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WDM Optical Network Analysis using EDFA and Raman Amplifier

KEYWORDS: gain flatness, pump power, EDFA, Raman

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ABSTRACT *Wavelength Division Multiplexing (WDM) is a technique where optical signals with different wavelengths are combined, transmitted together, and separated again. WDM is used for optical fiber communications to transmit data in several channels with slightly different wavelengths. This paper's purpose is to design a simulation of WDM Optical Network using Erbium Doped Fiber Amplifier (EDFA) and Raman Amplifier. The simulation is done primarily in terms of length and pump power. The simulation is done using Optisystem software to achieve gain flatness; Bit Error Rate (BER) and noise figure of EDFA through optimized fiber length and pump power. The performance of EDFA is also compared with that of Raman Amplifier.*

Introduction

Wavelength division multiplexing (WDM) is a technology or technique modulating numerous data streams, i.e. optical carrier signals of varying wavelengths (colors) of laser light, onto a single optical fiber. WDM enables bi-directional communication as well as multiplication of signal capacity. Multiple WDM channels can exist in a single fiber. A lot of components need to operate at electronics speed. Therefore, it is easy to implement WDM devices. [1]

Erbium Doped Fiber Amplifier (EDFA) is an optical amplifier that uses a doped optical fiber as a gain medium to amplify an optical signal. In EDFA, a relatively high-powered beam of light is mixed with the input signal using a wavelength selective coupler. 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. 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. EDFA gain-flattened is important in long haul multichannel light wave transmission systems especially WDM. Implementing a WDM system including EDFA's is difficult 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). [2]

A Raman amplifier basically uses intrinsic properties of silica fibers to obtain signal amplification. This means that transmission fibers can be used as a medium for amplification. Hence, the intrinsic attenuation of data signals transmitted over the fiber can be combated within the fiber.

Design

Both the circuits were designed using optisystem. The software was used to simulate the working of EDFA in real time scenario. Working of the WDM technique was analyzed by using spectrum analyzer power and noise analyzing in EDFA using power analyzer. Effects of changing the length of the EDFA amplifier and its effect on noise were analyzed. Using the gain flattening type of optimization, the pump powers are optimized for flattening the gain of a Raman amplifier.

Optisystem allows engineers to design the most correct and efficient design before the actual optical network constructed. Moreover, we are able to explore the merits of other design without physically building it. By using the simulation method, engineers are able to study problems that occur during the design phase. [4]

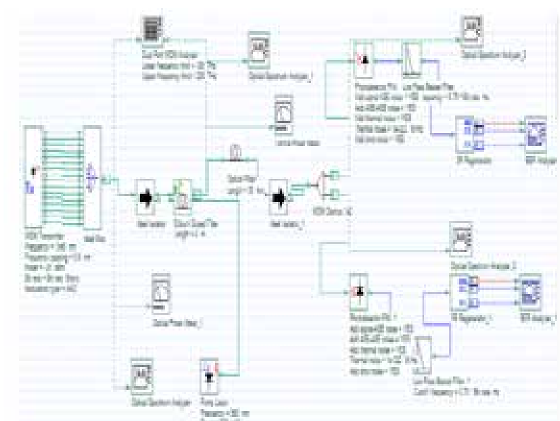

Fig1. EDFA WDM circuit

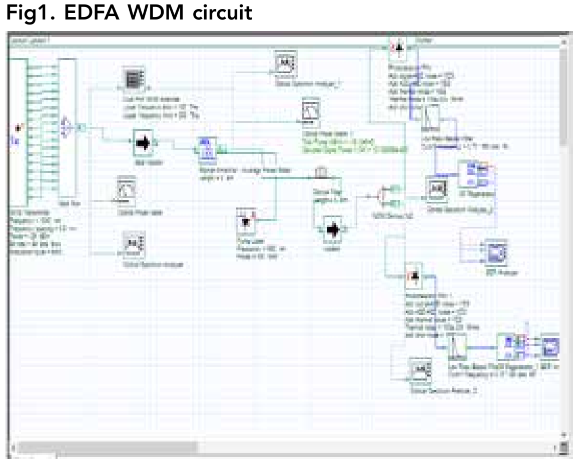

Fig2.. WDM Raman circuit

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Fig1 shows the EDFA WDM circuit while fig2 shows the EDFA Raman Circuit.

IMPLEMENTATION AND OBSERVATIONS

The effect of the increasing of pump power to the output power at different length of amplifier is analyzed. 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 increases, there will be more power used to transmit the signal in the system. For each pump power, the output power increases and then decreases after reaching a maximum value.

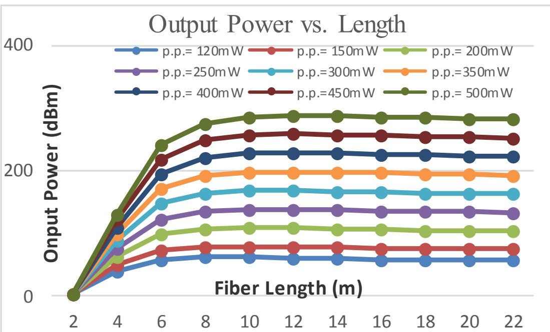

Fig3. Output Power vs. Length

Since the pump has a wavelength of 980nm, when the fiber length increases, the erbium ions will excite to the higher level, where the lifetime of this higher level is approximately to 1us. Therefore, it will increase output power. However, after a certain length when the pump power is exhausted, the unexcited erbium ions will decrease the output power.

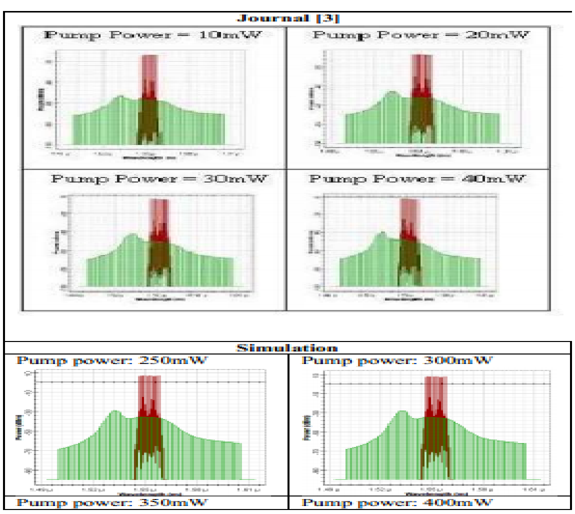

Fig4. Output power and noise figure

Fig4 shows the results which have been taken from the optical spectrum analyzer in the optisystem software. It clearly shows the gain flatness for the different pump powers from 150mW to 500mW for the power versus wavelength. The green wave in the result represents the noise. The noise decreases when the pump power increases while the red symbol in the graph represent the sample wavelength.

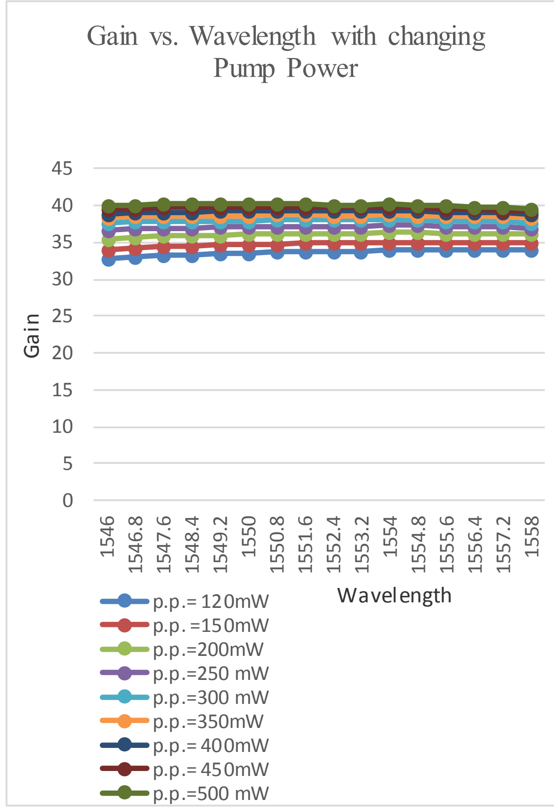

Fig5. Output gain vs. Wavelength

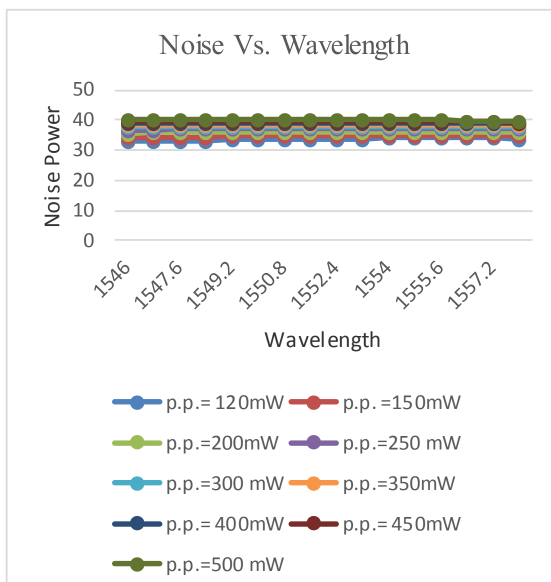

Fig 6. Output noise vs. wavelength

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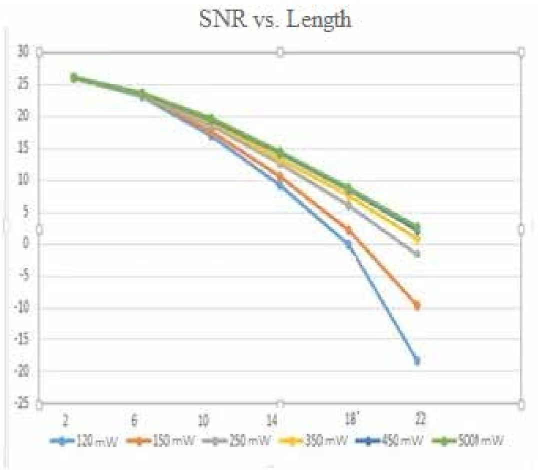

Fig7. SNR vs. length with increasing pump power

In fig7 we notice that the output signal-to-noise (SNR) ratio increases with increase in the pump power.

A Raman amplifier uses intrinsic properties of silica fibers to obtain signal amplification. This means that transmission fibers can be used as a medium for amplification, and hence that the intrinsic attenuation of data signals transmitted over the fiber can be combated within the fiber. An amplifier working on the basis of this principle is commonly known as a distributed Raman amplifier (DRA).

The physical property behind DRAs is called SRS. This occurs when a sufficiently large pump wave is co-launched at a lower wavelength than the signal to be amplified. The Raman gain depends strongly on the pump power and the frequency offset between pump and signal. Amplification occurs when the pump photon gives up its energy to create a new photon at the signal wavelength, plus some residual energy, which is absorbed as phonons (vibrational energy).

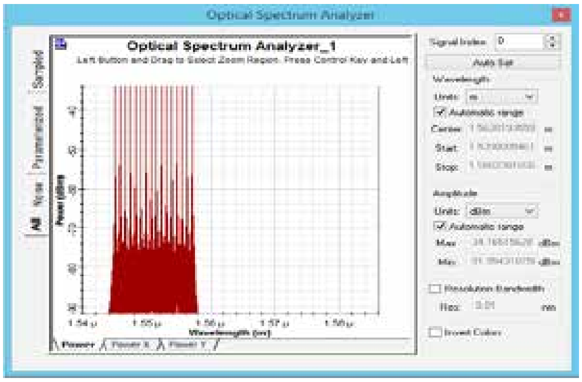

Fig8. WDM using Raman Amplifier

In EDFA we varied the length of the fiber and found the values of the output power whose results have been shown above. The same analysis was done for the Raman amplifier after which we came to the conclusion that whatever be the pump power variation (variation was done from 120mW to 500mW), the readings for output power were the same for the respective lengths.

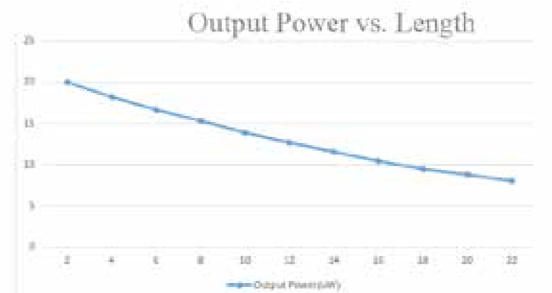

Fig9.Output Power vs. Length of Raman Amplifier

In EDFA we fixed the length of the fiber and found the values of the gain whose results have been shown above. The same analysis was done for the Raman amplifier after which we came to the conclusion that whatever be the pump power variation, the readings for gain were the same.

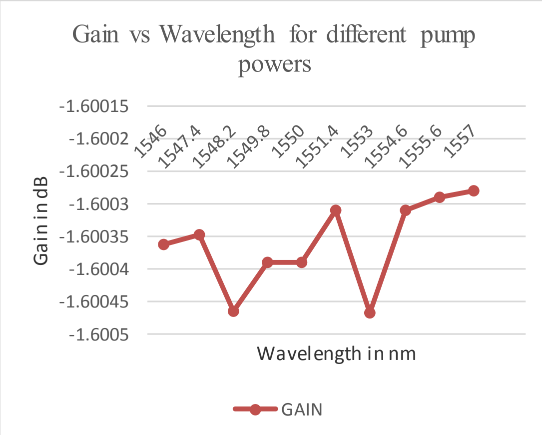

Fig10. Gain vs. Wavelength

In EDFA we fixed the length of the fibre and found the values of the gain whose results have been shown above. The same analysis was done for the Raman amplifier after which we came to the conclusion that whatever be the pump power variation, the readings for noise figure were the same.

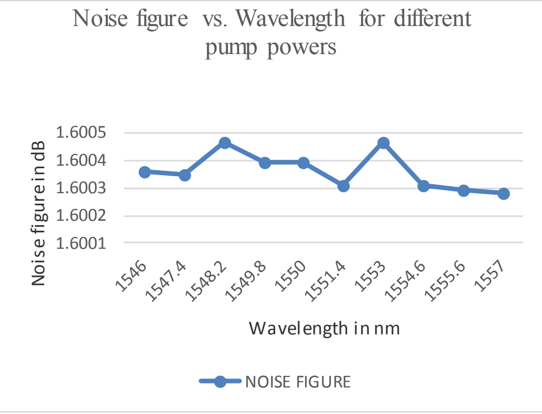

Fig11. Noise Figure vs. Wavelength

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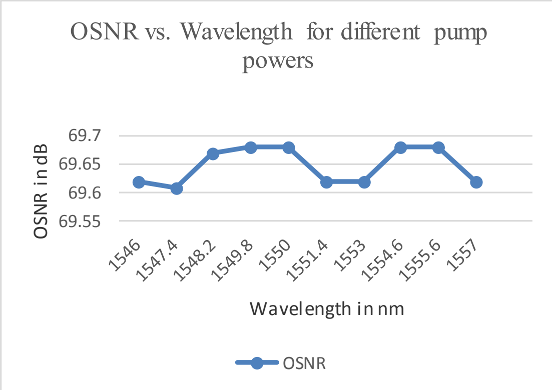

Fig12. Variation of SNR with Pump power and wavelength

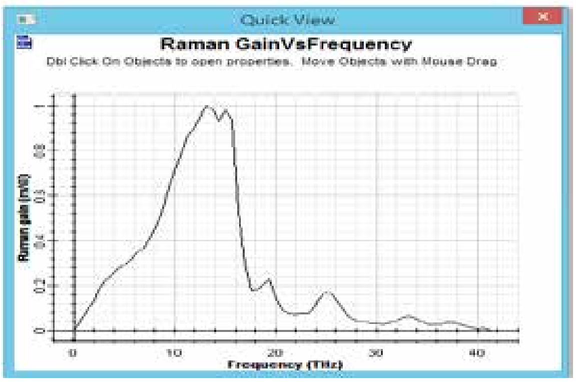

Fig.13. Raman Gain Curve

COMPARISION OF EDFA AND RAMAN AMPLIFIER

Raman amplifiers offer several advantages compared to EDFAs including low noise buildup and simple design, as direct signal amplification is achieved in the optical fiber. There is no special transmission medium needed.

Raman gain depends on the pump wavelength and not on a wavelength-sensitive material parameter of the medium, such as the emission cross-section of dopant in the erbium-doped fiber (EDF).

Broad gain bandwidth is achievable by combining the Raman amplification effect of several pump waves that are placed carefully in the wavelength domain.

However, despite the many advantages of Raman amplifier, there can be some degradation effects. For example, the specially launched pump wave channels may provide power to amplify the other channels. This would result in power exchange between WDM channels and thus crosstalk, leading to signal degradation.

These negative effects occur in unidirectional and bidirectional WDM transmission. So for accurate analysis of advanced WDM systems, it is crucial to model all Raman interactions. Additionally, degrading effects like spontaneous Raman scattering and backward Rayleigh scattering have to be considered. Raman amplifiers are more topologically easier to generate with respect to EDFA. [3]

V.CONCLUSION

In EDFA, when the length of the fiber increases, the pump power increases. This is because when the length of the amplifier increases, there will be more power used to transmit the signal in the system. For each pump power, the output power increases and then decreases after reaching a maximum value. Since the pump has a wavelength of 980nm, when the fiber length increases, the erbium ions will excite to a higher level where the lifetime of this higher level is approximately equal 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 depreciation of the pump power.

On the other hand, for Raman amplifier, whatever is the pump power variation, the readings for output power, gain and output SNR were the same for the respective lengths and pump powers.

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] M.A Othman et al, "EDFA-WDM Optical Network Analysis," International Journal of Electronics and Computer Science Engineering, ISSN2277-1956/ V1N4-1894-1904 | | [3] Performance Analysis of 4-Channel WDM Systemwith and without EDFA Jyoti Gujral, Maninder Singh, Indo Global College of Engineering, Abhipur, Mohali, Punjab. | | [4] Optisystem tutorials by Optiwave | | [5] Optical Fiber Communications by Keiser | | [6] Optical Fiber Communication by and its Applications by | S.C. Gupta |