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Investigating the Q-factor and BER of a WDM system in Optical Fiber Communication Network by using SOA

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ABSTRACT: This paper represents the analysis of Quality-factor and Bit Error Rate of an Optical signal in WDM system of a Fiber Optic communication network by using SOA. Vertical Cavity Surface Emitting Laser (VCSEL) is used as a transmitter. It is observed that by varying the frequency of bandwidth up to 34GHz a low BER with a high Q-factor is obtained. At 34GHz bandwidth maximum Q-factor of 13.1248 and minimum BER of $1.16972e^{-039}$ is obtained for 100km optical fiber length.

KEYWORDS: SOA, BER, Q-factor, WDM system, Optical Fiber.

1 INTRODUCTION

Q-factor and BER is one of the most important factors that limiting the transmission distance in optical communication systems. In order to transmit signals over long distances, it is necessary to have a low BER and high Q-factor within the fiber. The main advantage of optical amplifiers is that the optical signals to be directly amplified optically without any conversion [1], [2]. Here semiconductor optical amplifier (SOA) used as the fiber amplifier with WDM system [3].

This thesis aims to implement the SOA in WDM system and analyzed the performance in terms of BER and Q-Factor by varying the bandwidth.

Q factor measures the quality of an analog transmission signal in terms of its signal-to-noise ratio (SNR). As such, it takes into account physical impairments to the signal –for example, noise, chromatic dispersion and any polarization or non-linear effects – which can degrade the signal and ultimately cause bit errors. In other words, the higher the value of Q factor the better the SNR and therefore the lower the probability of bit errors [4].

In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission. For example, a transmission might have a BER of 10^{-6}, meaning that, out of 1,000,000 bits transmitted, one bit was in error. The BER is an indication of how often data has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be present.

Wavelength Division Multiplexing (WDM) is a technology which multiplexes a number of optical signals onto a single optical fiber by using different wavelengths of laser light [5], [6]. In WDM, several different wavelengths are transmitted over one single mode fiber at the same time. To increase the capacity of the system is to add additional channels by laying more fibers which is impractical because higher cost is responsible for such system. So, WDM systems are very popular for telecommunication companies because it permits them to extend the capacity of the system without laying more fibers. Capacity of a given system can be expanded simply by upgrading the multiplexers and de-multiplexers at each end without having to overhaul the backbone network. Generally a basic WDM system has been divided into three parts [7]: (i) Transmitter section, (ii) Transmission link section and (iii) Receiver section.

2 SIMULATION MODEL

For the simulation work Optisystem Simulation software is used. In transmitter section, externally modulated transmitter is used in order to achieve stability. This also helps to reduce the chirps and non-linear effects. Here, Pseudo Random Bit Sequence (PRBS) is used to generate digital data and Non-return zero (NRZ) pulse generator is used to convert digital signal into electrical signal. After that modulator mixes the electrical signal with the light source input signal and generate optical output signal which is then sent into the multiplexer.

In this design four transmitters are used of equal channel spacing of 50GHz starting from 193.1Thz.

In this transmission link design, single mode fiber (SMF) is used which has dispersion around 16.75 ps/nm.km and attenuation of 0.3 dB/km. Fiber Bragg Grating (FBG) is used to compensate the dispersion effect and SOA is used as amplifier to compensate the fiber linear loss(attenuation).

In receiver section, PIN photo-detector is connected to the output to detect the optical signal and convert it to electrical signal and send it to low pass Bessel filter which pass the low frequency signal and discard high frequency carrier signal. Then BER Analyzer is used to analyze the bit error rate and quality factor of the designed system.

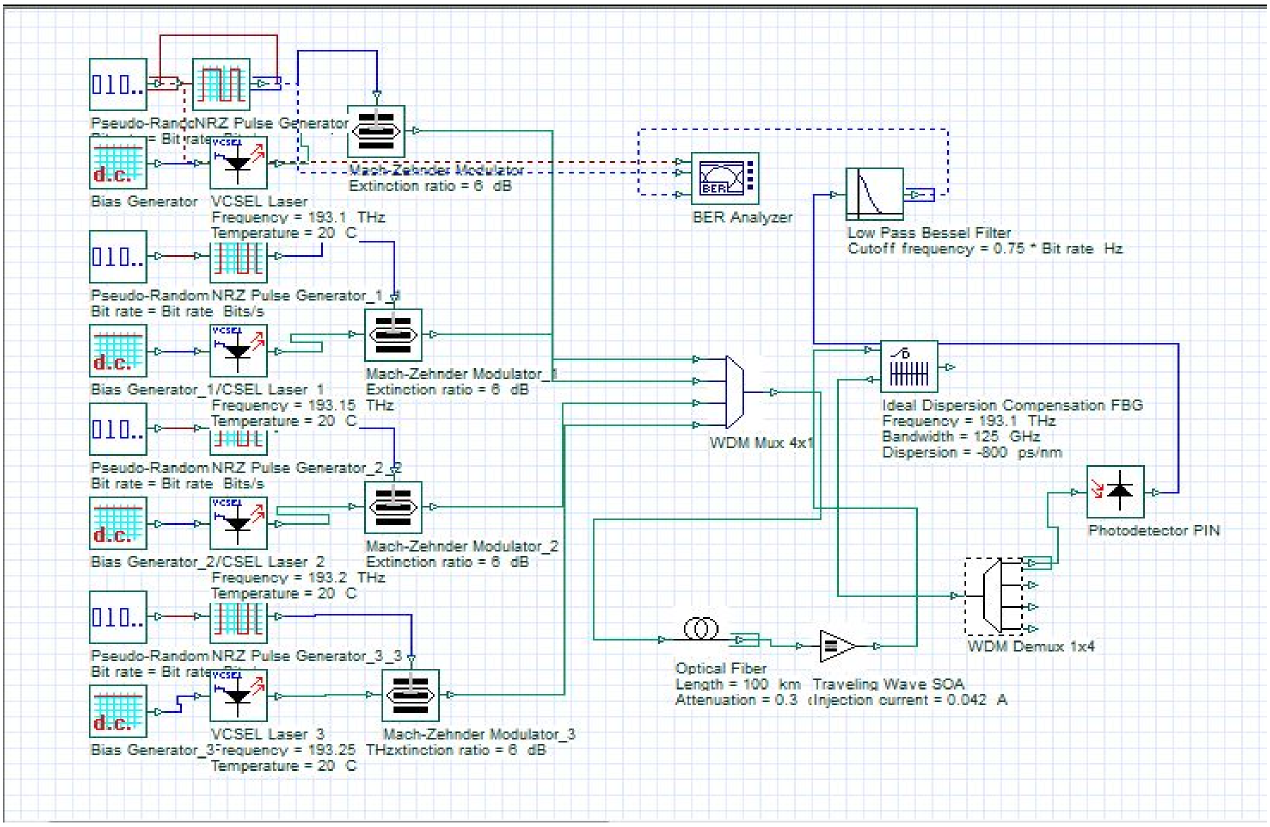

Fig. 1. WDM system using SOA

The circuit is designed for 100km optical fiber length where the SOA injection current is 0.042A, attenuation of the fiber is 0.3dB/km and the frequencies of the four channels are 193.1THz, 193.15THz, 193.2 THz and 193.25 THz.

3 RESULTS AND SIMULATION

The proposed circuit of figure 1 starts to operate at 6GHz bandwidth. At 6GHz the Q-factor is 1.87555 and BER is 0.0299241 which is very poor. The eye diagram of 6GHz bandwidth is given below:

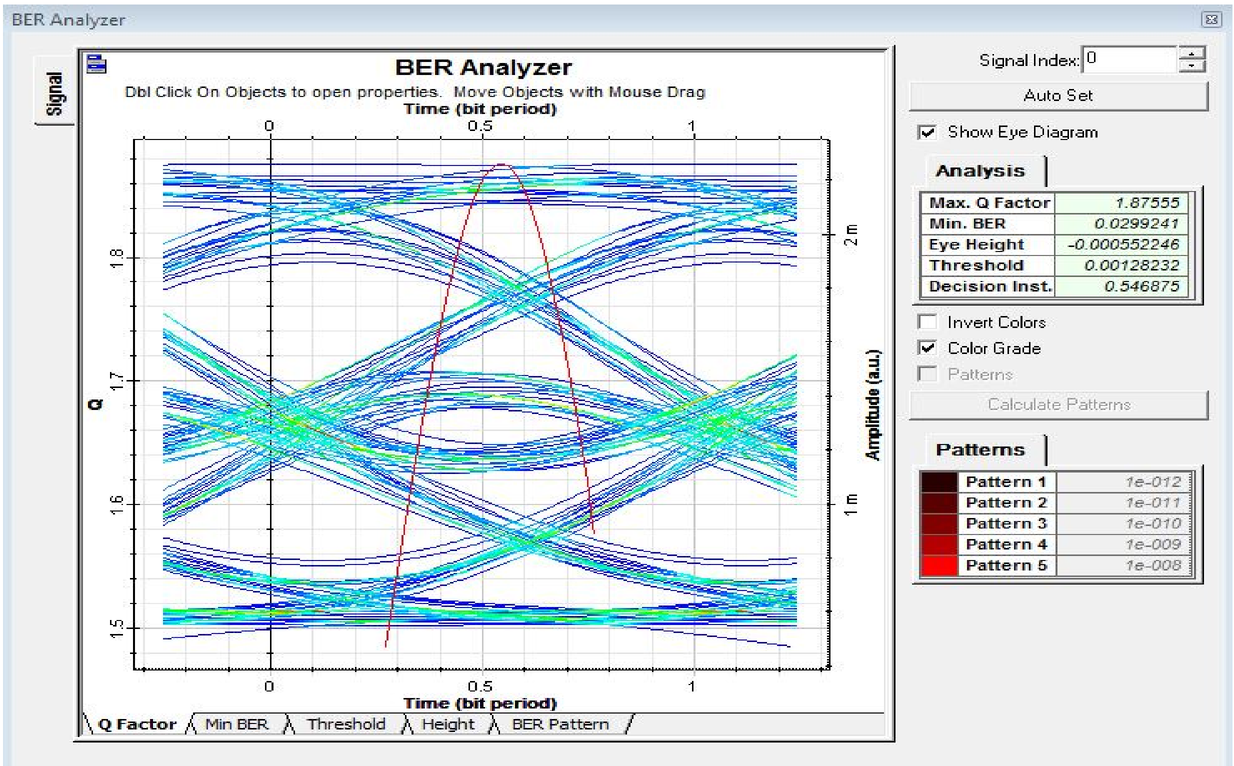

Fig. 2. Eye diagram for 6GHz bandwidth

If we increase the bandwidth up to 34GHz the Q-factor increases and BER decreases which is required for any optical transmission. Above 34GHz bandwidth Q-factor starts to decrease and BER increases. The value of Q-factor, BER and the corresponding eye diagrams for different values of bandwidth is given below:

For 10GHz the Q-factor is 4.18004 and BER is 1.43505e^{-005} and the eye diagram is given below:

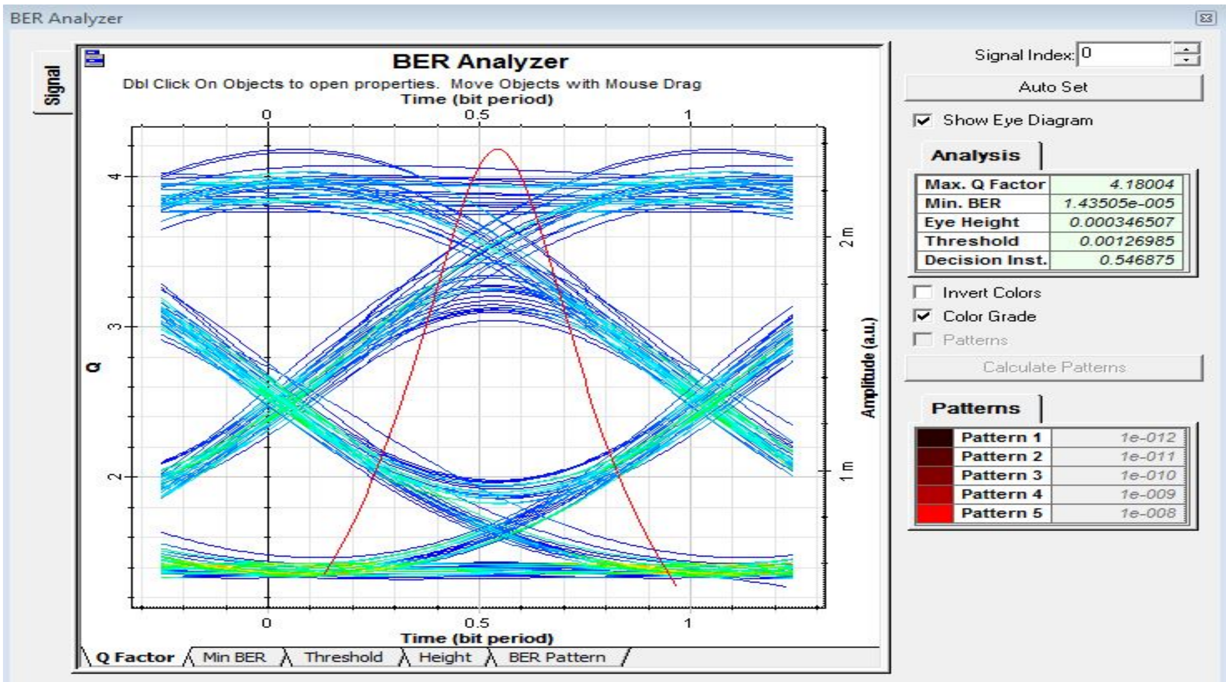

Fig. 3. Eye diagram for 10GHz bandwidth

For 20GHz the Q-factor is 11.3986and BER is $2.11826e^{-030}$ and the eye diagram is given below:

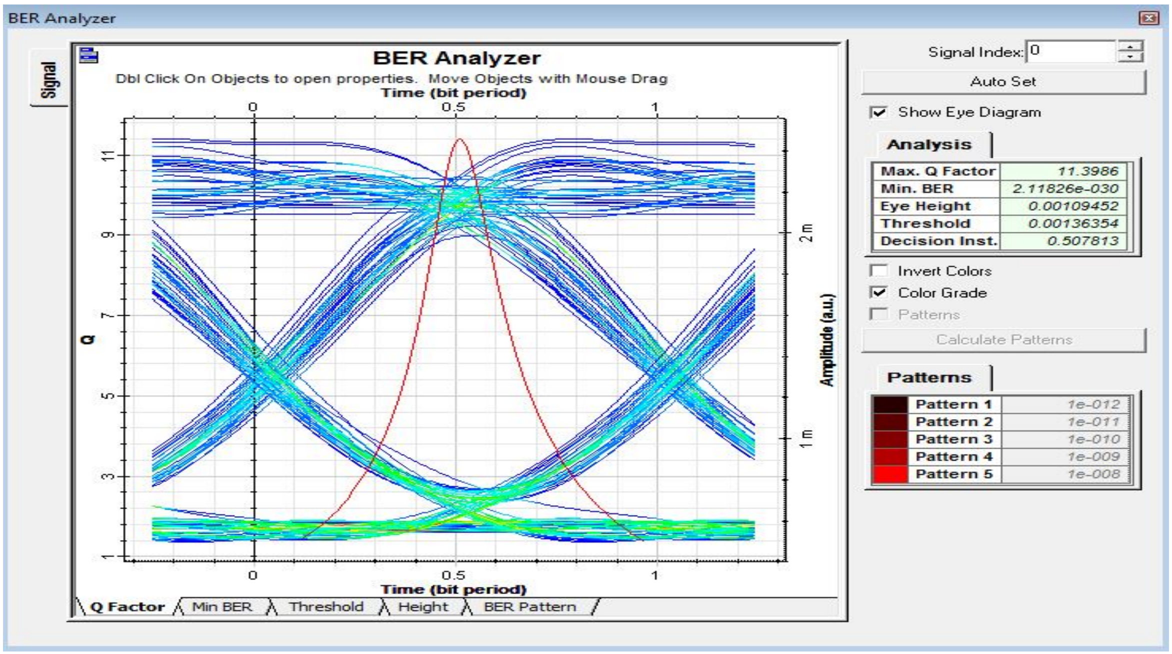

Fig. 4. Eye diagram for 20GHz bandwidth

For 30GHz the Q-factor is 13.0646 and BER is $2.59822e^{-039}$ and the eye diagram is given below:

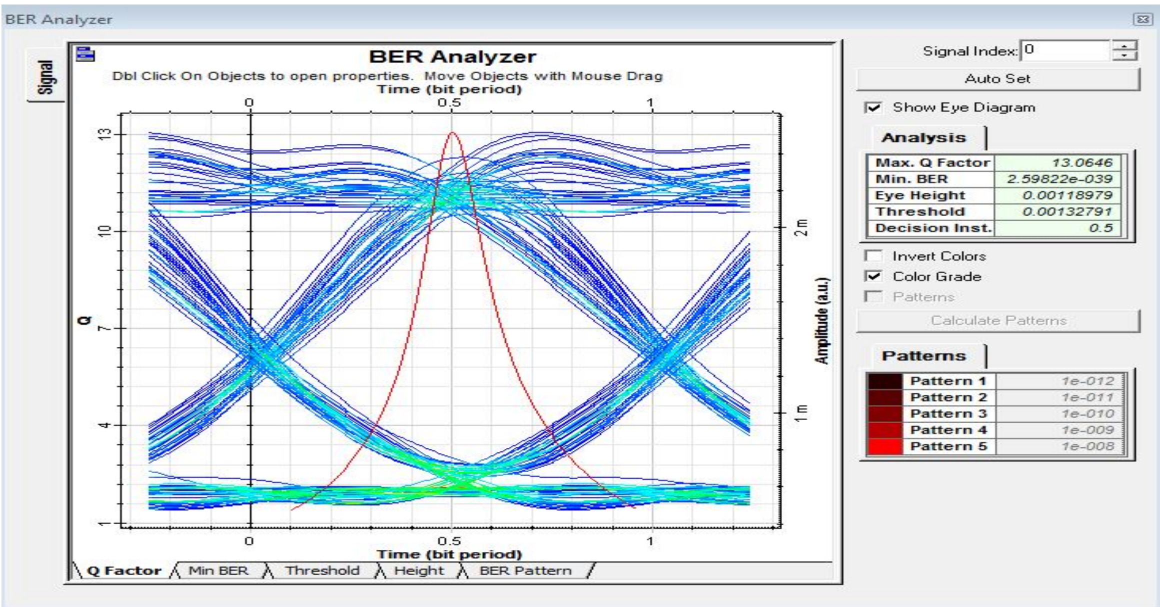

Fig. 5. Eye diagram for 30GHz bandwidth

At 34GHz maximum Q-factor of 13.1248 and minimum BER of $1.16972e^{-039}$ is obtained and the eye diagram is given below:

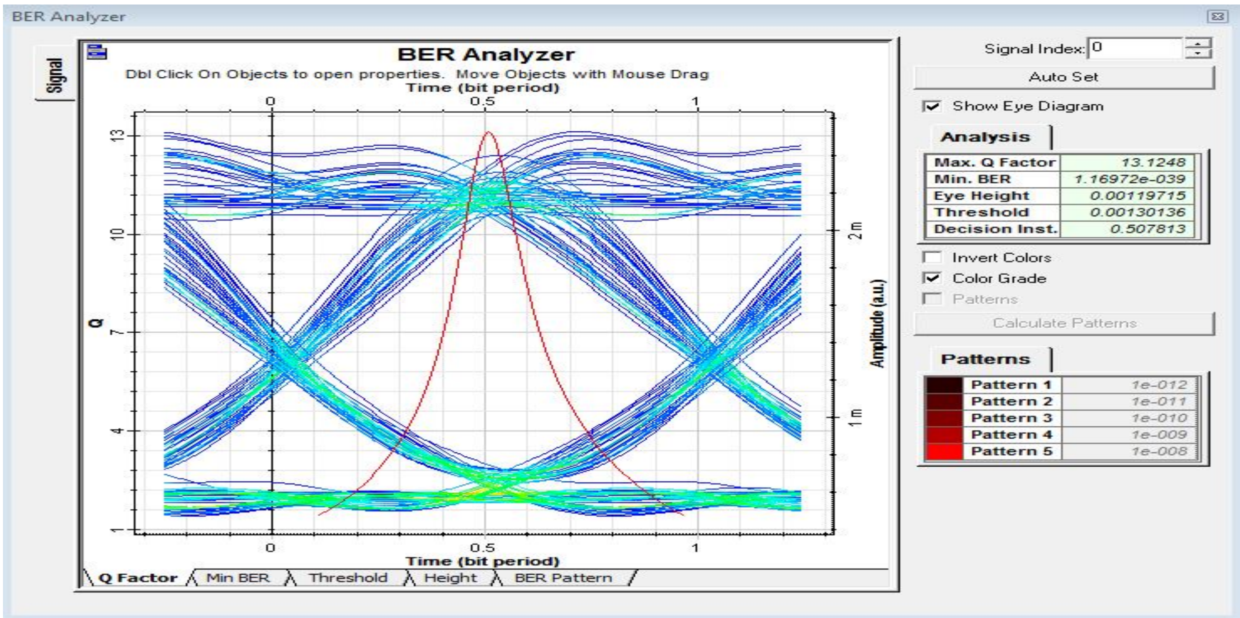

Fig. 6. Eye diagram for 34GHz bandwidth

Above 34GHz the Q-factor gradually decreases and BER increases as a result eye diagram become worst. For example at 40 GHz the Q-factor is 13.0616 and min BER is 2.67739e$^{-039.}$

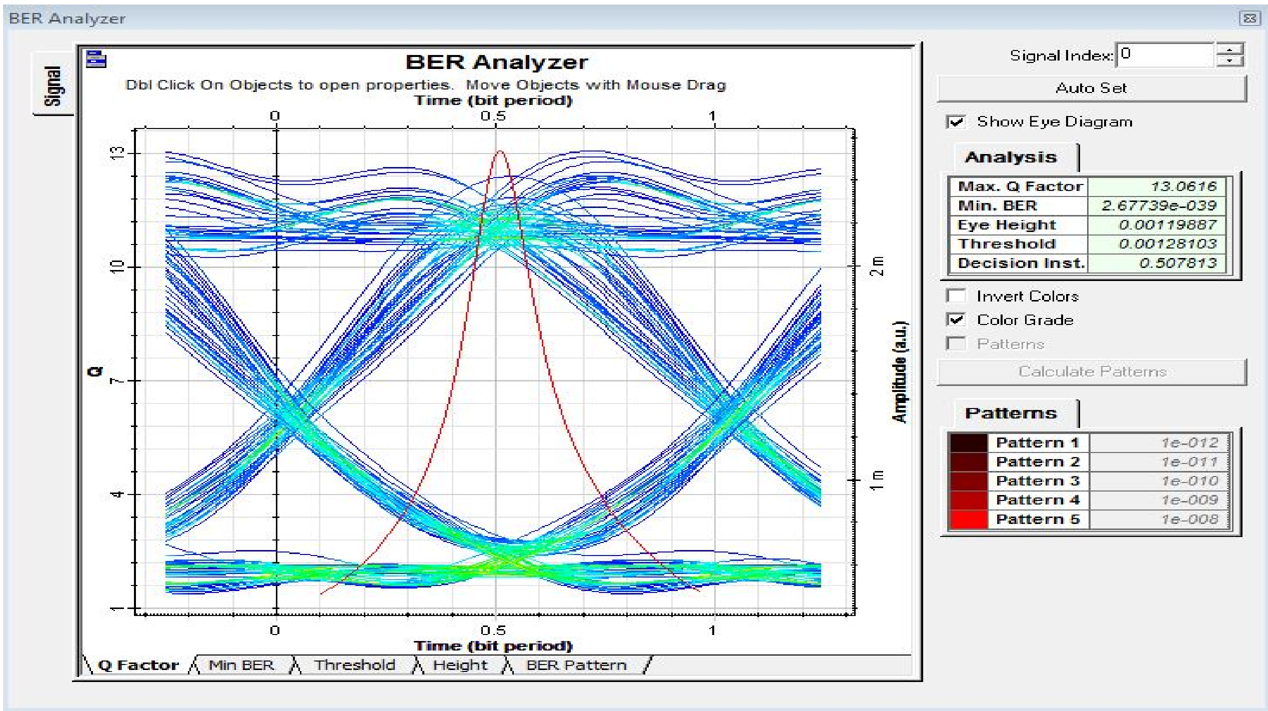

Fig. 7. Eye diagram for 40GHz bandwidth

The bit rate and the sample rate of the circuit of figure 1 is given below:

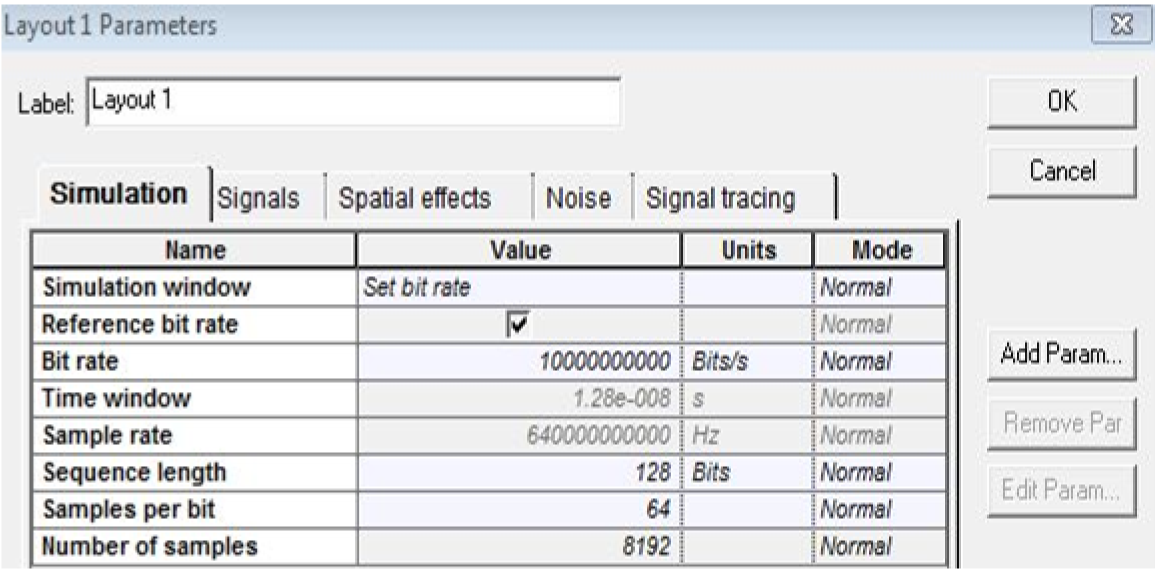

Fig. 8. The bit rate and the sample rate of the circuit of fig. 1

Without SOA the circuit gives zero Q-factor and maximum BER equal to 1. The eye diagram of the circuit without SOA is given below:

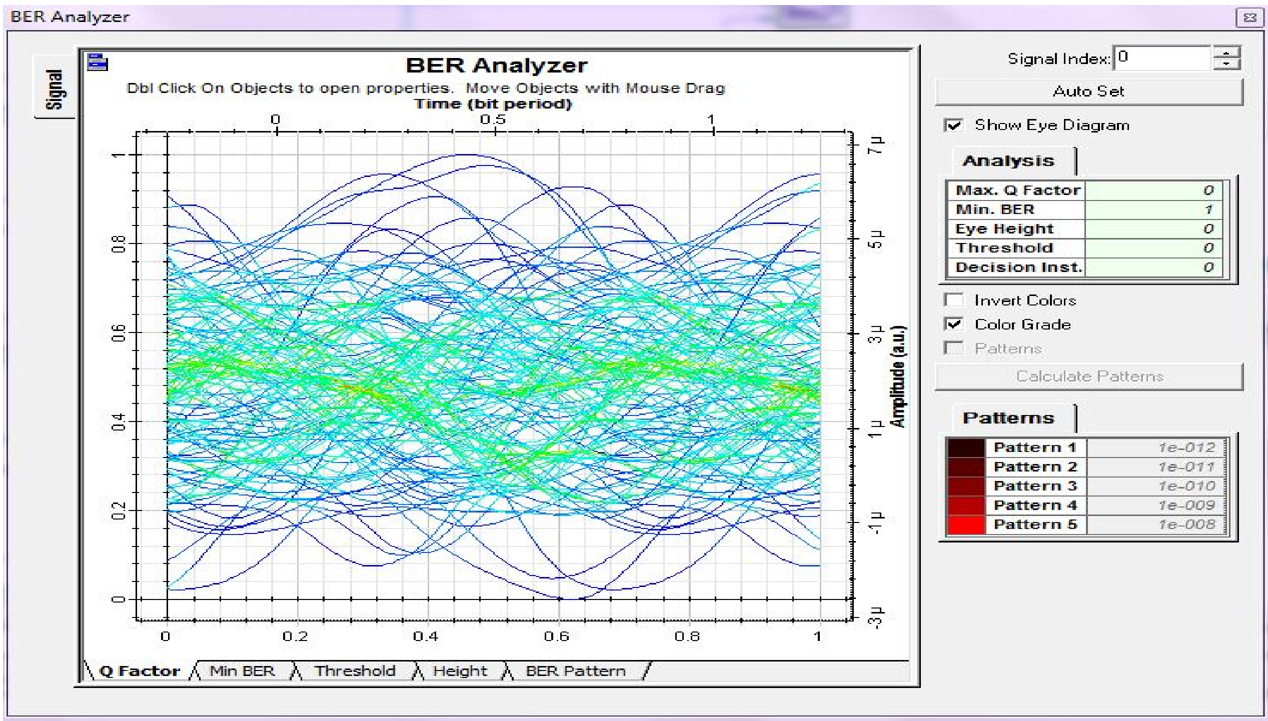

Fig. 9. Eye diagram without SOA

Table 01:Q-Factor and BER by varying the bandwidth using SOA and without SOA

Channel Spacing 50Ghz	With SOA		Without SOA	
Bandwidth (GHz)	Q-Factor	BER	Q-Factor	BER
6	1.8755	0.0299241	0	1
10	4.18004	1.43505e-005	0	1
20	11.3989	2.11826e-030	0	1
30	13.0646	2.59822e-039	0	1
34	13.1248	1.16972e-039	0	1
40	13.0616	2.67739e-039	0	1

From the table we can observe that using SOA with the increase in bandwidth Q-factor increases and bit error rate decreases. Without using SOA Q-factor is always zero and bit error rate is always 1. A plot of bandwidth versus Q-factor is given below:

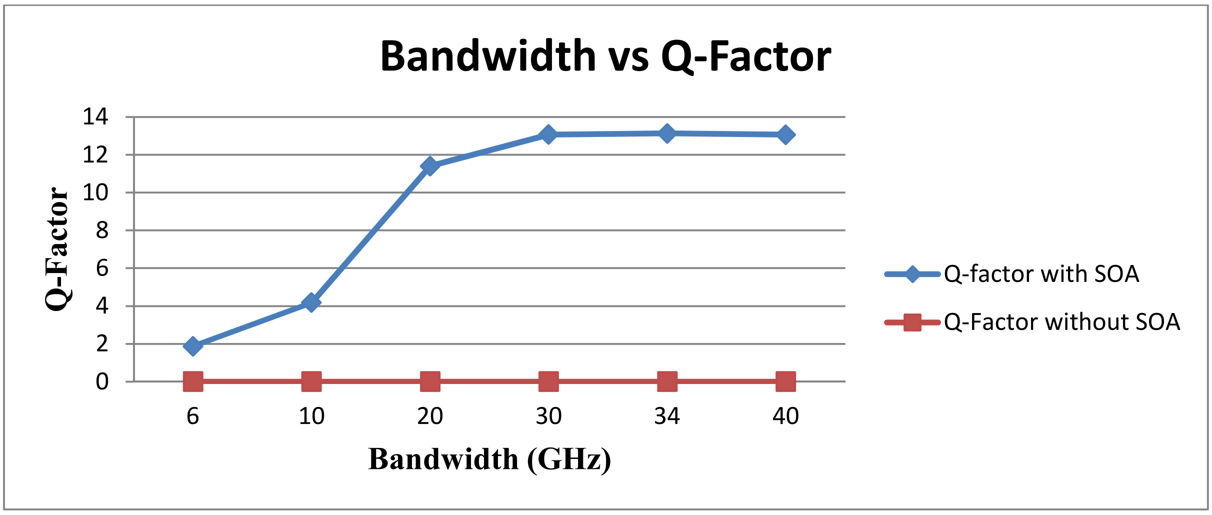

Fig. 10. Plot of Bandwidth vs. Q-factor with and without SOA

Table 02:Q-Factor and BER by varying the optical fiber length using SOA

Fiber Length (km)	Q-Factor	BER
20	2.53573	0.004864
40	1.52787	0.053499
60	3.99168	2.49E-05
80	4.74201	8.13E-07
100	13.0646	2.60E-39
120	9.12772	3.49E-20

From table 2 we can see that if we increase the fiber length up to 100km Q-factor increases and bit error rate decreases but above 100km Q-factor decreases and bit error rate increases. A plot of fiber length versus Q-factor is given below:

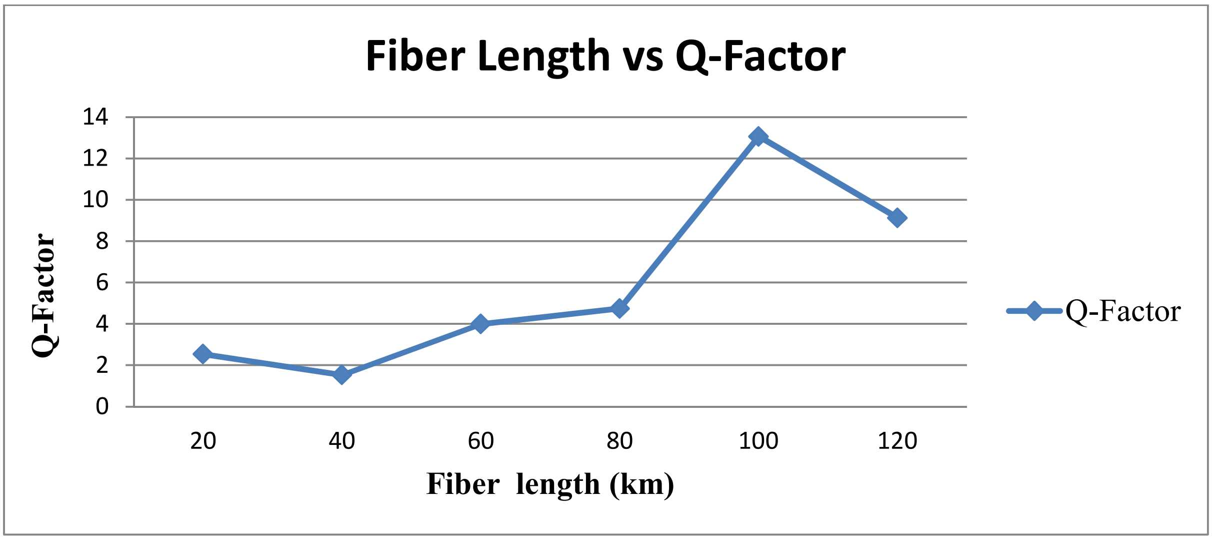

Fig. 11. Plot of Fiber length vs. Q-factor

4 CONCLUSIONS

In this paper a Wide Division Multiplexed (WDM) system using SOA is introduced. A circuit is designed for 100km optical fiber length where the SOA injection current is 0.042A, attenuation of the fiber is 0.3dB/km and the frequencies of the four channels are 193.1THz, 193.15THz, 193.2 THz and 193.25 THz with equal channel spacing of 50GHz. At 34GHz bandwidth a low BER of $1.16972e^{-0}$ with a high Q-factor of 13.1248 is achieved.

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