NOVEL COMPACT InP-BASED MONOLITHIC WIDELY TUNABLE DIFFERENTIAL MACH-ZEHNDER INTERFEROMETER WAVELENGTH CONVERTER FOR 40Gbps OPERATION

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Abstract: A novel, compact monolithic widely tunable differential SOA-Mach-Zehnder wavelength converter is described. Total internal reflection mirrors are used to realize on-chip differential delay for 40Gbps operation. This design allows reduced chip area and improved MZI balance.

1. Introduction

High functionality photonic integrated circuits (PIC) are a key technology to meet the cost, footprint and power consumption requirements of future high-speed optical networks. Wavelength conversion, in particular, is an important function for such networks that can be performed using PICs. Wavelength conversion at 40Gbps and higher data rates using InP based PICs has previously been demonstrated using a number of schemes [1-4]. SOA based integrated wavelength converters are a good candidate for systems operating at 40Gbps due to the ultra-fast carrier-depletion induced refractive index changes in an SOA. To overcome the SOA carrier recovery limitation, differential schemes have been shown in which the fast carrier-depletion is used to switch an interferometer on and, after a small delay, turn it back off using the same fast carrier-depletion process [2-4]. SOA based wavelength converters have also been used to perform 2R and 3R on the incoming signal.

In this paper we report on the first design and operation of a fully monolithic, widely-tunable differential Mach-Zehnder interferometer wavelength converter at 40Gbps RZ data rates. The wavelength converter requires only a single input fiber and a single output fiber, with the required CW source and delay being monolithically integrated on-chip, and is shown to operate across an output tuning range of over 25nm. TIR corner mirrors are used in a novel device layout to achieve a compact design that significantly reduces chip area. This device demonstrates the advantages that TIR corner mirror technology can offer for high functionality PICs.

II. Device Design and Results

The device is fabricated in the offset quantum well integration platform [5,6]. The epitaxial structure used in this platform is shown in Fig.1. It shows the active and passive regions formed on-chip by selective etching of the quantum well stack. The device consists of an on-chip widely-tunable SG-DBR laser integrated with a differential Mach-Zehnder interferometer.

To create a differential Mach-Zehnder, one of the arms of the MZI is made longer than the other by a fraction of the desired output pulse width to achieve the required differential delay. For 40Gbps operation, this delay needs to be typically around 6 to 12ps, depending on the input data pulse width. This delay is approximately 500µm to 1mm of additional length in the InP system. To implement this length difference on-chip with bends, using the same weakly confined waveguides used in the rest of the device, can lead to a very large footprint. To address this problem we use TIR corner mirrors [7]. The TIR mirrors are fabricated using a self aligned two layer process, that allows us to define the mirror facet along with the ridge layer and avoids any potential misalignment issues between the mirror facet and the waveguides.

The device has a single data input and a single output for the converted data. The input signal is amplified using a pre-amplifier SOA and coupled to an on-board widely-tunable SG-DBR laser. The coupled signal is then sent through a differential SOA-MZI. To achieve the required length differential the MZI is folded back towards the input using two TIR corner mirrors in each arm, resulting in one arm...
being longer than the other. The length differential can be easily designed by changing the location of the TIR corner mirrors. The device schematic and mirror SEMs are shown in Fig.2.

This folded layout results in a compact device that is only 0.8mm wide and 2.9mm long for a total chip area of under 2.4mm². The input and output waveguides are on the same facet and so require only a single AR-coating per device. The layout also results in the number of mirrors in each arm being the same, which balances the MZI with respect to any excess loss from the mirrors. This balance is necessary in achieving a high extinction ratio at the output of the MZI.

The on-board SGDBR laser is used to select the outgoing signal wavelength. Fig.3. shows the tuning spectra of the SGDBR laser. The laser itself can tune by over 35nm, but measurable the operating range of our device is limited by the gain bandwidth of the EDFA used in the receiver. Fig.4. shows the experimental setup used for characterizing these devices. The setup consists of a 40Gbps RZ data transmitter. The data signal is filtered, amplified and coupled into the device. A variable attenuator is used at the input to control the input power level and a polarization controller is used to maximize coupling to the TE polarization state. The output signal from the device is then filtered to remove the input signal and finally the converted data is amplified and sent to a 40Ghz detector. Fig.5. shows the output spectrum of the device for one set of input and output conditions.

The device operation is shown in Fig.6 for three different output wavelengths. The input wavelength is kept fixed at 1550nm, and the SGDBR is tuned from 1539 to 1563nm. We can see open eye patterns at 40Gbps-RZ for all output wavelengths.
The pre-amplifier SOAs in our current devices induce significant pattern dependence in the input signal, resulting in the eye closure at the high-level. Fig.6e clearly shows the pattern dependence in the output data pattern. Future work will address this issue through optimization of the pre-amplifier designs.

III. Conclusion

In this paper, we demonstrated a compact fully monolithic InP-based tunable differential high-speed wavelength converter. The novel device design incorporates an integrated signal delay of 6ps, designed for 40Gbps-RZ operation. The device also demonstrates the benefits of TIR corner mirror technology in designing compact high functionality PICs. Open eye patterns are shown for the converted signal with 25nm of output tuning range.

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Figure 6. Device performance showing open converted eyes at 40Gbps (a) Input eye at 1550nm (b) Output eye at 1539nm (c) Output eye at 1554nm (d) Output eye at 1563nm (e) Converted data at 1554nm showing pattern dependence