Performance Evaluation of BER and Q factor for EDFA Based WDM Network

R. S. Rifia Reen
Department of Electronics and Communication Engineering (PG)
Sona College of Technology
Salem, Tamil Nadu, India

G. Ravi
Department of Electronics and Communication Engineering (PG)
Sona College of Technology
Salem, Tamil Nadu, India

***Abstract* — Erbium-doped fiber amplifier (EDFA) is considered as a main aspect for wavelength division multiplexing (WDM) application and highly used in long distance telecommunication of modern optical networks. Challenges like Bit Error Rate (BER) and Q factor are generally faced by these networks. In this paper an 8 channel EDFA based WDM network is proposed and the performance of the network is analyzed. The proposed design uses a Dispersion Compensation Fiber (DCF) to identify the best BER and Q factor in a network. The DCF used for the measurement of these performances are fixed with an input frequency of 193.1 to 193.8 THz in continuous wave (CW) laser and the signals are sent through a EDFA based WDM network. In this network a Mach-zehnder modulator combine CW laser and return to zero (RZ) pulse generator signal to avoid more dispersion and crosstalk. The analysis of the design is carried out with the help of simulation in OptiSystem 7.0. Sweep iterations are done for 1 Gbps, 2.5 Gbps, 5 Gbps and 7 Gbps in the Bit Sequence Generator (BSG) to identify the efficient output. Comparison have been done among these bit rates and the results are obtained through BER analyzer. The best output is finally obtained for the proposed network.**

Keywords— CW laser, EDFA, Dispersion compensation fiber, WDM, BER and Q factor.

I. INTRODUCTION

Wavelength division multiplexing has a major role in optical communication that is wireline communication. Optical communication has a large number of advantages since the fiber has more capabilities [1] like large bandwidth of 50 terabits per second, cost effective, less power and space requirement. Because of this, more users can get the data based on bandwidth intensive networking and their application like World Wide Web (www). Video conferencing, data transferring are also some of the facilities provided by these advantages. In earlier period, one input signal is used which is transmitted to particular components to perform the specific operation. But it is not suitable in today's life because this is more costly and need separate component to handle each input signal in optical network. In order to avoid these inconvenience, the WDM is used which can transmit the specific set of frequency of 2, 4, 8, 16 and 32 channels.

In optical communication, the signal transmission will be of frequency in GHz range. Bit sequence generator is used in transmitter side to generate binary source in order to avoid error propagation at receiver. While transmitting the input signal of lower or higher frequency each have any one problem in it. When transmitting lower frequency it never arise any problem to the signal for short range communication. When the signal is examined for long distance, some distortion and loss may occur in it and sometimes the signal does not reach the destination. In order to avoid these problems an amplifier could be used with the design. One of the commonly used amplifier is EDFA. This amplifies the signal and generate some noise in the system [2] but these noise are insensitive.

EDFA amplifies more than 100 channels from WDM on a single fiber with variable fiber length. However while transmission in the higher frequencies and for large distances there is possibilities of occurrence of interference and dispersion between each signal. It may arise some delay and makes the signals to reach at different times. Sometimes it will make the signal useless for data transmission due to dispersion. Dispersion can be minimized by implementing the design with components like dispersion compensation fiber, fiber grating and by using different modulation techniques in it. In order to avoid the wastage of the signal dispersion compensation fiber [3] is used before the amplifier.

II. RELATED WORK

EDFA needs pumping signal from semiconductor laser of 980 nm or 1480 nm wavelength. In optical communication the mostly preferred wavelength is 980 nm. In which the population inversion occurs while execution. EDFA in optical network contains single, two and multiple stage design. Based on their stages output will change. Low noise, high output power could also be achieved. In [4] paper, two stages EDFA is used so that it improve the output in the design. EDFA has the main advantage of amplifying any set of channels like 4, 8,16,32,64, etc. Higher order channels are required for day-today life to serve many users.

In [5] paper, the WDM system with 4 channel is proposed which is mainly focused on EDFA. It describes the comparison and performance of the design with and without the use of EDFA. Without using EDFA, eye diagram is obtained with noise, output power is low and it suffers from losses and attenuation. These problems are overcome by using EDFA.

An 8 channel WDM is reported in [6] and the BER, Q factor, eye height were analyzed by changing the fiber length. The output is obtained for different wavelengths by the BER analyzer and then compared. Here 1550 nm wavelength was found to have good eye height. Filters were not used, hence the output result is not up to the level. In [7] paper, good gain flatness was obtained by using low pass chebyshev filter and by tuning the numerical aperture. This result is higher when compare to the last paper.

Normally isolators are used to prevent Amplified Spontaneous Emission (ASE) and to avoid backward propagations. In [8] paper two isolator were used to improve the gain and noise figure. One of the problem that occur while using WDM with EDFA is that all channels are not equally amplified. Pump power is used to overcome this problem. Fiber bragg grating act as notch filter which is used to block specific frequency in the design.

III. WDM SYSTEM USING DISPERSION COMPENSATION FIBER

The signal travels in optical fiber at different speed and reaches the receiver at different time. This delay occurs mainly on chromatic dispersion. Signal at input side will be perfect, however during transmission it experiences pulse broadening and it becomes wider. Here multiple light pulse of 16 signal are generated by CW laser and transmitted through WDM. Here there are possibilities for occurrence of overlap between the light pulses. This may arise a problem while detecting the individual signal at output side.

Chromatic dispersion occur due to the combination of material dispersion and waveguide dispersion. Material dispersion can’t be controlled because it mainly depends on refractive index. In waveguide dispersion, light pulse travels faster in core and slower in cladding. For error free transmission of light pulse, dispersion compensation fiber is used before the EDFA.

Dispersion compensation fiber has various schemes which are used in network. They are Precompensation Scheme and Post-compensation Scheme. When low positive dispersion occurs in transmission fiber, DCF will produce large negative dispersion. That time the total dispersion will be zero. In precompensation, the DCF is located after the EDFA and in post-compensation DCF is before the EDFA.

IV. EDFA PARAMETER

Erbium Doped Fiber Amplifier is a fiber made of silica which will be highly doped with erbium. EDFA normally operates in the range of 1530 to 1565 nm and has the spectral band of conventional band also called as C-band. It need external force to excite the electrons from ground state to higher energy level with the help of optical pumping. When reaching the excited level it release some of their electrons to desired level. After that the excited electron with signal photon is adjusted to simulated emission. Varying the EDFA parameter is very important to improve the performance of the system. The parameters like numerical aperture, absorption (dB/m) value is changed according to wavelength, the cladding diameter is set at 80µm or 125µm, core concentricity is maintained at ≤0.3.

V. EXPERIMENTAL SETUP

Basically simulation of optical network design is done in optical software before hardware fabrication. This will help us to avoid failures and make the design effective and efficient. By this procedure, problems appearing in network is easily noticeable and error correction can be done while executing the network in OptiSystem software. In the software implementation, signals are generated by various optical sources like CW laser, LED, VCSEL laser, white light source and pump laser. Here CW laser at a frequency range of 193.1 THz to 193.8 THz is used for the generation of input signals and it act as a laser source for whole network. To generate bit signal in network, Bit Sequence Generator (BSG) is used and output is sent to RZ pulse generator (RZ PG). Output is viewed based on 4 sweep iterations with bit rate of 1 Gbps, 2.5 Gbps, 5 Gbps and 7 Gbps in RZ pulse generator.

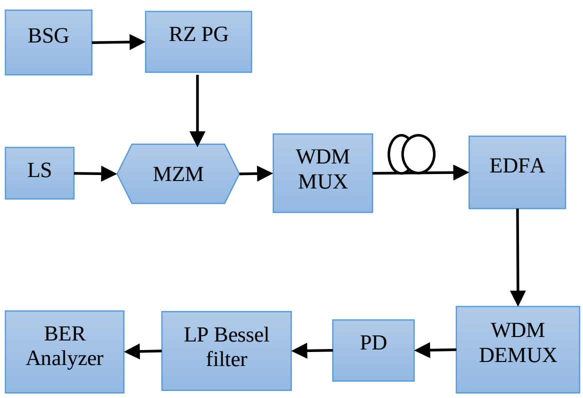

Fig. 1. Simulation Block Diagram.

Then the signal from laser source and RZ pulse generator are combined and is fed into the mach-zehnder modulator to generate the signal in sequence to avoid mismatch and dispersion between the input signals.

WDM mux combines all the input signals into one signal which could be transmitted through a single optical fiber. The optical fiber used here is DCF of length 17 km. This fiber is highly used to reduce dispersion. A Single Mode Fiber (SMF) of 83 km is connected after DCF which acts as an intermediate between input and output. EDFA is used between two ends to amplify the signals. It has the capability to amplify even ultrashort pulses.

Normally at receiver side, WDM demux fetches the input signal and generates the output signal. These signal is detected by photo detector (PD) and low pass (LP) bessel filter is used to yield the flat group/phase delay in it. The results are viewed in each BER analyzers for various sweep iterations and each BER and Q factor readings are compared to find the best readings.

VI. RESULT ANALYSIS

This paper is focused on obtaining minimum BER and high Q factor in WDM network for the frequency of 193.1 THz to 193.2 THz. The power for CW laser is fixed as 0 dBm and bit rate at RZ pulse generator is fixed as 1 Gbps, 2.5 Gbps, 5 Gbps and 7 Gbps in sweep basis. Length for DCF and SMF is fixed as 17 km and 83 km. The results for this design are obtained in which the Q factor was found to be very high with very low BER. Both the parameters were found to be inverse. Output is executed. The BER and Q factor for the sweep iterations were compared.

Initially the reading is noted for sweep iteration 1 at bit rate of 1 Gbps with the frequency of 193.1 THz to 193.8 THz. Results are verified in BER analyzer in which the BER and Q factor were noted. Output is shown in Fig. 2a and 2b for frequency of 193.1 THz. From the graph it is concluded that the BER is 0, Q factor is 173.869 and the eye diagram is clear. The result is found to be suitable for optical communication and then the next sweep iteration is examined.

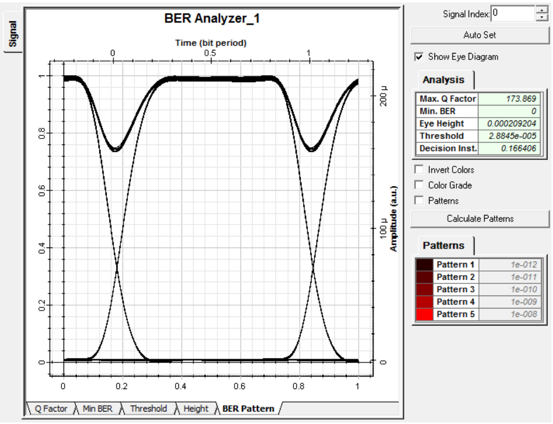

Fig. 2a. BER at 193.1 THz and bit rate at 1 Gbps

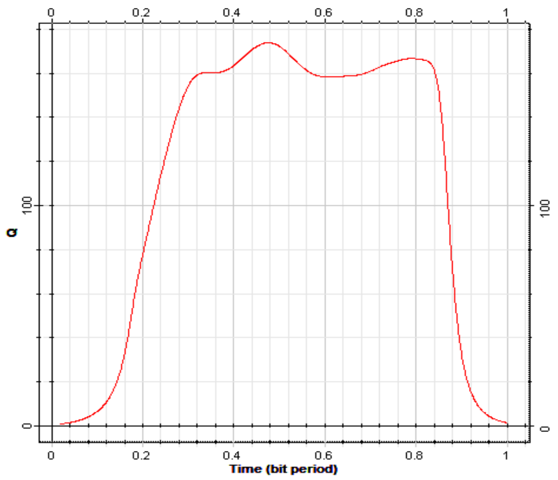

Fig. 2b. Q factor at 193.1 THz and bit rate at 1 Gbps

In sweep iteration 2, the bit rate is obtained as 2.5 Gbps and the obtained output has good eye opening. In this BER is 0 and Q factor is 102.091 at 193.1 THz as shown in Fig. 3a and 3b. This eye diagram is good, but the Q factor is low when compared with the previous output.

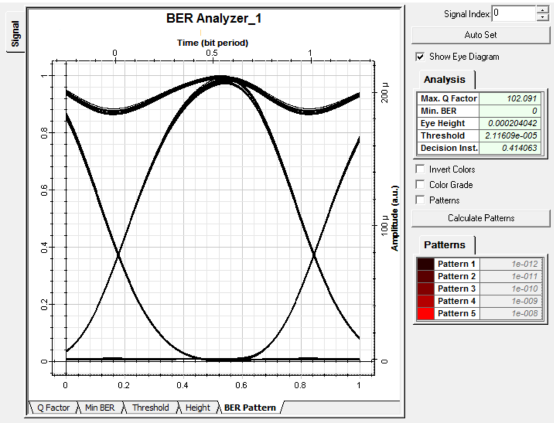

Fig. 3a. BER at 193.1 THz and bit rate at 2.5 Gbps

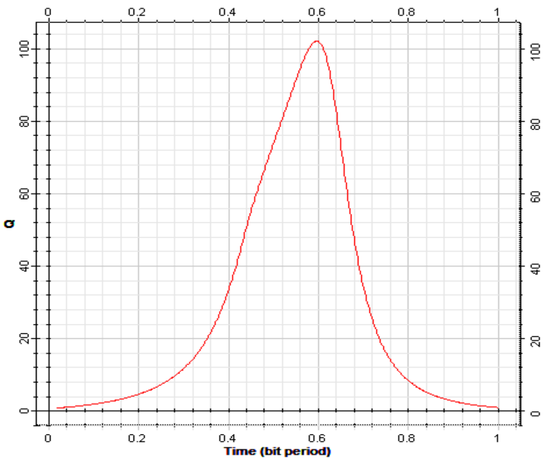

Fig. 3b. Q factor at 193.1 THz and bit rate at 2.5 Gbps

At sweep iteration 3, the bit rate at RZ pulse generator is fixed as 5 Gbps. Eye opening is not as much as good when compared with previous bit rates. The output for this sweep iteration is shown in Fig. 4a and 4b. Also the Q factor is very low for all output channel in this iteration.

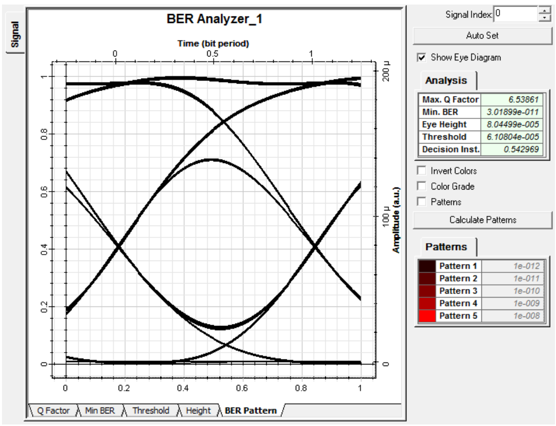

Fig. 4a. BER at 193.1 THz and bit rate at 5 Gbps

Another sweep iteration is carried out for the bit rate of 7 Gbps. Eye diagram is not clear for this iteration too. In this the BER is high (0.0038) and Q factor is low (2.664). The output at BER analyzer is shown in Fig. 5a and 5b. When comparing the outputs of the 4 sweep iterations, it is clearly identified that the output obtained for bit rate of 1 Gbps produces better and efficient result.

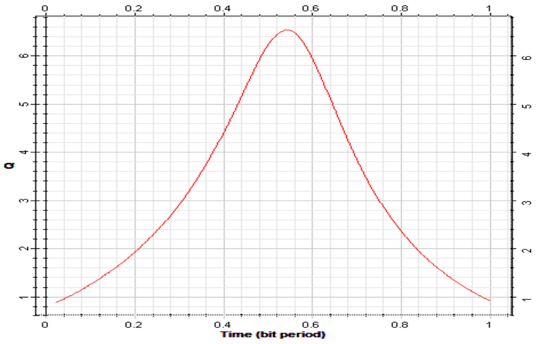

Fig. 4b. Q factor at 193.1 THz and Bit rate at 5 Gbps

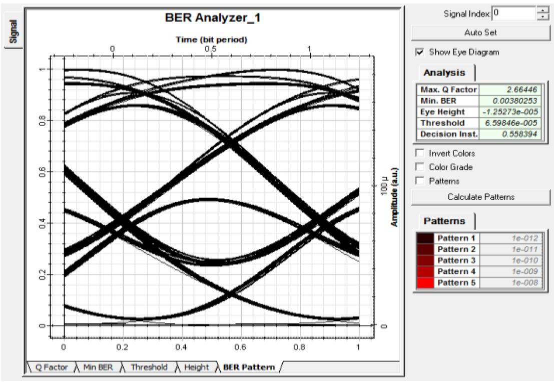

Fig. 5a. BER at 193.1 THz and bit rate at 7 Gbps

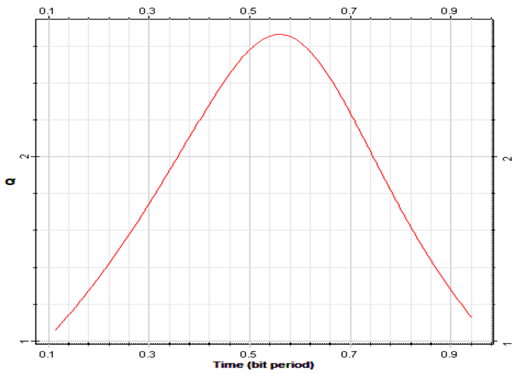

Fig 5b: Q factor at 193.1 THz and bit rate at 7 Gbps

Output is tabulated for input signal from 193.1 THz to 193.8 THz with their BER and Q factor as shown in Table for bit rate 1 Gbps, 2.5 Gbps, 5Gbps and 7Gbps.

TABLE 1. BER FOR ALL BIT RATE

Frequency (THZ)	BER at bit rate(Gbps)			
	1	2.5	5	7
193.1	0	0	$3.01e^{-011}$	0.0038
193.2	0	0	$4.13e^{-011}$	0.0038
193.3	0	0	$3.69e^{-012}$	0.0039
193.4	0	0	$4.84e^{-011}$	0.0038
193.5	0	0	$6.04e^{-011}$	0.0036
193.6	0	0	$3.49e^{-012}$	0.0039
193.7	0	0	$3.75e^{-011}$	0.0039
193.8	0	0	$2.40e^{-011}$	0.0039

Table II. Q FACTOR FOR ALL BIT RATE

Frequency (THZ)	Q factor at bit rate (Gbps)			
	1	2.5	5	7
193.1	173.87	102.09	6.54	2.664
193.2	221.8	164.1	6.49	2.661
193.3	238.65	141.99	6.85	2.652
193.4	241.26	140.41	6.47	2.66
193.5	150.83	129.95	6.43	2.678
193.6	148.15	115.17	6.85	2.654
193.7	82.88	118.76	6.51	2.653
193.8	338.21	122.61	6.57	2.649

VII. CONCLUSION

A paper on EDFA based WDM design is proposed, in which a signal reception is examined to produce most efficient and error free output. A network is designed in which the input signal of 193.1 THz to 193.8 THz is sent from a transmitter to the receiver. EDFA is used for the amplification purpose of the design. After reception the BER and Q factor of the input signal were analyzed for 4 sweep iterations with various bit rates. The result comparison was done for the outputs. Best and efficient result was achieved at 1 Gbps bit rate with 193.1 THz frequency. The obtained Q factor is 173.87 and BER is zero. For the other bit rates, the Q factor was low (<173.87) and eye diagram was not good. This best obtained result is found to be highly suitable for real time applications like telecommunication, avionics. As future work more number of channels could be employed.

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