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Performance Evaluation of EDFA Optical Amplifier for WDM System.

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Abstract: *The Wavelength Division Multiplexing (WDM) is the best option in terms of increasing channel capacity and support growing bandwidth demands by optical fiber communication. The optical signal will carry multiple streams of information; each stream with its own unique wavelength. The effective wavelength for the WDM system will be from 1525–1565 nm in the C-Band. The 50-channel wavelength division multiplexing system, with a high performance flowrate of 10 Gb/s, has been evaluated. This paper will compare the influence of the position of erbium-doped fiber amplifier (EDFA) against the preamplifier that was used to realize signals with enhanced Q-Factor and BER.*

Keywords:*Wavelength Division Multiplexing (WDM), erbium doped fiber amplifier(EDFA), Bit Error Rate BER, Q-factor.*

I. Introduction

The optical network is embedded with wavelength division multiplexing (WDM) to support multiple services with differing requirements for bandwidth, latency, reliability and other related features . Initially, this involves multiple WDM channels being installed simultaneously within the same optical fiber [1]. The communication channel is responsible for transporting optical signals from the transmitter to the receiver without undergoing distortion, therefore, an optical amplifier is required to amplify the optical signals. EDFA is a type of amplifier that utilizes doped optical fibers as its gain medium. EDFA is known as the most commonly utilized optical amplifier due to its low-loss optical window of silica based fiber . It also possesses a large large-gain bandwidth in the order to 10s of nanometers, which is more than enough to increase data channels to its highest without inducing gain narrowing [2]. The channel parameter is shown in Table [3].

II. Basic Function Of Wdm Network

To avoid losses, the system uses a huge bandwidth in the fiber. By using the wavelength division multiplexer, the signal light source can be sent to the single mode fiber at different wavelengths for transmission. Each light signal will split based on the carriers' signal. The SMF fiber is used for long distance communication, and for a distance of 50 km, we require that theamplification of the light signal to realize the target that it will de-multiplex, while servicing consumers [3] [4].

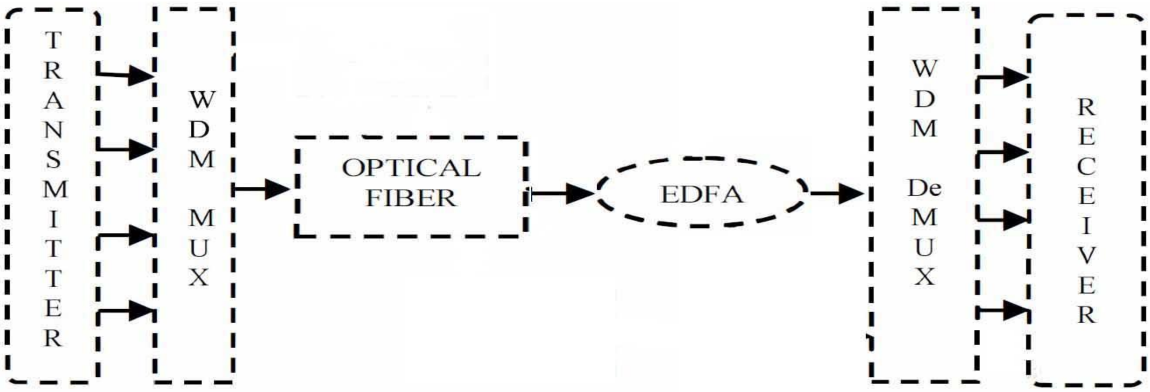


Figure 1.optical amplifier in WDM commutationsystem.

III. The Fifty Channels Wdm Network

An optical communication system is comprised of a transmitter, communication channel, and receiver . A transmitter convert a wide pulse optical signal into a narrow wavelength of the order of 1.6 nm, where the signal will be sent to the communication channel. The receiver receives the colored output from the demux, which is then converted into a wide pulse optical signal.

3.1 Transmitter

The WDM transmitter combines transmission lasers to form single fibers. Lasers rely on both purpose and intended application. We use the WDM transmitter to propagate the optical source into a single optical fiber, relying on lambda to increase the laser source. Within the WDM network, it is possible to expand the current network without utilizing a new optical fiber. The WDM transmitter specification are tabulated in Table [1].

3.2 Transmission Channel

SMF is a high capacity optical fiber that is used for long distance communication. The SMF specification tabulated in Table [2] was designed for 50 km. Post long-haul in the optical fiber, the signal was attenuated, necessitating the presence of an EDFA amplifier. Channel design based on EDFA specification is tabulated in Table [3], which was added to balance the loss after the fiber and near the receiver. The parameters pertaining to the SMF is shown in Table II. In order to calculate the performance based on distance, EDFA is used. By using the fiber's length, we can preset the number of times the signal will propagate through the components [6] [7].

3.3 Receiver

The optical receiver is a combination of the APD Photodiode. It helps operate optical fiber communication, which is crucial to fiber optics. The overall performance of fiber optic communication depends on the Bit Error Rate (BER) and Q-Factor. With a standard increase of optical communication in a single-mode fiber, the effect of spontaneous emission and noise in the receiver are partially increasing, therefore, BER is crucial in optical communication. One of the important criteria include 10 exp(-11) for optical receivers[5], with its specification tabulated in Table [4].

3. Tables

Table1. Specification of transmitter

Name	Value
Number of input port	50 channel
Wavelength	1550nm
Frequency spacing	100GHZ
Bit rate	1e10
Type of modulation	RZ
power	3 type of powers that is 0dBm، -5dBm، -15dBm.

Table2. Specification of Single mode optical fiber SMF

Name	Value
Dispersion Coefficient	16 Ps/(nm-Km)
Dispersion Slope	0.076 Ps/(nm2 -Km)
Non Linear Coefficient	0. 35 I/(Km. W)
Linear Loss	0. 2 dB/Km
Length	50Km
Attenuation	0.5dBm

Table3. Specification of erbium doped fiber amplifier(EDFA)

Name	Parameter
Operation mode	Gain Control
Gain	10dB
Power	15dBm
Noise figure	5dB
Operation mode	Gain Control

Table3. Specification of receiver

Name	Parameter
Filter Type Bandwidth	Gaussian optical filter Band pass filter 10 GHZ
Photodetector	avalanche photodiode APD
No of ports	50 channels

IV. Equation.

1) The Q-factor provides an analog quality of the digital signal vis-à-vis the signal-to-noise (SNR) ratio. The Q-factor and BER is inversely correlated, as per Equation (1).

$$Q = \frac{I_1 - I_0}{\sigma_1 - \sigma_0}\,[-],$$

where: I1 - logic level "1", I0 - logic level "0", Ϭ1 – standard deviation of the logic level "1", Ϭ2 - standard deviation of the logic level "0" [3].

2) Bit error rate is defined as the ratio of incorrectly received bits to the total number of bits received over time. The bit error rate is the main indicator of the overall quality of the optical system. The calculation of the bit error rate from the knowledge of the Q-factor is expressed by equation (2) [3]:

$$BER = {}^{1}\!/_{2}\ erfc\,\langle\frac{Q}{\sqrt{2}}\rangle \cong \frac{e^{-\frac{Q^2}{2}}}{Q\sqrt{2\pi}}[-],$$

V. Results And Discussion

WDM system simulation model is shown in Fig 2. Inorder to transmit the data rate 10Gbps, 100GHz channelspacing is selected in design [8][9].

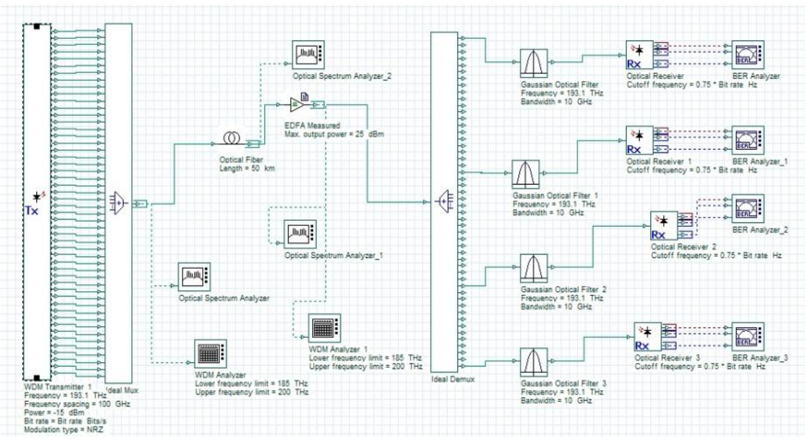


Fig. 2. Simulation Model of 50-Channel WDM System

5.1. Q Factor vs. Distance

Initially, we tested three types of position optical gain amplifier (booster amplifier, inline amplifier, pre amplifier) for the designed circuit at 2 channels, 4 channels, and 8 channels, and the results showed that the high performance in the Q Factor and BER is in the pre-amplifier. Then, the designer designed 50 channels at low power, as per Figure 3, with a high Q factor and lower BER, but this circuit only works at an optical fiber length of 50 km, where beyond this length, its performance decreases, where it is recommended that the amplifier be reinstalled.

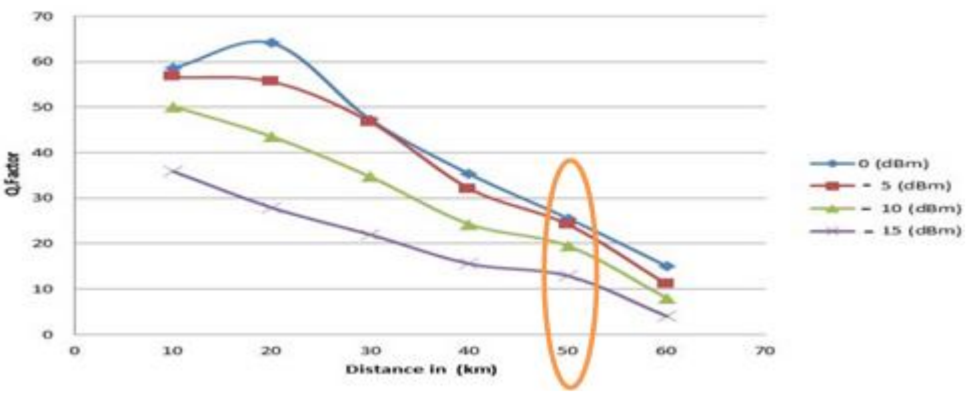


Figure.3.the relationship between Q Factor and distance with different power

5.2. Spectrum analysis

The optical spectrum analyzer is used to split signals into constituent wavelengths. The signal is graphically displayed, with power on the horizontal axis and wavelength on the vertical axis. The spectrum analyzer in the transmitter and receiver represents the spectrum signal of each signal. For each channel, the spectrum will be similar, but vary in amplitude due to its long transmission. The spectrum signal of the transmitter and receiver are shown in Figs. 4 and 5.

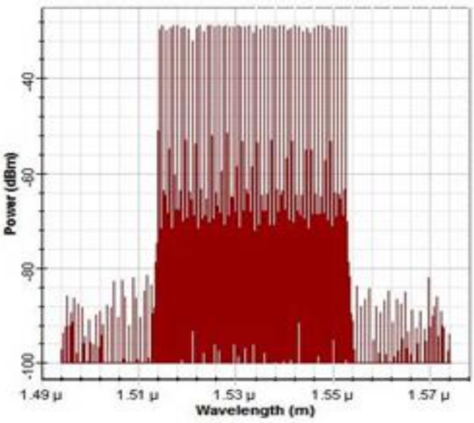


Fig.4. Spectrum Analyzer of transmitter side

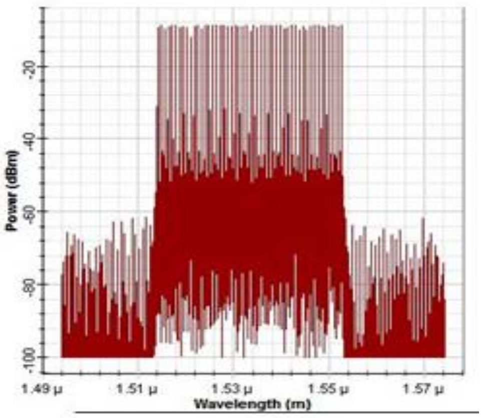


Fig.5. Spectrum Analyzer of receiver side

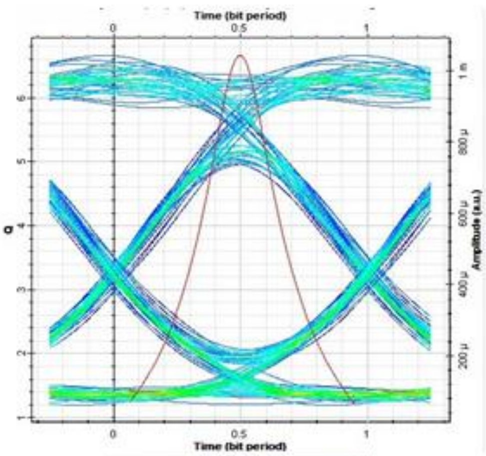
Wavelength(µm)	**Power(dBm)**
Center: 1.534 Start: 1.489 Stop: 1.578	Max:-25.5438 Min:-103.926

Wavelength(µm)	**Power(dBm)**
Center: 1.534 Start: 1.489 Stop: 1.578	Max:-4.04242 Min:-104.427

transmitter Side Spectrum Analyzer ValuesReceiver Side Spectrum Analyzer Values

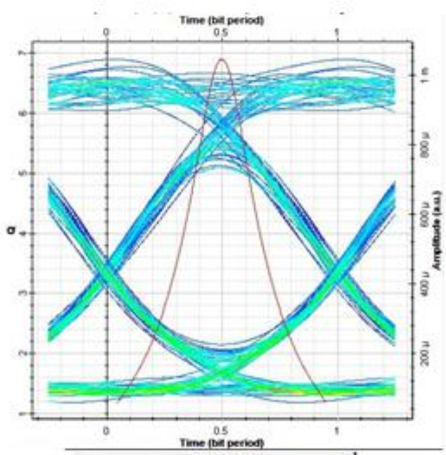
5.3. Eye diagram analysis

The eye diagram is used to view the performance in digital transmission. Figure 5 show the different channel of the received signal with low transmission power (-15dBm), with a data rate of 10Gb/s*50 channel. The eye diagram provides an instantaneous view by repetitively achieving good-view behavior [10].



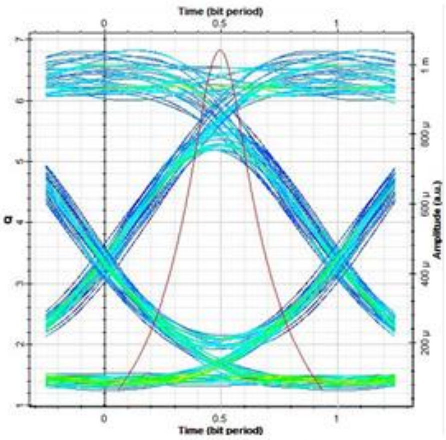
Max. Q Factor	6.65909
Min. BER	1.32519e-011
Eye Height	0.000390762
Threshold	0.000400272
Decision Inst.	0.498047

Fig 6. The eye diagram of channel 1



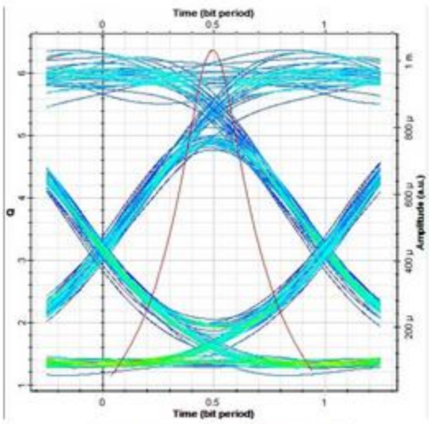
Max. Q Factor	6.88982
Min. BER	2.66913e-012
Eye Height	0.000401212
Threshold	0.000393094
Decision Inst.	0.498047

Fig 6. The eye diagram of channel 9



Max. Q Factor	6.82186
Min. BER	4.35916e-012
Eye Height	0.000400647
Threshold	0.000412328
Decision Inst.	0.494141

Fig. 6. The eye diagram of channel 33



Max. Q Factor	6.36906
Min. BER	9.12159e-011
Eye Height	0.00037379
Threshold	0.000396629
Decision Inst.	0.494141

Fig.9. The eye diagram of channel 48

VI. Conclusion

We have demonstrated a 10Gbps data rate, which is a high performance evaluation of the Wavelength Division Multiplexing (WDM) using NRZ modulation schemes. The transmitter section consists of 50 channels, with -15dBm input power, where we used a single mode fiber length of 50 km and a channel spacing of 100 GHz. The Bit Error rate we achieved was 10Exp(-11) for all of the channels. The DWDM Network of the optical fiber communication was designed using Optisystem 7.0. We concluded that the WDM transmitter should be used to design long distance transmissions with EDFA and SMF to guarantee the communication's quality. In the future, the work will be extended to a 64-channel WDM system, and its performance will be evaluated.

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