

# Analysis of Cross Polarization Modulation in Semiconductor Optical Amplifier for Wavelength Conversion

Keerthika.S.S <sup>(1)</sup>, Sivanantharaja.A <sup>(2)</sup>, Selvendran.S <sup>(3)</sup> and Mahendran.C <sup>(4)</sup>

<sup>(1)</sup> PG Student, <sup>(2)</sup><sup>(4)</sup> Associate Professor, <sup>(3)</sup> Research Scholar  
Alagappa Chettiar College of Engineering and Technology  
Karaikudi, Tamilnadu, India.

**Abstract:** This paper presents an inherent polarization technique using SOA to achieve cross polarization modulation for wavelength conversion to overcome the problems such as packet contention, wavelength contention, connectivity and scalability of the WDM networks, which improve the performance of the networks. The wavelength conversion takes place due to the Nonlinear Polarization Rotation, which is the intensity dependent rotation in the state of polarization of a signal injected into the SOA known as Cross polarization modulation. The appreciable quality factor and minimum bit error rate are observed for all wavelength converted signals at the bit rate of 10Gb/s.

**Keywords-** Semiconductor Optical Amplifier (SOA), Wavelength Conversion, Cross Polarization Modulation (XPoLM), Nonlinear Polarization Rotation (NPR).

## I. INTRODUCTION

All optical wavelength converters are expected to become key components in future broadband networks. Their most important use will be to avoid the wavelength blocking in optical cross connects in wavelength division multiplexing (WDM) networks. The growth of the existing and new broadband services is continuing to increase the traffic flow in the telecommunication networks. As a next step, future networks are expected to utilize WDM techniques for optical functionalities capable of handling multi-gigabit signals [1]. There are some problems remain unsolved including packet contention and wavelength contentions [2].

Semiconductor optical amplifiers are key enablers for optical networks. They can have a significant impact on the architecture and shape the economics of future optical networks [3].

Many studies have paid more attention on SOAs performance for implementing wavelength conversion using cross-gain modulation [4], cross-phase modulation [5] and four-wave mixing [6]. Each configuration has its advantages and disadvantages. The XGM method is the simplest to realize. However, it has two obvious shortcomings i.e., the converted signal has the relatively large chirp and the extinction ratio (ER) can be significantly be degraded [7]. The four wave mixing is simple to implement. But it has low conversion efficiency.

In this paper, we explained wavelength conversion for 10Gbps NRZ signal using cross polarization modulation effects in a semiconductor optical amplifier. With minimum input signal power, we achieved appreciable

wavelength spacing for both up and down converted signals. We obtained a good quality factor and low bit error rate for all wavelength converted signals.

This paper is organized as follows. In Section II, the cross polarization modulation is described. The experimental setup is given in Section III and its performances are discussed in Section IV. Lastly, in Section V, conclusions are drawn.

## II. CROSS POLARIZATION MODULATION

Nonlinear polarization rotation in the SOA is caused by several effects. One of the principle causes is due to waveguide asymmetry in the device. Another significant effect is the birefringence introduced in the structure. When two signals are injected simultaneously in the SOA, there is an induction of different phase and gain compression on the TE and TM components. Consequently, the polarization state for each signal is changed, and thus, a polarization rotation is created [8]. To analyze the polarization rotation in an SOA structure, there are two well-known parameters, which are the azimuth  $\psi$  and the ellipticity  $\chi$  as shown in Figure 1. They are expressed as function of Stokes parameters in equations (1) and (2):

$$\psi = \frac{1}{2} \arctan \left( \frac{S_2}{S_1} \right) \quad (1)$$

$$\chi = \frac{1}{2} \arcsin \left( \frac{S_3}{\sqrt{S_1^2 + S_2^2 + S_3^2}} \right) \quad (2)$$

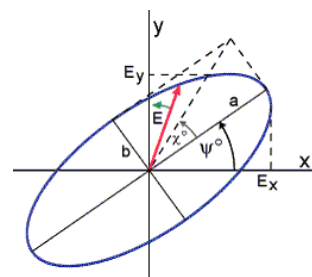


Figure 1. Descriptive diagram of the polarization angle (azimuth) noted  $\psi$  and the ellipticity noted  $\chi$ .

Owing to the asymmetry of the SOA structure [9], the distribution of the carriers' density along this structure, in saturation regime will be strongly disrupted in presence of a pump signal. This perturbation will take place with a

different manner according to the axes of the SOA structure [10], on account of two essential factors: the difference of gain and the difference between TE/TM confinement factors that will induce a different saturation of the SOA axes.

While injecting a signal at the input along TE axis or TM axis of the SOA with a linear polarization, then the polarization at the output is going to undergo a change that is bound to the difference of the TE gain and TM gain and due to the birefringence. This leads to a phase difference between the TE and TM modes of the probe signal, causing the polarization angle of the probe light to be rotated because of a different refractive index [11].

### III. EXPERIMENTAL SETUP OF A WAVELENGTH CONVERTER BASED ON XPOLM USING SOA

The experimental setup of a wavelength converter based on XPolM using SOA is shown in figure 2. It consists of a transmitter section, SOA and receiver sections. The transmitter section includes CW laser and modulator. The input signal of wavelength 1550 nm with the bit rate of 10Gb/s is produced by encoding CW signal with NRZ data into the amplitude Mach-Zehnder modulator with the minimum signal power of 2 dBm, which is driven by  $2^{31}$ -1 pseudorandom bit sequence. The probe signal after modulation is applied to the input port of the circulator. Circulator is used to maintain the polarization of the input signal. This polarization controlled information optical signal is injected into the SOA. The pump signal is generated using a CW laser at a wavelength of 1550.5 nm which is also injected into the SOA device. The states of polarization, of both the pump and probe signals, are controlled using polarization controllers. Two optical signals are simultaneously injected into the SOA which is biased at the minimum bias current for XPolM effect.

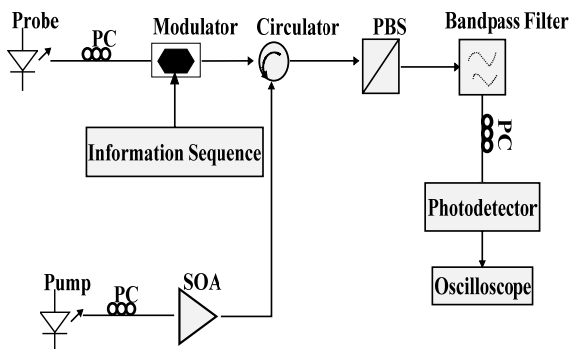


Figure 2. Experimental setup of a wavelength converter based on XPolM using SOA

The output from the SOA structure is split by a polarization beam splitter (PBS) which is used to filter optical signals according to the polarization state. These two beams recombine by another PBS and leaves at the output port of a circulator. The receiver section consists of a filter and photodetector. A Band pass filter is placed after the PBS which blocked the pump pulse and allowed only the NRZ data to pass through. Finally the converted signal is detected at the receiver for measuring the quality factor and bit error rate of the converted signal.

### IV. PERFORMANCES OF THE WAVELENGTH CONVERSION USING XPOLM

In order to enhance cross polarization modulation, certain parameters involved in the process are to be defined properly in the particular range. The input wavelength is taken as 1550 nm and converted wavelength is tunable with the wavelength spacing of 1nm for up and down converted signals. The plots have been drawn for input signal powers versus quality factor.

To achieve a wavelength conversion with extended wavelength spacing and also to have a strong reduction of the carriers' density in the SOA active region, the pump power of 20 dBm is chosen. Higher the value of confinement factor the shorter is the gain recovery time. So the confinement factor of SOA is 0.35. Increasing the SOA bias current, increases the pumping rate which in turn increase the gain because of the electrons at excited state increases. So the bias current of 150mA is opted. The amplifier length of 500 m is chosen without any power penalty.

By taking these parameters, the cross polarization modulation based wavelength converter can be realized and its performance is measured in terms of quality factor and bit error rate of the converted wavelength signal. Using the above mentioned parameters in the experimental set up of the XPolM wavelength converter, the clear eye diagram is observed in figure 3 for wavelength converted signal at 1550.5 nm signal by using SOA with quality factor of more than 19.

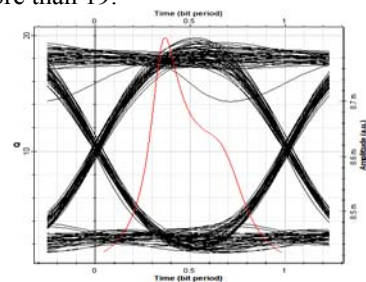


Figure 3. Eye diagram of wavelength converted signal using optimized SOA

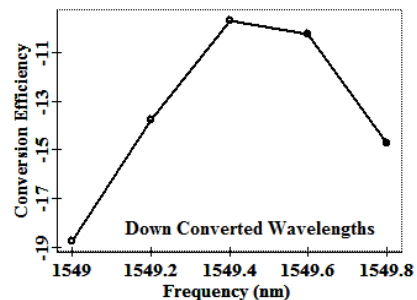
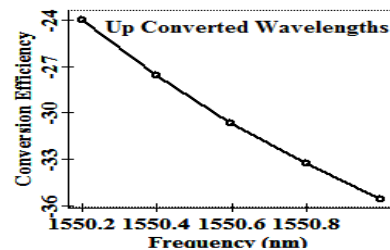


Figure 4. Conversion Efficiency with the variations of frequencies for both up and down wavelength conversions

Figure 4 shows the conversion efficiency with the variation of frequencies for both up and down conversions for the range up to 1 nm frequency spacing. The conversion efficiency increases as the wavelength separation increases. It is seen that the conversion efficiency for up and down conversion is almost nearly same. As the wavelength is moved to longer wavelengths, further from the gain peak, the depletion of the gain is reduced which increases the level of the converted signal because of the higher impact of the NPR effects.

The Table I and Table II show the BER values for both the up and down wavelength converted signals at a bit-rate of 10 Gbit/s. The converted signal achieves good BER performance. Moreover, it can be seen that no BER floor is observed up to BERs of  $10^{-91}$ , which indicates excellent performance of the wavelength converter.

Table I. BER values for up wavelength converted signals

Frequency	BER
1550.2	5.39e-91
1550.4	1e-99
1550.6	6.19e-108
1550.8	4.34e-109
1551	2.06e-116

Table II. BER values for down wavelength converted signals

Frequency	BER
1549.8	3.85e-84
1549.6	2.27e-82
1549.4	2.99e-98
1549.2	1.37e-99
1549	1.07e-102

## V. CONCLUSION

We concluded that we obtained a good wavelength converter based on nonlinear polarization rotation inside an SOA. The pump power injected into SOA is 20dB for attaining appreciable wavelength spacing of 1nm for both up and down wavelength converted signals. By using a highly nonlinear SOA medium with minimum input signal power of 2 dBm, we obtain a maximum cross polarization modulation with a quality factor of more than 19. This wavelength converter at 10 Gbit/s has very low minimum BER value.

## REFERENCES

- [1] Jennifer M. Yates and Michael P. Rumsewicz., "Wavelength Converters in Dynamically Reconfigurable WDM Networks," IEEE Communications Surveys, Second Quarter 1999.
- [2] J. Leuthold, C.H. Joyner, B. Mikkelsen, G. Raybon, J.L. Pleumeekers, B.I. Miller, K. Dreyer and C.A. Burrus, "100Gbit/s all-optical wavelength conversion with integrated SOA delayed-interference configuration," Electronics Letters, vol. 36, June, 2000.
- [3] Gurmeet Kaura, M.L.Singh "Effect of four-wave mixing in WDM optical fiber systems" Optik - International Journal for Light and Electron Optics, volume 120(2009), pages268-273
- [4] Wei CC, Huang MF, Chen J., "Enhancing the frequency response of cross-polarization" vol. 17, pp. 1683-85, 2005.
- [5] Matsumoto A, Nishimura K, Utaka K, Usami M., "Operational design on high-speed Semiconductor optical amplifier with assist light for application to wavelength converters using cross-phase modulation," IEEE J Quantum Electron, vol. 42, pp.313-23, 2006.
- [6] Contestabile G, Presi M, Ciaramella E., "Multiple wavelength conversion for WDM Multicasting by FWM in an SOA," IEEE Photon Technol. Lett., vol.16, pp. 1775-77, 2004.
- [7] R. Sabella, E. Ianone, and E. Pagano, "All optical wavelength converters based on semiconductor optical amplifiers," IEEE J. Sel. Areas Commun., vol. 14, no. 5, pp. 968-978, Jun. 1996.
- [8] Y. Liu, M. T. Hill, E. Tangdiongga et al., "Wavelength conversion using nonlinear polarization rotation in a single semiconductor optical amplifier," IEEE Photonics Technology Letters, vol. 15, no. 1, pp. 90-92, 2003.
- [9] H.J.S.Dorren, D.Lenstra, Y.Liu, M.T.Hill, G.-D.Khoe, "Nonlinear polarization rotation in semiconductor optical amplifiers: theory and application to all-optical flip-flop memories", IEEE Journal of Quantum Electronics, vol. 39, pp. 141-148, 2003.
- [10] H. Soto, D. Erasme and G. Guekos, "All-optical switch demonstration using a semiconductor optical amplifier", Lasers and Electro-optics, CLEO, Pacific Rim'99, pp.888-889, 1999.
- [11] M. F. C. Stephens, M. Asghari, R. V. Penty, and I. H. White, "Demonstration of ultrafast all-optical wavelength conversion utilizing birefringence in semiconductor optical amplifiers," IEEE Photon. Technol. Lett., vol. 9, pp. 449-451, Apr. 1997.