# A novel 1310 nm to 1550 nm wavelength converter

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*We propose a novel all-optical 1310 nm to 1550 nm wavelength converter utilizing nonlinear polarization rotation in a semiconductor optical amplifier. We demonstrate that inverted and non-inverted wavelength conversion can be obtained. Error-free wavelength conversion at 10 Gbit/s is shown.*

## Introduction

A key component in all-optical communication networks utilizing the whole low loss bandwidth of the silica fibre is an ultra wideband wavelength converter [1]. Use of all-optical ultra wideband wavelength converters will enhance network flexibility, allowing wavelength conversion between different transmission windows without optical-electrical-optical conversion. This will become of particular importance at the network nodes interfacing access systems employing 1310 nm window and the core network traditionally centered in 1550 nm window. A number of access schemes utilizing simultaneously 1310 nm and 1550 nm transmission window have been proposed [2, 3]. Ultra wideband wavelength converters applied in local access systems have to deliver high performance while maintaining the low cost.

Several 1310 nm to 1550 nm wavelengths converters based on: a $LiNbO_3$ waveguide [4], a semiconductor optical amplifier (SOA) in a Mach-Zehnder Interferometer (MZI) configuration (1.25 Gbit/s error free up-conversion) [1], a split contact SOA [5], a distributed feedback SOA [6] have been reported. The demonstrated wavelength converters required extremely expensive components [4], a complicated control mechanism [1], or the bit rate was limited to below 1 Gbit/s [5-6].

In this paper, we report all-optical 1310 nm to 1550 nm wavelength conversion based on nonlinear polarization rotation in an SOA. We demonstrate that error-free wavelength conversion from 1310 nm to 1550 nm can be realized at bit rate 10 Gbit/s by using a single SOA. The nonlinear polarization rotation in the SOA was applied previously for: demultiplexing [7] or in-band wavelength conversion [8]. However, nonlinear polarization rotation in the transparency region of the SOA has not been reported. The presented wavelength converter has several key advantages: it uses a single SOA, it eliminates optical-electrical-optical conversion enabling transparent all-optical networking, it operates at high bit rates, and it offers an inverting and non-inverting conversion. Moreover, depending on the converter architecture, the wavelength converter can be used to any wavelength up-conversion from the 1310 nm transmission window, e.g. 1410 nm transmission window, and up- and down-conversion within the 1310 nm transmission window.

## Experimental setup

Fig. 1 shows the experimental setup. An intensity modulated 10 Gbit/s nonreturn-to-zero (NRZ) signal at 1310 nm enters the wavelength converter through a polarization controller (PC1). Next, the 1310 nm NRZ signal passes through a 1310 nm/1550 nm

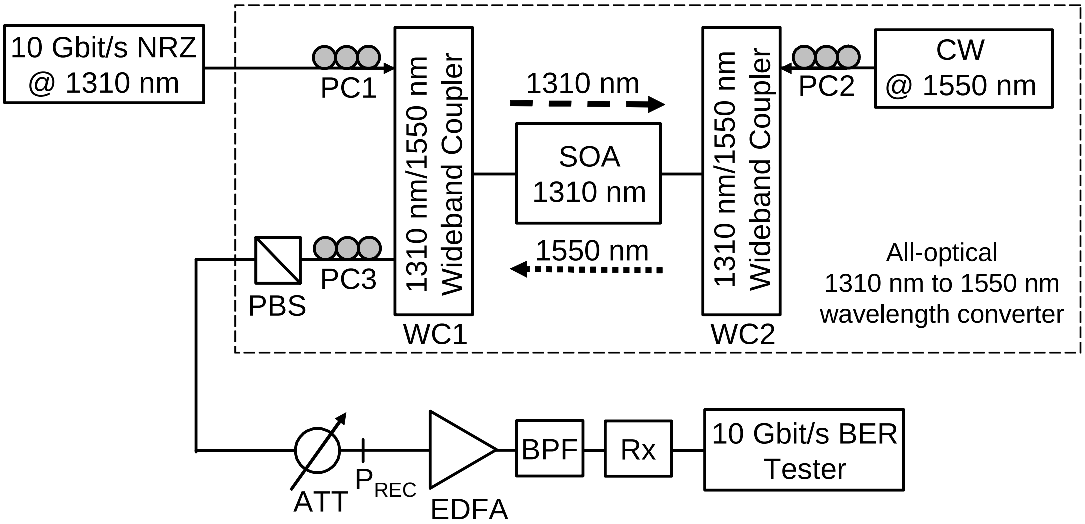


**Fig. 1 Experimental setup**

wideband coupler (WC1) and finally enters a 1310 nm SOA. The multi-quantum well SOA employed (produced by Philips, The Netherlands) has an active length of 800 μm and 300 mA driving current. The polarization of a 1550 nm continuous wave (CW) light is adjusted by polarization controller (PC2) to be approximately 45° to the orientation of the SOA polarization axes. Then, the 1550 nm CW signal passes through a second wideband coupler (WC2) and is fed into the 1310 nm SOA. The 1310 nm SOA is employed in a bidirectional configuration and the 1550 nm signal travels through the 1310 nm SOA in the opposite direction to the 1310 nm NRZ signal. The SOA is generally a birefringent device [9]. The injected 1310 nm light introduces additional birefringence in the SOA via carrier density changes [9, 10]. This causes the transverse magnetic (TM) and the transverse electric (TE) modes of the signals traveling through the SOA to experience a different refractive index, also in the transparency region of the SOA. Therefore, the 1550 nm signal at the SOA output has a changed state of polarization with respect to the 1550 nm signal without any 1310 nm signal present. After passing through the SOA, the 1550 nm signal is separated from the 1310 nm signal in the WC1 and enters a polarization filter formed by a polarization beam splitter (PBS) and a polarization controller (PC3). The PBS has an extinction ration better than 20 dB. The PC3 is adjusted in such a way that the 1550 nm signal with the rotated polarization passes through the PBS. Obviously, the PC3 can be adjusted in that the 1550 nm signal with the rotated polarization can not pass through the PBS, and therefore as a result inverting and non-inverting conversion can be obtained. After passing through the PBS, the 1550 nm signal is evaluated in a pre-amplified receiver and the bit error rate (BER) tester. The pre-amplified receiver consists of a variable attenuator (ATT), an erbium doped fibre amplifier (EDFA), bandpass filter (BPA), and a 10 Gbit/s data receiver. Fig. 2 shows the photograph of the wavelength converter.

## Results and discussion

Fig. 3(a) presents signal traces at 10 Gbit/s: an input 1310 nm signal, an output non-inverted 1550 nm signal, and an output 1550 nm inverted signal.

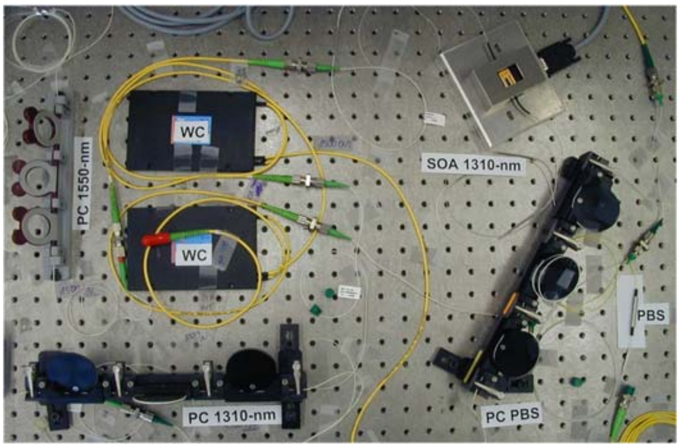


**Fig. 2 Photograph of the wavelength converter setup**

Both inverted and non-inverted conversions are visible. The signal trace for the non-inverted 1550 nm indicates excellent operation of the wavelength converter. However, the signal trace for an inverted conversion shows an enhanced pattern effect. The signal has a slow rise and fast fall time, which can be attributed to the slow carrier recovery time of the SOA. Finally, we investigated the performance of the proposed wavelength converter by measuring BER. We generated a 9.95328 Gbit/s NRZ signal by modulating a CW signal at 1310 nm in an external Mach-Zehnder modulator with the pseudorandom bit sequence (PRBS) of length $2^{31}$-1. The input NRZ 1310 nm signal power was set at 4.6 dBm and the 1550 nm CW laser power at 7.0 dBm. Fig.3(b) shows the BER curves for non-inverted and inverted conversion and a reference back-to-back signal as a function of the measured optical power before a pre-amplifying EDFA. As a reference we used a 1550 nm NRZ signal generated in the same external Mach-Zehnder modulator. The power penalty at BER $10^{-9}$ for the non-inverted conversion is 2.4 dB and 6.9 dB for the inverted conversion. No BER error floor is observed, which indicates again excellent operation of the wavelength converter.

## Conclusion

We have demonstrated a novel all-optical 1310 nm to 1550 nm wavelength converter based on nonlinear polarization rotation in a single SOA. We achieved the inverting and non-inverting wavelength conversion in a single SOA. Due to the slow recovery time of the SOA the signal for the inverted conversion was corrupted. Error-free wavelength conversion at 10 Gbit/s is shown. The wavelength converter operates at high bit rate and maintains low cost, which makes it attractive solution for interfacing access systems and core networks. The presented wavelength converter concept can in principle be used for any wavelength up-conversion from the gain region of the SOA, making it interesting for applications in networks utilizing the whole low loss bandwidth of silica fibre.

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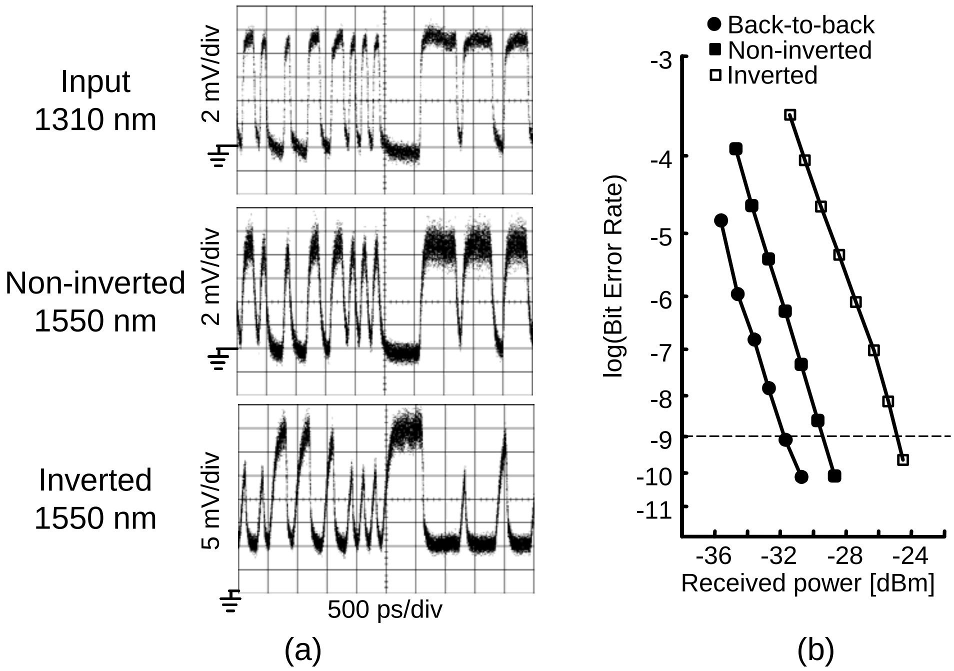


**Fig. 3 Results of measurements: 10 Gbit/s signal traces (a), and BER measurements; PRBS $2^{31}$-1 (b)**

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