40 Gb/s NRZ Wavelength Conversion with Enhanced 2R Regeneration Characteristics using a Differentially-biased SOA-MZI switch

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Abstract We present error-free 40 Gb/s NRZ signal wavelength conversion with a differential biasing scheme in a SOA – Mach Zehnder Interferometer. Experimental performance analysis shows 1.7 dB negative power penalty and enhanced 2R regenerative characteristics.

1. Introduction

Semiconductor Optical Amplifier-Mach Zehnder Interferometers (SOA-MZI) have been shown to be capable of Wavelength Conversion (WC) with Return-to-Zero (RZ) signals at rates well beyond 100 Gb/s [1]. Such achievements have not been matched with the NRZ format due to the continuous carrier depletion in the SOAs. As bit periods approach or go below the characteristic gain recovery time constant, the standard single control WC scheme results in severe patterning and pulse broadening. These effects cannot be mitigated with the differential phase modulation of two control schemes used with RZ signals [1]. At 40 Gb/s two main successful approaches of WC with NRZ signals have been reported. The differential scheme uses a sub-bit period relative time delay between two, identical data control signals [2] and the bidirectional scheme uses a counter-propagating arrangement of these identical control signals [3]. More recently, we have proposed and demonstrated at 10 Gb/s, a differentially biased SOA-MZI scheme that provides NRZ wavelength conversion with enhanced 2R regenerative characteristics [4]. Our scheme uses a differential push-pull arrangement of counter-propagating identical control signals and is also assisted with a separate external continuous wavelength (CW) to bias the SOAs.

In this letter, we extend this concept to 40 Gb/s NRZ signal wavelength conversion and show improved 2R regenerative properties. We use the counter-propagating push-pull control arrangement, but this time the differential biasing of the SOAs in the MZI is achieved with two external CW signals, one for each of the SOAs. In this way it is possible to achieve good balance both in the gain and phase imparted to the signals in the two arms of the MZI.

2. Experimental setup

Figure 1 illustrates the experimental setup that was used for the performance evaluation of the new wavelength conversion scheme at 40 Gb/s and its comparison with the other NRZ wavelength conversion solutions. The set-up consists of an optical signal generator, a commercially available, hybridly integrated, SOA-MZI regenerator fabricated by CIP Technologies and a 40 Gb/s receiver. The optical signal generator employs a CW signal at 1560 nm (CW1) that was injected into a Ti:$LiNbO_3$ electro-optic modulator (MOD) driven by a 40 Gb/s NRZ pulse pattern generator, producing a 2^7-1 PRBS data pattern. This pulse train was then inserted into a variable optical attenuator (VOA) and an erbium doped fibre amplifier (EDFA) to degrade its quality in terms of optical signal to noise ratio (OSNR) prior being split into two identical streams that comprise the two MZI control signals, denoted as control 1 (CTR1) and control 2 (CTR2), respectively. The extinction ratio of these signals could also be reduced with the polarization controller prior to the electro-optic modulator. The NRZ data content was wavelength converted to 1553 nm and was finally filtered with a 2 nm bandwidth filter. In the standard WC scheme, only the degraded CTR1 was fed into the MZI as control signal. In the bidirectional scheme, both CTR1 and CTR2 signals were inserted in counter-propagating directions

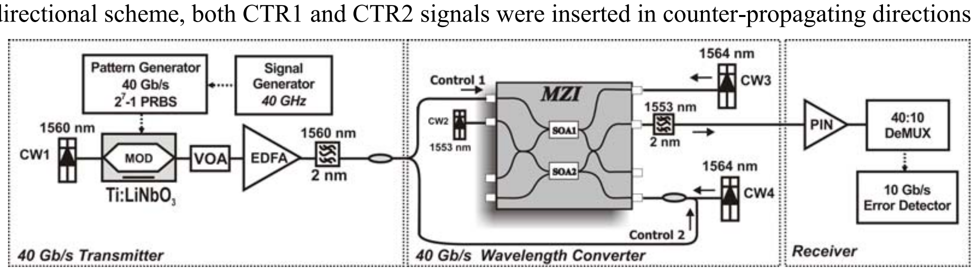

Figure 1: Experimental setup

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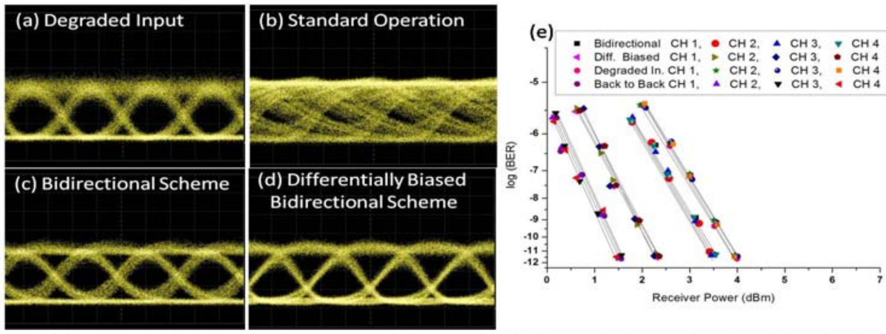

Figure 2: 40 Gb/s NRZ Eye diagrams for the (a) Degraded Input signal, (b) Standard Operation, (c) Bidirectional Scheme, (d) Differentially Biased Bidirectional Push-Pull Scheme, (e) BER measurements. The timescale is 10 ps/div

into the upper and lower SOAs, respectively, of the MZI. The two control signals were synchronized so as to arrive simultaneously at the two SOAs yielding an inverted replica of the incoming data at the MZI's output. In the differentially biased bidirectional push-pull scheme, two additional CW signals at 1564 nm (CW3 and CW4) counter-propagate SOA1 and SOA2. They allowed for full and independent adjustment of the gain saturation levels and associated phase shifts induced in the CW2 signal travelling in the two arms of the MZI. The key role of the external CW signals is to help bias the gains of the two SOAs so as to provide a π differential phase shift between the input signal components when no control pulse is present. Power level adjustment between CTR1 and CTR2 ensures that whenever a control pulse is present, equal gains and phase shifts are experienced by the two CW2 input signal. This also results in optimized destructive interference at the MZI's switches output port and an ideal '0' wavelength converted level. The SOAs of the MZI were 1.6 μm long multi-quantum-well structures with 500 μm mode converters at both ends, a small-signal gain of 28 dB and 25 ps 1/e gain recovery time under gain saturation. Both SOAs were driven at 300mA. BER measurements were obtained for the wavelength converted signal after electrical de-multiplexing to 10 Gb/s. The power requirements for the three WC schemes were the following: 7dB for the input CW and 6.9 dB for the CTR1 for the standard scheme, 5.6 dB, 4.7dB and 4.3 dB for the Input CW, CTR1 and CTR2 respectively for the Bidirectional scheme and 4dB, 6.9dB, 4.7dB, -8.9dB and 3.2 dB for the Input CW, CTR1, CTR2, CTR3 and CTR4 respectively for the Differential Biased Push-Pull scheme.

3. Results and Discussion

Figure 2 shows the eye diagrams of the degraded input and the wavelength converted signal at the output of each scheme. An improvement in signal quality is observed for the differentially biased push-pull scheme compared to the standard and bidirectional schemes. The superiority of the differentially biased push-pull scheme is also observed in the Bit Error Rate (BER) measurements of figure 2 e). For an input signal degraded by 2.5 dB with respect to the back-to-back signal, the bidirectional scheme provides 0.4 dB improvement and the differentially biased push-pull scheme provides improvement of 1.7 dB. With respect to the initial back-to-back signal, the schemes incur 2.1 and 0.8 dB power penalties and hence the superior performance of the differentially biased push-pull scheme. Finally it should also be noted that for the standard scheme an error floor at 10^{-3} was obtained even for maximum input power at the receiver.

4. Conclusion

We have presented a new all-optical wavelength conversion scheme for NRZ data signals at 40 Gb/s with improved 2R regeneration capabilities Our technique utilizes a differentially biased SOA-MZI switch operating in a bidirectional configuration.

Acknowledgement

The work described in this paper was carried out with the support of the EURO-FOS Network of Excellence funded by the European Commission through the 7th ICT-Framework Programme.

References

[1] S. Nakamura et al, "168-Gb/s all-optical wavelength conversion with a symmetric-Mach–Zehnder-type switch" IEEE PTL, 13, (2001) 1091

[2] S. Nakamura et al, "Bit-rate-transparent nonreturn-to-zero all-optical wavelength conversion at up to 42 Gb/s by operating symmetric-Mach-Zehnder switch with new scheme" OFC 2004, (2004), FD3

[3] M. Hattori et al, **"**Bidirectional Data Injection Operation of Hybrid Integrated SOA–MZI All-Optical Wavelength Converter" IEEE/OSA JLT, 25 (2007), 512

[4] K. Vyrsokinos et al, "Wavelength conversion for NRZ signals with enhanced regenerative characteristics", OFC 2009, (2009), JWA32