for 1550-1300nm range and bit error rate is also high. Minimum BER is at 4 channels.
 Table 4 Shows performance analysis for the 11 number of inputs for different frequencies ranging from 200 THz to 245 THz.

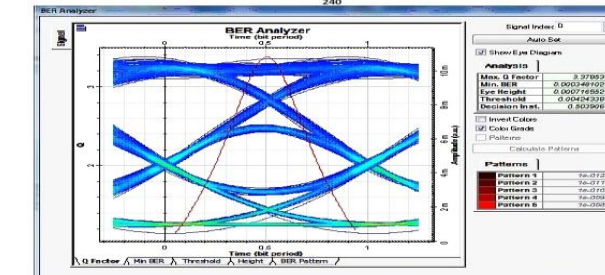
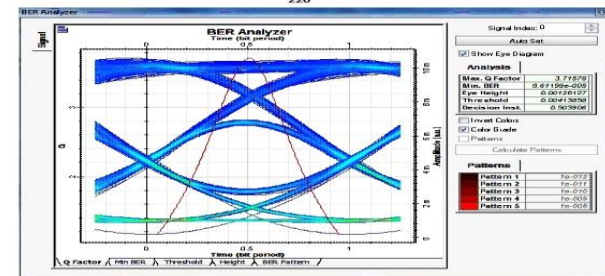
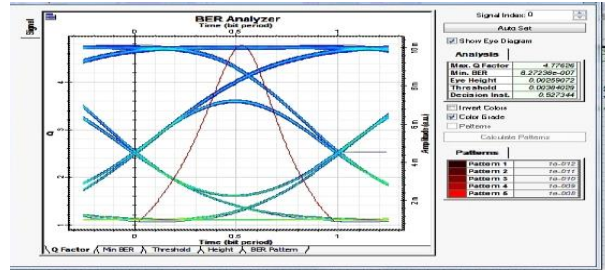


Fig. 8. Eye diagram and BER analysis for 11 input channels in DWDM

3.WDM WITH OPTICAL NONLINEARITIES

There are some optical nonlinearities present in the optical fibers at high frequencies. These nonlinearities are known as self-phase modulation (SPM), Cross phase modulation (CPM) [Fig. 10] and four wave mixing. Figure 10 shows four wave mixing. Figure 11 shows the difference in Q factor between the ideal(linear) WDM and WDM with optical nonlinearities.

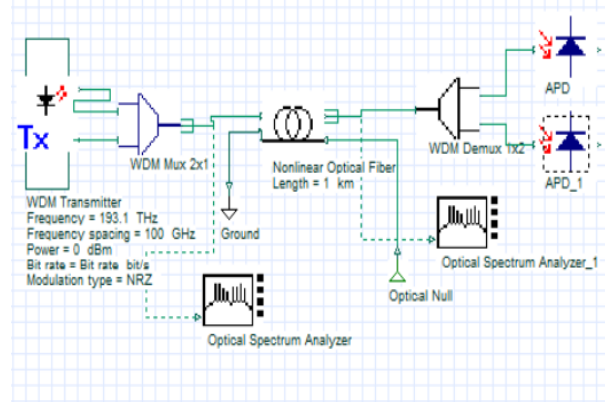
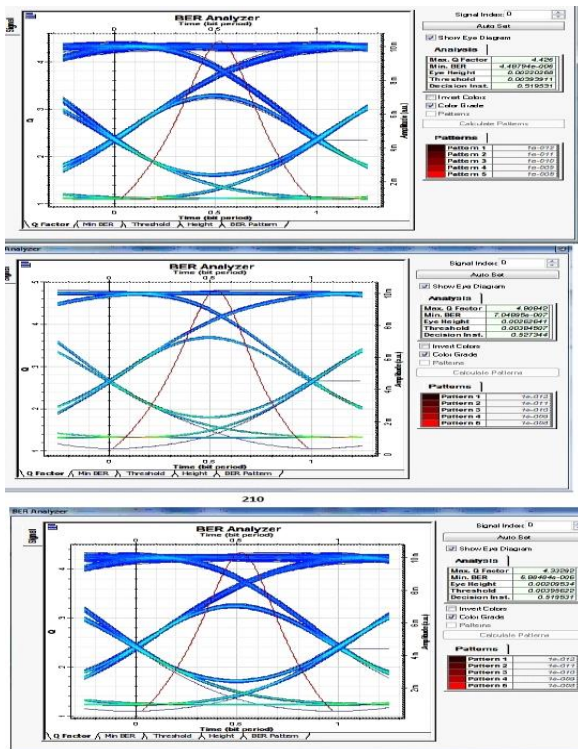


Fig. 9. 2X1 WDM with nonlinear (Cross-phase modulation) optical fiber

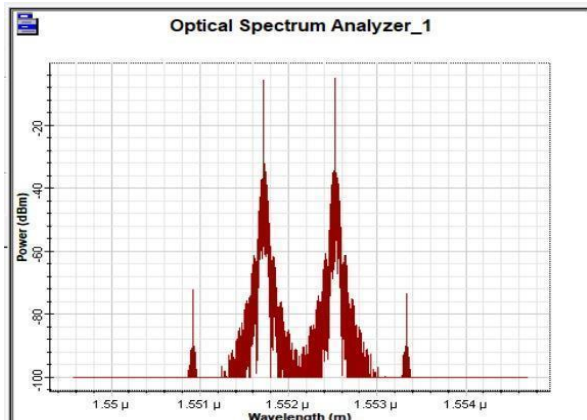


Fig. 10. Multiple frequencies at the end of fiber (Four wave mixing)

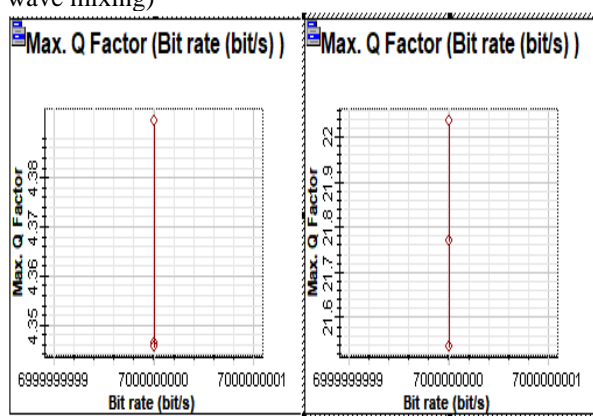


Fig. 11. (a) Q Factor vs bitrate with nonlinearity and (b) Without nonlinearity

4.RESULTS

A single channel can carry maximum data rate upto 20 Gbps with Q factor 6. For 11 channel Bit error rate is minimum at 210THz with quality factor 4.8 which is comparable to the quality factor at 128 channels for 10 Gbps data rate. For ITU standardization is done at 100GHz which gives a high-quality factor. As we move towards terabit communication nonlinear effects arise and due to that there is reduction in Q factor and increase in BER. In THz wavelengths maximum Q factor is obtained at 210THz.

5.CONCLUSION

The performance of the system is shown for THz input carrier signal. We observe the channel bit error rate for different numbers of inputs. To get better results chromatic dispersion should be compensated in optical fiber. We increase the length of fiber to transmit the signal to long length with less dispersion. Whenever we increase the length of grating the extension of pulse will be decreased because of that the signal will cover more length without or less dispersion. So, the quality of the

signal will be the same at the receiver as it is at the transmitter. Because the analysis of a multi-channel system is useful, the natural starting point is with the analysis of a simple one-channel system.

A single 100 Ghz channel has a maximum capacity of 200 Gbps [5], but we can transmit only up to 20 Gbps with Q factor = 6. As we increase no of channels and transmit the same data rate Q factor decreases. The basic design steps are done with Opti System. *References*

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