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Cross Gain Modulation (XGM) Based On Wavelength Conversion Using Semiconductor Optical Amplifier and Filter

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***Abstract* - A wavelength converter made out of a semiconductor optical amplifier and an optical bandpass filter is presented in this paper. The wavelength converter has a simple configuration and allows future photonic integration.**

***Index Terms* - Semiconductor optical amplifier (SOA), optical bandpass filter, cross gain modulation.**

I. INTRODUCTION

Semiconductor optical amplifier (SOA) is a promising candidate among such nonlinear elements, its have practical advantages of high nonlinearity, low power consumption, short latency, high stability, and strong compactness. SOAs also can be used as cost effective solution to implementing optical amplification in advanced optical networking subsystems for core, metro, and ultimately access applications [2]. The use of SOAs in optical networks allows added functionality not possible with fiber amplifiers due to the non-linear interaction of photons in the semiconductor medium that give rise to potentially useful effects, including signal processing, switching and wavelength conversion [2, 3].

The cross gain modulation (XGM) is a technique that utilizes the homogeneously broadened gain of an SOA. A pump data stream modulates the gain of the SOA, and this modulation is imprinted onto a probe beam at another wavelength [4]. The cross gain modulation (XGM), based on SOAs, is simple to implement and has shown impressive operation for a high bit rate. Moreover, the XGM shows a high conversion efficiency as well as insensitivity to the polarization of input signals [5]. Comparing to techniques based on a fiber, wavelength conversion techniques based semiconductor optical amplifiers (SOA) are attractive because of their high gain, high saturation output power, wide gain bandwidth, compactness, and integratibility with other photonic devices. Optical wavelength converters play an important role in broadband optical network. They are be used primarily to avoid wavelength blocking in cross connects in WDM system [4, 5].

II. DESIGN CONSIDERATION

The probe signal can be injected at the same facet as the pump (co-propagation) or at the opposite facet (counter-propagation) as shown in Figure 1. When injected in co-propagation mode, an optical band-pass filter must be used at the output of the SOA in order to pass the converted probe signal and block the pump.

The modulation bandwidth of an XGM converter is determined by the carrier recovery time. If the data rate is high enough such that the conduction band population, and hence the gain, does not have time to recover, patterning effects begin to appear. Since carrier changes in SOA can effect all of the input signal level, it is possible for a strong signal at one wavelength to affect the gain of a weak signal at another wavelength.

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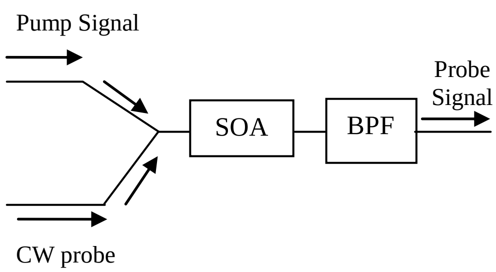

Figure 1: Principal of wavelength converter

Wavelength conversion can be induced by injecting a strong signal into an SOA. Due to cross gain modulation (XGM), the stronger signal will force the weaker signal to its modulation. As a result wavelength of a signal can be converted to that of another input signal with a single wavelength.

III. SIMULATION

A tunable laser emits a continuous wave (CW) probe beam at 4 wavelength variable input and fixed output wavelength 1550 nm to 1556 nm that is fed into an SOA. The centre wavelengths of the 40 Gbit/s RZ data signal and the CW probe beam are 1550 to 1556 and 1560 nm. The RZ data signal is combined with a continuous wave (CW) probe light and fed into the SOA via a 3 dB coupler. The SOA is pumped with 700 mA.

An SOA is used to realize error-free wavelength conversion at a bit-rate of 40 Gb/s. An optical filter is used to block the pump data signal and allow the converted probe light to pass through. As a result, the CW probe light is modulated via cross-gain modulation, causing inverted wavelength conversion. Moreover, the injected data signal also modulates the refractive index of the SOA, resulting in a chirped converted signal.

Data signal is fed into a receiver and a bit-error-rate (BER) tester. At the exit of the optical bandpass filter, both inverted and non-inverted wavelength conversion can be achieved depending on the optical bandpass filter detuning from the probe wavelength. The modulated input signal modulates the gain in the SOA due to gain saturation. A continuous wave (CW) signal at the desire output wavelength 1560nm is modulated by the gain variation so that it carriers the same information as the original input signal.

IV. RESULTS AND DISCUSSION

The input signal which is multiplexed at 10 Gb/s. Thus 40 Gb/s RZ signal is obtained from four multiplexing channels. An optical filter is used to block the pump data signal and allow the converted probe light to pass through. As a result, the CW probe light is modulated via cross-gain modulation, causing inverted wavelength conversion as depicted in Figure 3(a) . Moreover, the injected data signal also modulates the refractive index of the SOA, resulting in a chirped converted signal.

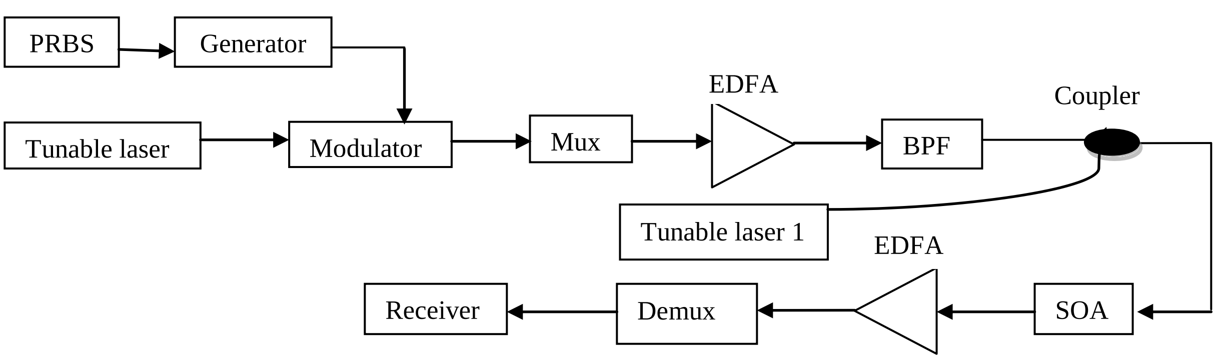

Figure 2: Wavelength converter using semiconductor optical amplifier and bandpass filter.

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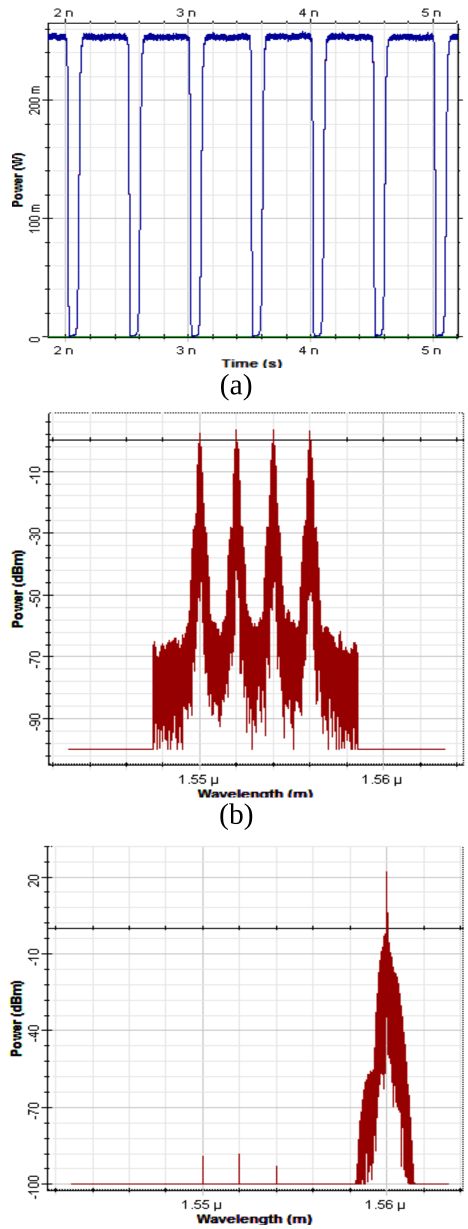
Data signal is fed into a receiver and a bit-error-rate (BER) tester in verifying an error-free operation. At the exit of the optical band pass filter, both inverted and non-inverted wavelength conversion can be achieved depending on the optical band pass filter detuning from the probe wavelength. The modulated input signal modulates the gain in the SOA due to gain saturation. A continuous wave (CW) signal at the desire output wavelength 1560 nm is modulated by the gain variation in the SOA so that it carries the same information as the original input signal.

Figure 3(b) shows 4 input wavelengths at the same power level that are multiplexed to produce 40 Gb/s. The output spectrum which is observed in Figure 3(c) realizes the wavelength conversion. Also, it can be seen clearly that the output power is higher than the actual input power. Cross gain modulation takes advantage of the non-linear gain suppression mechanism in semiconductor optical amplifiers. As the input power to an SOA is increased, the optical gain is decreased due to the stimulated recombination of carriers, which is proportional to the input signal photon density.

V. CONCLUSION

Wavelength conversion can be all-optically performed in a simple yet effective set up. Its ability in converting WDM system is additionally value added to the existing data conversion capacities. Moreover, it also has potential for integration on silicon based fabrication facilities. This work is successfully implemented in a low density input data of the WDM system. However, it can be easily upgraded to more channels by applying the same wavelength conversion principle as described in the previous section. Thus the wavelength conversion in DWDM can also be realized too.



(c)

Figure 3: Observer simulation results; (a) 40 Gb/s inverted wavelength, (b) Input spectra at 4 wavelength, (c) output spectrum at 1560 nm.

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