

Monolithic Widely-Tunable All-Optical Wavelength Converter with Spatial Filtering of Input and Output Signals for 10Gbps NRZ Operation

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1. Introduction

Wavelength converters (WCs) are key components of next generation WDM optical networks, enabling functions such as wavelength routing, add/drop multiplexing, contention resolution and signal regeneration. Among the variety of available wavelength conversion schemes, semiconductor-based WCs have generated substantial interest due to their potential for monolithic integration of several components on chip.

Recent integration efforts by our group have successfully demonstrated monolithic integration of widely-tunable SG-DBR lasers with Mach Zehnder Interferometer (MZI) SOA-based WCs using an offset quantum well (OQW) integration platform in InP [1]. These previous integrated designs have relied on the use of an external tunable bandpass filter at the output of the device to remove the input signal from the converted signal. Such filters must be tuned to the output wavelength, introduce additional loss and can cause signal distortion at high bit rates due to the limited bandwidth of the filter function. An external filter also inhibits integration by preventing cascading of WCs with other active components on chip.

To replace the function of an external filter, several schemes have been introduced which spatially filter the input signal from the output signal on chip [2,3,4]. These schemes have proven to be effective at providing >20 dB of separation between the input and output signals and have been demonstrated at speeds up to 10Gbps NRZ.

This paper describes a new approach to a spatially-filtered MZI-SOA based widely-tunable wavelength converter showing error-free operation, and fabricated using our standard OQW integration platform.

2. Design and Operation

A schematic of the wavelength converter design is shown below in Figure 1. The input pump signal enters the device through a waveguide (shown as a black line) on the left and is amplified by a pre-amp SOA before entering a 2x2 MMI splitter/combiner. The MMI evenly distributes the input signal between the top two arms of a three-arm MZI, and combines it with a portion of the CW SG-DBR probe signal. The pump and probe signals co-propagate out of phase in the identical SOAs of the top two arms, and as the pump depletes carriers through stimulated emission, the probe in both arms is modulated by both cross-gain (XGM) and cross-phase (XPM) modulation. The signals from the two arms interfere through a second 2x2 MMI splitter/combiner, which images the probe and the pump to separate waveguides due to their opposite phase as described in [4]. Phase electrodes in the top two arms allow this phase to be tuned to optimize signal separation, or to statically switch them from one output port to the other. To utilize the XPM in the top two arms, the pump signal is routed to an absorber, and the modulated SG-DBR probe signal is recombined with the CW SG-DBR probe signal in the bottom arm of the MZI using a 2x2 MMI splitter/combiner. A phase electrode in the bottom arms allows the extinction of the converted signal to be optimized and the wavelength converter to be switched between inverting and non-inverting modes of operation.

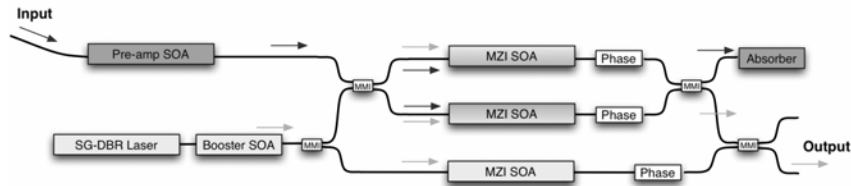


Fig. 1. Schematic of the widely-tunable MZI-SOA wavelength converter with spatial filtering of input and output signals

3. Results

For good thermal and electrical conduction, the device was soldered onto a copper bar and maintained at 16°C using a thermo-electric cooler. DC needle probes provided current to the SOAs and phase electrodes, and light was coupled into and out of the device using lensed fibers mounted on piezo-controlled translational stages.

The input pump signal was produced by a tunable laser operating at 1550nm and encoded with 2^7-1 PRBS data at 10Gbps NRZ using a pattern generator and an electro-optic modulator. Erbium doped fiber amplifiers (EDFAs) were placed before and after the device to amplify the input and output signals.

The SG-DBR was tuned to several output wavelengths over 30nm, and the phase of the top MZI arm was adjusted to minimize the presence of the input signal at the output of the device for each wavelength. The output spectrum is shown on the left of Figure 2 for conversion from 1550nm to 1555nm. This demonstrates more than 20dB of separation between the input pump and converted probe signals. The corresponding eye diagrams for the input and converted signal are shown on the right of Figure 2, with the device operating in inverting mode.

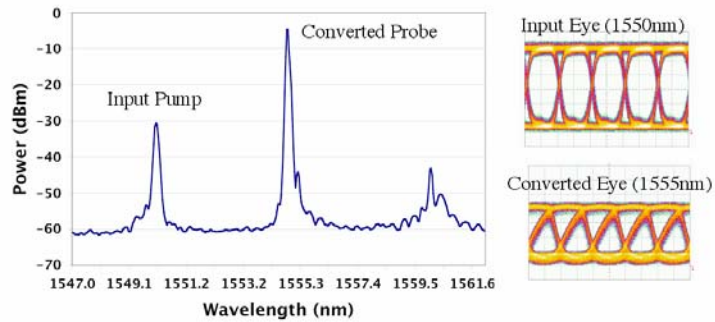


Fig. 2. Output spectra for wavelength conversion from 1550nm to 1555nm (left); with corresponding eye diagrams for the input signal (top right) and converted signal (bottom right)

Bit error rates were performed on the wavelength converter for conversion from 1550nm to two different output wavelengths of 1555nm and 1540nm. These curves are shown in Figure 4, showing approximately 3dB of power penalty from the devices.

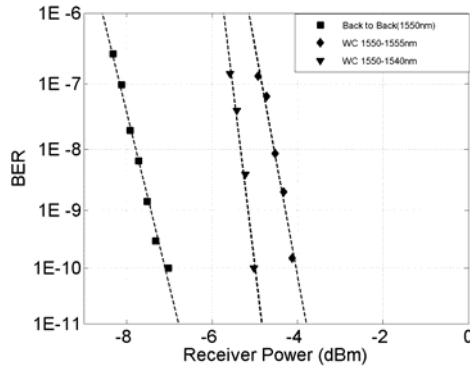


Fig. 3. Bit error rate curves for 2^7-1 PRBS data at 10Gbps NRZ for conversion from 1550nm to 1555nm, and 1550nm to 1540nm.

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