Performance Evaluation of 64x20 Gb/s DWDM Optical system using Raman-EDFA for different channel spacing

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Abstract:

In this paper hybrid optical amplifier is investigated by cascading configuration of distributed fiber Raman amplifier and Erbium doped fiber amplifier for 64 X 20 Gb/s dense wavelength division multiplexing operating at different channel spacing (25, 50, 100, 150 GHz). At the input power of -10 dBm and variation in the Raman fiber length (20 to 100 km) of Raman amplifier, the on-off gain of more than 34 dB up to 40 km of Raman fiber length at 100 GHz channel spacing. The noise figure is 8 to 11 dB and is minimum up to 40 km and output signal is also maintained at this Raman fiber length. When the input power is varied from -10 dBm to 4 dBm at 40 km of Raman fiber length the on-off gain is 35.7 dB and it is slightly decrease with increase of input power and noise figure is maintained less than 12 dB at 100 GHz channel spacing. From the investigations 40 km is found to be the optimum Raman fiber length, and among different channel spacing 100 GHz may be a better choice for obtaining better gain and noise figure results.

Keywords—Wavelength Division Multiplexing (WDM), Hybrid Optical Amplifier (HOA), Erbium Doped Fiber Amplifier (EDFA), RAMAN Amplifier**.**

I. INTRODUCTION

Hybrid optical amplifiers are the significant devices for long haul transmission systems. The power level of signal degrades as travel along the fiber due to non-linearities of the fiber. In the early days, regenerators were used to overcome the losses of fiber. These regenerators convert optical to electrical signal and vice versa, hence they became complex and expensive in long haul transmission systems. So, to overcome these drawbacks optical amplifiers are invented. They amplify the optical signal directly without conversion of signal. M. kaur [2] investigates 32 × 10Gb/s dense wavelength division multiplexing (DWDM) optical system using ytterbium doped fiber amplifier (YDFA) having 100GHz, 75GHz, 50GHz and 25GHz channel spacing with starting frequency 193.414THz has been investigated. The DWDM system is evaluated by varying the length for the optical fiber from 40-160km. It has been found that as the channel spacing decreases the performance drastically degrades owing to four wave mixing (FWM) effect. The best results have been reported for the system at the 100GHz channel spacing where the maximum Q factor (23.35dB) and output power (-1.156dBm) is achieved at 40km fiber length.

Among the various hybrid optical amplifier configurations, Raman/EDFA is most preferred in comparison with others for high gain spectrum and low noise figure [9, 10]. Erbium doped fiber amplifier (EDFAs) is very effective technology and its bandwidth is fully utilized for multichannel optical transmission system. Distributed fiber Raman amplifiers (DFRAs) are nowadays essential components of long haul DWDM system as due to low noise figure and low nonlinearity impact is preferred in HOA configurations. Multi pumping of DFRAs improve gain, noise figure etc [3, 4].

The channel spacing should be consider for analysing as it might help to choose the viable value of channel spacing for DWDM systems [2,17]. The fiber length of Raman amplifier should also be considered as which length is better operating for analysing characteristics of HOA. A lot of works have been reported in the literature on this issue but still there is big scope of improvement such as gain bandwidth needs to be addressed. G. Singh [13] evaluates the performance of HOA in terms of gain, noise figure, OSNR and gain bandwidth using two and four cases of Raman pumps. Ahmed [14] investigate the quality of the transmission of each channel for a Wavelength Division Multiplexed (WDM) system with a 640 GB/s data rate (16 x 40 GB/s) with RZ modulation for different channel spacing. Then they found that more we increase the channel spacing the quality factor increases with.

S. Singh [1] had investigated the EDFA/DRFA gain and gain ripple by varying input power with channel spacing of 25 GHz in WDM optical communication systems, and also novel optical gain of HOA [7]. K. Singh et. al. [8] has solved propagation equations of multi pump fiber Raman amplifier (RK 4^{th} order) numerical method and pump power along with the fiber length. A comparative analysis of dual order bidirectional backward pumping schemes in distributed Raman amplifier [11, 12].

The ultimate capacity of WDM fiber links depends on how closely channels can be packed in the wavelength domain. The minimum channel spacing is limited by inter channel crosstalk. Typically, channel spacing $\Delta\nu$ ch (channel spacing) should exceed $2B$ at the bit rate B. This requirement wastes considerable bandwidth. It is common to introduce a measure of the spectral efficiency of a WDM system as $\eta s = B/\Delta\nu ch$. Attempts are made to make ηs as large as possible [15].

The EDFA-Raman combination as a hybrid amplifier may be a efficient configuration as compare to other configurations[16]. To estimate its performance the metrics like gain, noise figure, and OSNR are required to be critically observed.

The simulation setup of hybrid configuration is explained in Section II. Section III describes the results and their explanations and Section IV summarizes the conclusions.

II. SIMULATION SETUP

From the transmitter side, 64 channels NRZ WDM transmitter at 20 Gb/s bit rate with five standard values of channel spacing (25, 50, 100, 150 GHz) are taken for analyzing the hybrid configuration. An ideal WDM MUX is employed to multiplex the channels. These multiplexed channels are launched in 100 km single mode fiber (SMF). To compensate the chromatic dispersion a 17 km dispersion compensating fiber (DCF) is employed at the end of SMF.

The Raman amplifier with variation in the length from 20 to 100 km fiber length is employed with effective interaction area of 75 μm^2 connecting with four backward signal pumps and the dispersion of 16 ps/nm/Km is enabled to Raman amplifier. The input optical power is varied from -10 dBm to 4 dBm to analyse the performance of hybrid amplifier. Fig. 1 shows the simulation setup of HOA transmission system with Raman-

EDFA configuration [13]. The parameters which are selected for the simulation setup with their investigated values are listed in table 1.

WDM DEMUX is employed to demultiplex the channels and these demultiplexed channels are received by an optical receiver. To investigate parameters of HOA such as gain, noise figure and OSNR, WDM analyser is connected to the ports of EDFA and Raman amplifier.BER analyzer is connected to investigate performance parameters of hybrid amplifier at the receiver. In case of HOAs (Hybrid Optical Amplifier) total gain is the product of separate gains of individual cascade amplifiers as report in [9]. The total gain of HOA can be described as,

$$G_{RE} = G_{Raman} + G_{EDFA}$$

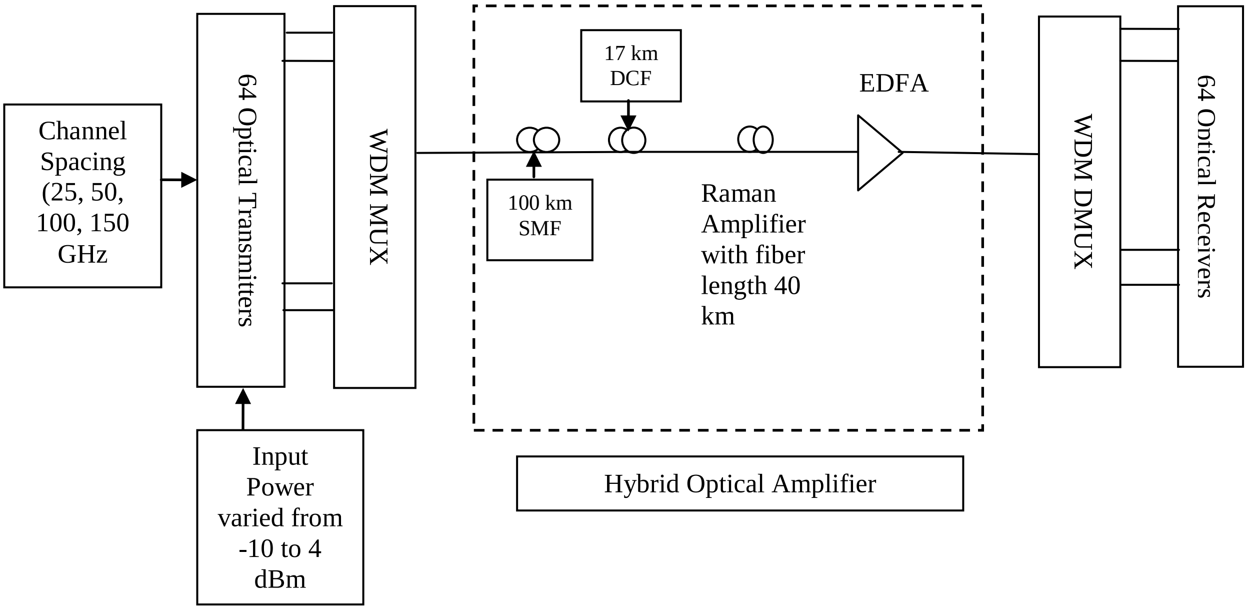


Fig.1 Simulation setup

Table 1 Selected Parameters for simulation setup

S. No.	Parameters	Investigated values
1	Bit rate (Gb/s)	20
2	No. of Channels	64
3	Channel Spacing (GHz)	25, 50, 100, 150
4	SMF (km) DCF (km)	100 17
4	Raman fiber length (km)	(20 to 100 km)
5	Raman Pump wavelengths (nm)	Four Pumps: 1450, 1465, 1480, 1495
6	Raman Pump Powers (mW)	Four Pumps 200,160, 160, 150

III. RESULTS AND EXPLANATION

Investigations are performed for Hybrid amplifier configuration by taking five values of channel spacing (25, 50, 100, 150 GHz) for the setup shown in Fig. 1. The on-off gain versus Raman fiber length is plotted for 20 km to 100 km Raman fiber length and is shown in Fig. 2 (a). The gain is more than 32 dB up to 40 km at 25 GHz and after this length the gain is decreasing and reached to 28 dB. As the channel spacing is increased the gain is also increasing as due to less effect of non linearity's of fiber on maximum channel spacing . The value of gain reached up to 34 dB at 50 GHz and 35 dB at 100 and 125 GHz, after 40 km of Raman fiber length the gain starts decreasing up to length 100 km. The gain is 35.5 dB which is maximum at 40 km of Raman fiber length at 100 GHz channel spacing.

Corresponding noise figure of the hybrid configuration is plotted against Raman fiber length as shown in Fig. 2 (b). The noise figure is decreasing as increase of the channel spacing and is increasing with increase of Raman fiber length. The noise figure at these channel spacing is increasing from 8 dB. From 20 km to 40 km of Raman fiber length the noise figure is minimum which is less than 10 dB at 100 and 150 GHz but after 40 km the noise figure is minimum at 100 GHz and 150 GHz. OSNR is plotted versus Raman fiber length from 15 to 50 km as shown in Fig. 4.

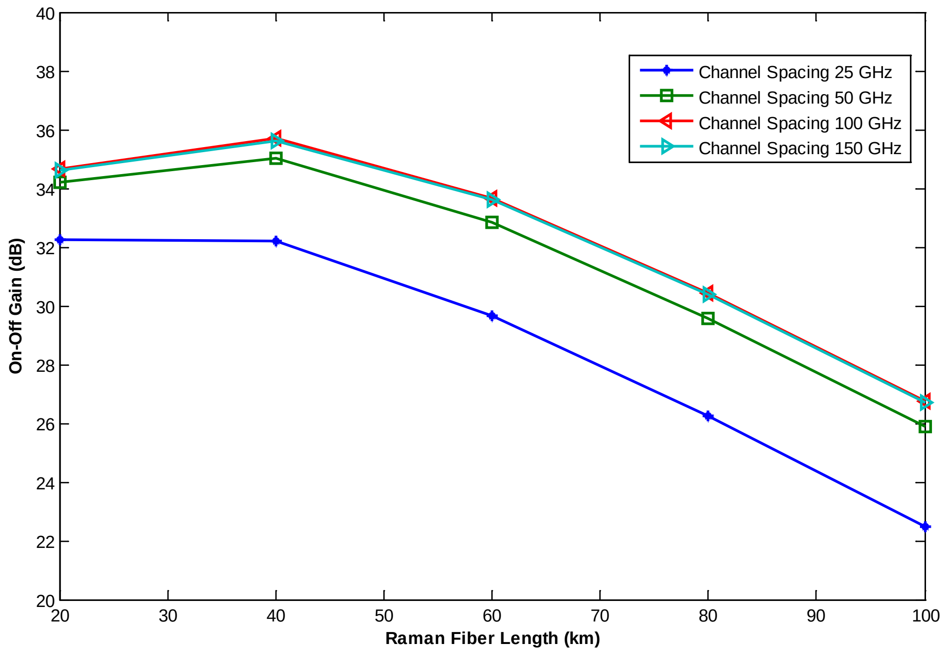
OSNR is plotted against the Raman fiber length at different channel spacing as shown in Fig. (c)The value of OSNR is very slightly increase as increase in channel spacing and is decreasing with increase of Raman fiber length. At 25 GHz the value of OSNR is 8 dB at 20 km of Raman fiber length and reduces to - 4 dB at 100 km of fiber length. OSNR is maximum at 150 GHz which starts from 8.7 dB and reduces to -1 dB. There is less variation in the OSNR up to 40 km of Raman fiber length as it is around 7 to 8 dB but after 40 km it is decreasing as sudden.

The output signal versus Raman fiber length is also analysed at different channel spacing as shown in fig. 2 (d). The output signal is constant which is -9 dBm at 25 GHz channel spacing up to Raman length of 40 km but after than fiber length it is decreasing up to entire length of 100 km. The output signal is slightly increase which is around -6 dBm at 50, 100 and 150 GHz channel spacing up to 40 km of fiber length, thereafter the output signal is decreasing and fall down to -14 dBm. Therefore, 40 km of Raman fiber length may be an optimum length for output signal.

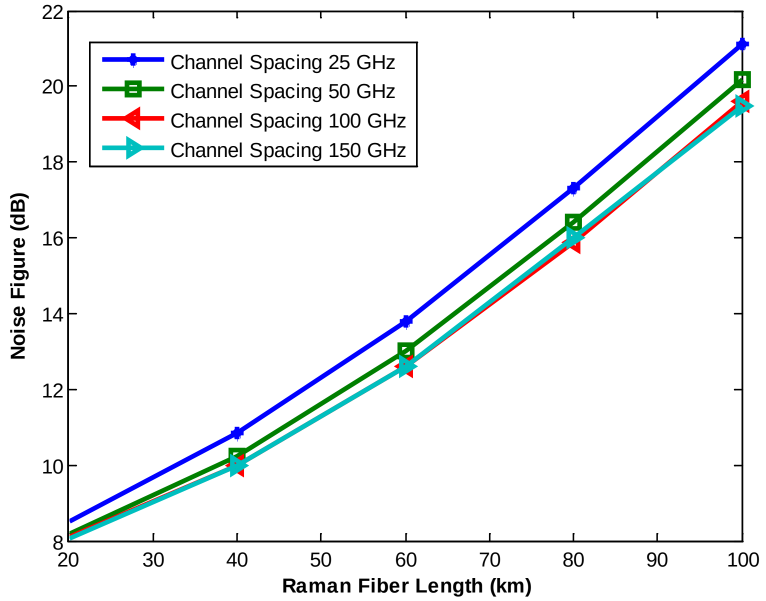
The input optical power is varied from -10 dBm to 4 dBm and with respect to this on-off gain is analysed at 100 and 150 GHz channel spacing as shown in Fig. 3 (a). The Raman fiber length is set to 40 km in this investigation. In case of 100 GHz channel spacing, the gain is around 36 dB at input power of -10 dBm. As the input power is increased the gain is slightly decrease as it is 35.67 at 4 dBm input power. Similarly in other case of 150 GHz, the gain is 35.7 dB at -10 dBm input power and decreases to 35.6 dBm.

The noise figure is plotted versus input optical power at 100 and 150 GHz channel spacing as shown in Fig. 3 (b). When channel spacing is 100 GHz the noise figure is 11.6 dB at the starting input power of -10 dBm, after increase in the input power noise figure is slightly increase as it is 11.8 dB at 4 dBm input power. When channel spacing is 150 GHz the noise figure is increased as it reaches up to 12.2 to 12.3 dB.

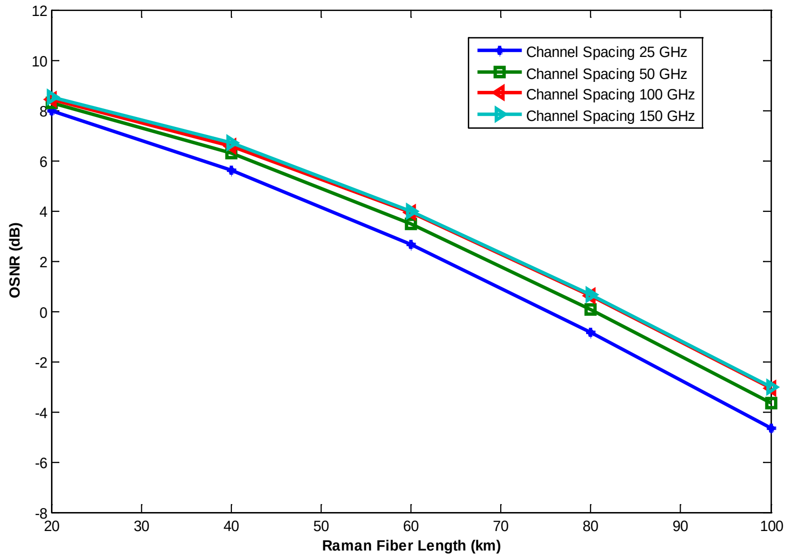
OSNR is plotted with respect to input optical power at two channel spacing as shown in fig. 3 (c). The OSNR is increasing as increase in the input power. In case of 100 GHz, OSNR is 6 dB at -10 dBm input power and reaches to 17 dB at 0 dBm power. When the input power is 4 dBm the OSNR is 20.5 dB. In other case of 150 GHz channel spacing the noise figure is 6.8 dB at -10 dBm power and rocketed up to 20.8 dB at 4 dBm input power.



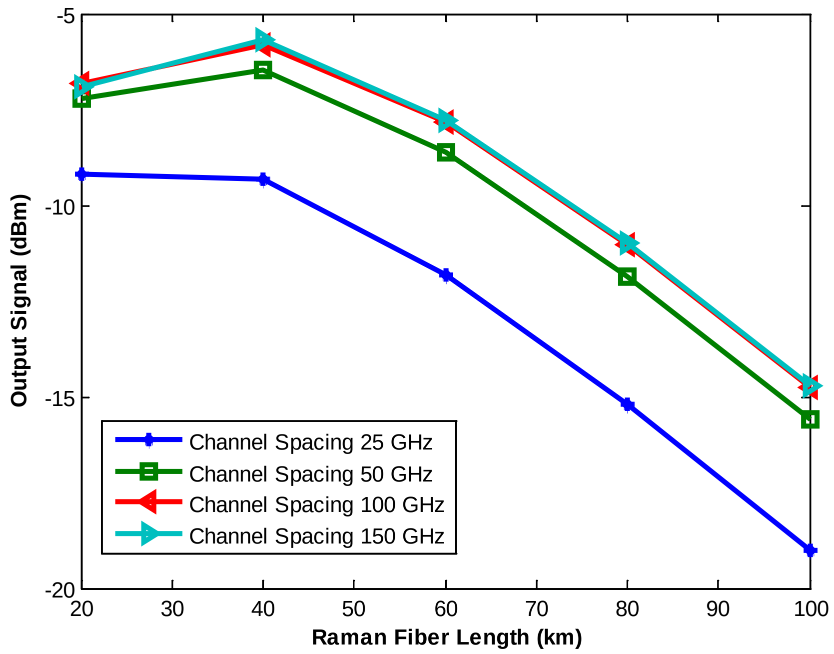
2.(a)


Noise Figure (dB)
Raman Fiber Length (km)
Channel Spacing 25 GHz
Channel Spacing 50 GHz
Channel Spacing 100 GHz
Channel Spacing 150 GHz
22
20
18
16
14
12
10
8
20
30
40
50
60
70
80
90
100

2.(b)

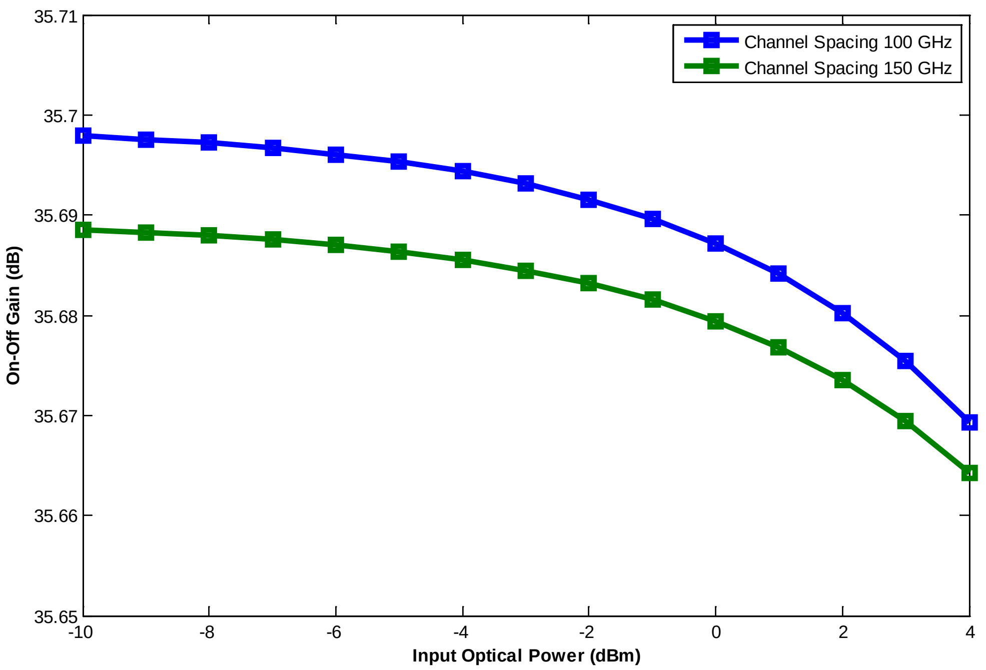

OSNR (dB)
Raman Fiber Length (km)
Channel Spacing 25 GHz
Channel Spacing 50 GHz
Channel Spacing 100 GHz
Channel Spacing 150 GHz
12
10
8
6
4
2
0
-2
-4
-6
-8
20
30
40
50
60
70
80
90
100

2. (c)

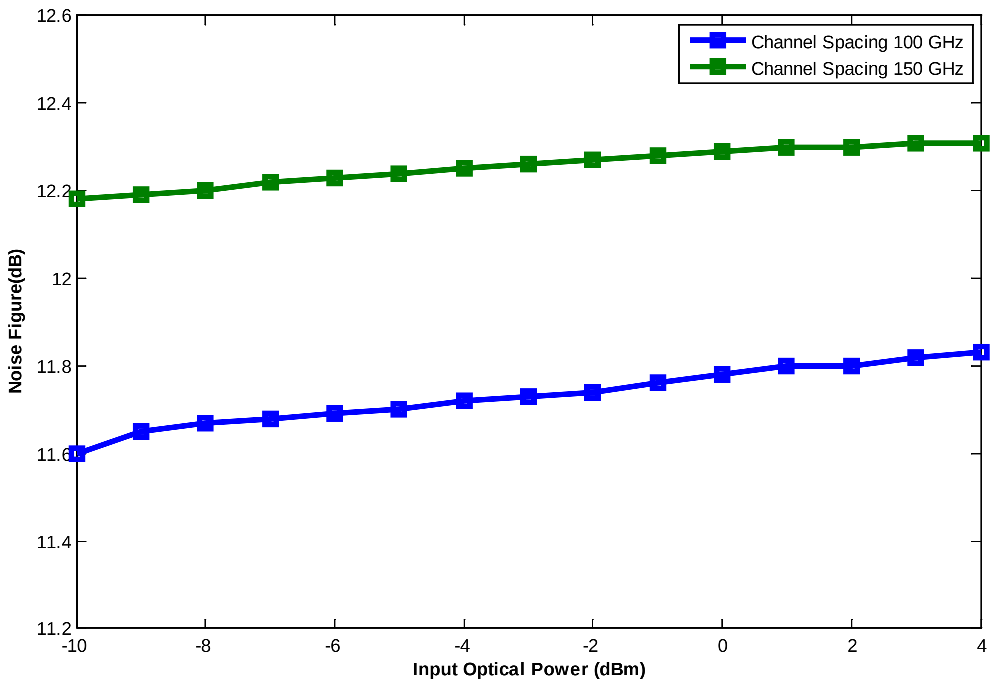


2. (d)

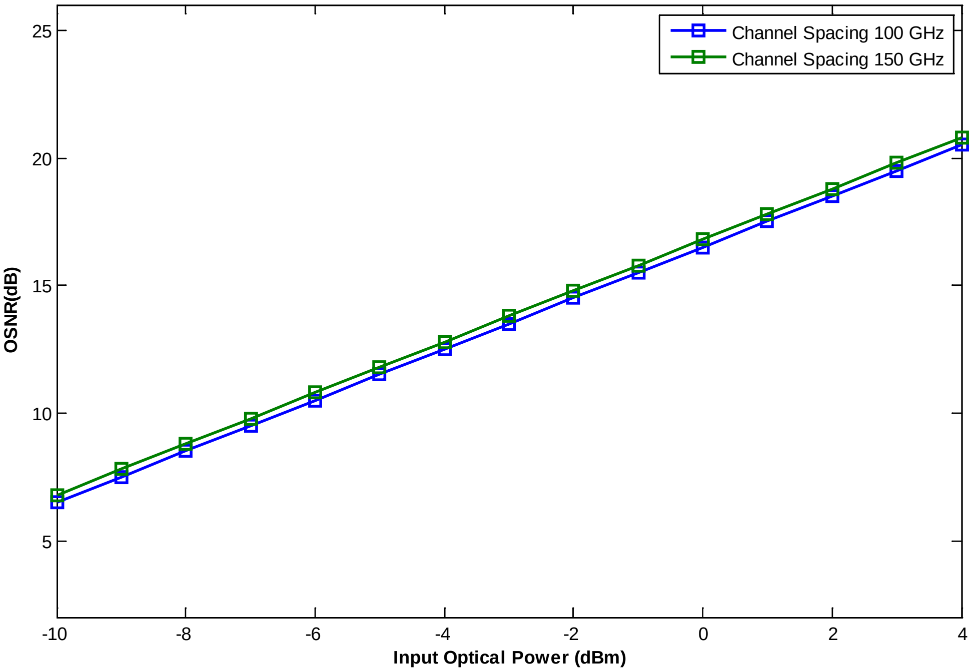
Fig. 2 (a) On-off gain (dB), (b) noise figure (dB), (c) OSNR (dB), and (d) Output signal power (dBm) versus Raman fiber length (km) at channel spacing 25, 50, 100 and 150 GHz.


Channel Spacing 100 GHz
Channel Spacing 150 GHz
On-Off Gain (dB)
Input Optical Power (dBm)
35.71
35.7
35.69
35.68
35.67
35.66
35.65
-10
-8
-6
-4
-2
0
2
4

3. (a)


Channel Spacing 100 GHz
Channel Spacing 150 GHz
Noise Figure(dB)
Input Optical Power (dBm)
12.6
12.4
12.2
12
11.8
11.6
11.4
11.2
-10
-8
-6
-4
-2
0
2
4

3. (b)



3. (c)

Fig. 3 (a) On-off gain (dB), (b) noise figure (dB), (c) OSNR (dB) versus Input optical power (dBm) at channel spacing 100 and 150 GHz.

IV. CONCLUSIONS AND FUTURE SCOPE

The hybrid Raman-EDFA amplifier has been investigated to optimize its performance using multiple pump wavelengths and powers of Raman amplifier. The channel spacing is varied and the parameters such as gain, noise figure, OSNR of HOA have been investigated. At the input power of -10 dBm and variation in the Raman fiber length (20 to 100 km) of Raman amplifier having four Raman pumps, the on-off gain of more than 34 dB is obtained at 40 km of Raman fiber length at 100 GHz channel spacing. The noise figure is 8 to 11 dB and is minimum also up to 40 km of Raman fiber length. When the input power is varied from -10 dBm to 4 dBm at 40 km of Raman fiber length the on-off gain is 35.7 dB and it is slightly decrease with increase of input power and noise figure is maintained less than 12 dB at 100 GHz channel spacing. From the investigations 40 km is found to be the optimum Raman fiber length, and among different channel spacing 100 GHz may be a better choice for obtaining better gain and noise figure results.

For future work, one can include more Raman pumps and other wavelength combinations. The forward pumping of Raman amplifier may also be examined.

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