Available Online at www.ijecse.org ISSN- 2277-1956

EDFA-WDM Optical Network Analysis

M.A. Othman [1], M.M. Ismail [1], H.A. Sulaiman [1], M.H. Misran [1], M.A.M. Said [1],

[1]Centre for Telecommunication Research and Innovation (CeTRi)
Fak.Kej.ElektronikdanKej.Komputer
UniversitiTeknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

azlishah@utem.edu.my,muzafar@utem.edu.my, asyrani@utem.edu.my,
haris@utem.edu.my, maizatul@utem.edu.my

Abstract- Optical network that apply wavelength division multiplexing (WDM) is currently widely used in existing telecommunications infrastructures and is expected to play a significant role in next generation networks and the future Internet supporting a large variety of services having very different requirements in terms of bandwidth, latency, reliability and other features. The purpose of this paper is to design a simulation of WDM Optical Network in terms of length and pump power. The system is simulated using Optisystem software to achieve gain flatness, BER (Bit error rate), and noise figure of EDFA through optimized fiber length and pump power. The gains are flattened within 38±0.5dB from 1546nm to 1558nm band of wavelength with bit error rate (BER) < 10-4and noise figure (NF) <9dB for 16-channels simultaneous amplification in a single stage EDFA. The results obtain from simulation are compared with the result from the previous journal.

Keywords –EDFA, gain flatness, fiber length, pump power

I. INTRODUCTION

Wavelength-division multiplexing (WDM) is a method that can use huge optoelectronic bandwidth mismatch, which is each end-user's equipment need to operate only at electronic rate, but multiple WDM channels from different end-users may be multiplexed on the same fiber. One can tap into the huge fiber bandwidth when multiple WDM channels coexist on a single fiber. Since all components in a WDM device need to operate at electronic speed commonly, it is easier to implement any WDM devices. Therefore, several WDM devices are available in the marketplace today, and more are emerging [1].

EDFA is an optical amplifier that uses a doped optical fiber as a gain medium to amplify an optical signal. The signal which is to be amplified and a pump laser are multiplexed into the doped fiber, and the signal is amplified through interaction with the doping ions [2].EDFA is the most often used optical amplifier due to low loss optical window of silica based fiber. EDFA also have large gain bandwidth, which is normally tens of nanometers and it is more than enough to amplify data channels with the highest data rates without present any effects of gain narrowing. [2]. EDFA gain-flattened is important in long haul multichannel lightwave transmission systems especially WDM[3]. Implementing a WDM system including EDFA's is the tricky part because the EDFA gain spectrum is wavelength dependent. The EDFA does not have to amplify the wavelength of the channels equally and frequently to have equalized gain spectra in order to obtain uniform output powers and similar signal-noise ratios (SNR)[4]. There are several methods in designing a flat spectral gain EDFA such as by controlling the doped fiber length and the pump power[3][4], proper choosing of optical notch filter's characteristic, by using an acousto-optic tunable filter and by employing an inhomogeneously broadened gain medium[5].

II.METHOD ANALYSIS

In analyzing and designing optical network there are several methods can be used. For this EDFA (Erbium doped fiber amplifier) gain optimization for WDM (Wavelength Division Multiplexer) system optical network, used simulation approach rather than fabrication methods. Simulator allows engineers to design the most correct and efficient design before the actual optical network constructed. Moreover, able to explore the merits of other design without physically build it. Besides, by using simulation method engineers able to study problem that occur during designing the optical network.Optisystem software was selected to be use in designing EDFA in WDM system.

IJECSE
International Journal of Electronics and Computer Science Engineering
WWW.IJECSE.ORG

Optisystem is a comprehensive simulation package developed by Optiwave. This software enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks. A robust graphical user interface controls the optical component layout, component models and presentation graphics. An extensive library of active and passive components includes realistic, wavelength-dependent parameters. Parameters sweeps allow us to investigate the effect of particular device specifications on system performance.

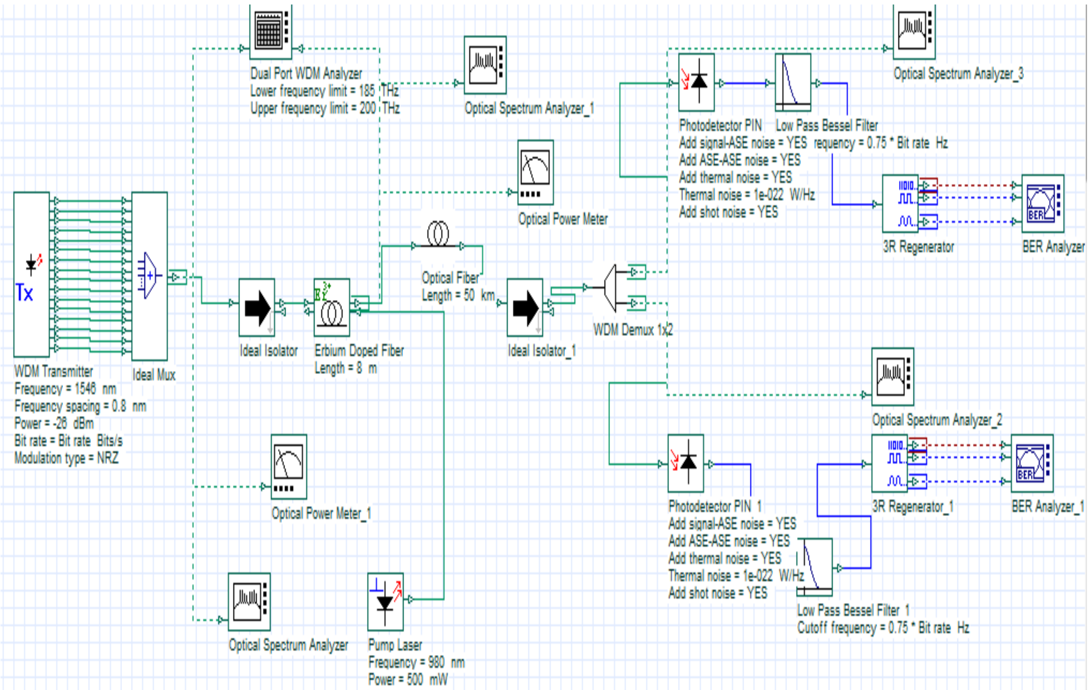


Figure 1: Schematic Design of WDM System

Figure 1 shows EDFA gain optimization for WDM system optical network design consist of WDM Transmitter (16 input signals channels), Ideal Multiplexer, 2 Ideal Isolators, Pump laser, Erbium Doped Fiber (EDF), Demultiplexer, Photodetector PIN, Low pass Bessel filter and 3R regenerator. The WDM Transmitter holds 16 equalized wavelengths that fed to Ideal Multiplexer. Power of each channel is -26dBm. While pump power used is 980nm to excite the doped atoms to a higher energy level [2]. Implementations of 2 isolators are to prevent Amplified Spontaneous Emission (ASE) and signals from propagating in backward direction. The effect from reflected ASE would reduce the population inversion, hence reducing the gain and increasing the noise figure [2]. The desired gain is more than 30dB. While, the output power are more than 5dBm but less than 25dBm. Two parameters are selected to be optimized in achieving the desired gain under output power and gain flatness constraints are fiber length and pump power.

III. Results and Discussions

The reference pump power is set to 120mW. After that it's measured at different pump power such as 150mW, 200mW, 250mW and etc with an increasing of 50mW each until 500mW. In the other hand, the length of the fiber is bound between 2 and 22m. Therefore the output power is measured by varying the suitable length for different pump power at a constant input power which is -26dBm. Therefore, the reference pump power is set to 120mW for the measurement of different length for the amplifier used in this system as shown in Table 1 to get the optimum length.

A suitable length of fiber of 8m is chosen as an optimum length for this system because at 8m the output power gave the maximum value at the reference power. Therefore, the gain and noise figure are measured at 8m length with different pump power as shown in the result above.

Table 1: Transmitted and received power with different length of amplifier

Length (m)	Input power (e-3) W	Output power (e-3) W	dBm
2	21.959	3.238	5.103
4	21.959	39.640	15.981
6	21.959	57.919	17.628
8	21.959	61.714	17.904
10	21.959	61.672	17.900
12	21.959	60.747	17.835
14	21.959	59.707	17.760
16	21.959	58.722	17.688
18	21.959	57.921	17.628
20	21.959	57.354	17.586
22	21.959	57.072	17.564

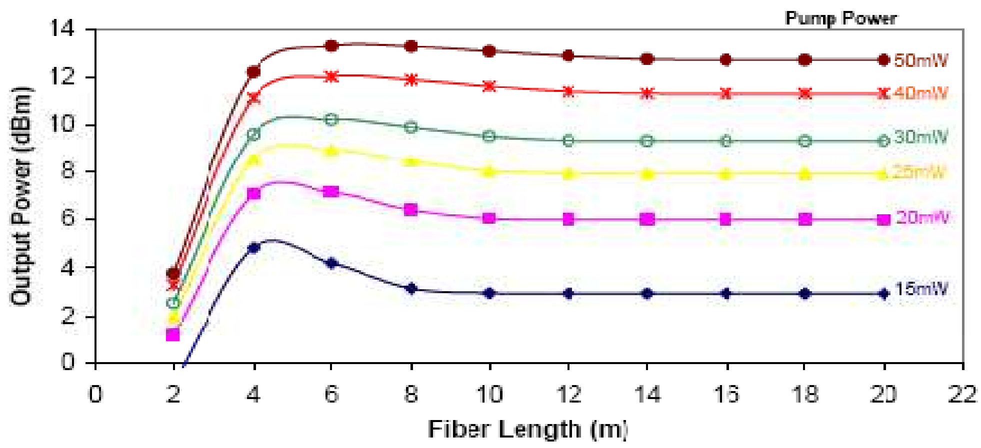


Figure 2(a): Power output vs Fiber Length from previous research.

IJECSE
International Journal of Electronics and Computer Science Engineering
WWW.IJECSE.ORG

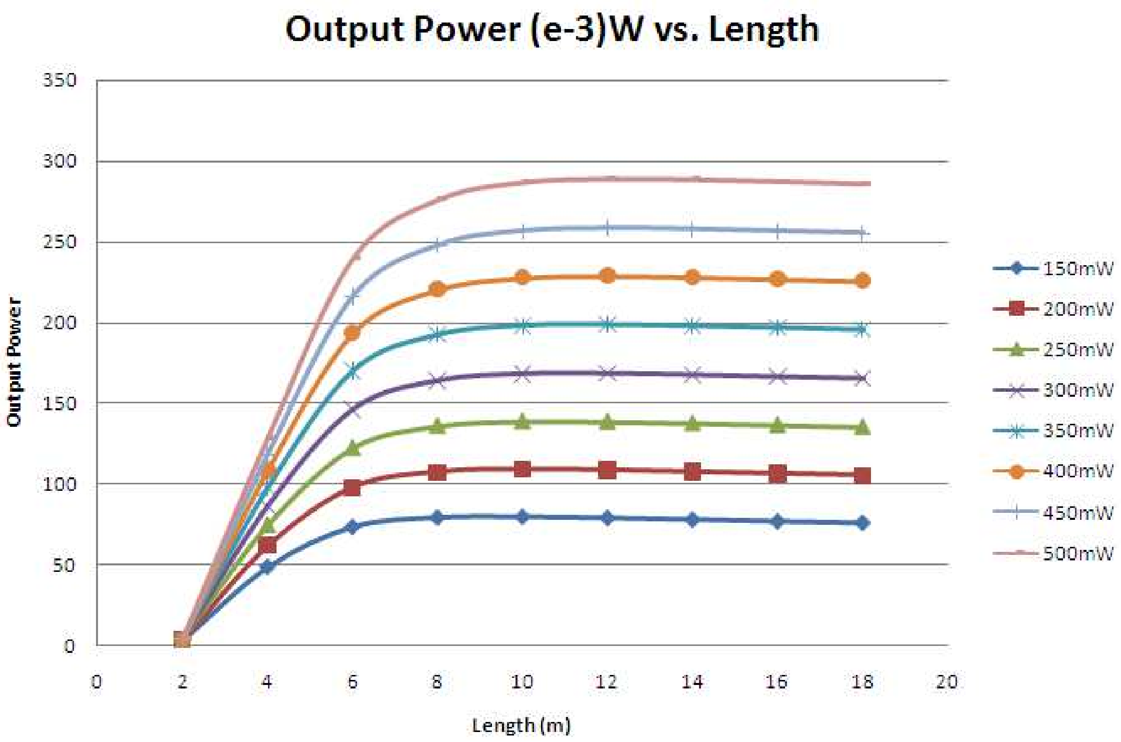


Figure 2: Graph comparison of Gain versus Wavelength (nm) using Optisystem

Figure 2 shows that the effect of the increasing of pump power to the output power at different length of amplifier. The increasing of pump power will increase the output power at each meter of the length. This is because when the length of the amplifier is increase, there will be more power used to transmit the signal in the system.

By comparing the result between reference journal and simulation result, it shows that the output power of simulation result is much higher compared to the journal result because the maximum pump power used for simulation is 500mW while the maximum pump power used for journal is 50mW. Therefore the maximum power for journal result is 13.5dBm for 50mW and the simulation result has a maximum output power of 288.603mW or 24.6dBm.

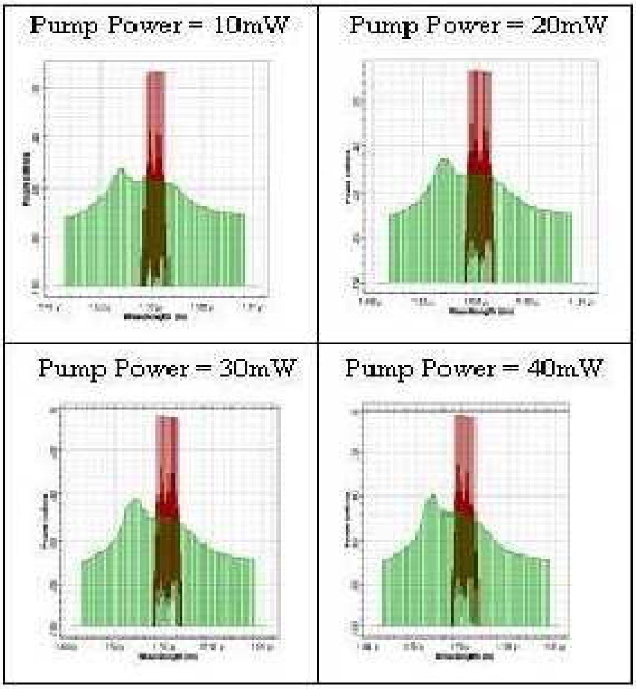
For each of the pump power, the output power increase and decreases after reaching a maximum value. Since the pump is at wavelength of 980nm, when the fiber length increase, the erbium ions will excite to the higher level where the lifetime of this higher level is approximately to 1us. Therefore, it will cause the increasing of the output power. However, after a certain length when the pump power is exhausted, the unexcited erbium ions will results in the decreased of output power.

Figure 3 below shows the results which been taken from the optical spectrum analyzer in the Optisystem software. It clearly showed the gain flatness for the different pump powers from 150mW to 500mW for the power versus wavelength. The green wave in the result is representing the noise which it shown that the noise is decreasing when the pump power is increasing while the red symbol in the graph represent the sample wavelength. By comparing the result from journal and simulation results, it shows that higher pump power used for the simulation will gives a noise compared to the results from the journal. The result from the journal shows that the maximum noise at maximum pump power is greater than -30dBm for maximum pump power of 40mW, while the maximum

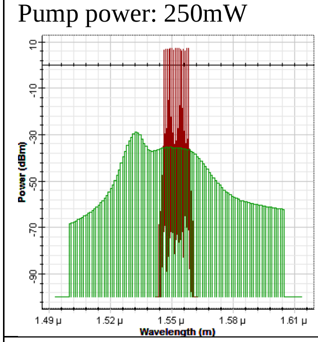
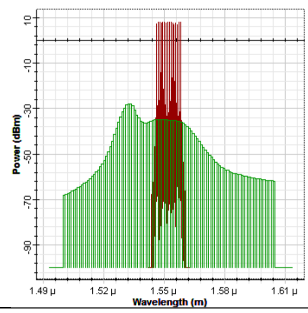
IJECSE
International Journal of Electronics and Computer Science Engineering
WWW.IJECSE.ORG

noise for simulation at pump power 500mW is less than -30dBm. Therefore, this result can be concluded as high pump power will give a lower noise.

Journal [3]



Simulation

Pump power: 250mW	Pump power: 300mW
	
Pump power: 350mW	Pump power: 400mW

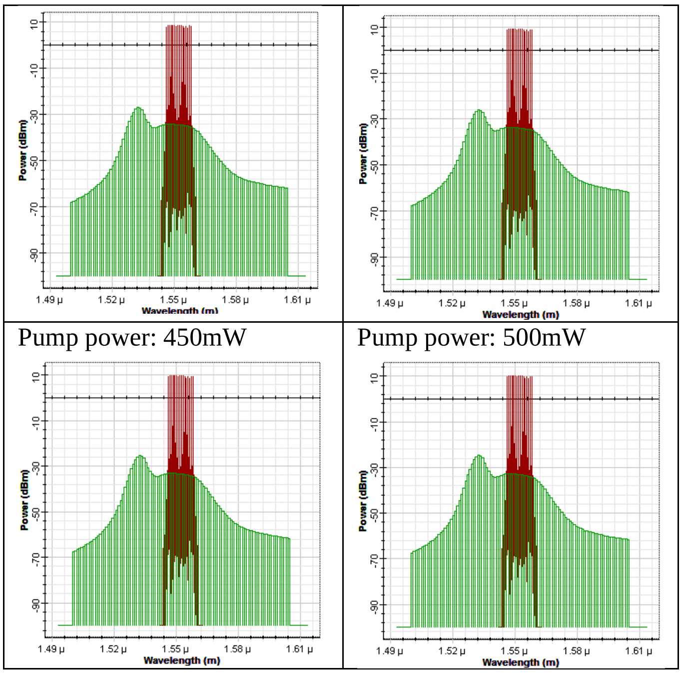


Figure 3: Output power and noise spectrum at different pump power

By comparing the result from the journal with the simulation, it shows that higher pump power will provide higher gain but inversely in terms of noise figure. The maximum gain can be achieve in the journal at the maximum pump power of 40mW is 28dB with the lowest noise figure of 5dB. While the maximum gain can be achieved in the simulation at maximum pump power of 500mw is 40.2dB with the lowest noise figure of 6dB.

The pump power of 150mW has the lowest gain and highest noise figure while the pump power of 500mW has the highest gain and lowest noise figure. Therefore, it shows that the pump power of 150mW and 500mW does not have a good performance in this system.

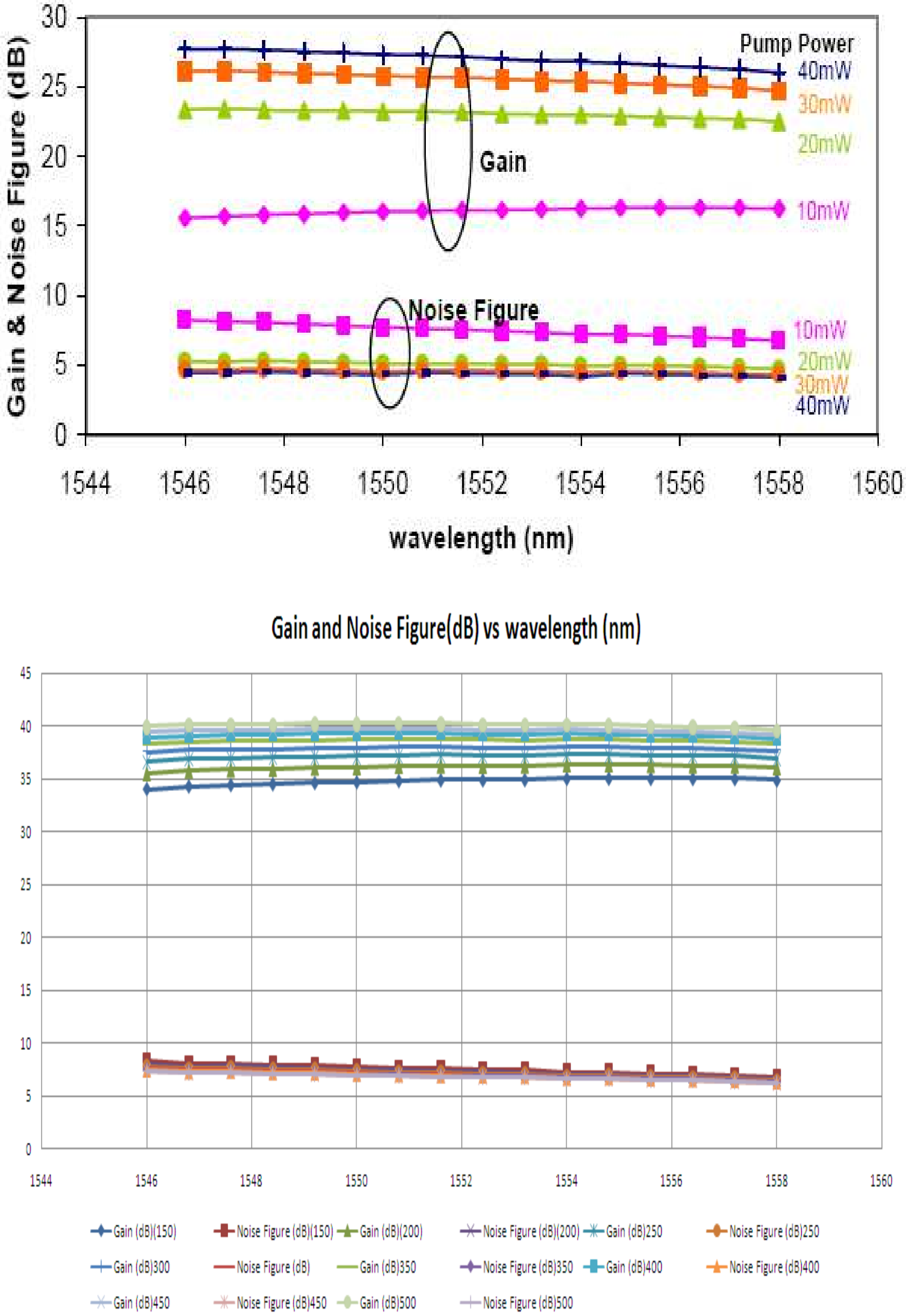


Figure 4: Gain and NF variation of -26dBm amplification for different pump powers

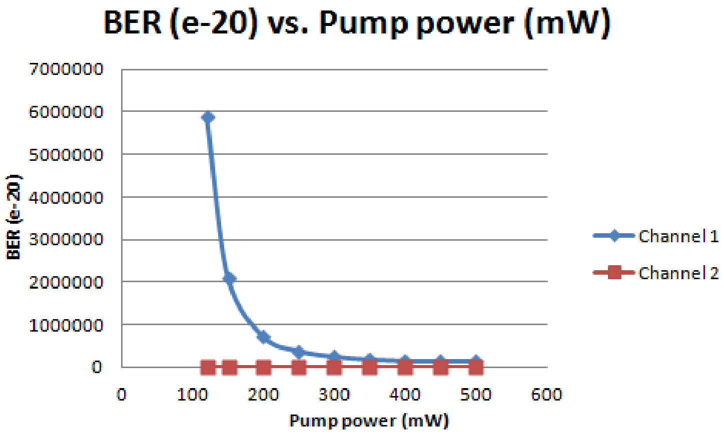
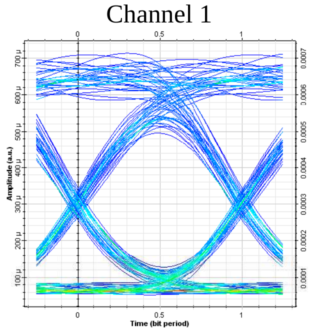
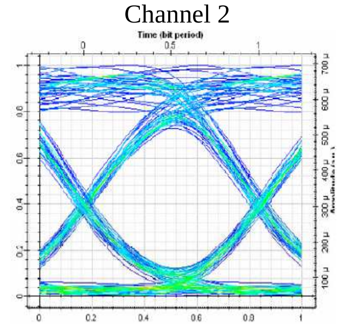


Figure 5: Graph of BER versus Pump power

Based on the data in Table 2, it shows that the BER for this system is between 10^{-14} and 10^{-20}**.** This is because when higher power is injected to the amplifier, the chances of getting an error in the system is getting lower therefore the BER is decreasing.Graph in Figure 5 above, it shows clearly the decreasing of the BER for both channels when the pump power increasing. The performance of this BER is analyzed by using the BER analyzer in the Optisystem software.

Figure 6 above shows the comparison of the eye diagram from the journal and the simulation result. The eye diagram for Channel 1 gives a big opening which means that the intersymbol interference (ISI) is low. While the width of the opening indicated the time over which sampling for detection is performed. The optimum sampling time corresponding to the maximum eye opening, yielding the greatest protection against noise. Therefore the average bit error rate is measured at 10^{-14} for both result from journal and simulation for channel 1 while the average BER is measure at 10^{-16} from the journal and 10^{-20} from the simulation for Channel 12. Therefore, the WDM system is having a good performance of BER at the range of 10^{-14} to 10^{-20}.

Journal [4]	
Channel 1	Channel 2
	

Simulation

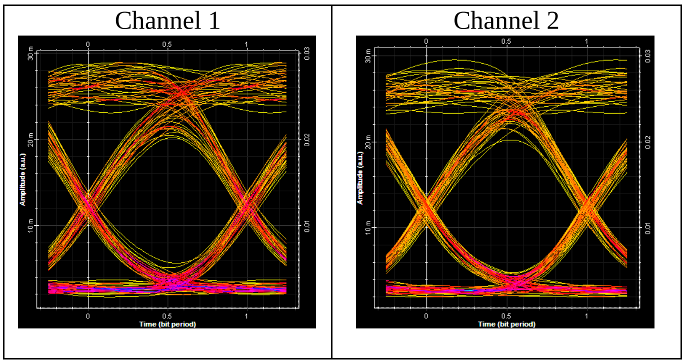


Figure 6: Eye Diagram from channel 1 and channel 2

For the reference pump power given, there exists of a corresponding input signal power with which the power penalty is minimum. This minimum power penalty represents the optimal trade-off at the lower signal power. The power penalty indicates the different characteristics at different pump power. At lower pump power, the power penalty is more sensitive to the signal power. Therefore the system should be operated at a higher pump power for getting a wide dynamic range of input power for getting a wide dynamic range of the input signal power.

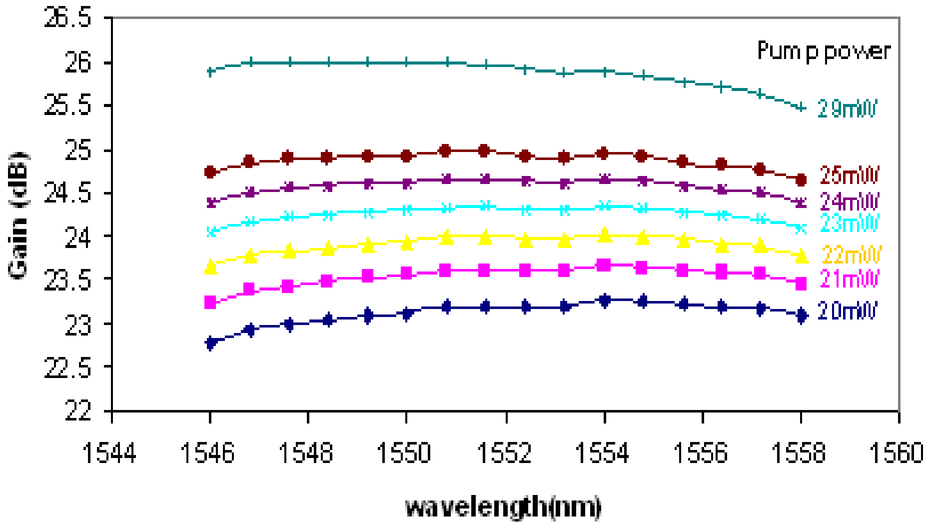


Figure 7 (b) : Comparison of Output power at different wavelength with pump power of 150mW to 500mW from previous journal.

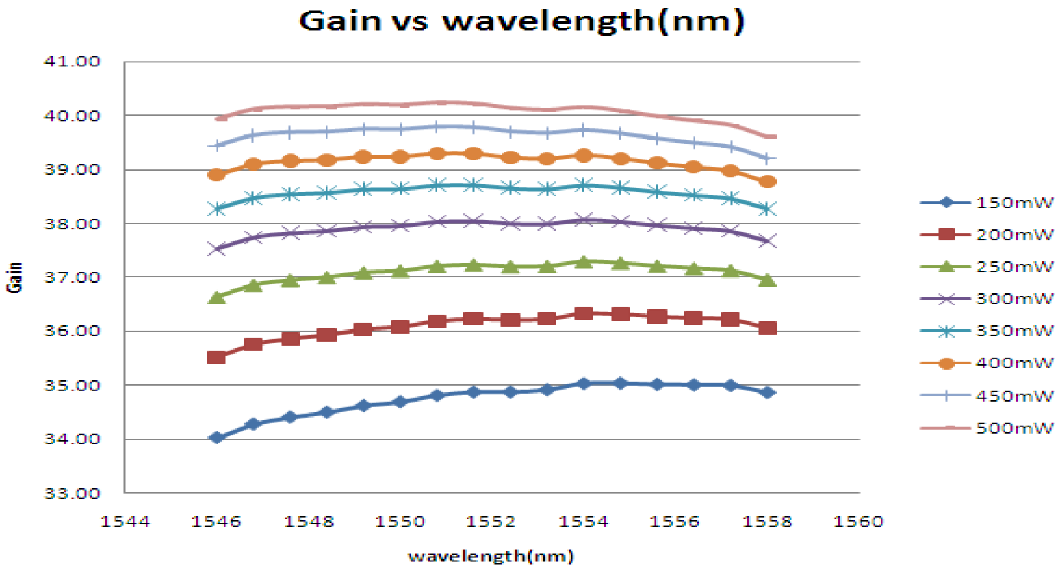


Figure 7 (b) : Comparison of Output power at different wavelength with pump power of 150mW to 500mW using Optisystem

From the simulation results, it shows that as the pump power increases, the gain increases while the noise figure decrease. However, the gain flatness increases along with the increasing of pump power as shown in Figure 7. Based on the results from the journal, the highest pump power injected to the system gives a maximum gain of 26dB with the length of amplifier of 8m. While the maximum pump power of 500mW gives the maximum gain of more than 40dB for the 8m length of amplifier.

IV.CONCLUSION

In the EDFA each stage's pump power and mid-stage attenuation were controlled according to the power variations of the input signal channels and the optical supervisory channel, respectively. The different pump power can affect the output power base on their length of fiber. As the pump power increases, the gain flatness became worst which lead to more noise and bit-error-rate (BER). The optimum fiber length is 8m with a constant input power -26dBm. The result between journal and simulation are slightly different depend on different pump power.For this simulation, BER has aminimumratio of 10^{-14} and maximum ratio of 10^{-20} for the chosen pump power and it decreasing base on increasing pump power. The output power of 288.603mW or 24.6dBm and average noise figure of 7.544dB for 150mW and 6.757dB for 500mW were obtained from the simulation.

ACKNOWLEDGMENT

Authors would like to thanks UniversitiTeknikal Malaysia Melaka for their support in term of financing and experimental purposes in this project.

Reference

[1] B. Mukherjee, "WDM Optical Communication Network; Progress and Challenges ," IEEE Journal on Selected Areas in Communications, vol. 18, no. 10, pp. 1810-1824, October 2000.

[2] Abu Sahmah Supa'at and Farah Diana Mahad, "EDFA Gain Optimization for WDM System," ELEKTRIKA, vol. 11, no. 1, pp. 34-37, 2009.

[3] S.Y. Park, H.K. Kim, C.S. Park, and S.-Y. Shin, "Doped fibre length and pump power of gain-flattened EDFAs," Electronics Letters, vol. 32, no. 23, pp. 2161-2162, November 1996.

[4] Atul K. Srivastava, JianHui Zhou, James W. Sulhoff Yan Sun, "Optical Fiber Amplifiers for WDM Optical Networks," Bell Labs Technical Journal, vol. 4, pp. 187-206, January-March 1999.

[5] E.L. Goldstein, L. Eskilden, V. da Silva, M. Andrejco, and Y. Silberberg, "Inhomogeneously broadened fiber-amplifier cascades for transparent multiwavelength lightwave networks," Lightwave Technology, vol. 13, no. 5, pp. 782-790, May 1995.