

# Performance evaluation of DWDM system using Semiconductor optical amplifier in the presence of fiber non-linearities

Aruna Rani<sup>1</sup>, Mr. Sanjeev Dewra<sup>2</sup>

Shaheed Bhagat Singh State Technical Campus, Ferozepur, Punjab, India

**Abstract:** In this paper 16 channels DWDM system at 10Gbps has been investigated with Semiconductor optical amplifier at 0.8 nm channel spacing and the performance has been calculated on the basis of bit error rate, quality factor and optical output power. It is observed that the signal can be transmitted with acceptable BER and Q-factor using Semiconductor optical amplifier at low signal input power of -20dBm upto 243km transmission distance in the presence of fiber non-linearities.

**Keywords:** Semiconductor Optical Amplifier (SOA), Dense Wavelength Division Multiplexing (DWDM), Bit error rate (BER), Stimulated emission

## 1. Introduction

Dense Wavelength-division-multiplexing (DWDM), a key technology, comes into picture to enable the very high-capacity photonic networks required by our communication thirsty society and is well known for its dramatic increase in transmission capacity and flexibility in optical networking [1]. The advancement in the optical communications has been promoted in part by development of efficient and powerful optical amplifiers which eliminate the need for costly conversions from optical to electrical signal and vice versa [2]. SOA is considered as the key component in the next generation of optical networks [3]. SOAs are excellent devices to have large optical gain, small size [4], low power consumption, ease of integration with other devices and low cost [5]. SOAs have been widely used to perform a variety of all optical functions such as wavelength conversion [6], signal regeneration and pulse reshaping [7]. The use of SOA as multifunctional device permits to perform all optical functions based on its nonlinearities [8]. To meet the requirement SOAs are promising because of their compactness and simple current pumping. The gain in a SOA saturates as the optical power level increases [9]. Kim et al. [10] successfully transmitted 10Gb/s optical signals over 80km through SSMF (Standard single mode fiber) with the transmitter using SOAs as booster amplifiers. They have further found the appropriate parameters of input signals for SOAs, such as extinction ratio, rising/falling time, and chirp parameter to maximize output dynamic range and available maximum output power. Singh et al. [11] investigated placement of semiconductor optical amplifier for 10Gbps non-return to zero format in single mode and dispersion-compensated fiber link. In this work, different compensation methods (pre, post and symmetrical) for different positions of the SOA in fiber link have been described. The effect of increase in signal input power for these three power compensation methods are compared in terms of eye diagram, bit error rate, eye closure penalty and output received power. It was found that the post power compensation method is superior to symmetrical and pre power compensation methods when SOA is used.

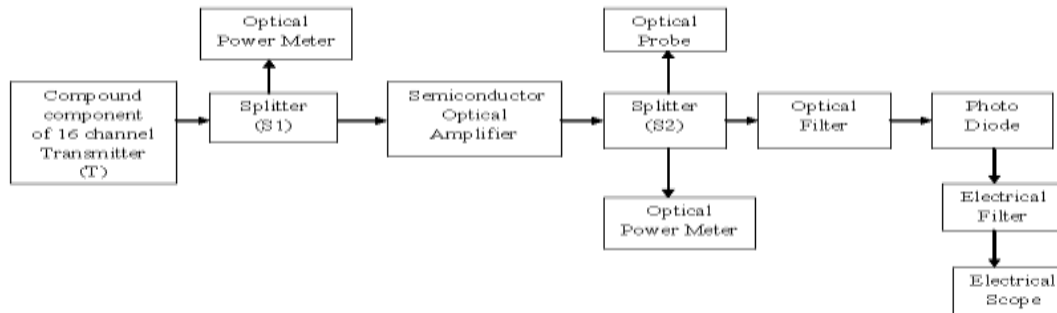
The investigation presented in [11] for Semiconductor optical amplifier was restricted to number of channels i.e. only one channel. The single mode and dispersion-compensated fiber link were used with different power compensation methods. In this paper, the previous work has been extended in the context of 16 channels using DS-Normal fiber with Semiconductor optical amplifier without dispersion compensation methods.

The paper is organized into four sections. Section 1 presents the introduction. In Section 2, the system setup and description of its components is described. In Section 3, simulation results have been reported and Section 4 includes the conclusion about the feasibility of the system.

## 2. System Setup

An optical transmission link consists of three stages i.e. transmitter, optical amplifier and receiver as shown in Fig.1. Sixteen channels with different center frequencies i.e. 192.35 THz-193.85 THz are fed to the each input ports. Each transmitter section consists of the data source, electrical driver and laser source and amplitude modulator. Data source generates a pseudorandom binary sequence of data stream. Electrical driver here generates data format of the type NRZ

rectangular with a signal dynamics i.e. low level  $-2.5$  and high level  $+2.5$ . Laser block shows simplified continuous wave Lorentzian (CW) laser. The output from the driver and laser source is passed to the optical amplitude modulator. The pulses are modulated using MZ modulator at 10Gbps bit rate. The amplitude modulator is a sine square Mach-Zehnder modulator with an excess loss of 3 dB. The output of the modulator is fed to an optical link by using the Semiconductor optical amplifier through an optical splitter. The parameters of SOA used in the simulation are as shown in Table.1 [12].



**Fig.1 System model**

For DS normal fiber the reference frequency is 192.35 THz and attenuation is 0.2dB/km. The optical splitter (S1) is used for the measurement of the optical input power for the transmission link. Optical Power meter and Optical probe with splitter (S2) are used for measuring the optical signal power and spectrum at different levels.

**Table1. Typical SOA Parameters**

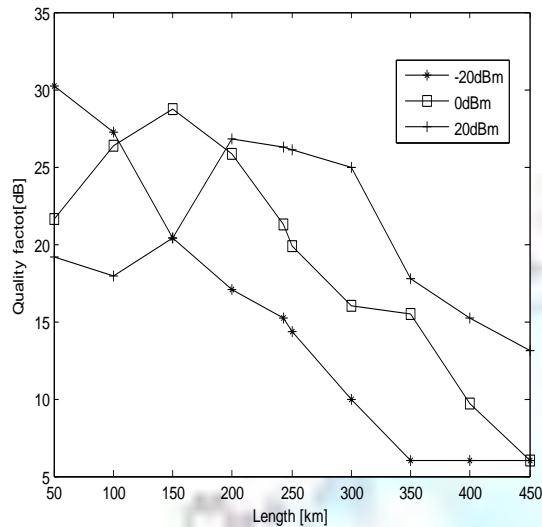
| Parameters                   | Symbol                | Value                               |
|------------------------------|-----------------------|-------------------------------------|
| Bias current                 | I                     | 100mA                               |
| Amplifier Length             | L                     | 300 $\mu\text{m}$                   |
| Active Layer width           | W                     | 1.5 $\mu\text{m}$                   |
| Active Layer thickness       | T                     | 0.2 $\mu\text{m}$                   |
| Confinement Factor           | $\Gamma$              | 0.4                                 |
| Spontaneous Carrier lifetime | T                     | 0.3 ns                              |
| Transparency Carrier density | $N_t$                 | $1.5 \times 10^{24} \text{ m}^{-3}$ |
| Material gain Constant       | A                     | $2 \times 10^{-20} \text{ m}^2$     |
| Material Loss                | $\alpha_p$            | $10.5 \text{ cm}^{-1}$              |
| Input/output insertion Loss  | $\alpha_{\text{int}}$ | 3 dB                                |
| Saturation power             | P                     | 9.1 mw                              |

Single receiver is composed of optical raised cosine filter, PIN photodiode and electrical raised cosine filter. Electrical scopes are used to observe change in performance. Optical filter component implements a raised cosine transfer function filter having band pass filter synthesis, 1 as raised cosine exponent, 0.2 raised cosine roll off, 193.15 THz center frequency, 40 GHz bandwidth. PIN photodiode is used to detect the optical signal, i.e. conversion into electrical signal. The responsivity of the PIN detector is 0.875, quantum efficiency is 0.7 A/W and zero dark current. Electrical filter at the receiver side is implemented by raised cosine filter and has bandwidth 8GHz. Electrical scope as the measurement component is used to obtain the eye diagram. From the eye diagram, the values of Q factor, BER, can be analyzed.

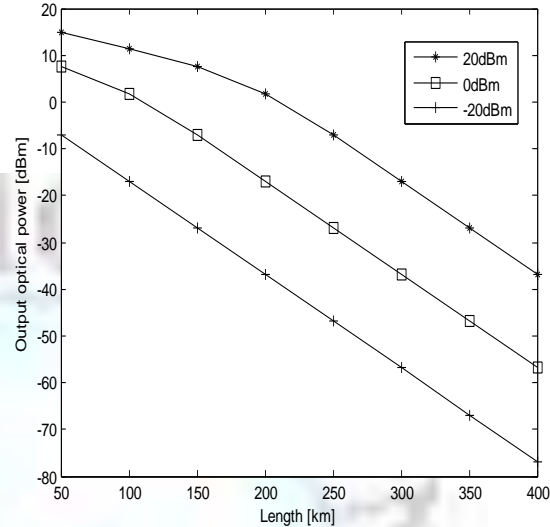
### 3. Results and discussion

To analyze the performance of the system quality factor, bit error rate and output power are examined at 192.35THz frequency (channel-1). The Q factor vs. length for different signal input power is as shown in Fig.2. It is evident that the quality of the received signal decreases with increasing the length of the fiber. The acceptable Q factor is obtained at 20dBm signal input power up to 400km transmission distance. It is observed that at -20dBm & 0dBm signal input power acceptable quality factor is achieved for 243km and 350km transmission distance respectively in the presence of fiber

nonlinearities without dispersion compensation methods. This shows good agreement with [11], where they analyzed the transmission distance of 204km using post, pre and symmetrical power compensation methods with only one channel. Here in this paper the reported total length of optical communication link is 243km without any power compensation techniques with 16 channels. This result shows improvement of 39km transmission distance over the results reported in [11]. Fig.3 reveals the plot of output power vs. length for different signal input power. For high signal input power of 20dBm sufficient output power of 1.66dBm is achieved at 200km and at low signal input power of -20dBm it becomes -45.5dBm. It is observed that the optical signal output power decreases due to the fiber non-linearities and fiber attenuation.

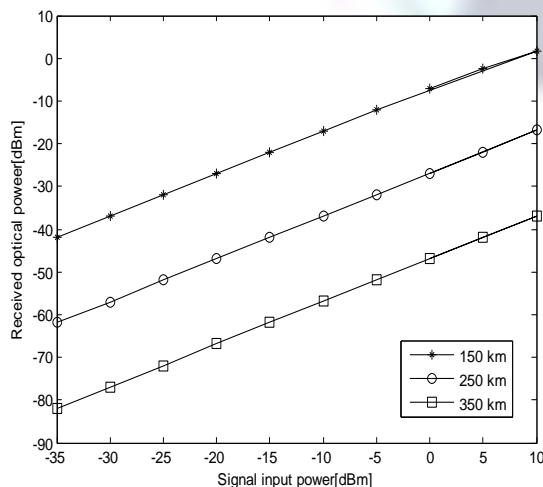


**Fig.2. Q factor vs. length for different signal input power at frequency 192.35THz**

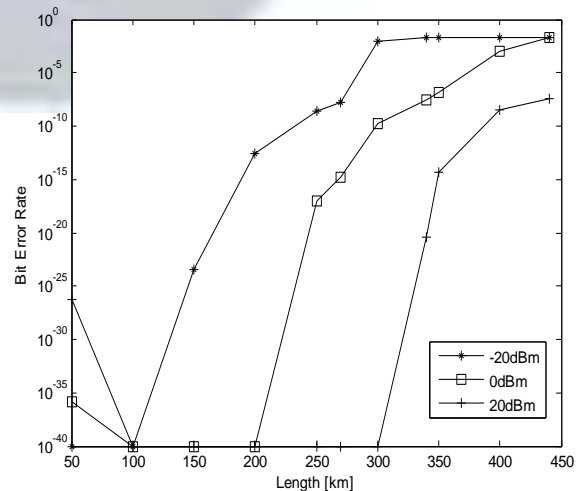


**Fig.3 Output optical power vs. length for different signal input power at frequency 192.35 THz**

Fig.4 depicts the received signal power for an applied signal input power. For 150km transmission distance 7.61dBm output power with the large signal input power of 20dBm is obtained. For large transmission distance up to 350km, the effect of ASE noise power on the SOA degraded the output signal power. In Fig.5 bit error rate vs. length for different signal input power is plotted. It is observed that minimum BER is obtained which is  $10^{-40}$  at 100km transmission distance. At -20dBm signal input power, acceptable bit error rate ( $10^{-9}$ ) is achieved up to 250km. It is also observed that the bit error rate decreases with an increase in the signal input power at the optical fiber link. At 0dBm & 20dBm signal input power, bit error rate increases up to 338km & 440km respectively which is not acceptable for high data rate optical transmission.



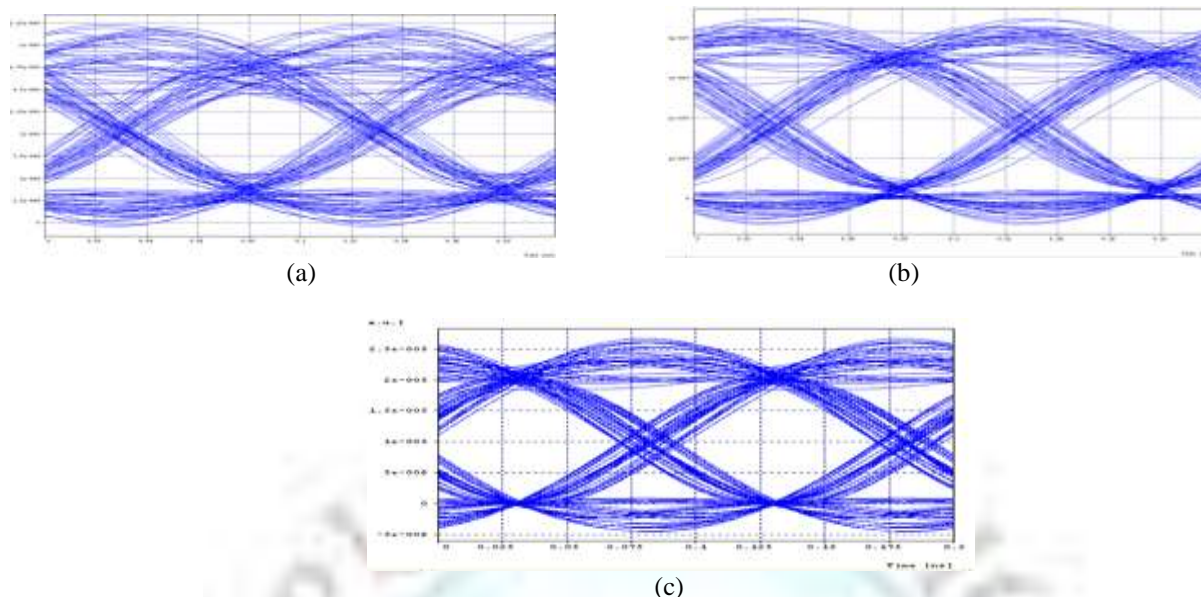
**Fig.4 Received optical signal vs. signal input power**



**Fig.5 Bit error rate vs. length for different signal input power**

**for different transmission distance at frequency  
192.35THz**

**input power at frequency 192.35THz**



**Fig. 6 Eye diagrams for various values of signal input power: (a) -20dBm (b) 0dBm (c) +20dBm.**

The clear eye diagrams for different input power are shown in Fig.6. At low signal input power of -20dBm acceptable bit error rate and quality factor for a transmission distance is achieved up to 243km in the presence of fiber nonlinearities. If the fiber nonlinearities are not considered acceptable quality factor and BER is provided by the SOA is upto 250km, this result shows improvement over the results reported in [11]. At 0dBm signal input power 348km transmission distance is covered. At high signal input power of 20dBm total length of the optical communication link is 400km. The applied signal higher than the saturation power of the SOA will move the SOA towards saturation; hence, the output signal is degraded. This degraded output signal propagates through the optical fiber links. The optical link degrades the power of the signal further, but the quality is almost the same as of the SOA.

#### **4. Conclusion**

The 16 channel DWDM system at 10Gbps has been investigated with the placement of the Semiconductor optical amplifier and the performance has been evaluated on the basis of output power level, eye patterns, BER measurement, and Q factor in the presence of fiber nonlinearities. From this work it is concluded that in the presence of fiber nonlinearities, SOA provides better results up to 243km transmission distance at -20dBm signal input power with acceptable quality factor (15 dB) and bit error rate ( $10^{-9}$ ) without any dispersion compensation methods.

#### **References**

- [1]. Sanjeev Dewra, R.S. Kaler "performance evaluations of optical add drop multiplexers with Mach-Zehnder interferometer Techniques for dense wavelength division multiplexed System," Journal of Optical Technology, Vol.80, Issue 9, pp.526- 531, Nov 2013.
- [2]. Simranjit Singh, R.S. Kaler "Comparison of pre-, post- and symmetrical compensation for 96 channel DWDM system Using PDCF and PSMF" Optik 124, pp.1808– 1813, 2013.
- [3]. Abd El Aziz, W. P. Ng, Z. Ghassemlooy, Moustafa H. Aly, R. Ngah and M. F. Chiang "Characterization of the Semiconductor Optical Amplifier for Amplification and Photonic Switching Employing the Segmentation Model" ICTON-MW'08, IEEE, 2008.
- [4]. Minoru Yamada, Nobuhito Takeuchi, Kyohei Sakumoto and Yuji Kuwamura, "Variation of Relative Intensity Noise with Optical Power in InGaAsP Semiconductor Optical Amplifier" IEEE Photonics Technology Letters, vol. 24 no. 22, November 15, 2012.
- [5]. Aruna Rani, Mr. Sanjeev Dewra "Semiconductor optical amplifiers in optical Communication system-Review" International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 10, October 2013.



- [6]. Prashant P. Baveja, Drew N. Maywar, Aaron M. Kaplan, and Govind P. Agrawal, "Self-Phase Modulation in Semiconductor Optical Amplifiers: Impact of Amplified Spontaneous Emission" IEEE Journal of Quantum Electronics, Vol. 46, No. 9, pp. 1396-1402, September 2010.
- [7]. G. Contestabile, M. Presi R. Proiletti, and E. Ciaramella, "Optical reshaping of 40-Gb/s NRZ and RZ signals without Wavelength conversion," IEEE Photonics Technology Letters, vol. 20, no. 15, pp. 1133-1135, July 2008 .
- [8]. Christian Bohémond, Thierry Ramp one, and Ammar Sharaiha, "Performances of Photonic Microwave Mixer Based on Cross-Gain Modulation in a Semiconductor Optical Amplifier" Journal of Light wave Technology, vol. 29, no.16, pp. 2402-2409, August 15, 2011.
- [9]. Bobby Barua, "Evaluate the Performance of Optical Time Division Demultiplexing with the Gain Saturation effect of Semiconductor Optical Amplifier" IACSIT International Journal of Engineering and Technology, Vol. 3, No. 5, October 2011.
- [10]. Y. Kim, H. Jang, Y. Kim, J. Lee, D. Jang, J. Jeong "Transmission performance of 10-Gb/s 1550-nm transmitters using Semiconductor optical amplifiers as booster amplifiers" IEE Journal of Light wave Technology, Vol. 21, No.2, pp.476-481, 2003.
- [11]. Surinder Singh, R.S. Kaler "Placement of optimized semiconductor optical amplifier in Fiber optical communication systems" Optik 119, pp.296-302, 2008.
- [12]. Sanjeev Dewra, R.S. Kaler, "Performance analysis of optical network based on optical Add drop multiplexers with different MZI techniques" Optic 124, pp. 347- 351, 2013.

