Simulation and Performance Analysis of Optical Wavelength Converters based on Cross Gain Modulation (XGM) in SOA

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Abstract— In Fiber optic communication when signals are transmitted over fibers, there exist various kinds of non-linear effects. These non-linearities are serious issues in optical system, but on the other hand it can be useful for many applications. Wavelength converters are one of the applications of these non-linearities. It can be realized by fiber non-linearities or Semiconductor Optical Amplifier (SOA) non-linearities. The analysis of the Cross Gain Modulation (XGM) based Wavelength Converters done at10Gb/s in terms of SOA current, converted signal power and quality factor. The simulations are done using a commercial optical system simulator   named   OptiSystem 12.0 by Optiwave.

Keywords — Semiconductor optical amplifier, Cross gain modulation, OptiSystem 12.0.

INTRODUCTION

Optical wavelength conversion is anticipated to be an essential function for the emerging bandwidth-intensive applications (video conferencing, video-on-demand services etc.) of high-speed wavelength division multiplexing (WDM) optical networks by enabling rapid resolution of output-port contention and wavelength reuse. The field of nonlinear optics has proven to be an inexhaustible source of this optical technique. This wavelength converter can be realized by using fiber nonlinearities or nonlinearities in semiconductor devices. Nonlinearity effects arose as optical fiber data rates, transmission lengths, number of wavelengths, and optical power levels increases. The only worries that troubled optical fiber in the early day were fiber attenuation and, sometimes, fiber dispersion, however, these issues are easily dealt with using a variety of dispersion avoidance and cancellation techniques. Fiber nonlinearities previously appeared in specialized applications such as undersea installations. However, the new nonlinearities that need special attention when designing state-of-the-art fiber optic systems include stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), four wave mixing (FWM), self-phase modulation (SPM), cross-phase modulation (XPM), and intermodulation.

WAVELENGTH CONVERTERS

Wavelength converter changes the input wavelength to a new wavelength without modifying the data contents of the signal. Their most important use will be for avoidance of wavelength blocking in optical cross connects in wavelength division multiplexed (WDM) networks. Thereby the converters increase the flexibility and the capacity of the network for a fixed set of wavelengths. The converters features are [2], [11]:

- Bit-rate transparency (up to at least "10Gb/s").

- No extinction ratio degradation.

- High signal-to-noise ratio at the output (to ensure cascadability).

- Moderate input power levels (~ "0 dBm").

- Large wavelength span for both input and output signals.

- Possibility for same input and output wavelengths (no conversion).

- Low chirp.

- Fast setup time of output wavelength.

- Insensitivity to input signal polarization.

- Simple implementation.

These wavelength converters can be realized by using fibre nonlinearities or nonlinearities in semiconductor devices. Out of the different wavelength conversion schemes, the most straight forward way is the opto-electronic conversion using either a direct

detection or a heterodyne receiver and a transmitter. However, this method does not provide efficient conversion of wavelength due to energy conversion from optical to electrical and vice-versa. As a consequence, all-optical wavelength conversion is very much attractive due to higher efficiency and fast response. Several methods, such as a self-phase modulation (SPM), a cross-gain modulation (XGM), cross phase modulation(XPM) and four-wave mixing (FWM) based on nonlinear media, such as optical fiber and semiconductor optical amplifier (SOA)can be used to realize all optical wavelength conversion.

WAVELENGTH CONVERTERS BASED ON CROSS-GAIN MODULATION (XGM) IN SOA

A simple technique for the realization of wavelength conversion is the use of cross gain modulation in semiconductor optical amplifiers. The XGM effect consists on the variation of the SOA gain in function of the input power. The increase of the power of the input signal causes a depletion of the carrier density, and therefore the amplification gain is reduced. Gain saturation can be simply used for XGM by transmitting two different optical signals together through the semiconductor optical amplifier [1]. The Figure 2.5 shows the Wavelength conversion through XGM in SOA.
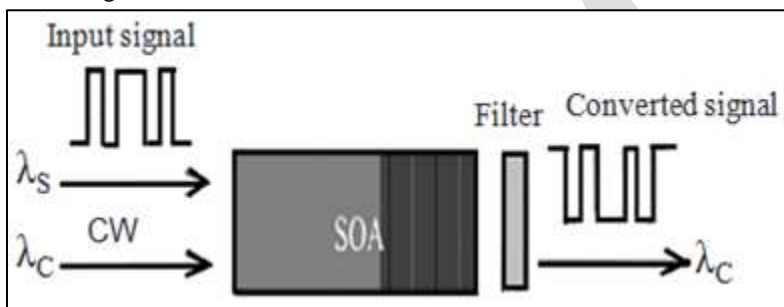

Fig.1Wavelength Converter based on XGM in SOA

Two input data signals are coupled to the SOA: a low power continuous wave signal and a pulsed signal, both at different wavelengths. If an optical pulse is present on the pulsed signal the gain of the SOA decreases, and therefore the continuous signal experiences low amplification. If no light is present on the pulsed signal, the gain of the SOA increases, and consequently the continuous wave signal experiences high amplification. The first signal is the information signal on λ_s wavelength. The other is a continuous wave on λ_c wavelength. In this case the intensity modulation of the first signal will change the gain value of the SOA according to the gain saturation, so that the device will function as an external modulator for the second signal. Here the converted output is the inverted input. The attractions of XGM wavelength conversion devices lie in their simplicity, high conversion efficiency, polarization independence, and their insensitivity to the wavelength of the input data. One disadvantage of devices using XGM for wavelength conversion is extinction ratio degradation. This can be a serious limitation in cascading such devices in an optical network. Another important drawback of XGM wavelength converters is the wavelength chirp induced on the target waveform. This wavelength chirp can severely limit the transmission distance [7].

SIMULATION SETUP

The XGM wavelength converter is simulated using Optisystem 12.0 by Optiwave. The simulation is done at a data rate of 10Gbps. Here pump signal at wavelength 1550nm with 10dBm power and probe signal of 5dBm power at 1540nm are applied to the WDM mux and the multiplexed signal applied to the SOA. From the SOA ouput, the converted signal can be filtered out by using an optical filter, here bessel filter is used [1]. The converted signal power is also analysed here. This simulation uses three visualizers namely optical power meter, optical spectrum analyser and BER analyser. Optical spectrum analysers provide the facility to analyse the optical spectrum. Optical power meters gives the power received in both dBm and Watts. Eye diagram analyzer automatically calculates the Q factor and display eye diagram. Also inorder to find the effect of SOA current, the current is varied from 200mA to 500mA. The corresponding converted signal power and Q factor is noted.
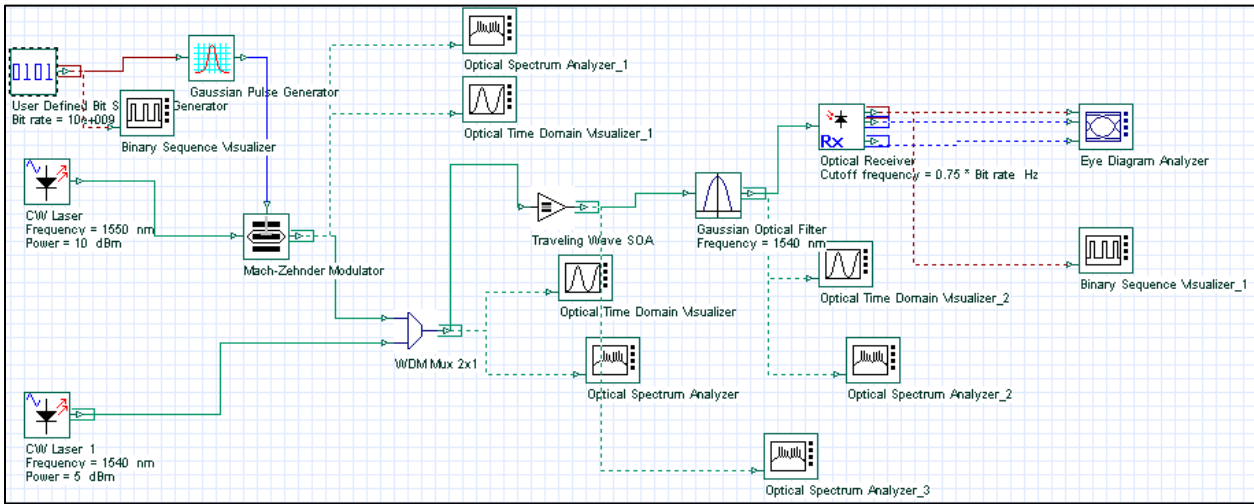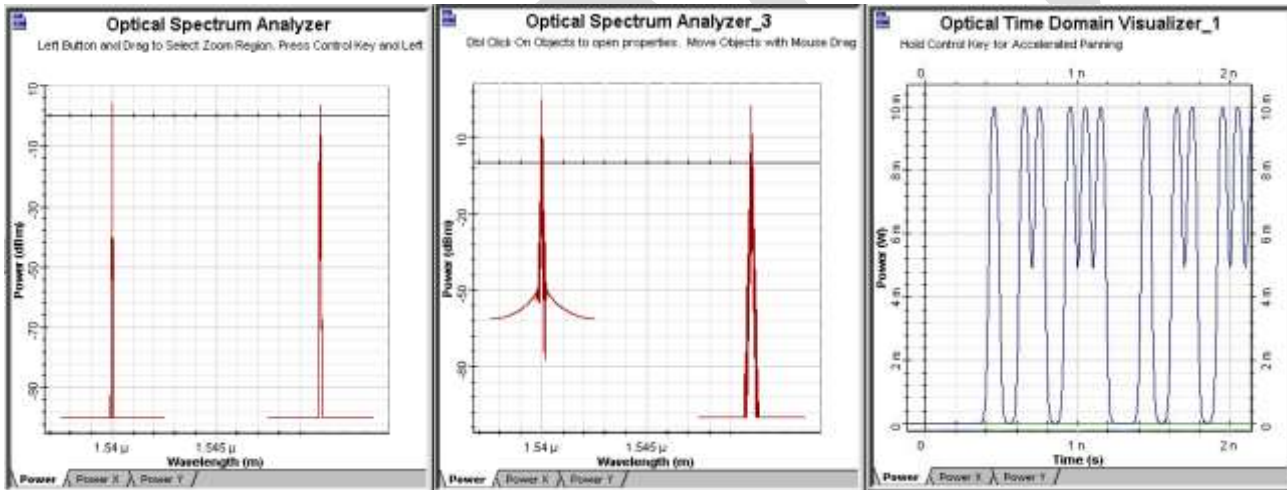
Fig.2Simulation layout of XGM based Wavelength converter

RESULTS AND DISCUSSIONS

| (a) | (b) | (c) |

Fig.3 (a) Multiplexed signal (b) SOA output (c) Signal at 1550nm, pump signal

In the above figure, multiplexed output of pump signal (1550nm) and probe signal (1540nm) is shown in fig.3 (a).This multiplexed signal is applied into the SOA. Fig.3 (b) shows the SOA output. From that it is clear that the input signals are get amplified. The fig3 (c) shows the OTDM output of pump signal at 1550nm. The pump signal has a power of 10dBm. From the SOA, the converted signal which is the 1540nm signal can be filtered out by using gaussian optical filter. A binary sequence visualizer is used at the output inorder to view the converted signal. The Quality factor and the BER of the conversion can be find by Eye diagram analyzer. The input from the binary sequence visualizer is shown in figure.4 (a). A bit sequence of 01011 is used in the input. The converted signal is shown in the below figures.
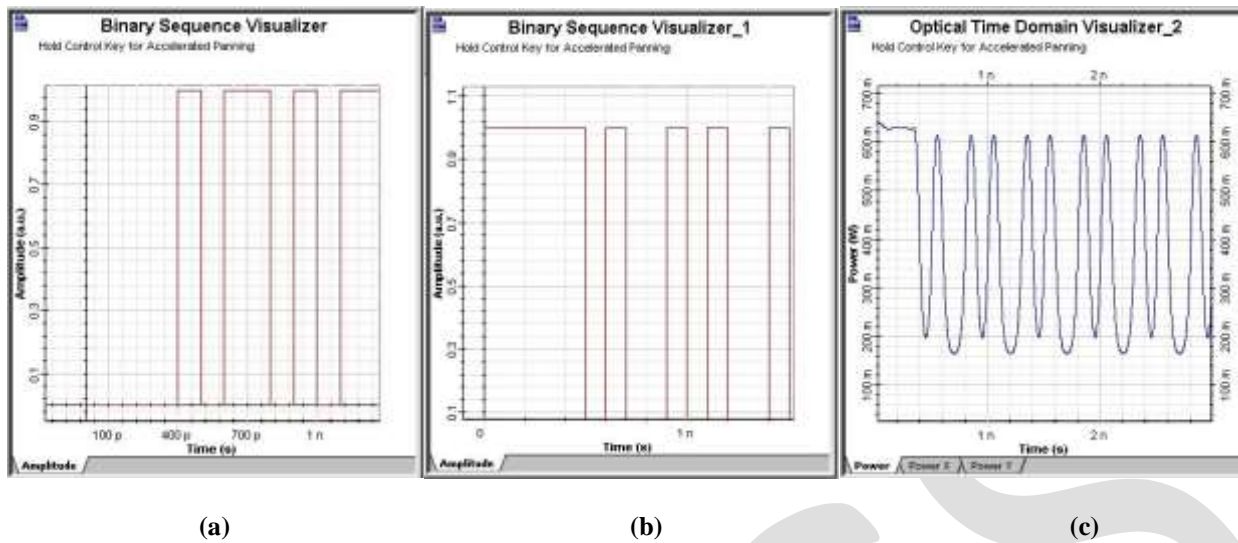
(a)   (b)   (c)

Fig.4 (a) Input data (b) Converted data at 1540nm (c) OTDM out of Converted signal at 1540nm

By comparing the figures 4 (a) and (b), it is clear that the converted signal is the inverted input. An output data of 10100 is obtained. That is, the XGM results the inverted gain modulation. Also the OTDM output shows that the power is increased to 27.78dBm.
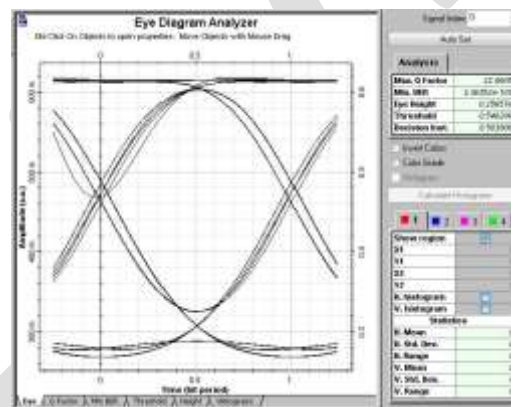

Fig.5 Eye diagram for 500mA SOA current
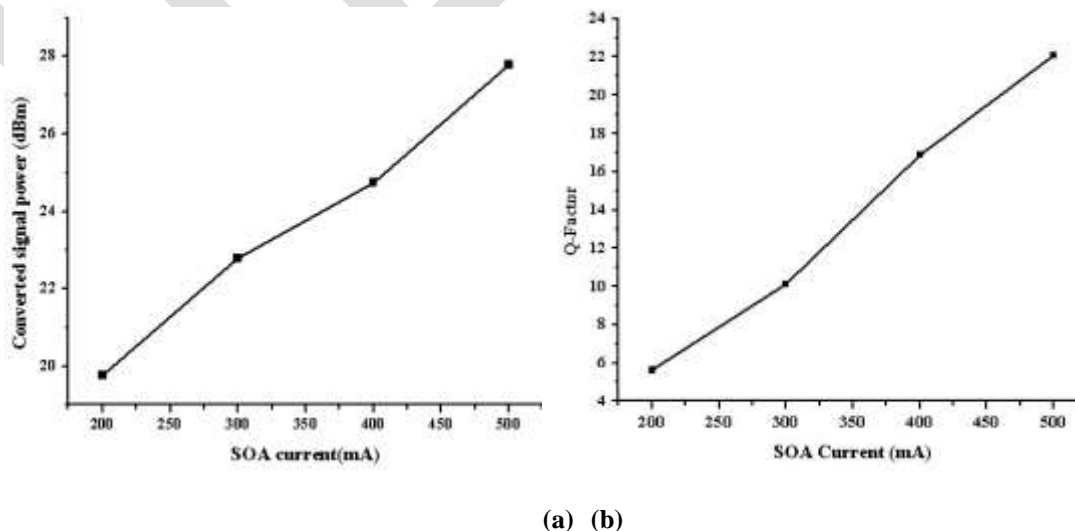

(a)   (b)

Fig.6 Relation between SOA current and (a) Converted signal power (b) Q-Factor

The eye diagram obtained at 500mA SOA current is shown in figure5.When varying the SOA current from 200mA to 500mA, the converted signal power increases also , Q-Factor increases. The maximum converted signal power and Q-Factor are obtained at 500mA SOA current. Figure 6 shows these results.

CONCLUSION

Wavelength Converter based on XGM in SOA is simulated. It can be concluded that the wavelength converted output signal is the inverted and the power is increased from 10dBm to 27.78dBm. That is, the SOA provides amplification. Also the converted signal power and Q-Factor increse with increase in SOA current.

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