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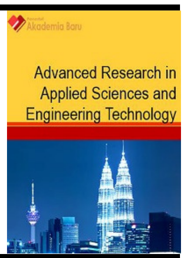

Investigation on Gain Improvement of Erbium Doped Fiber Amplifier (EDFA) By Using Dual Pumped Double Pass Scheme

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ABSTRACT

The purpose of this research is to enhance the gain signal amplification by using dual pump double pass configuration in comparative with single pump double pass that are commonly used as conventional optical amplifier configuration in optical communication system nowadays. Two input signals power have been implemented which are -30 and 0 decibel (dB). The input signal defined as low and high input signals power by using a pump power of 1480 nm. The amplification of EDFA in this study have been taken place in conventional band (C) band and long wavelength band (L) band of EDFA within the range of 1515 to 1615 nm. Therefore, to understand the performance of the gain amplification, the OptiSystem software simulator version 13 has been used for simulation and the values of fiber length and pump power has been varied for both configurations. It has been found that the, dual pump double pass configuration has shown better gain performance at lower input signal power compared to the single pump double pass configuration.

1. Introduction

The transmission of the signal for a long distance and for a high speed is significantly important in telecommunication system. In a long-distance transmission, the performance is decreases due to high attenuation. Therefore, the improvement of gain is very important to solve and overcome the loss during transmission. The invention of the Erbium Doped Fiber Amplifier (EDFA) in the late eighties was one of the major events in the history of optical communications. The current development of optical fiber amplifier such as EDFA has allow a better performance in transmitting data signal over the world. In addition, EDFA has the properties that can reduce the data loss which is high gain and low noise figure [1]. Hence, EDFA is suitable for a long-haul application. Basically, the performance of the transmission signal is affected by the two factors including system configuration and total pump power injected to the system [2]. Therefore, to enhance the performance of EDFA in

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terms of gain amplification, various configurations have been proposed such as single pass, double pass, triple pass and quadruple pass scheme [3].

Therefore, with the improvement of gain amplification in Optical Fiber Communication System (OFCS), it is believed that OFCS will continue to be the dominant communication technology in the future and the potential of this technology will be emerged for future needs. In this paper, there are two configurations that are considered and compared for gain improvement which are single and dual pump double pass configurations. Therefore, evaluation of gain improvement are based on the values of fibre length, input signals power and pump power that are varied using OptiSystem simulator version 13.

2. Research Methodology

Two types of schemes are analysed which are single and dual pump double pass scheme of EDFA by using the computational simulation which is OptiSystem version 13 software. OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks. Both configurations are investigated through Amplified Spontaneous Emission (ASE) and gain performance by varying fiber length, pump power and input signals power. Two types of input power that are implemented in this study are high and low input signals power which are 0 decibel (dB) and -30 dB for both configurations. There are many configurations that have been proposed based on previous researches to improve the gain amplification of EDFA and increase the capacity of transmitted data at high speed for a long distance of transmission. According to this study, two types of schemes or configuration are discussed specifically on single pump double pass and dual pump double pass scheme of EDFA.

Single Pump Double Pass Scheme: Figure 1 shows the configuration of single pump double pass of EDFA in OFCS. The amplifications are taken place in C and L band. The signal within the wavelength of 1515 and 1615 nm are travelled from Tuneable Laser Source (TLS) through the Variable Optical Attenuator (VOA) in order to attenuate all the channel uniformly to achieve a range of gain values. Therefore, the Wavelength Division Multiplexing (WDM) is used to select between the combined of the signal and the 1480 nm pump wavelength so that the combined signal can be propagated in the same direction of the signal path. The combined signal will pass through the EDFA. The signal will react with both stimulated emission and the ASE. Both signals are reflected back to pass the active medium twice by the reflector and it is displayed in the Optical Spectrum Analyser (OSA). The common type of reflector is mirror and Fiber Bragg Grating (FBG) [4].

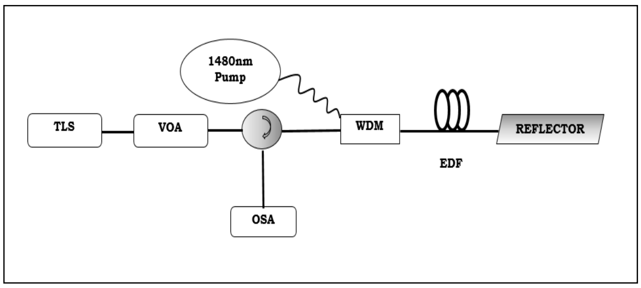

Fig. 1. Configuration of Single Pump Double Pass of EDFA

Simulation of Single Pump Double Pass Scheme: Figure 2 shows the layout of the single pump double pass scheme that has been sketched using OptiSystem version 13 for the simulation approach method. Based on the figure, the OSA is connected at the circulator with the combination of Dual Port WDM Analyzer to calculate the gain of the amplifier.

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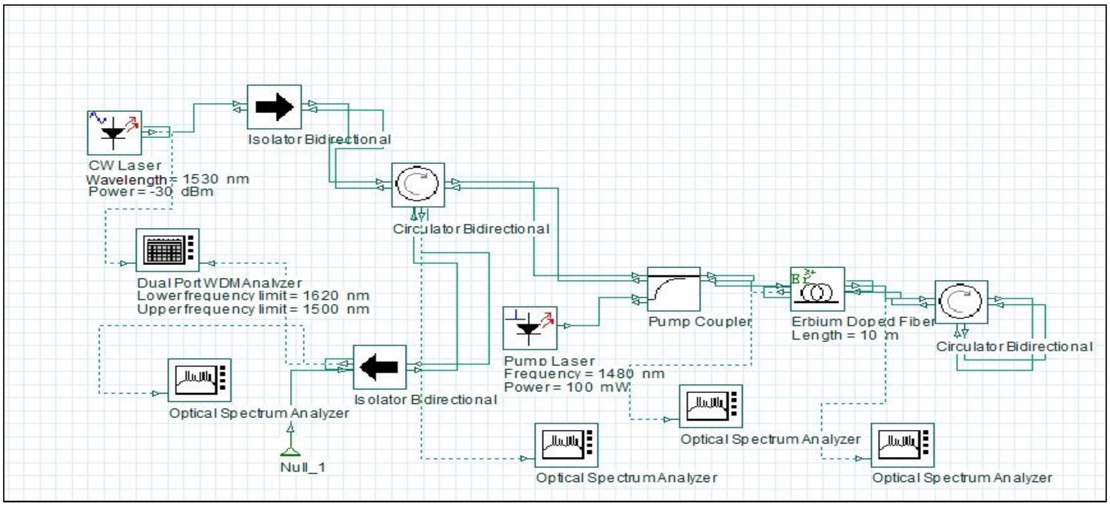

Fig. 2. Single Pump Double Pass Scheme of EDFA OptiSystem Simulator

Dual Pump Double Pass Scheme: Figure 3 shows the proposed configuration which is double pass scheme of EDFA with dual pumping. Differences between Figure 1 and Figure 3 are at the number of pump injected to the amplifier is twice and two EDFs which are EDF1 and EDF2 for dual pump double pass scheme. As the single pump, the signal travel from TLS through the circulator. At the WDM, the signal is combined with 1480 nm pump power. After the signal pass through the EDF1, once again the signal is injected with 1480 nm pump wavelength and then there are combined by the WDM. After pass through the EDF2, the signal are reflected by the reflector so that the signal will pass through the active medium twice and the output is displayed in OSA.

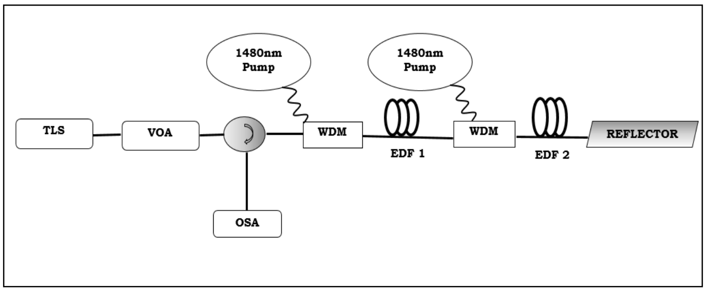

Fig. 3. Configuration of Dual Pump Double Pass of EDFA

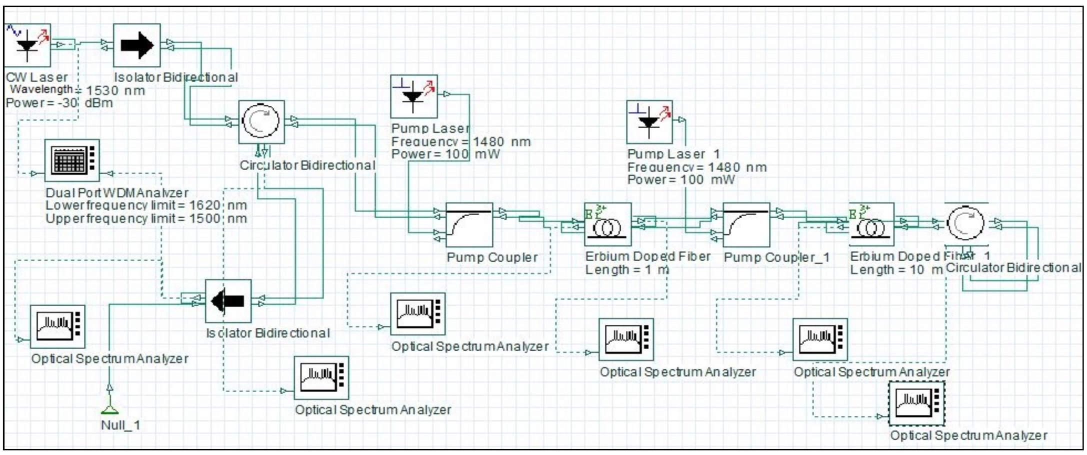

Fig. 4. Dual Pump Double Pass Scheme of EDFA OptiSystem Simulator

Simulation of Dual Pump Double Pass Scheme: Figure 4 shows the layout of the dual pump double pass scheme that has been sketched using OptiSystem for the simulation approach method. As single pump double pass scheme, the Optical Spectrum Analysis is connected at the circulator with the combination of Dual Port WDM Analyzer to calculate the gain of the amplifier.

3. Results and Discussion

In this section, the performance of the gain amplification for both single and dual pump double pass configurations EDFA are analyzed with varying fiber length, pump power and input signals power. In the meantime, the value of the ASE for both configurations are indicated as well along the signal transmission.

Amplified Spontaneous Emission: Amplified Spontaneous Emission (ASE) is one of the major source of noise that occur in the amplifier [5]. Figure 5(a) and (b) shows the ASE value for single and dual pump double pass scheme of EDFA. During the light emission in stimulated emission, there are two situations happen whereby the ions emit the photon energy the same wavelength with the input signal or the atoms return to the lower energy randomly and become noise as known as ASE. The output of the ASE is displayed on the OSA within the range of the 1515 to 1615 nm wavelength.

Based on the result shown in Figure 5, the value of ASE power exhibited by dual pump is higher compared to single pump double pass scheme with -35 and -36 decibel (dB) respectively. This is because higher the gain provided from a higher injecting pumping power into the signal lead to the ASE generated in EDFA to be high [6]. Thus, the value of ASE of dual pump is higher compared to the value of ASE of single pump double pass scheme as the amount of pumping power injected into the dual pump is higher compared to single pump double pass scheme.

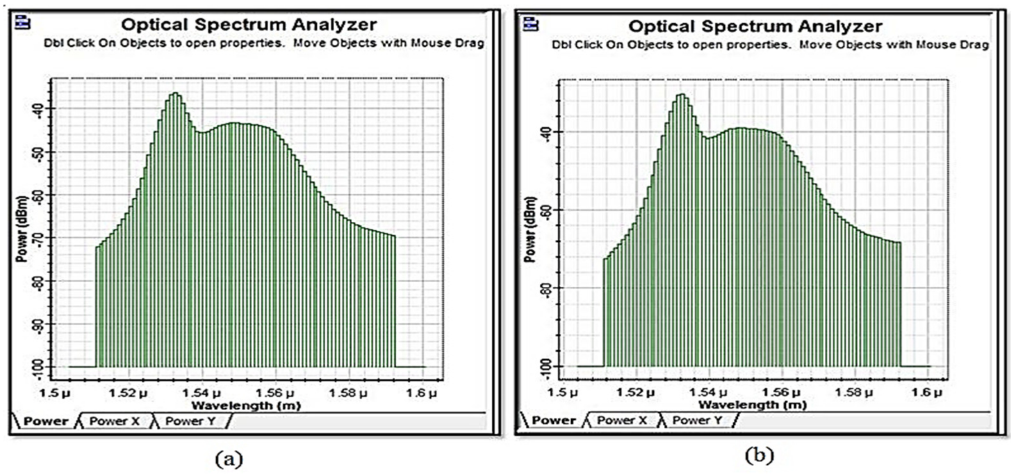

Fig. 5. ASE for (a) Single Pump Double Pass (b) Dual Pump Double Pass

Gain Performance with Varying Fiber Length (Single Pump Double Pass Scheme): Figure 6 (a) and Figure 6(b) show the gain of the single pump double pass scheme at high and low input signals power of 0 and -30 dB. The EDF length that varied in single pump double pass scheme are from 5 to 30 m with a constant pump power which is 100 mW. Basically, in designing the EDFA configuration, it is very important to determine the optimization amplifier parameter such as optimal fiber length [7]. Thus, the justification of gain performance must be considered for both band.

It is found that with the length of fiber at 10 nm shows the flat and wide band for both band at higher input signal power. However, in comparison gain of the other fiber lengths at higher input signal power such as 30m and 25m, it is obtained that the gain is higher compared to 10 nm fiber

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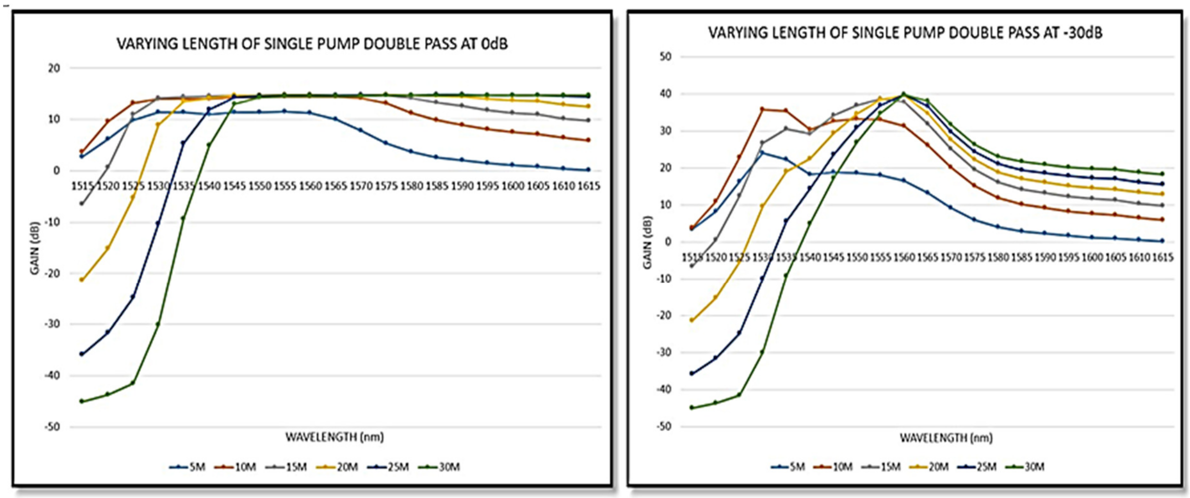
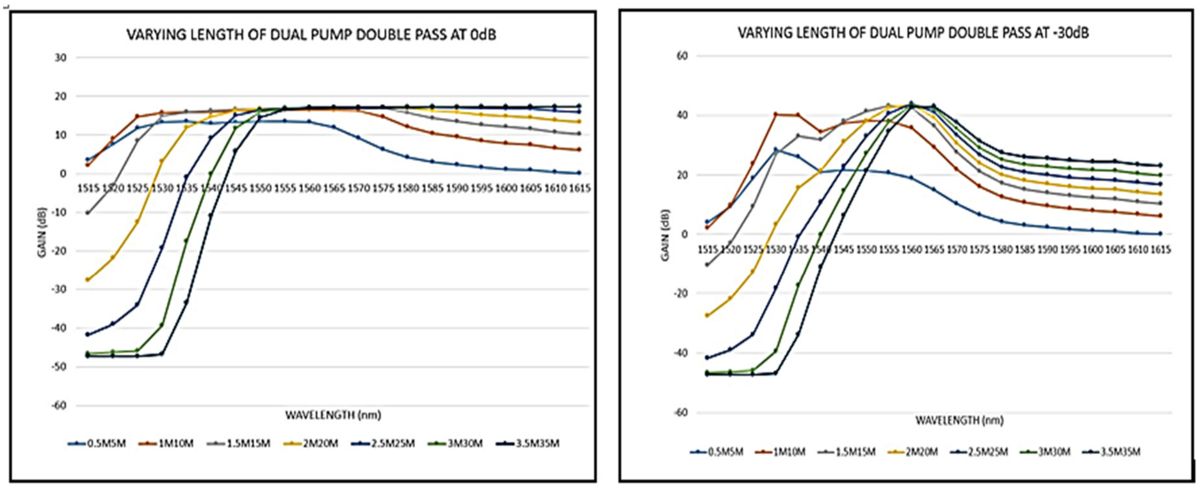
length only at L-band but totally resulted the negative values which are -45.12 and -35.86 dB respectively compared to 10 nm fiber length at C-band which is 3.73dB. This reason can be implemented as well for lower input signal power of -30 dB.



(a) (b)

Fig. 6. Graph of Gain Performance for Single Pump Double Pass with Varying EDF Length at (a) 0 dB (b) -30 dB

Gain Performance with Varying Fiber Length (Dual Pump Double Pass Scheme): The Figure 7 shows that the gain of 10 nm fiber length has a wide and flat gain that is very good for C-band and L-band amplification so that the signal can be transmitted for a long-haul transmission effectively. Figure 7(a) and Figure 7(b) show the gain performance obtained from varying fiber length of dual pump double pass scheme. It is known that there are two EDFs that are varied their length at fixed pump power which is 100 mW of 0 dB and -30 dB input signals power. For EDF1, the length are varied from 0.5 to 3.5 m while the length for EDF2 are varied from 5 to 35 m. The same concept that implemented in single pump double pass scheme is applied in choosing fiber length for both EDF1 and EDF2. It is found that the combination of 1 and 10 nm for EDF1 and EDF2 length is very optimum fiber length and it is suitable for this study.



(a) (b)

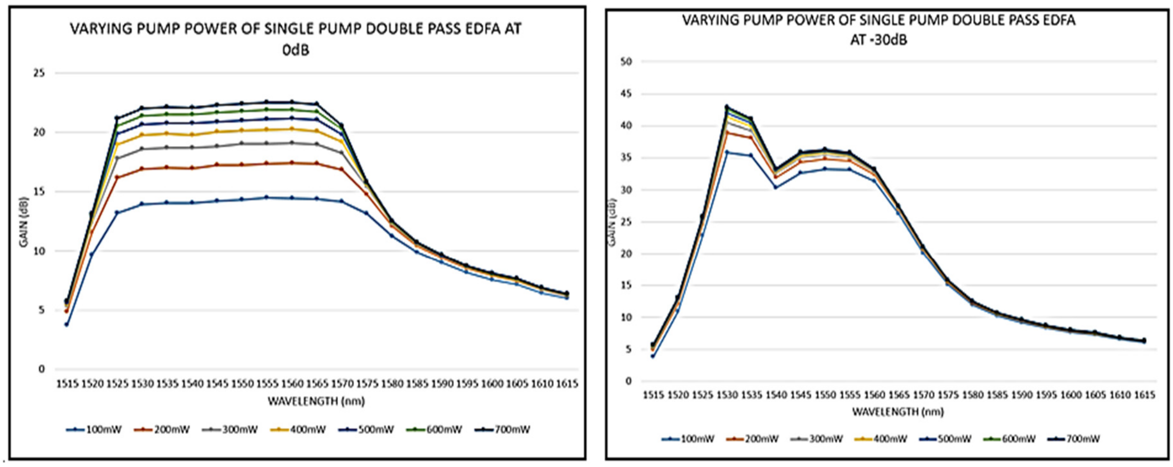
Fig. 7. Graph of Gain Performance for Dual Pump Double Pass with Varying EDFA Length at (a) 0 dB (b) -30 dB

The gain of the combination of 1 and 10 nm for EDF1 and EDF2 length can be seen very wide and flat gain at higher input signal power of 0 dB. On the other hand, at the lower input signal, 1 and 10 nm of EDF1 and EDF2 showing a slightly highest gain at region C-band which is 40.31 dB at 1530 nm wavelength compared to the other combination fiber length of EDF1 and EDF2. Although the gain generated by the 1 and 10 nm of EDF1 and EDF2 respectively is only higher at C-band region but lower at L-band region, but the differences is not very significant compared to the other fiber length combinations which is 2.07 dB gap at the wavelength of 1550 nm.

In comparison with the other combinations, the negative gain are recorded at C-band even though the value of gain at L-band is higher compared to 1 and 10 nm. However, the gain recorded along the wavelength become decrease as the population inversion provided by the erbium ion then the amplifier become saturated.

Gain Performance with Varying Pump Power (Single Pump Double Pass Scheme): Since the bandwidth or gain performance is one of the variable that is influenced by the pumping power injected to the system, therefore, seven different pump power values are varied from 100 to 700 mW for both configurations at higher and lower input signal power of 0 and -30 dB. Figure 8(a) and Figure 8(b) show the gain obtained from varying pump power of single pump double pass scheme at higher and lower input signals power of 0 dB and -30 dB respectively. It is shown that, higher pump power resulted higher gain of the amplifier. This is because, higher the pump power means higher the total power injected to the system. Thus, the gain will increase. At higher input signal power, 700 mW pump power shown the highest gain with 42.89 dB followed by 600 mW and 500 mW which are 42.51 and 41.97 dB respectively and at 1530 nm wavelength indicate the threshold gain for all seven pump powers.

Based on the properties of the gain shape, it can be clearly found that the gain performance dropped after certain level. This is due to the saturation of Erbium ion during the population inversion.

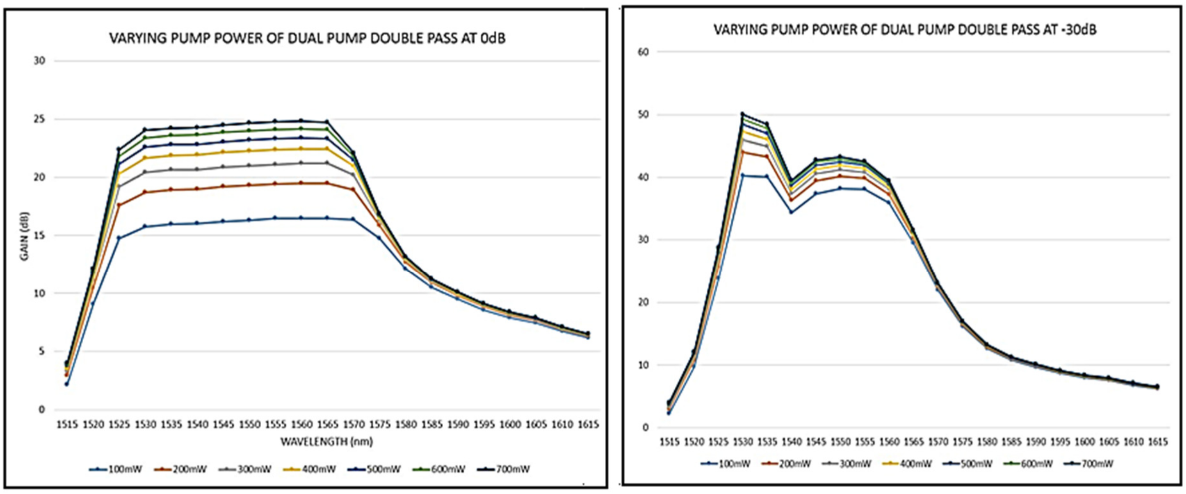


(a) (b)

Fig. 8. Graph of Gain Performance for Single Pump Double Pass with Varying Pump Power at (a) 0 dB (b) -30dB

Gain Performance with Varying Pump Power (Dual Pump Double Pass Scheme): As simulation of single pump double pass scheme, the pump power of dual pump double pass scheme is also varied with 100 to 700 mW pump power shown in Figure 9(a) and Figure 9(b) at higher and lower input signal power of 0 dB and -30 dB. Highest pump power resulted the highest gain performance.

Based on simple analysis, at -30 dB, at wavelength of 1530 nm the highest gain is achieved, 700 mW pump power of dual pump as well shown the highest gain with 49.99dB followed by 600 mW and 500 mW which are 49.28 and 48.41 dB respectively. Therefore, it can be said that the highest pump power will give out the highest gain performance due to the amount of power injecting to the amplifier.



(a) (b)

Fig. 9. Graph of Gain Performance for Dual Pump Double Pass with Varying Pump Power at (a) 0 dB (b) -30dB

Gain Performance with Varying Input Signals Power: Figure 10 shows the comparison between the input signals power between single and dual pump double pass scheme of EDFA at wavelength 1530nm which is the peak gain. The input signal power are varied from -50 to 20 dB with fixed pump power at 100 mW. As a result, it is shown that the gain performance of dual pump double pass configuration is higher at lower input signal power compared to single pump double pass scheme with the gap of 5.2dB at -50 dB due to the effect on population inversion by the higher injecting pump power by two pump in dual pump double pass scheme.

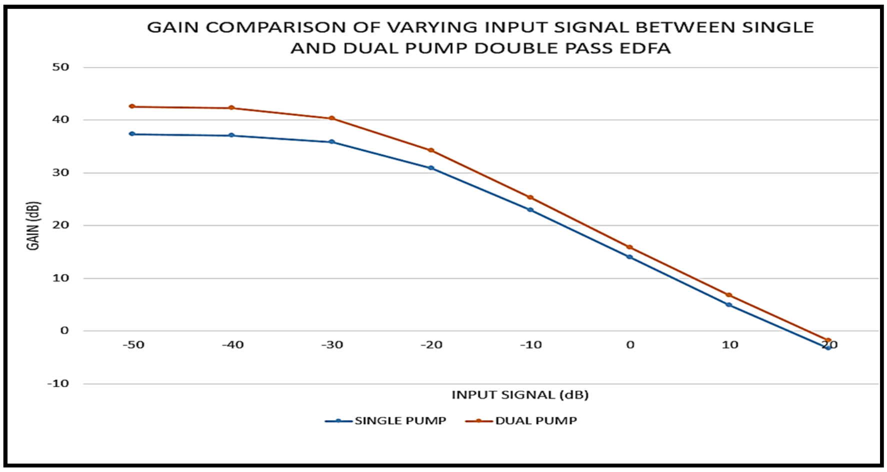


Fig. 10. Graph of Gain Comparison between Single and Dual Pump Double Pass Configurations of EDFA with Varying Input Signal

4. Conclusion

In conclusion, the gain performance of the dual pump scheme has better performance compared to the single pump double pass scheme. For the input signals power, higher the input signal power lead to higher gain performance. While for pump power, higher the pump power resulting higher the gain performance. Contrarily, the gain is reduced at the certain level when the population inversion is provided for all erbium ion in the fiber and amplifier goes saturated. Thus, the objectives of the project are successfully fulfilled. However, there are several recommendations that need to be highlighted for gain improvement to ensure that there are more innovation and improvement for better used applications in the future. For example, applying a backward for single and dual pump double pass scheme. There is a lot type of configuration available in EDFA including forward and backward configuration. With that, the gain of backward pump configuration can be investigated and compared with the forward configuration. Besides that, it is recommended that beyond the simulation works, it is suggested to apply the experimental procedure to compare the result with the computational simulation.

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