MULTIPLE WAVELENGTH CONVERSION FOR WDM MULTICASTING BY MEANS OF NON-LINEAR EFFECTS IN SOAs

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Abstract: Using Four Wave Mixing in SOAs, we produce six simultaneous optical copies of an input NRZ data signal, all signals are compliant with a 200 GHz channel grid.

Index   Terms: Multicasting, Nonlinear Optics, Semiconductor Optical Amplifier, Wavelength Conversion.

1.   INTRODUCTION

Future *transparent* all-optical networks may take serious advantage by the introduction of the optical multicast functionality [1]. Multicast is a well-known feature of IP protocol, used when one source sends the same information to several different destinations (note: multicast is similar to broadcast, the two corresponding to *one-to-many* and to *one-to-all* situations, respectively). Currently, multicast is implemented in IP digital routers, but the effectiveness of the all-optical network will further increase when actual optical multicast will be performed in the optical nodes.

At first, optical multicast will be required for circuit-switched data at fixed wavelength: in that case it could be easily implemented by means of power splitters. However the natural evolution will soon ask for the optical WDM multicast, i.e. multicast to different wavelengths.

WDM multicast could be achieved by means of a 1:N power splitter and N-1 wavelength converters, but clearly we would prefer a single device providing the N-1 wavelength converted copies simultaneously. A common demultiplexer can then be used for routing the channels on a wavelength basis.

Although wavelength conversion has been largely investigated in the past, there are very few results on optical multicast demonstrations. To the best of our knowledge, actual WDM multicast was demonstrated in [2], using a nonlinear SOA-based interferometer, in [3], using injection locking of a Fabry-Perot laser, in [4], using Cross Phase Modulation in a Dispersion Shifted Fiber (DSF) and, finally, in [5], with an electro-absorption modulator.

Here, we introduce a new technique for multicasting an input signal by exploiting multipump Four Wave Mixing (FWM) in a Semiconductor Optical Amplifiers (SOA).

2. OPERATING PRINCIPLE

Our scheme is a modified version of a FWM configuration that was proposed in [6] in order to obtain a flat wavelength conversion efficiency in SOAs. The scheme of this configuration is depicted in Fig. 1. A first pump (P1) has the same State Of polarization (SOP) as the incoming signal, while the other two (P2 and P3) have orthogonal SOP. Thanks to the orthogonal SOP scheme no efficient FWM contribution arises due to mixing of the pumps, as indeed modulation of gain and refraction index in the semiconductor medium is practically only due to the beating between S and P1. This modulation affects P2 and P3 and leads to the generation of two copolarized sidebands for both pumps, thus producing Ch. 1, 2, 5 and 6, respectively. Moreover, the usual FWM process produces the channel 3 signal.
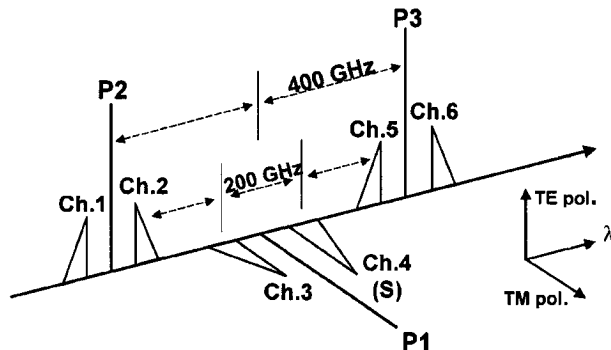

Fig.1: *Scheme of the interacting signals in the SOA and their SOPs. P1, P2 and P3 are the CW pumps. Ch.4 is the input signal S.*

3. EXPERIMENT

In this experimental demonstration, we produce six copies of an input 10 Gbit/s Non-Return-to-Zero (NRZ) signal S.

Our setup is illustrated in Fig. 2. The signal S, at λ_S=1554.3 nm, is generated by modulating a CW laser at λ_S, by means of a LiNbO$_3$ Mach-Zehnder intensity modulator driven by a 2^{31}-1 long PRBS sequence at 9.95328 Gbit/s (STM-64). The signal passes then in the multicast device where it is coupled together with the three local pumps. The orthogonal SOP between the pumps is accomplished by means of Polarization Controllers (PCs) and a Polarization Beam Splitter (PBS). The main experimental parameters are summarized in Table 1, reporting the wavelengths of the signals and pumps (2nd column), together with the input power (3rd column), output power (4th column), Optical Signal to Noise Ratio (5th column) and the single channel conversion efficiency (6th column) of all the generated signals.
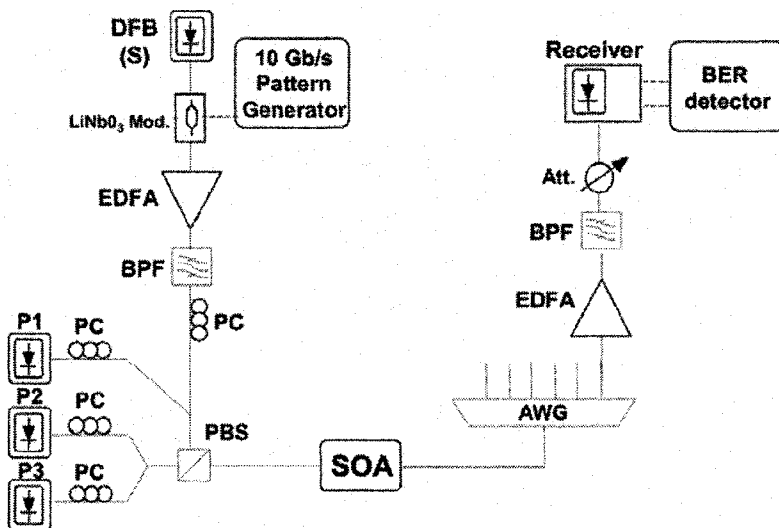

Fig.2: *Experimental setup. PC: Polarization Controller; PBS: Polarization Beam Splitter; BPF: Band Pass Filter; AWG: Array Wave-guide Grating.*

Moreover we outline that, due to the physics of the process [6], when the wavelength of P2 or P3 is changed, the corresponding couple of multicast signals is wavelength-shifted by the same amount, without any change in the conversion efficiency as long as the pumps wavelength lies within the gain curve of the SOA. This fact allows flexible selection of output wavelengths. When we set the values

of the pumps as in the Table I, all the six channels comply with an equally spaced 200 GHz frequency (see Fig. 3).

Properly balancing pumps and signal power levels, we optimized conversion efficiency and OSNR controlling deleterious effects that could arise either from spurious Cross Gain Modulation (XGM) or from in-band cross-talk due to high-order FWM products. Obtained optical powers and OSNRs of the various copies are greater than -22.5 dBm and 23 dB, respectively (Tab. 1).

Table 1

	λ(nm)	Input Power (dBm)	Output Power (dBm)	Estimated OSNR (dB)	Conversion Efficiency: P_{OUT}/P_S (dB)
Ch.1	1549.5		-17.3	28	-24.3
P2	1550.3	9.3			
Ch.2	1551.1		-22.5	23	-29.5
Ch.3	1552.7		-15.4	30	-22.4
P1	1553.5	9.8			
Ch.4 (S)	1554.3	7	3.7	48	-3.3
Ch.5	1555.9		-16.5	25	-23.5
P3	1556.7	8.9			
Ch.6	1557.5		-20.7	23	-27.7

To check the quality of the multicasted signals we performed BER measurements on each of them. Every channel is extracted by means of a WDM
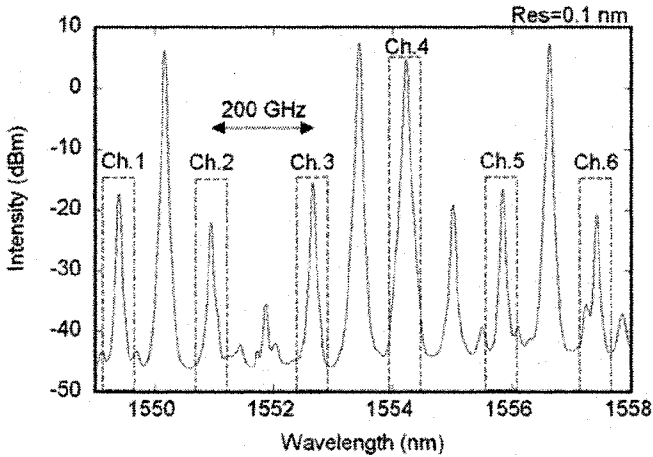

Fig.3: *Optical spectrum at the SOA output.*

demultiplexer and sent to a common STM-64 SDH receiver. The obtained Bit Error Rate (BER) curves are shown in Fig. 4. As can be seen, with respect to the input signal in back-to-back configuration, all channels exhibit a limited penalty (less than 2.5 dB for BER=10^{-9}). A slight penalty is partially due to degraded OSNR and, principally, to spurious XGM.
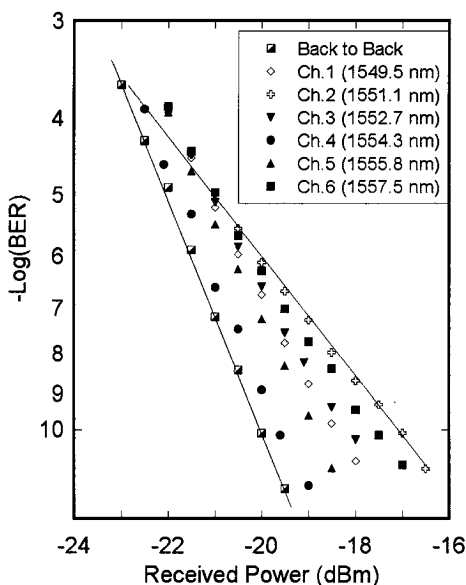

Fig.4: *BER curves for the back-to-back configuration and for all the converted signals.*

4.   CONCLUSIONS

We demonstrated 1:6 all-optical WDM multicast of a 10 Gb/s NRZ signal. By exploiting a new scheme for Four Wave Mixing in Semiconductor Optical Amplifiers, we obtained six copies of an input signal, all compliant with a 200 GHz grid. Although in the present demonstration we used a polarization controller to match the SOP of the input signal and P1, our scheme can be made polarization-independent by using a more involved setup (analogous to what shown in [7] for the wavelength conversion). Finally, we outline that a higher number of multicast channels could be produced by the same scheme, using additional copolarized pumps and a SOA device with higher output saturation power.

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