



# Gain and Noise figure Performance of Raman-SOA Hybrid Amplifier at Different Channel Spacing using NRZ and RZ Modulation Format

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**ABSTRACT:** In this paper, 32×10Gb/s DWDM using Raman-SOA(semiconductor optical amplifier) hybrid amplifier has been investigated at different channel spacing (0.4nm, 0.8nm, 1.6nm) by using NRZ and RZ modulation format to obtain the gain and noise figure of hybrid amplifier. Raman-SOA hybrid amplifier (HA) is proposed and studied to improve the gain and noise figure of hybrid amplifiers. Different channel spacing are used for Raman-SOA HA with -23dBm input signal power, length of 0.0003m for SOA and 10km length of Raman amplifier. It has been observed that as the channel spacing decreases, the performance drastically degrades owing to FWM effect.

**KEYWORDS:** RAMAN, SOA, DWDM, Gain, Noise Figure

## I.INTRODUCTION

Now a days there is increase in demand for higher transmission capacity, to achieve the higher capacity DWDM system is the basic promising technology [1]. This technology cheaply solves the problem of increasing communication channels without deploying new cables. The conventional optical amplifiers, such as the erbium-doped fiber amplifier (EDFA), the semiconductor optical amplifier (SOA) and the Raman amplifier are the vital components for DWDM systems [2, 3]. Raman amplifiers have attracted huge attention in recent years due to the fact that any wavelength, within the transparency window of an optical fiber, can be amplified by simply adjusting the pump wavelength [4]. Various Drawback of a Raman amplifier is that nonlinear effects such as stimulated Brillouin scattering, self-phase modulation, cross-phase modulation, and four-wave mixing degrade the signal when the amplifier has large output power [5].SOAs produces large amount of amplified spontaneous emission(ASE). Also gain dynamics cause signal distortions [6]. Raman amplifiers provide noise free amplification. In Raman amplifier spectrum can be changed by using different pumps and their frequencies [7]. To improve the drawbacks of different amplifiers they are used together by forming a hybrid amplifier (HA).

The combination of more than one optical amplifier in any configuration is called hybrid optical amplifier (HOA), that combine several amplifiers with different gain bandwidths to extend the gain bandwidth product of the optical amplifiers. Mohammed N. Islam described that the net gain of the Raman-EDFA HOA ( $G_{Hybrid}$ ) is the sum of the two individual gain of Raman and EDFA respectively [8]. Therefore, in the case of Raman-EDFA HOA the net gain is:

$$G_{Hybrid} = G_{EDFA} + G_{Raman} \quad (1)$$

S.H. Xu et al. [9] measured the gain and noise figure of single mode highly Er/Yb co-doped phosphate with dual pump configuration at different values of input signal power. They obtained a net gain coefficient as high as 3.3dB/cm from a micro EDFA based on a 5cm long phosphate fiber. Lee et al. [10] studied experimentally the characteristics of EDFA/Raman HA for three different types of pumping configurations and they obtained a net gain of 19dB and 6dB noise figure at 1535nm. Thomas et al. [11] proposed a hybrid thulium doped fluoride amplifier (TDFA) and distributed Raman amplifier (DRA) for short wavelength amplification. Using the offered hybrid amplifier, a gain of greater than 20 dB over a broad bandwidth (that is 75 nm ranging from 1445 to 1520 nm) was achieved with noise figure (NFs) of

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between 7 and 8 dB. Also, due to the similar gain profile of these amplifiers, the expensive gain flattening techniques are exempt from achieving large gain flatness.

This paper propose a model of HOA (Raman-SOA) at different channel spacing such as 0.4, 0.8 and 1.6nm. The system is investigated for 32 channel DWDM system, and the results are further compared in the term of Gain and Noise Figure.

The paper is organized as follows: In section II, the setup of hybrid amplifier is described. In section III discusses the results and at last conclusions are made in section IV.

## II. SYSTEM DESCRIPTION

The system for 32 channel DWDM system at various channel spacing that are amplified by RAMAN-SOA hybrid amplifier is shown in Fig.1 amplifier is shown in Fig.1

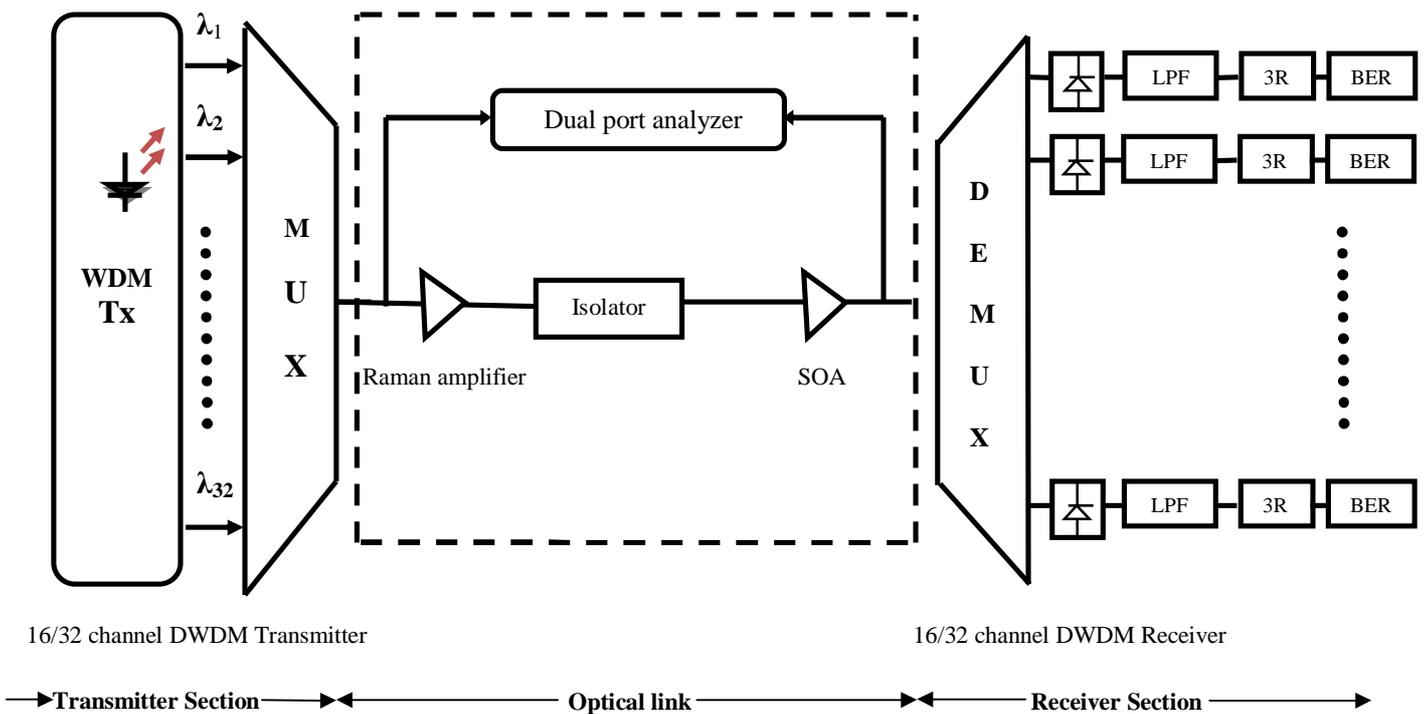


Figure 3.1 schematic diagram of DWDM system

In this system, 32 channels are transmitted by using DWDM transmitter at 10Gb/s data rate using 0.4, 0.8 and 1.6nm channel spacing at a frequency of 1550nm. The power of input signal for each channel is taken as -23dBm using NRZ and RZ modulation format. All the 32 channels are multiplexed using WDM MUX and the signal thus obtained is used in WDM communication system. The gain, noise figure is obtained through Dual port WDM analyzer. Isolator is placed between Raman and wideband SOA because it allows the transmission of light in only one direction. It is typically used to prevent unwanted feedback into an optical oscillator, such as a laser cavity. Transmitted signals are multiplexed and launched in to optical fiber, where hybrid optical amplifiers (Raman-SOA) are used to amplify the signals. The various parameters for Raman amplifier are: Length = 10km, operating temperature = 300k, different pump wavelength (1405nm-1457nm) and different pump powers of 100mW. These amplified signals are then received by optical receivers. Optical receivers comprise of PIN photo detector, low pass Bessel's filter and 3R regenerator. Parameters of PIN photodiode are Dark current = 10nA and responsivity = 1A/W. Low pass Bessel filter having cut off frequency = 7.5GHz and order = 4. BER analyzer and spectrum analyzer are used as visualizer to obtain the value of Q-

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factor, BER, output power, eye diagrams and signal spectrums. In Dense wavelength division multiplexed system the channel spacing becomes denser but more wavelengths can be accommodated in same C Band (1530-1565nm). In case of 1.6nm, system would use 32 channels but as the channel spacing reduces to 0.8nm, system should use 64 channels and further channel spacing reduces to 0.4nm, system should use 32 channels.

### III.RESULTS AND DISCUSSION

#### Case 1: Performance evaluation of Raman-SOA HOA by using NRZ modulation format

Fig. 2 shows the gain of HOA is plotted against the signal wavelength. It is clear that the maximum gain of 19.8dB has been reported at 1.6nm of channel spacing, similarly gain 17.26dB is obtained at 0.8nm and lowest gain 14.26dB at 0.4nm of channel spacing at a wavelength of 1500-1550nm and the results shows that as the channel spacing reduces, performance gets deteriorate due to non linear effect such as FWM and XPM [13]. Due to the gain dynamics induced by the optimized HOA, distortion of pulse shapes and crosstalk between channels are present. These crosstalk effects are due to the induced nonlinearities such as stimulated Raman scattering, four-wave mixing, self and cross-phase modulation, etc.

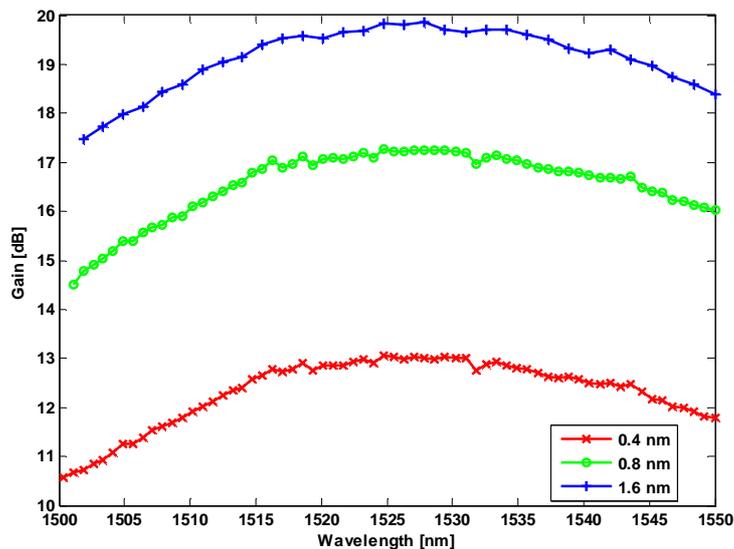


Fig.2 Gain vs Wavelength

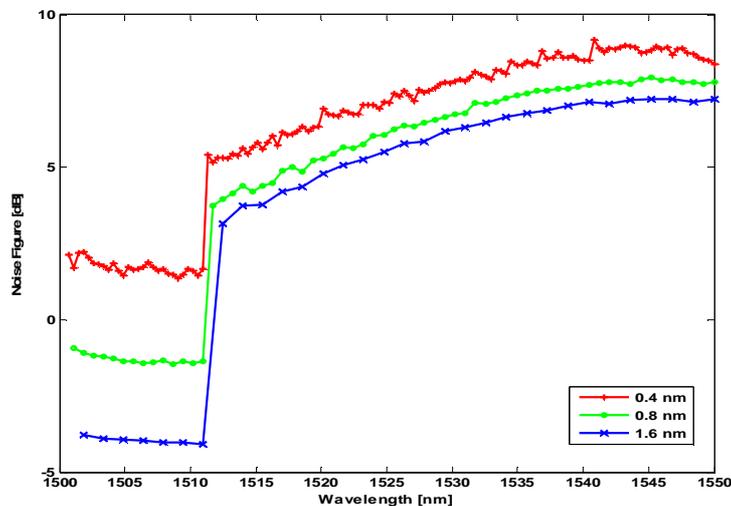


Fig. 3 Noise Figure vs Wavelength

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From the results of gain, it can further be consolidated by observing the noise figure also. From Fig.3 the performance of noise figure can be evaluated. The largest values of noise figure at the signal wavelength range are found at 0.4nm of spacing while the lower values are found at higher channel spacing i.e. 1.6nm. The noise figure is likely to be opposite of gain of Raman-SOA hybrid amplifier.

## Case 2: Performance evaluation of Raman-SOA HOA by using RZ modulation format

Graph of gain versus wavelength is shown in Fig 4. It is observed from the graph that maximum gain of 21dB has been reported at 1.6nm of channel spacing with less than <6dB noise figure at 1.6nm is obtained and the disturbance is more at lowest channel spacing i.e. 0.4nm. As the channel spacing decreases, gain also decreases that shows as the channel spacing reduces the performance of the system drastically degrades.

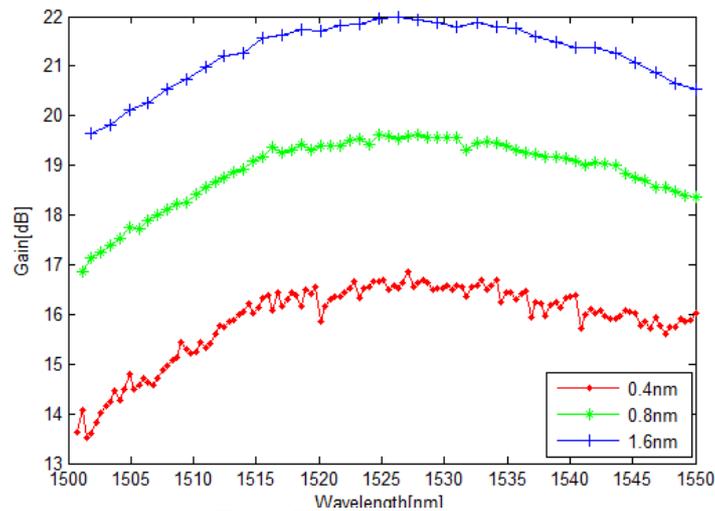


Fig. 4 Gain vs Wavelength

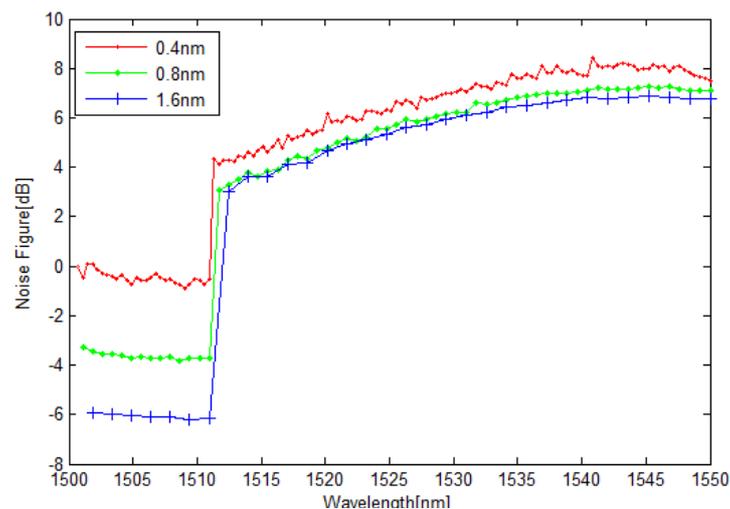


Fig. 5 Noise Figure vs Wavelength

From the results of gain, it can further be consolidated by observing the noise figure also. From Fig.5 the performance of noise figure can be evaluated. The largest values of noise figure at the signal wavelength range are found at 0.4nm of spacing while the lower values are found at higher channel spacing i.e. 1.6nm. The NF is essentially the inverse of the gain spectrum of Raman-SOA hybrid amplifier.



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**Table 1** Gain and noise figure comparison at different channel spacing for 32 channels

Parameters	Modulation formats					
	NRZ			RZ		
Channel spacing	0.4	0.8	1.6	0.4	0.8	1.6
Gain(max -min)[dB]	14.6-11.4	17.2-14.5	19.8-17.4	16.6-13.3	19.1-16.3	21.5-19.1
Noise Figure [dB]	< 9	< 7	< 7	< 8	< 7	< 7

Table 1 shows the gain and noise figure comparison between the NRZ and RZ modulation format. In this the gain at maximum and minimum value is given at different channel spacing. That shows that as the channel spacing increases, gain decreases due to four wave mixing.

## IV.CONCLUSION

In this paper, the comparison of NRZ and RZ modulation format is analyzed for Raman-SOA at Different channel spacing. The HOAs are one of the possible ways to amplify the broad gain bandwidth product with minimum gain variation among the channels. Maximum gain of 21.5 dB and 19.8 dB is obtained at 1.6nm of channel spacing by using RZ and NRZ modulation format. It is concluded that gain is maximum of using RZ modulation format with minimum NF and overall result shows that as the channel spacing reduces more channel can be accommodated in available bandwidth and effect of four wave mixing increases.

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