40Gbps Operation of an Offset Quantum Well Active Region Based Widely-Tunable All-Optical Wavelength Converter

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Abstract: We demonstrate for the first time 40Gbps operation of a quantum well based monolithically-integrated widely-tunable all-optical wavelength converter. We show open eyes at 40GbpsRZ with an output switching window of 6ps and low pattern dependence across a 25nm output tuning.

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1. Introduction

All-optical wavelength conversion will be a key function in future high speed wavelength agile networks due to potential advantages such as increased connection flexibility, network capacity, ease of network management, and potential reduction in optical buffering requirements [1]. Also, to meet the cost, footprint and power consumption requirements it is important to monolithically integrate these wavelength converters on a single chip. SOA-MZI based integrated wavelength converters are a good candidate for systems operating at 40 Gbps due to the ultra-fast carrier-depletion induced refractive index changes in an SOA. The maximum speed of the SOA-MZI converters is limited primarily by the carrier recovery lifetimes in the SOA. An attractive approach that has been previously demonstrated to overcome the SOA carrier recovery limitation is a differential scheme in which the fast carrier-depletion in one arm is used to switch the MZI on, while the same fast carrier-depletion is used, after a small delay, in the other arm to turn it back off [2][3].

In this paper we report for the first time on the 40Gbps operation of a widely tunable all-optical wavelength converter (TAO-WC) with on-board widely tunable laser. The wavelength converter consists of an MZI-SOA monolithically integrated with an SGDBR laser and is fabricated using an offset quantum well integration platform [6]. The offset quantum well (OQW) integration platform offers a robust and, simple, high yield approach for high density integration of active/passive components on chip. We have previously demonstrated the operation of wavelength converters in the OQW platform operating at 10GbpsNRZ [6][7]. The OQW platform offers an excellent approach for fabricating complex quantum well based, low power consumption PICs. The one potential limitation of this platform is the low confinement factor that results due to having quantum wells on top of the waveguide [7].

For the 40Gbps RZ operation reported in this paper, the devices were redesigned to optimize the performance at 40 Gbps and to add functionality for use in an external differential delay based configuration. The on-chip SGDBR laser allows us to select any output wavelength in a fast, simple and power efficient manner. We demonstrate open eyes at 40Gbps-RZ with low pattern dependence across an output wavelength tuning range of 25nm, limited by the available EDFA gain bandwidth in the receiver.

Figure 1. Device Schematic and Output tuning spectra of the widely tunable 40 Gbps all-optical wavelength converter

2. Device Design, Fabrication and Experimental setup

Figure 1 shows the device design schematic and the overlaid spectra of representative output wavelengths. The device consists of a widely-tunable SGDBR integrated with an MZI-SOA [7]. Having an on-chip SGDBR to provide the CW light and to select the output wavelength greatly increases the functionality of the device and simplifies the
operation by providing a stable, high CW coupling efficiency, and maintaining a fixed CW polarization state. The 1mm long SOAs in the Mach-Zehnder interferometer were chosen based on our previous experiments [7] to get a large phase swing in the MZI and fast SOA operation. Longer SOAs are not expected to offer any advantages in terms of phase swing or speed but rather degrade device performance with excessive ASE and decreased OSNR.

Critical components in these devices are the input pre-amplifier SOAs. The slow gain recovery in the pre-amplifiers leads to pattern dependence that can severely hamper the device performance. It is therefore very important to minimize the pattern dependence introduced by the pre-amplifier SOAs. Our current device design has 600um long pre-amplifiers; the reduced length was chosen to minimize the saturation, while still getting sufficient output power to drive the MZI. Further optimization of the pre-amplifier design for integrated high-speed tunable wavelength converters is a current topic of our research.

Figure 2 shows the experimental setup for 40Gbps wavelength conversion using an external differential arm. The input signal is obtained by first generating 10Gbps-RZ data and then using a passive optical 10:40 multiplexer to get the data at 40Gbps. The input signal is then split into two paths, which are delayed with respect to each other, this delay can be controlled in order to control the output pulse with from the TAO-WC. The two versions of the input data are coupled into the device and the relative delay and gain of the arms are adjusted to optimize the wavelength converter output. By proper selection of the relative gain between the arms, to balance the phase change, we use the fast carrier depletion process to turn the MZI on and off [3].

3. Results

40 Gbps device operation was conducted for varying output wavelengths while keeping the input data wavelength fixed at 1550nm. The 10Gbps data is PRBS $2^{21}$-1 bit stream. The input pulse width from our ring laser pulse source is 2.2ps FWHM, with an average power level of around 3dBm. The MZI SOAs in the device are biased at 250mA, and the SGDBR power going into the MZI is measured to be 10dBm. The 600um long pre-amplifier SOAs are biased at a low current of 80mA to reduce the pattern dependence.

The output wavelength was varied from 1540 to 1565nm and the converted eyes recorded using a high speed photodetector and oscilloscope, with results shown in Figure 3. We see that the converted eyes are fully open and have a high extinction ratio (>9dB). The ripple observed at the zero level in the eye is due to the electrical ringing in the 50GHz photodetector used in the receiver. Output pulse widths are measured using an auto-correlator, and for our current device, pulse widths as short as 6ps are possible with fully open eyes at the output. Figure 3(b) also shows the output pulse pattern, and we can see the pattern dependent pulse amplitude variation. Very little degradation occurs even when switching the input data from PRBS $2^{21}$-1 to PRBS $2^{23}$-1, as shown in Figure 4, signifying low pattern dependence in the converted signal.
Figure 3. 40Gbps wavelength converter operation. (a) Input data eye at 1550nm (b) Converted data showing pattern dependence (c) Converted eye at 1540nm (d) Converted eye at 1545nm (e) Converted eye at 1555nm (f) Converted eye at 1565nm

Figure 4. 40Gbps wavelength converted data at (a) prbs2^7-1 (b) prbs2^31-1 show very little difference. Longer sequences of ones and zeroes than those present in prbs 2^7-1 do not seem to further degrade performance

4. Conclusions
In this paper, we demonstrated the first ever 40Gbps operation of an offset quantum well based monolithically-integrated widely-tunable all-optical wavelength converter. Open eye patterns were obtained at 40GbpsRZ with an output switching window of 6ps, extinction ratio > 9dB and low pattern dependence across a 25nm output tuning. The offset quantum well platform used allowed robust integration of active/passive components on-chip. We believe that this demonstration of high-speed wavelength conversion using offset quantum well active region devices opens the way towards realizing more functional and complex future device generations which will have integrated on-chip delays, thus enabling the creation of a truly monolithic high-speed widely-tunable wavelength converter.

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