Analysis of Gain and NF using Raman and hybrid RFA-EDFA

Abdallah M. Hassan[1], Ashraf Aboshosha[2], Mohamed B. El_Mashade[3]
Electrical Engineering Dept., Faculty of Engineering, Al-Azhar University, Nasr City, Cairo, Egypt[1,3].
NCRRT, Atomic Energy Authority, Nasr City, Cairo, Egypt[2].
abdallah.4abd@yahoo.com[1], editor@icgdt.com[2], elmashade@yahoo.com[3].

***Abstract*— In WDM networks, optical fibers are used and signals suffer from some loss due to attenuation, which is the major limitation imposed by the transmission medium for long-distance. So, it is required to amplify all the light signals simultaneously after a certain interval of light propagation to return to its initial power. The aim of this paper is to analyze the performance of Raman amplifier only and different hybrid optical amplifiers (Raman-EDFA, EDFA-Raman). The configuration consists of 16 channels at speed of 10 Gbps. We have realized the different amplifiers and their parameters like gain, noise figure, BER, Q-factor. It is observed that EDFA-Raman showed good performance for get high gain, low noise figure (NF), high Q factor and bit error rate.**

Keywords—Raman, hybrid amplifier, Raman-EDFA, EDFA-Raman, optical gain, noise figure, bit error rate.

I. INTRODUCTION

Due to a lot of losses which the signal suffers from, such as fiber loss, splice loss, etc, in optical fiber communication system the signal becomes weak. Thus, it is necessary to use amplifier with good gain and low NF to compensate all losses occur in the fiber, to transmit signals over long distances. To transmit multiple signals in the same fiber and increase the information capacities of a fiber system, Wavelength Division Multiplexing (WDM) technique is used.

An optical amplifier is a device that amplifies an optical signal directly without the need to first convert it to an electrical signal in optical fiber communications. There are several types of optical amplifiers as erbium doped fiber amplifier (EDFA) and Raman fiber amplifier (RFA).

EDFA is a silica fiber doped with erbium (Er^{+3}) ions and can operate at the conventional(C)-band (1525 - 1565 nm) and can operate at Long(L) -band (1565-1605 nm) with long length and high pump power and the pumping wavelength is at 980nm or 1480 nm. By using EDFA it can be simultaneously amplifying many data channels at different wavelengths within the gain region and for 1.55µm range it can be obtained High gain (30~50 dB), high output power (10~20 dBm), large bandwidth (≥ 90 nm) and low noise figure (3~5 dB) [1].

Raman fiber amplifier (RFA) can be used to amplify data channels at any band, the amplification in every type of fiber, the ability to provide gain at any wavelength by using the proper pumping scheme by adjusting the pump wavelengths [2], multiple pump wavelengths can be used to increase the amplification bandwidth, and wide gain bandwidth. Thus, L-band optical amplifier is better to adopt RFA rather than L-band EDFA [3]. The gain bandwidth is only limited by the available pump powers and wavelengths, flat gain bandwidths up to 100 nm has been demonstrated [4].

El-Mashade et al. [5] performed a performance of Multi-Stage Optical Amplifier EDFA for different pump wavelengths and pump configurations and EDFA-length to get optimum value for gain, NF and BER.

Rashmi et al. [6] investigated the performance evaluation of different Hybrid Optical Amplifiers (EDFA-SOA, Raman-SOA, Raman-EDFA), in order to compare performance at 64, 96 and 128 channels at speed of 10 Gbps, it is observed that EDFA-SOA provides good performance.

V. Bobrovs et al. [7] performed comparison of Raman-EDFA and Raman-SOA hybrid optical amplifier in DWDM transmission systems, the combination of EDFA and Raman Amplifier showed better results over a longer optical link than the SOA-Distributed Raman amplifier.

Piyush Jain et al. [8] investigated the performance comparison of different hybrid optical amplifiers (SOA-EDFA, RAMAN-SOA, RAMAN-EDFA, EDFA-RAMAN-EDFA), compare performance at 16 and 32 channels at speed of 10 Gbps, it is observed that EDFA-Raman-EDFA provides better results for output power.

O. Mahran et al. [9]studied the characteristics of a dual-pump EDFA/Raman hybrid optical amplifier including the gain and noise figure. The EDFA is forward biased with 980 nm while the RA is reverse biased with 1450 nm.

In this paper several methods are used to obtain high gain and low noise figure between sixteen channels by using Raman amplifier alone at first and then use hybrid amplifier which consist of EDFA and Raman amplifiers and compare the results from different configuration.

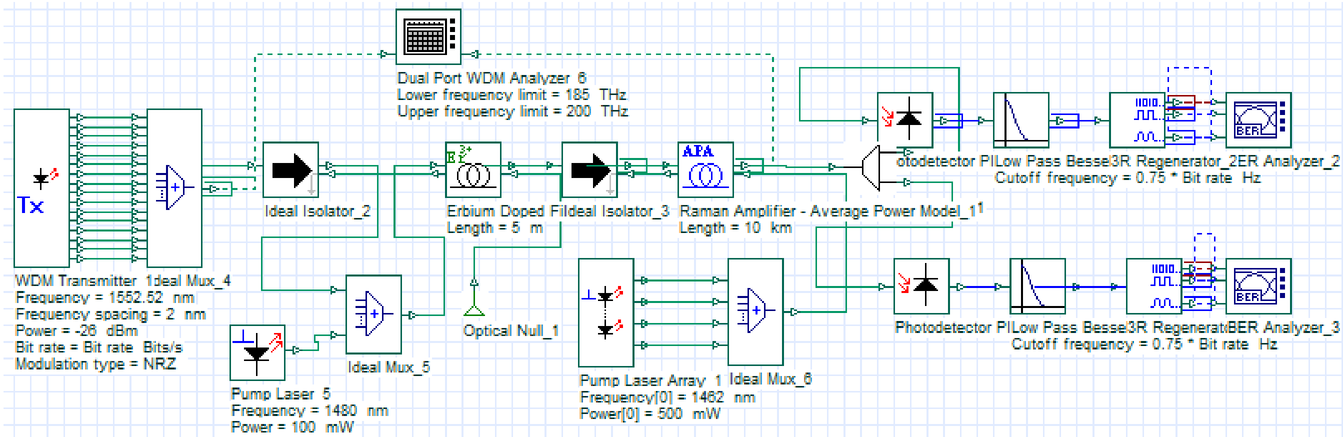


Fig. 1. Schematic simulation of hybrid EDFA/RFA in WDM system

II. SIMULATION SETUP

The simulation setup of EDFA and Raman fiber amplifier in the WDM system is performed using Optisystem software. Fig. 1 shows a schematic model of hybrid EDFA-RFA, in this model sixteen channels are transmitted at 10 Gb/s data rate with 2nm channel spacing from 1552nm to 1582nm. The power of input signal for each channel is taken as -26dBm. Each input signal is modulated in NRZ format. The signals is fed to a multiplexer and then the signal is passed through the hybrid amplifiers consist of EDFA and Raman, optical isolators prevent the amplified signal from reflecting back into the device, then by using a demultiplexer to convert single input to sixteen outputs and the conversion to electrical signal is by using the photo-detector PIN, finally the eye pattern is analyzed using eye analyzer. The measurement components used is dual port WDM analyzer. The parameters of RFA are Raman fiber length is 10 km, counter pump at various wavelength and pump power. The length of EDFA is 5m long.

III. RESULTS AND DISCUSSIONS

The variations of gain and noise figure spectrums are shown by using Raman fiber amplifier only and then by using hybrid EDFA- Raman amplifier and study of Bit Error Rate (BER) and Q-factor will also be considered.

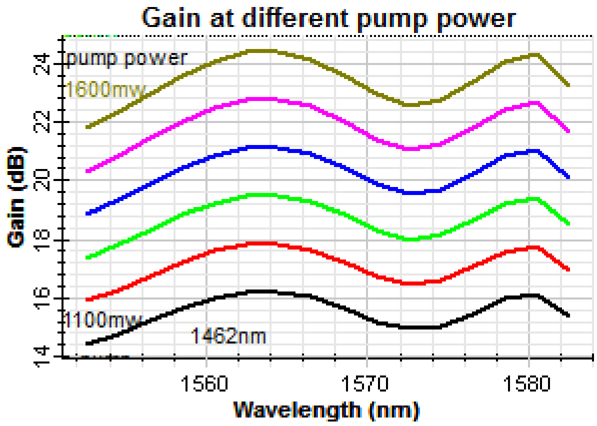
A. Raman Amplifier

At first, the system is analyzed by using Raman Amplifier alone as amplifier at different pumping configuration and compare gain and noise figure.

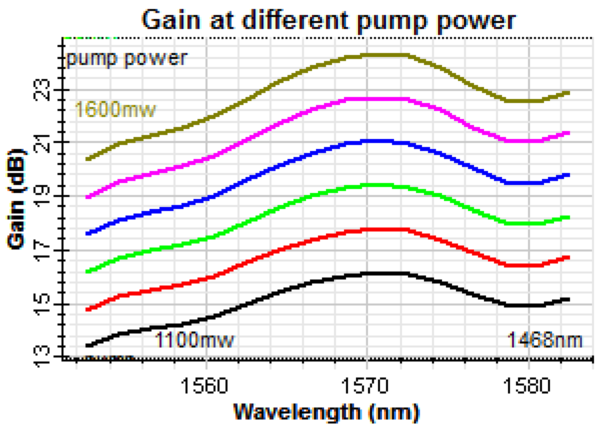
1) Raman (1-Pump)

For this system the use of Raman Amplifier with one pump wavelength.

Fig. 2 depicts a comparison of the gain spectrum obtained from an Raman Amplifier system, for 1462 nm and 1468 nm pump wavelength at different pump power, from 1100 mw to 1600 mw, it's seen that as pump power increase the gain increase, but at the same time it's difficult to get high pump power, and it can be notice that maximum gain obtained at about 100 nm wavelength difference between pump and wavelength.



a) 1462nm pump



b) 1468nm pump

Fig. 2. Gain spectrum at different pump power for RFA

Fig. 3 illustrates the variation of the NF as a function of the operating wavelengths at different pump power from 1100 mw to 1600 mw for 1462 nm and 1468 nm pump wavelength. The displayed results show that as pump power increase the noise figure decrease, but the variance value is not high.

The system is now analyzed for gain and NF spectrums at different pump wavelength. Fig. 4 shows gain and noise figure spectrums for Raman amplifier at constant 1000 mw pump power for different pump wavelength from 1458 nm to 1468 nm.

It's seen that gain vary as pump wavelength change from 1458 nm to 1468 nm but the changed value is not high and max value of 14.6 dB gain get at 1458 nm, the best result for gain and noise figure variation is found at 1462nm pump wavelength.

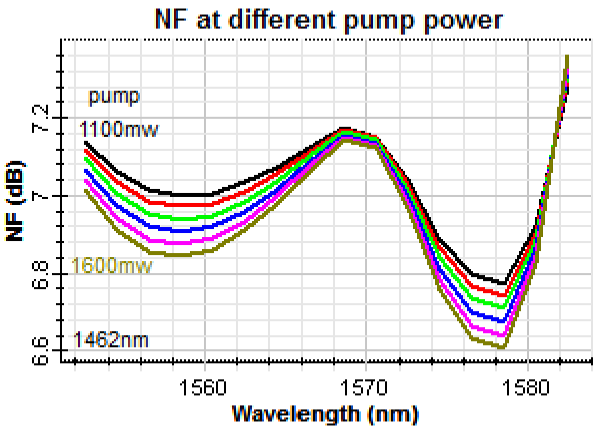
2) Raman (2-Pump)

For this system, the use of Raman Amplifier with two pumps wavelengths at 1462 nm and 1468 nm.

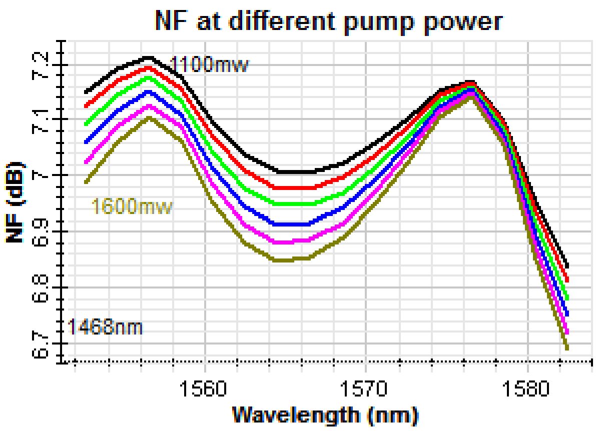
Fig. 5 depicts a comparison of the gain spectrum obtained from an Raman Amplifier system for 1462 nm and 1468 nm pump wavelength at different pump power from 1100 mw to 1600 mw, it's seen that gain increase as pump power increase and maximum gain obtained at about 100 nm wavelength difference between pump and wavelength as in one-pump wavelength.

Fig. 6 shows the gain and NF spectrums for two pump wavelengths at 1462nm and 1468nm, the first one 1462nm and constant power of 1000mw and the second one 1468nm at different pump power varies from 1000mw to 1600mw.

When use 2 pump wavelengths at 1462nm and 1468nm, the results appear better than as compared to two similar wavelengths.



a) 1462nm pump



b) 1468nm pump

Fig. 3. NF spectrum at different pump power for RFA

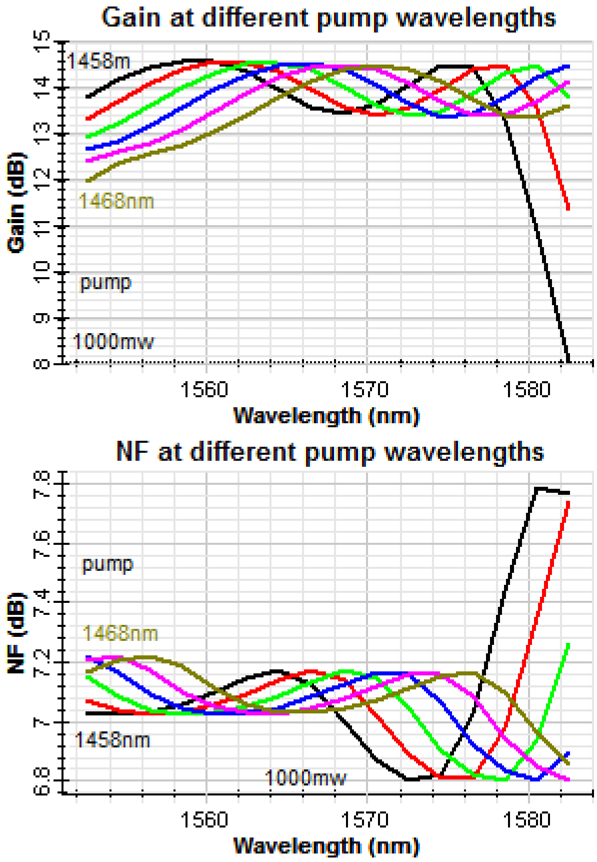
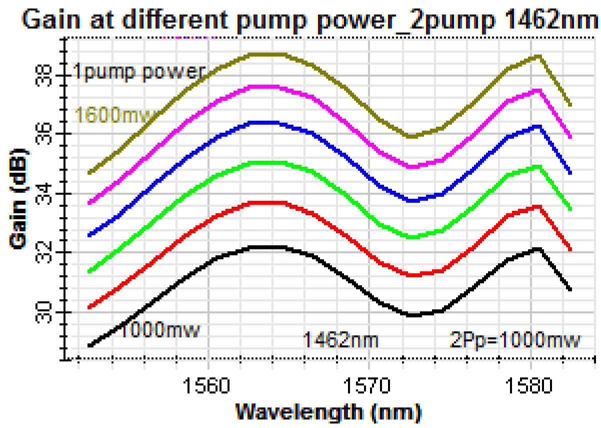
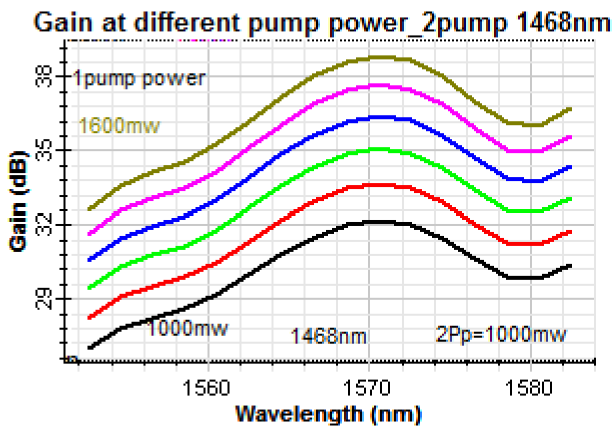


Fig. 4. Gain and NF spectrums at different pump power for RFA



a) two pump at 1462nm



b) two pump at 1468nm

Fig. 5. Gain spectrum for two pump wavelengths RFA

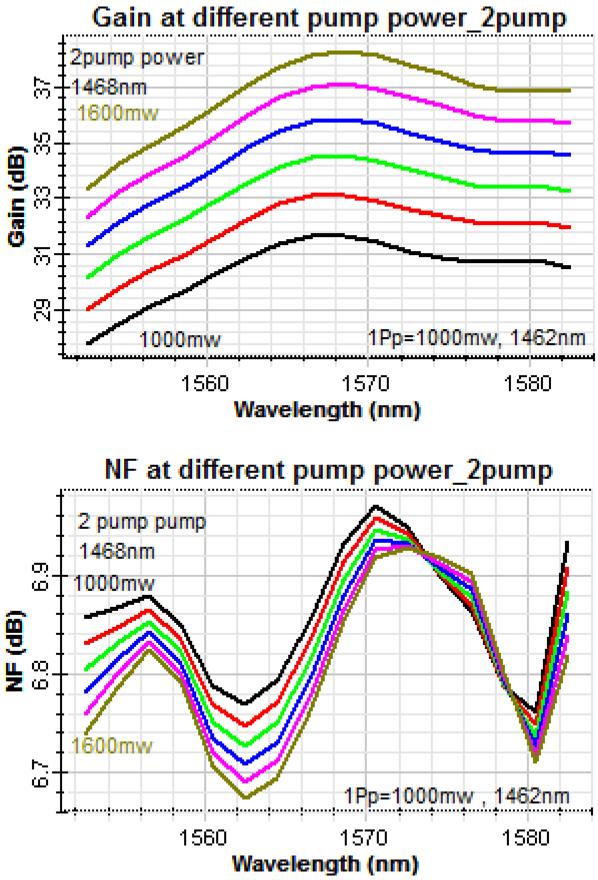


Fig. 6. Gain and NF spectrum two pump wavelengths at 1462nm and 1468nm

We can conclude from using Raman only as an amplifier that, it can be getting some relatively high gain at high pump power, but it's difficult to build pump source with high power. Therefore, we will use hybrid EDFA - Raman as amplifier.

B. Hybrid EDFA - Raman Amplifier:

At this part, we analyze the gain and NF by using the two stages hybrid amplifier with EDFA and Raman amplifiers

1) Raman-EDFA

At first, the system is analyzed by using EDFA-Raman with first stage 10-km length of Raman have backward pump at 1462 nm and second stage is 5-m length of EDFA at 1480 nm forward pump.

Fig.7 shows a gain and noise figure spectrums for Raman- EDFA at constant 1000 mw Raman pump power and different EDFA pump power varies from 10 mw to 100 mw.

It's seen that, gain increase as pump power of EDFA increase and variation of gain between several channels is also increase, but in noise figure the results is almost vary by small value. The following results at Table I is obtained at 100mw EDFA pump power:

TABLE I. RAMAN-EDFA

Gain	NF	Q-factor	BER	Eye height
24.6 - 36.6	6.9 - 7.4	17.1	$2.5*10^{-66}$	0.006

TABLE II. EDFA-RAMAN

Gain	NF	Q-factor	BER	Eye height
26 - 41.7	4 - 4.6	23.6	$9*10^{-124}$	0.027

2) EDFA-Raman

The system is analyzed by using Raman-EDFA with first stage is 5m-EDFA forward pump at 1480 nm and second stage10-km length of Raman have backward pumps at 1462 nm.

Gain and noise figure spectrum for EDFA- Raman at different EDFA pump power varies from 10 mw to 100 mw and constant Raman pump power of 1000 mw are shown in Fig. 8. The following results at Table II is obtained at 100mw EDFA pump power

When comparing two configurations of Raman-EDFA and EDFA-Raman hybrid amplifier, we can obtain that the gain, NF, Q-factor and BER at EDFA-Raman performs better than Raman-EDFA hybrid amplifier. Therefore, we will use EDFA-Raman configuration as a hybrid amplifier.

3) EDFA-Raman (4pump)

As getting one pump source has high power is difficult, to some extent, we use multiple pump source with each one has lower power.

We use four pump wavelengths for Raman amplifier, the system analyzed by using one stage 5m-length of EDFA as first stage and second stage is Raman pumped at 1462 nm wavelengths and each pump power of 500 mw. The gain and noise figure are shown in Fig. 9. The following results at Table III is obtained at 100mw EDFA pump power.

TABLE III. EDFA-RAMAN (4-PUMP)

Gain	NF	Q-factor	BER	Eye height
43.7 - 59.4	4 - 4.6	23.6	$8.5*10^{-126}$	1.1

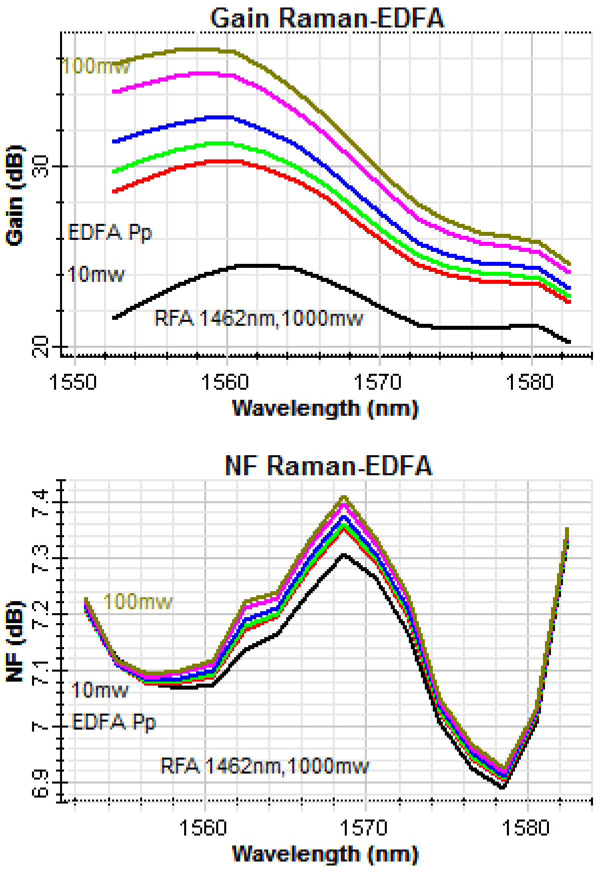


Fig. 7. Gain and NF spectrums for hybrid Raman - EDFA

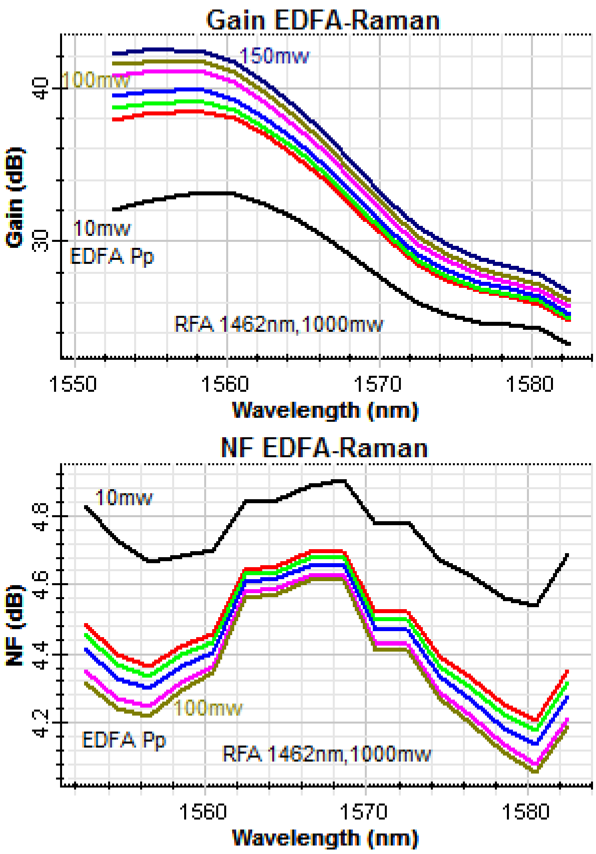


Fig. 8. Gain and NF spectrums for hybrid EDFA - Raman

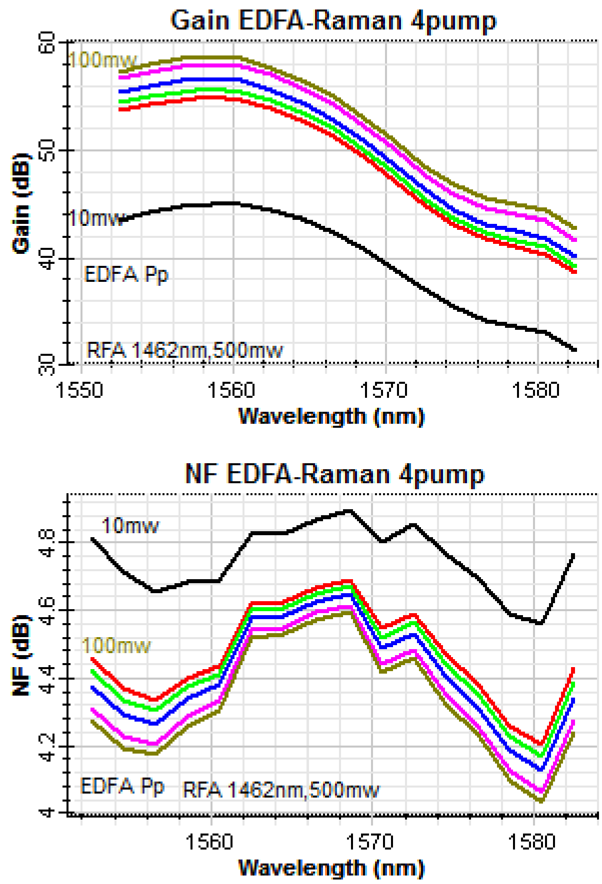


Fig. 9. Gain and NF spectrums for hybrid EDFA - Raman (4pump)

IV. Conclusion

We have analyzed the 16 channel WDM system at 10 Gb/s with different configuration for Raman amplifier only and hybrid amplifiers of EDFA and RFA at different pump power and pump wavelengths of RFA and different configurations of hybrid EDFA-RFA and get best value for each configuration. The performance of optical amplifiers was evaluated using the gain, NF, Q factor and BER and a comparison between the several techniques is made.

We observed that the gain and NF are better at hybrid EDFA-RFA than Raman amplifier only, and when compare several configurations of hybrid amplifier; we find that EDFA-Raman is better than Raman-EDFA for get high gain, low NF, high Q factor and BER. We used 4 pump sources each one has lower power instead of using one source has high power as it's almost difficult to get high power for pump source.

REFERENCES

[1] A.Cem Çokrak, Ahmet Altuncu "Gain and noise figure performance of Erbium doped fiber amplifiers (EDFA)", Journal Of Electrical & Electronics Engineering, vol:4,no.2,pp1111-1122, 2004.

[2] Mohammed N. Islam, "Raman Amplifiers for Telecommunications-1 Physical Principles", Springer, 2004.

[3] Farah Diana Binti Mahad, Abu Sahmah Bin Mohd Supa'at "EDFA Gain Optimization for WDM System", International conference on Communication and Signal Processing, April 3-5, 2013.

[4] H. Kidorf, K. Rottwitt, M. Nissov, M. Ma, and E. Rabarijaona. "Pump Interactions in a 100-nm Bandwidth Raman Amplifier", IEEE Photonics Technology Letters, vol. 11, no. 5, pp. 530–532, 1999.

[5] Mohamed B. El-Mashade and A. Mohamed, "Characteristics Evaluation of Multi-Stage Optical Amplifier EDFA", British Journal of Applied Science & Technology, Vol. 19(4): 1-20, 2017.

[6] Rashmi, Anurag Sharma, Vikrant Sharma, "Performance Evaluation of Different Hybrid Optical Amplifiers for 64×10, 96×10 and 128×10 Gbps DWDM transmission system",(IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (6) , 7199-7203, 2014.

[7] V. Bobrovs, S. Olonkins, A. Alsevska, L. Gegere and G. Lvanovs, "Comparative performance of Raman-SOA and Raman-EDFA hybrid optical amplifiers in DWDM transmission systems", International Journal of Physical Sciences, Vol 8, Issue 39, October 2013, Pg 1898-1906.

[8] Piyush Jain, Mr. Bipin Koushal, Shrija Jain, "Performance analysis of different Hybrid optical amplifier due to varying Transmission distance at 10 Gbps", International Journal of Emerging Technologies in Computional and Applied Sciences (IJETCAS), Vol 13, Issue 347, Pg 246-250, 2013.

[9] O. Mahran and Moustafa H. ALy, "Performance characteristics of dual-pumped hybrid EDFA/Raman optical amplifier", Applied Optics, Vol.55, No.1, 2016.