Optical Multicasting based on All-Optical Triode Wavelength Converter

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We demonstrated all-optical multicasting by using a wavelength converter based on an all-optical triode circuit. The all-optical triode is based on a tandem wavelength converter exploiting cross-gain modulation in SOAs. The wavelength range operation of the all-optical triode based multicasting wavelength converter with non-inverting polarity at the data rate of 10 Gb/s for signals with 2^{31}-1 PRBS is experimentally assessed. Experimental results show multicast operation from a 10 Gb/s modulated signal to two channels at 1550.9 nm and 1552.5 nm with preserved polarity and a power penalty of 0.6 dB and 3.2 dB, respectively.

Introduction

Demand for the wavelength division multiplexing (WDM) in wider band has progressed especially in the future technology of photonic networks. WDM network nodes employ conventional optical/electrical/optical (O/E/O) for forwarding the high data rate signals. This results in high cost and power consumption as the data rate increase. It is therefore convenient to remove the conventional O/E/O with data rate transparent all optical (O/O) solutions. 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 WDM optical networks by enabling rapid resolution of output-port contention and wavelength reuse [1]. In addition, all-optical wavelength converter becomes a key functional element in WDM optical network due to its capabilities of transparent interoperability, contention resolution, wavelength routing and, in general, better utilization of the fixed set of wavelengths [2]. Nowadays, multicasting is a potentially useful networking function to forward the same data stream from a single node to several destinations nodes. This network is also called as photonic network. Photonic network is commonly enforced via IP digital routers in electrical domain. Photonic network effectiveness will be encouraged when the multicasting can be performed all-optically. The optical routers will be able to multicast an input signal to different wavelengths. There are several wavelength conversion and multicasting techniques proposed so far. The techniques include a nonlinear semiconductor optical amplifier (SOA) based interferometer, an injection locking of a Fabry-Perot laser [3], and cross gain modulation (XGM) in SOA or cross phase modulation (XPM) in SOA [4]. In this paper, we investigated a new wavelength converter technique. Wavelength conversion and switching characteristics was investigated by introducing a control light together with input signal light [5]. The optical amplifier consists of an InGaAsP/InP SOA and an optical add/drop filter. We demonstrated the conversion of input wavelength to multiple wavelengths by using two SOAs based optical triode. We experimentally show that this device can realize an all-optical multicasting and wavelength conversion to two channels at the speed of 10 Gbps. Measured bit error rate (BER) characteristics for each wavelength is reported.

Experimental setup

The experimental setup is reported in Fig 1. The principle of operation of the wavelength conversion with no polarity inversion by using optical triode is explained as follows. In this experiment, we used full band tunable distributed-feedback (DFB) laser diode module. To cover the full band, the tunable laser was designed to integrate the 12 different DFB lasers with wavelength spacing 3.45nm with consideration given to fabrication variations. Figure 2 shows the optical micrograph of the integrated device. The photonic device includes an optical combiner that couples the 12 DFB laser array and an optical amplifier that compensates the loss of the optical combiner. The size of the element is 500 μm × 2600 μm, the length of each DFB laser is 600 μm, and the length of the optical amplifier is 900 μm. By applying a non-reflective coating and a bend waveguide, the end surface is controlled by the reflection from another end surface. There is no optical isolator to allow external signals injection to the SOA for signal processing purpose. This device is used as the SOA and laser diode (LD) in the wavelength converter setup shown in Fig.1 as one of the optical triode stage.

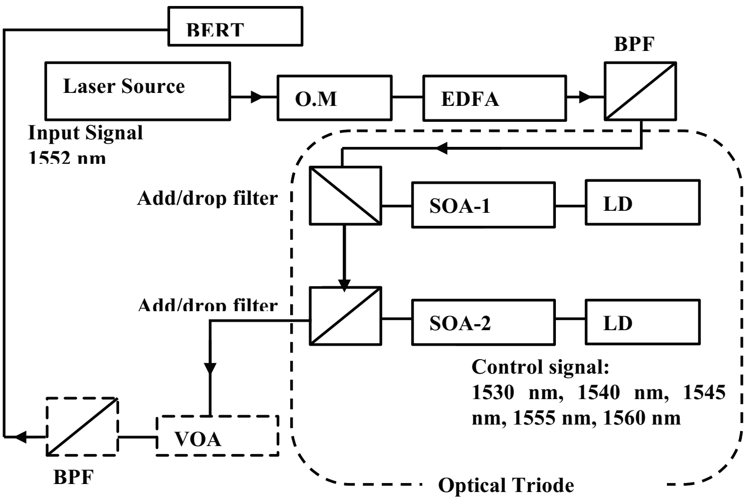

Fig. 1: Experimental setup

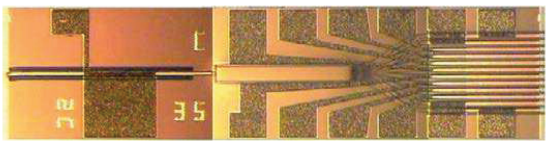

Fig. 2: Optical integrated chip of full-band tunable laser (DFB laser array, coupler and SOA).

We created an optical triode by using XGM in two stages of SOAs, SOA-1 for the first stage and SOA-2 for the second stage of the circuit. Two optical add/drop filters have been used to filter out the converted signal at each stage. An optical signal with wavelength 1552 nm has been modulated by the external 10 Gb/s optical modulator

(O.M) to a nonreturn zero (NRZ) 2^{31}-1 pseudorandom bit sequence (PRBS) with a transfer speed of 10 Gbps. The modulated signal is amplified by the Erbium doped fiber amplifier (EDFA) before fed into the SOA-1 of the stage 1 of the optical triode via an optical multiplexer. A CW probe light generated by LD1 at 1551 nm is launched in a counter-propagation direction with respect to the data signal in the SOA-1. Due to the XGM mechanism in SOA-1, the pattern of the input data signal is imprinted with inverted polarity to the CW probe light. This inverted optical signal then passes through an optical multiplexer thenceforth it is fed into the second stage. The second stage consists of the photonic integrated chip with the array of 12 DFB lasers (LDs) and the integrated SOA (SOA-2) at the stage 2, the inverted polarity signal from stage 1, and multiple CW lights from the photonic integrated transmitter LDs are fed, in counter propagation direction, into the SOA-2. In order to perform multicasting in wavelength conversion through this experiment, two different wavelengths are lit by the LDs. Five different wavelengths are chosen as the CW lights to be used in this research. They are 1530 nm, 1540 nm, 1545 nm, 1555 nm, and 1560 nm. These CW lights (two wavelengths at a time) will be fed into the SOA-2. Again, the due to the XGM mechanism in SOA-2, the inverted polarity signal is imprinted, with an inverted polarity, to the CW lights of LDs. As results of the double inversion, the converted multiple signals at the output of stage 2 have a non-inverted polarity. The two wavelength converted optical signals with non-inverted polarity will be output via the optical multiplexer 2. To perform the bit error rate, the two wavelengths are separated by a BPF and then analyzed by a bit error rate tester (BERT).

Experimental results

Table 1 reports the measured eye aperture, extinction ratio and zero level from the baseline of each wavelength converted signal. The baseline of output signal eye diagrams arose gradually compared to the input signal eye diagram. As shown in Table 1, zero level from baseline of output signals increase when wavelength becomes longer, from 1530 nm to 1560 nm. In addition, the degradation in eye aperture of output signals is clearly reported in Table 1. The obtained results show that, the highest extinction ratio is 7.39 dB when the output signal wavelength is 1530 nm. Based on the reported results, it proved that during the wavelength conversion in the SOAs consumed large amount of power and noise has been found due to the distortion of the eye diagrams as clearly.

Table 1: Summarization of measurement result.

Wavelength [nm]	Eye aperture [dB]	Extinction ratio [dB]	Zero level [μW]
1530	4.35	7.39	49
1540	3.90	6.97	54
1545	3.45	6.19	63
1555	2.22	4.40	83
1560	2.12	4.28	84

In order to quantitatively assess multicasting characteristics, we reported in Fig. 3 the measured the BER curves of the converted output signals at 1530 nm, 1540 nm, 1545 nm, 1555 nm, and 1560 nm as a function of the average optical power. We have also reported in the figure the BER curve of the back-to-back input signal as reference. We studied that it may be an effect of the dependence of the speed propagation light through the medium during the conversion of wavelengths that produce errors. From the result of BER test, relationship of power penalty with respect to B to B and control signals when the BER is 10^{-9} is summarized.

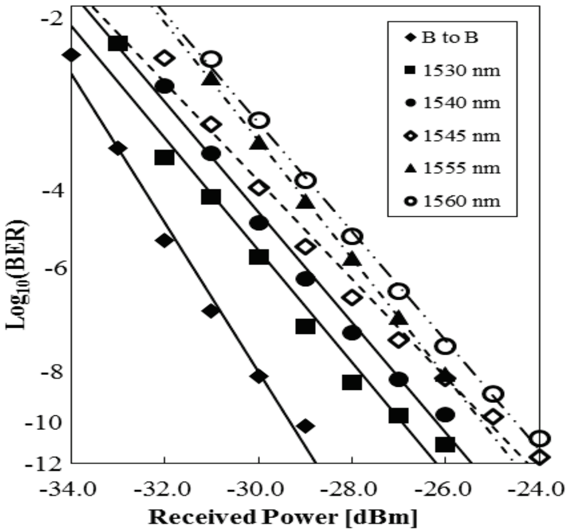

Fig. 3: Result of bit error rate test

Conclusion

We investigated multicasting characteristics by using an optical triode based on two stages of SOAs. Experimental results based on the BER measurement indicate error free multicast wavelength conversion operation with different power penalty. Converted signals at shorter wavelength show better performance than longer wavelengths. The results proved that all-optical multicasting and wavelength conversion with two channels with a transfer speed of 10 Gbps is possible.

References

[1] Y. Yuang et al., "Nonblocking WDM multicast switching networks," IEEE Trans On Parallel and Distrib. Sys., pp. 1274-1287, 2000.

[2] J. M. H. Elmirghani and H. T. Mouftah, "All-optical wavelength conversion: Technologies and applications in DWDM networks," IEEE Commun. Mag., vol. 38, pp. 86-92, March 2000.

[3] C. W. Chow et al., "8×10 Gb/s multiwavelength injection locking of a FP laser diode for WDM multicast," Proc. Of IEEE LEOS, pp. 682-683, 2003.

[4] M. Matsuura, N. Kishi, and T. Miki, "Broadband regenerative wavelength conversion and multicasting using triple-stage semiconductor-based wavelength converters," IEEE Photon. Technol. Lett., pp. 2659, 2006.

[5] Y. Maeda and L. Occhi, "All-optical triode based on a tandem wavelength converter using reflective semiconductor optical amplifiers," IEEE Photonics. Technol. Lett., pp. 257, 2003.