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Performance Investigation of 320Gbps High Speed Hybrid Optical Amplifier (HOA) Based DWDM Long Haul Optical Transmission Link Under Varying Data Rate

Engineering

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Harpreet Dhami — Department of Electronics and Communication Engineering, DAV Institute of Engineering and Technology, Jalandhar

Love Kumar — Department of Electronics and Communication Engineering, DAV Institute of Engineering and Technology, Jalandhar

ABSTRACT

We have investigated the performance of 320 Gbps DWDM network with different Hybrid Optical Amplifiers (EDFA-SOA, Raman-SOA, EDFA-EDFA) under varying data rates .The proposed network consists of 64, 96 and 128 channels at a speed of 2.5 Gbps. We have realized the different hybrid amplifiers and their parameters like BER, Q factor at different numbers of channels and at varying data rates. It is observed that EDFA-EDFA showed better performance as it can travel max distance of 100 at 128 channels. BER of the order of e-14 and Q factor as high as 12 has been achieved for EDFA-EDFA hybrid amplifier. Hence 320 Gbps (128X2.5Gbps) data rate has been achieved using designed system.

Introduction

Today's optical backhaul network consists of dense wavelength division multiplexing (DWDM), which is fundamentally wavelength division multiplexing (WDM) with dense channel spacing, where different optical signal frequencies are used in order to achieve coincident transmission of a exact number of optical channels over a single fiber [1].The high speed transmission over the global telecommunication network not including repeaters will continue to grow at an exponential rate and only optical fiber amplifiers will be able to meet up the challenge [2]. It is important to maintain the required level of system performance for a longer transmission length. Multichannel systems are highly sensitive to optical attenuation and chromatic dispersion and nonlinearity [3].Optical amplifiers are used to maintain the level of the signal. Optical gain depends on the frequency of the incoming signal. Optical amplifiers are better than regenerators. Semiconductor Optical Amplifier (OA) and Erbium Doped Fiber Amplifier (EDFA) amplifier optical gain is provided through stimulated emission, and Raman Amplifier (RA) uses non-linearity. In the amplifier medium spontaneous emission occurs, which amplified with the transmitted signal, and hence the amplified spontaneous emission (ASE) noise produce, which affect the whole transmission distance [3]. In WDM Semiconductor optical amplifiers (SOAs), doped fiber amplifiers (DFAs), and Raman amplifiers (RA) are used [4]. HoA have their own benefits and drawbacks. SOAs has problem to produce large amount of ASE and gain dynamics cause signal distortions. Erbium Doped fiber amplifiers provide amplifications with less signal impairments than SOA. EDFAs gain is highly frequency dependent due to doped material [12]. Raman amplifiers provide noise free amplification. Raman amplifier spectrum can be changed by using different pumps and their frequencies [6]. To recover the drawbacks of different amplifiers they are used together by forming a hybrid amplifier. In this paper authors have designed a DWDM transmission system with different combinations of amplifiers and studied different hybrid amplifiers in different number of channels with 100,150,200 and 250 km distance.Bobrovs V. *et al.* [1] performed comparison of Raman-SOA and Raman-EDFA hybrid optical amplifier in DWDM transmission systems. In this the combination of EDFA and distributed Raman Amplifier showed better results and provided transmission over a longer optical link than the SOA-Distributed Raman amplifier.

Jain P. *et al.* [3] investigated the performance comparison of different hybrid optical. In order to compare performance at 16 and 32 channels at speed of 10 Gbps. These comparisons have been done by varying transmission distance in between 10 to 200 km with dispersion 16.75 ps/nm/km. It has been observed that EDFA-RAMAN-EDFA provides better results for output power. In 16 channels system both RAMAN-EDFA & EDFA-RAMAN-EDFA have same value for BER for short distance but for long distance EDFA-RAMAN-EDFA has highest value among all.

Singh S. *et al.* [4] demonstrated long haul WDM transmission of 32x10 Gbits/s and 64 x 10 Gbits/s over single mode fiber of varying length by using RAMAN-EDFA hybrid optical amplifier at inline and preamplifier amplifiers. In this it is observed that before 650 and 530 km BER and Q-factor and eye opening is acceptable and after 530 km Q-factor and BER increases.

Singh S. *et al.* [5] demonstrated using hybrid configuration with a distributed Raman amplifier and EDFA for 160 x 10 Gb/s DWDM system at 25 GHz. Hybrid optical amplifier

proposed using two configurations and observed that when input power increases gain over the bandwidth also increases. This technique is cost effective technique for flattening the gain.

Bhaskar S. et al. [6] investigated the performance of different hybrid optical amplifiers such as RAMAN-SOA, SOA-EDFA, EDFA-RAMAN-EDFA. and analyzed channels 16, 32 and 64 channels at the speed of 10 Gbps. Author observed parameters like Q-factor, BER, eye opening and jitter at varying number of channels. Different combinations provide different results. SOA-EDFA showed good performance because it can travel maximum distance of 220, 240, 260 km at 16, 32 and 64 channels respectively. Raman-EDFA observed a good performance as it has high Q-factor and BER at 16 channels.

Rashmi et al. [14] compared different hybrid amplifiers on DWDM ring network and found EDFA-SOA is the best combination for the designed network.

This paper is categorized into different sections for different Hybrid Optical Amplifiers for DWDM transmission system. In section 2, the simulation set up for 64, 96 and 128 channels at 2.5 Gb/s speed. Section 3 gives the discussion of the results observed after the simulation. And section 4 gives the conclusion of the system performance.

Simulation setup

Figure 1 shows 128 channels are transmitted at 2.5 Gb/s speed with 0.4nm channel spacing. DWDM transmission system designed on simulation software OptSim 5.4. Input signals preamplified by a booster and these signals are transmitted over optical fiber by different transmission distances. A transmitter consists of the PRBS data source, NRZ electrical driver. CW laser source and external Mach-Zehnder modulator are consisted by transmitter section. Electrical driver converts the logical input signal into an electrical signal. The CW laser source gen-

erates the laser beam at 187-190.975THz with 0.4nm channel spacing. Optically coded signal is transmitted and measured over different distance for 100,150,200 and 250 km at 0.09ps/nm/km dispersion. The modulated signal is transformed into original signals with the help of PIN photodiode and filters. The receiver module is used to detect all signals and converts these into electrical form. Different types of optical amplifiers are also applied at the receiver side. The simulation is repeated for measuring the signal strength by using different hybrid amplifiers and BER has been evaluated.

For Single Mode Fiber (SMF) reference frequency is 1550nm and attenuation is 0.25dB/km. In this paper the various parameters are biased current that is 100mA.insertion loss is 3dB and output insertion is 3 dB. Various parameters of EDFA are length 5 kmeters, numerical aperture 0.24. Various parameters for RAMAN are Raman fibre length is 10 km, operating temperature is 300 K and pump wavelength is 1480 nm and pump power is 300 mW.

RESULTS AND DISCUSSIONS

Table 1 shows the BER and Q factor for channel 1, 32, 64 and 128 on sampling basis. It has been observed from the table that BER as high as e-14 has been achieved for channel 1 and BER of the order of e-09 has been achieved for channel 128, which is under acceptable limit.

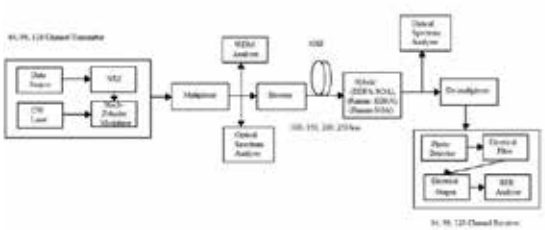


Table 1: Simulation Parameters of Designed System

S.No	Channel	BER	Q Factor
1	1	2.56E-14	15
2	32	1.28E-12	14
3	64	4.56E-10	12
4	128	2.22E-09	10

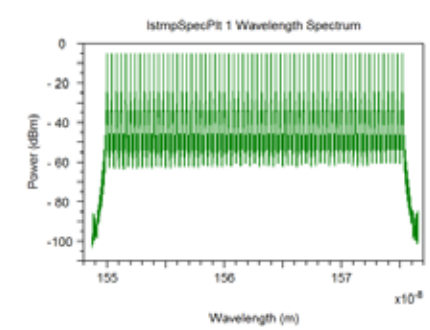


Fig. 2 shows the frequency spectrum of 128 channels multiplexed signal.

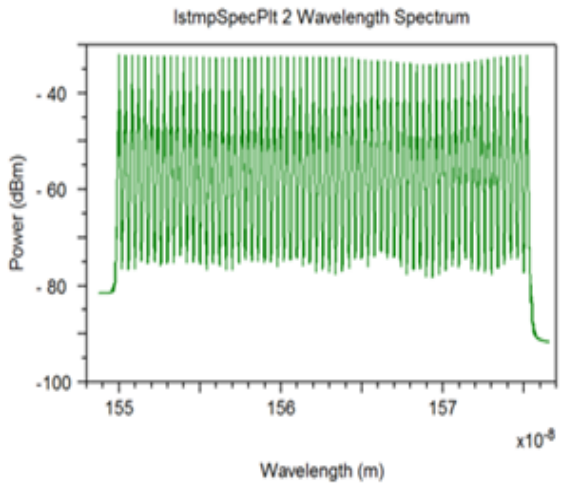
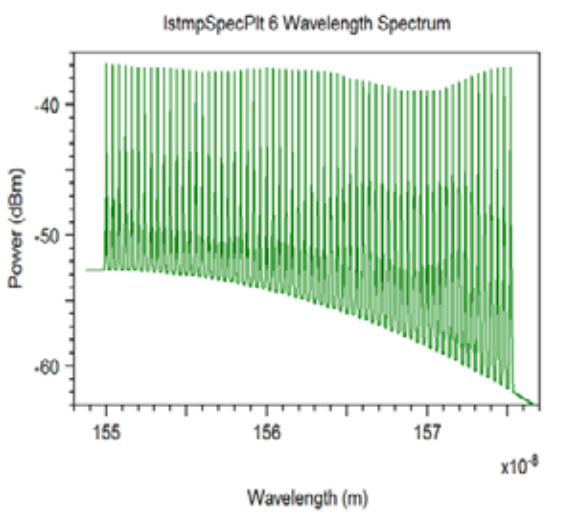


Figure 2 shows 128 channels multiplexed signal go through booster and then cross the single mode fiber. Fig.3 shows the spectrum of 128channels after crossing span length of 100 km. After crossing the span length of single mode fiber the signal enter into the hybrid amplifier. Fig. 4 shows the 128 channel spectrum at the receiver of the DWDM system received by the receiver.

Fig 3. Signal after EDFA-EDFA Amplifier after 100km



After getting amplified at hybrid amplifier spectrum move towards demultiplexer.Fig.5 shows the spectrum which will be

Fig.4 128 channels spectrum received at receiver

The performance of different hybrid amplifiers EDFA-EDFA, RAMAN-SOA, EDFA-SOA are evaluated and compared for 128 x 10 Gbps DWDM systems in term of received output power, minimum BER at different transmission distance. The distance from 100 to 250 km in steps of 50 Km. As we increase the distance, BER decreases simultaneously.

Table 2 shows the performance of designed system under varying distance and has been observed that system works better for 100km, BER as better as e-14 and Q factor of the order of 12 has been achieved using EDFA-EDFA hybrid amplifier.

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Table 2. Performance Analysis under varying length

Type of amplifier	No.of Channels	Distance	BER (Channel1)	BER(Channel128)	Min Q Factor
EDFA+EDFA	128	100	2.25x10e-14	2.22x10e-9	12
EDFA+EDFA	128	150	1.10x10e-8	1.8x10e-6	8
EDFA+EDFA	128	200	1.7x10e-5	1.4x10e-3	4
EDFA+EDFA	128	250	1.3x10e-1	1.1x10e-1	2
EDFA+SOA	128	100	1.22x10e-10	1.99x10e-6	8
EDFA+SOA	128	150	1.2x10e-5	2.4x10e-4	5
EDFA+SOA	128	200	1.19x10e-2	1.2x10e-2	4
EDFA+SOA	128	250	1.0x10e-1	1.1x10e-1	2
Raman+SOA	128	100	1.22x10e-7	1.19x10e-6	8
Raman+SOA	128	150	1.19x10e-4	1.2x10e-4	6
Raman+SOA	128	200	1.10x10e-3	1.1x10e-2	4
Raman+SOA	128	250	1.09x10e-2	1.0x10e-1	2

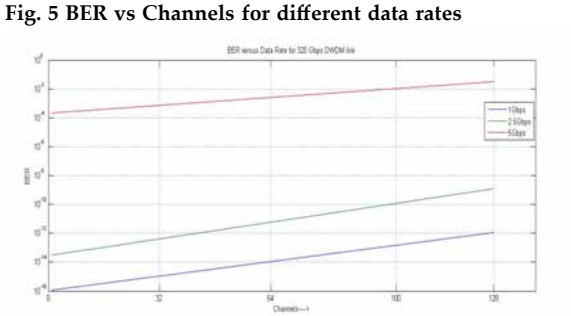
Table 3 shows the performance under varying data rate for EDFA-EDFA hybrid amplifier for 128 channels. It has been observed that designed system works better for 2.5 Gbps data rate for 100km distance, BER as good as e-14 for channel 1 and e-9 for channel 128 can be achieved using CRZ modulation format.

Type of amplifier	Data Rate(Gbps)	No.of Channels	Distance	BER(λ1)	BER(λ128)
EDFA+EDFA	1	128	100	1.15x10e-16	1.10x10e-12
	2.5			3.23X10-14	1.23X10-9
	5			2.12X10-4	3.32X10-2

Table 3. Variation in Data Rate

Figure 5 depicts the graph of the system under varying data rates. In order to observe the performance of different hybrid amplifiers,the graph shows that as we increase the data rate from 1Gbps to 5Gbps, the BER increases simultaneously. The BER increases from 10^-16 .The variation in Output power for different hybrid optical amplifier at different distance 100 km to 250 km is 14.92 dBm for EDFA-EDFA, 12.90 dBm for SOA-EDFA, 5.32 dBm for RAMAN-SOA. for 128 channels.

Fig. 5 BER vs Channels for different data rates



In order to observer the BER of different hybrid amplifiers for different distance from 100 km to 250 km for 128 channels is 10^-12 for EDFA-SOA, 10^-8 for RAMAN-EDFA, 10^-7 for RAMAN-SOA. for 128 channels as shown in Fig.9. The variation in output power for different Hybrid optical amplifier at distance from 100 km to 250 km is 15.55 dBm for EDFA-SOA,11.80 dBm for RAMAN-EDFA and 4.44 for RAMAN-SOA as shown in Fig.10.

CONCLUSION

The performance of different hybrid amplifiers has been compared at different distances under varying data rates. The results shows that the combination of EDFA-EDFA shows good performance and it increase the maximum reachable distance. EDFA-EDFA showed good performance at all the channels as it can go up to maximum distance. The proposed configuration consists of 64, 96 and 128 channels. Hybrid EDFA-EDFA are enabling and promising for future as it can travel the maximum distance.

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