

Wavelength conversion with Polarisation Labelling for Rejection and Isolation of Signals (POLARIS).

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VPI-simulation of a new all-optical wavelength converter is presented. It is based on interferometric effects in two Mach-Zehnder interferometers (MZI), parallel connected by polarization components (PLCs). The PLCs provide filtering between probe and control wavelengths, and polarization-insensitive operation. Different efficiency values for PLCs are taken into account. Simulation shows wide operational range (> 10 dB) for the input power. Results obtained are also suitable for cascading these devices in optical networks (extinction ration (power difference between level one and zero signal in dB) > 10 dB, isolation > 20 dB).

Keywords: wavelength conversion, filter free, polarization insensitive operation, VPI simulation

Introduction

For wavelength routed optical networks, a compact and monolithical integration of components for all-optical wavelength conversion is highly needed. It increases the flexibility of networks by offering a dynamic exchange of signals between different wavelengths. Interferometric wavelength converters based on cross phase modulation (XPM) by using Semiconductor Optical Amplifiers (SOA) as nonlinear elements seems to be the most promising. They are compact, stable, they give low chirp and high extinction ratio. In these configurations, SOAs are placed in the two arms of a standard Mach Zehnder interferometer (MZI).

The swapping of the wavelengths is produced by launching the new wavelength (the probe) coming from a CW laser equally in the two arms of the MZI. Simultaneously the old wavelength (the control signal) is introduced in one of the arms in such a way that a phase difference between two arms can be obtained, resulting in different interference at the output of the MZI. Co-directional coupling (the two signals propagate in the same direction) has a better performance (higher extinction ratio (ER)), larger input dynamic range) at high speed than counter-directional because the interaction time between the two signals in the SOA is longer. Also co-propagation gives higher optical signal to noise ratio compared to counter-propagation [1]. However tunable filters are needed in that case at the output of the wavelength converter to separate the control and the probe signals. These filters introduce losses and can modify the pulse form. They are difficult to integrate, they are expensive and conversion to the same wavelength is impossible. This latter option is desirable to keep full flexibility, to provide the implicit regeneration at the wavelength converter and to strip the frequency and phase noise from the signal. To circumvent external wavelength filters and have the possibility to convert to the same wavelength, a counter-propagation configuration may be used despite the limitations mentioned above.

As the signal in the network has an unknown state of polarization, polarization insensitive wavelength converters are needed. This can be achieved by using polarization insensitive SOAs. This will limit the design options for these devices [2].

In this paper we present POLarisation LABelling for Rejection and Isolation of Signals (POLARIS). It is new co-directional polarization insensitive SOA-based wavelength converter. POLARIS allows polarization insensitivity (even when using polarization sensitive SOAs), filter-free, co-propagation wavelength conversion and conversion to the same wavelength. It uses MZIs and polarization components which can be monolithically integrated.

Concept of POLARIS

The POLARIS concept is shown in figure 1. It consists of two Mach-Zehnder interferometers (MZIs) parallel connected by polarization components. The aim of using the polarization components is to have a polarization insensitive co-propagation wavelength-converter even when using polarization sensitive SOAs, and high isolation between the two signals.

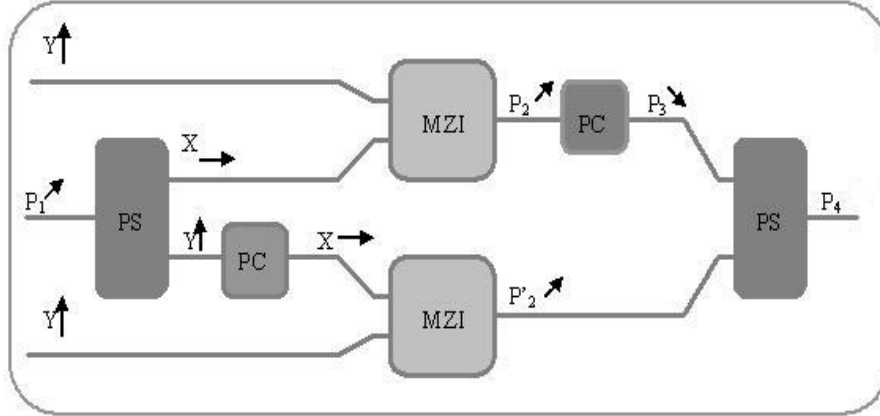


Fig. 1: POLARIS layout, MZIs provide the wavelength conversion and the polarization components ensure the polarization insensitivity and free filtering operations. PS: polarization splitter/combiner, PC: polarization converter.

In this configuration the probe coming from the CW laser is launched in two MZIs with polarization Y (e.g. TM), however the control signal coming from the network is with the other polarization X (e.g. TE). As the control signal has an arbitrary polarization a polarization splitter (PS) [3] is used to split the signal into X and Y polarizations. Then a polarization converter (PC) [4] rotates Y polarization to X polarization. In this way, the control can be dropped out by the PS at the output of POLARIS after modulating the probe in the MZIs. One of the advantage of POLARIS is that injecting the control signal in one of the MZI branches, does not require a 3 dB-coupler anymore, but can be done with a PS, thereby avoiding 3dB loss. The PS component is a 1x2 directional coupler. It is described in detail in [3]. It can be used for splitting or combining two orthogonal polarizations. For the combination function, from one of the input waveguides of the PS only X polarization is coupled to the output, from the other input waveguide only Y polarization. Hence, for combining the probe and dropping the control, a PC is introduced at the appropriate branch after the MZIs. In the case of the figure 1, a PC is introduced in the upper branch. It converts the Y polarization of the probe to the X polarization and the X polarization of the control to the Y polarization. Therefore, Y polarization of the control will be irradiated and the same thing will happen to the X polarization of the control in lower branch.

Simulation results

In the simulation study, some key parameters of the basic components are changed to find out the tolerance allowed in their fabrication. Parameters of the SOA used in the simulation are shown in table 1. The polarization components are assumed to have efficiencies of 95 % or 99 %. And excess loss of 2 dB.

In figure 2 the Bit Error Rate (BER) versus input power for different incoming polarizations is presented. It is clear from the curves that this configuration shows a wide operation range despite the change in polarization and power of the input signal. When the linewidth enhancement factor and the polarization efficiency are increased, shift of the curves to lower powers is found.

The isolation between the probe and the control signal is also studied, since the polarization components are introduced mainly to separate the two signals from each other.

Figure 3 shows the isolation versus the input power for a polarization of 45° (worst case). To reach high isolation (more than 20 dB), polarization components with 99 % efficiency and SOAs with linewidth enhancement factor of 8 are needed. The reason is that for high line width enhancement factors the control signal modulates the probe signal stronger. Furthermore, increase in the efficiency of the polarization components improves the filtering of the signals, as well as corrects the polarization for best interaction in the MZI. In the case where devices with such performance can not be obtained, devices with lower performance are studied.

Table 1 : parameters of SOA used for simulation

Injection current	250 mA
Length	500 μm
Width	2 μm
Height	80e-9 m
Confinement factor	0.25
Internal losses	40e2 m^{-1}
Differential Gain	2.78e-20 m^2
Carrier density at transparency	1.4e24 m^{-3}
Linewidth enhancement factor	5 or 8
Recombination constant A	1.43e8 s^{-1}
Recombination constant B	1e-16 m^3/s
Recombination constant C	3e-41 m^6/s
Initial carrier density	3e24 m^{-3}

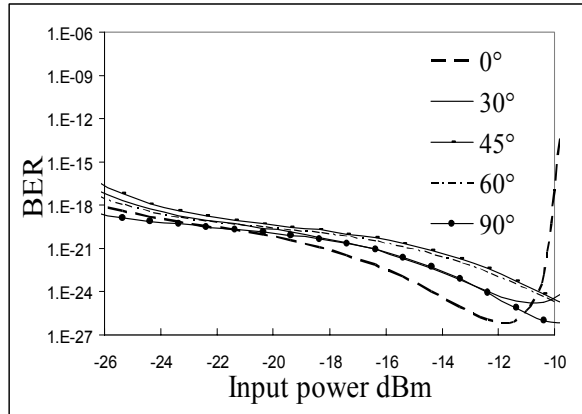


Fig. 2: BER for different polarizations of the incoming light. Results obtained for linewidth enhancement factor of 8 and polarization components efficiency of 99%

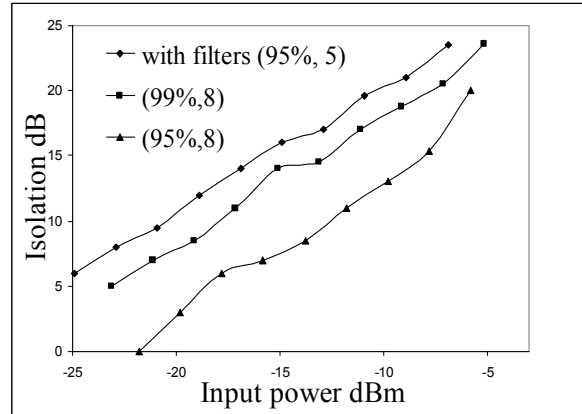


Fig. 3: Isolation between the probe and the control signal for polarization of the control signal of 45° (worst case). The data are shown for different values of the PLC efficiency and the line width enhancement factor.

In the figure 3, the upper curve is found in case of polarization components with 95 % (already achieved) and SOAs with linewidth enhancement factor of 5. For this alternative extra filters are used. These filters are nothing else than PSs. Therefore, in case of figure 1, the X polarization is filtered in the both branches before reaching the MZIs, the same thing for the Y polarization before reaching the output PS. With these filters more than 20 dB isolation is obtained for the highest input power. Of course, even higher isolation can be obtained by combing the best considered performance with extra filters.

Values more then 20 dB offer the possibility to cascade POLARIS converters in the network. Another crucial parameter for cascading these devices is the extinction ratio (ER). In figure 4, the behavior of this parameter as a function of input power, linewidth enhancement factor and polarization components efficiency is shown. The input ER was 7 dB. 2R regeneration can be obtained for input power less than -9 dBm. The upper curve in the figure 4 is obtained in case filters are added. As can be seen, better results for the ER also are achieved. therefore, well defining of the polarization seems to improve also the ER. Furthermore, ER improves also when the line width enhancement factor and the filtering increase. This is presumably because of the same reasons as mentioned before for the isolation between the wavelengths.

We also looked at the change in the output power versus the input power for different polarizations of the incoming light (Figure 5). The output power shows a weak dependence on the polarization of the incoming signal. This low variation in output power avoids the problem of the dynamic range of the functionality of these devices. The losses introduced by the polarization components contribute slightly to the variation of the output power, since the signal will see somewhat different losses according to its polarization.

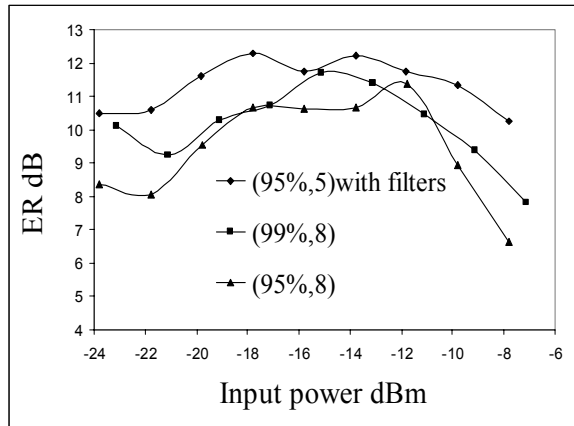


Fig. 4: Extinction ratio versus input power for polarization of the control signal of 45° (worst case). The data are shown for different values of the PLC efficiency and the line width enhancement factor.

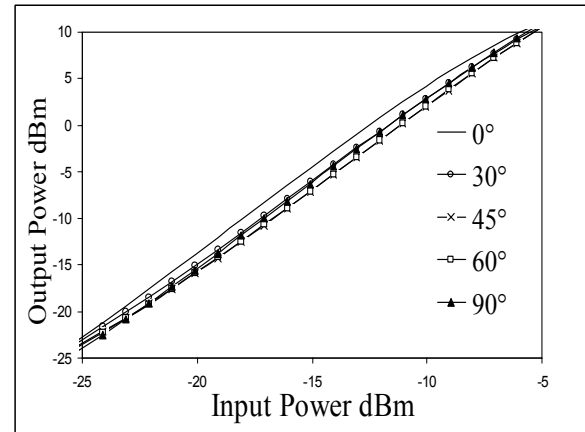


Fig. 5: Output power versus input power for different polarizations of the incoming signal (results obtained for linewidth enhancement factor of 5 and polarization efficiency of 95 % with filters)

Conclusions and discussion

As a conclusion, we studied a new configuration for a wavelength converter based on XPM in a SOA-MZI, which uses polarization components to isolate the probe and the control signals.

The configuration seems promising since it works in co-propagation and allows conversion to the same wavelength. Despite the wide range in which the BER is lower than 10^{-12} , only a narrow input power range (of around 3 dB) can be found where high ER (more than 10 dB), high isolation (more than 20 dB) and low BER can be obtained at the same time. This range is found around -11 dBm in this simulation study. And is typical for SOA-MZI wavelength converter [1,2].

The polarization components needed for an integration of this configuration on InP based materials are already fabricated in our laboratory. The structure will be developed and realized within the framework of the European project IST-STOLAS. The European commission is acknowledged for financing the project.

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