DTU Library

# All-optical 2R regeneration at 40 Gbit/s in an SOA-based Mach-Zehnder interferometer

**Wolfson, David; Hansen, Peter Bukhave; Fjelde, Tina; Kloch, Allan; Janz, C.; Coquelin, A.; Guillemot, I; Gaborit, F.; Poingt, F.; Renaud, M.**

*Published in:*
Optical Fiber Communication Conference, 1999, and the International Conference on Integrated Optics and Optical Fiber Communication. OFC/IOOC '99. Technical Digest

*Link to article, DOI:*
10.1109/OFC.1999.766069

*Publication date:*
1999

*Document Version*
Publisher's PDF, also known as Version of record

**All-optical 2R regeneration at 40 Gbit/s in an SOA-based Mach-Zehnder interferometer**

D. Wolfson, P. B. Hansen, A. Kloch and T. Fjelde

Research Center COM, Technical University of Denmark, Bldg. 349, DK - 2800 Lyngby, Denmark
Telephone: +45 4588 1444, Fax: +45 4593 6581, e-mail: dw@com.dtu.dk

C. Janz, A. Coquelin, I. Guillemot, F. Gaborit, F. Poingt and M. Renaud

OPTO+, Groupement d'Intérêt Economique
Route de Nozay, 91460 Marcoussis, France, Alcatel Corporate Research Center
Telephone: +33 (0)1 6963 1561, Fax: +33 (0)1 6963 1422, e-mail: Christopher.Janz@alcatel.fr

**Introduction:** All-optical regeneration is essential for future high-speed optical systems to suppress noise and jitter, which severely limits the network node cascadability. Several techniques for all-optical regeneration have been investigated, where some of the most promising results have been achieved with interferometric wavelength converters (IWC) [1,2]. In these devices, 2R regeneration is accomplished due to the non-linear transfer function of the converter. Moreover, all-optical 3R regeneration has been demonstrated in IWCs at 20 Gbit/s [3]. However, so far, regeneration has been performed with simultaneous wavelength conversion at the expense of an increased complexity, i.e., a CW laser as well as an optical filter at the output of the converter are needed. In the approach described in [4], regeneration was suggested using only the data signal in an interferometric structure incorporating gain-clamped SOAs as phase shifters.

Here, we demonstrate for the first time at 40 Gbit/s all-optical 2R regeneration in an all-active SOA-based interferometric Mach-Zehnder structure using only the data signal. The regenerative capabilities combined with an input power dynamic range of 16 dB demonstrate the feasibility of this simple technique at very high bit rates.

**Experimental set-up:** The experimental set-up for the all-optical regeneration scheme is shown in Fig. 1, where the 2R regenerator is an all-active Mach-Zehnder interferometer with 1200 μm long interferometer arms [5]. The 40 Gbit/s data signal at 1554 nm is generated by passive multiplexing of 10 Gbit/s external modulated pulses from a gain switched DFB laser. The signal is then transmitted through an in-line EDFA, where an attenuator at the input of the EDFA is used to control the input power. Thus, the optical signal-to-noise ratio (OSNR) at the input of the 2R regenerator can be controlled. The signal is then coupled into the all-active Mach-Zehnder interferometer, where it splits equally in the two interferometer arms and recombines at the output, either constructively or destructively depending on the phase difference between the two interferometer arms. We note that the phase difference is introduced by asymmetrically biasing of the interferometer. Finally, the signal is demultiplexed to 10 Gbit/s by an EA-modulator before detection and BER measurements. It is important to note that no filter is required at the output of the 2R regenerator, since only one wavelength is used.

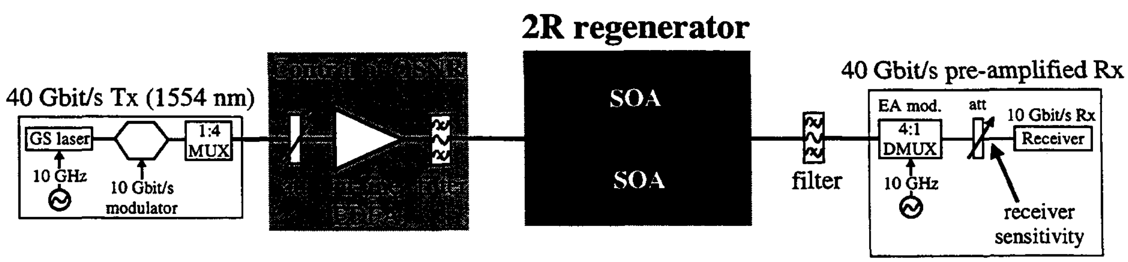


*Fig. 1: Experimental set-up for all-optical 2R regeneration at 40 Gbit/s.*

**Results:** In Fig. 2.a, the measured bit error rate against received power is showed for both the back-to-back case and the output signal from the 2R regenerator. As seen, inserting the 2R regenerator at 40 Gbit/s results in a negligible penalty of ~0.2 dB. The clear and open eye diagram showed in Fig. 2.b, with an extinction ratio of ~13 dB also verifies the good performance. Additionally, operation of the 2R regenerator is non-inverting as seen in Fig. 2.b, which is desirable with respect to transmission due to the chirp characteristics of an SOA-based interferometer [6]. We also note that the 2R regenerator is lossless, i.e., both the input and the output power are –5 dBm (in the fibres), clearly a very important feature for future all-optical networks.

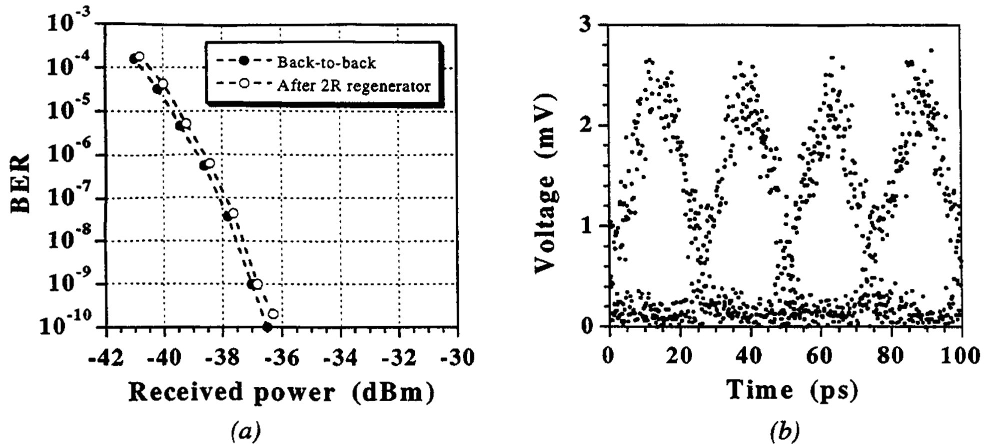


*Fig. 2: (a) Bit error rate for back-to-back and the output signal from the 2R regenerator, (b) eye diagram after the 2R regenerator. The signal wavelength is 1554 nm.*

Furthermore, this scheme has been shown to result in a transfer function close to that of a decision gate, a transfer function measured for a Michelson interferometer is shown in Fig. 3 [7]. This is in contrast to the transfer function obtained from an interferometric structure performing wavelength conversion.

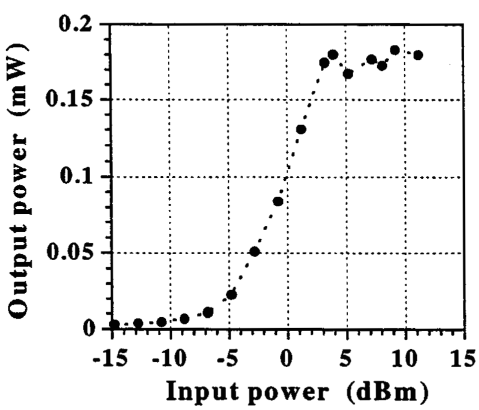


Fig. 3: Measured output power as function of input power to a Michelson interferometer [7].

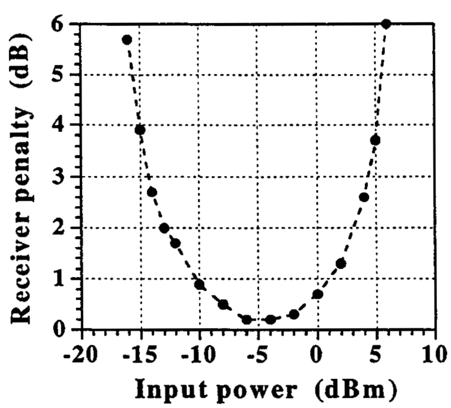


Fig. 4: Measured receiver penalty as function of the input power to the 2R regenerator. The EDFA input power is 0 dBm.

A very desirable feature resulting from the decision gate characteristic, is a large input power dynamic range (IPDR). This is demonstrated in Fig. 4, showing the receiver penalty as a function of the signal input power to the 2R regenerator. As seen in Fig. 4, the IPDR is as large as ~16 dB at 40 Gbit/s (measured at 2 dB of penalty since a pre-amplified receiver was used). It is emphasised that no control scheme was applied when measuring the IPDR. For comparison, the IPDR of an interferometric wavelength converter is limited to a few dB at the same bit rate.

The regenerative capabilities of the 2R regenerator are demonstrated in Fig. 5 showing the excess receiver penalty with and without regeneration as function of the in-line EDFA input power. As seen, noise suppression is achieved for an EDFA input power below –20 dBm. As an example, a ~2.5 dB lower input power to the EDFA is allowed at a pre-amplified receiver penalty of 2 dB.

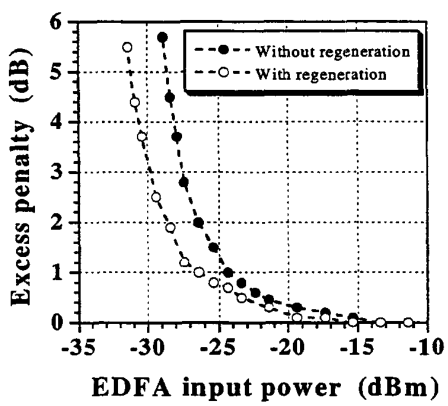


*Fig. 5: Excess penalty as function of the EDFA input power with and without regeneration.*

Therefore, taking the simplicity of the regeneration scheme as well as the good performance into account, this approach is a competitive technique for all-optical 2R regeneration, where wavelength conversion is not needed.

**Conclusion:** A scheme for all-optical 2R regeneration in an all-active SOA-based interferometric Mach-Zehnder structure has been demonstrated for the first time at 40 Gbit/s using only the data signal. Regenerative capabilities combined with an input power dynamic range of ~16 dB demonstrates the feasibility of this technique at very high bit rates.

**References:**


[1] D. Chiaroni et al., Proc. of ECOC'97, Vol. 5, pp. 41-44, Edinburgh, UK, 1997.

[2] B. Lavigne et al., In Technical Digest of OFC'98, paper Th07, San Jose, USA, 1998.

[3] L. Billés et al., Proc. of ECOC'97, Vol. 2, pp. 269-272, Edinburgh, UK, 1997.

[4] G. Morthier et al., IEEE Photonics Technology Letters, Vol. 10, No. 8, pp. 1162-1164, 1998.

[5] C. Janz et al., In Technical Digest of OCF'99, paper FB3, San Diego, USA, 1999.

[6] T. Durhuus et al., Journal of Lightwave Technology, Vol. 13, No. 6, pp. 942-954, 1996.

[7] D. Wolfson et al., IEE Electronics Letters, Vol. 35, No. 1, pp. 59-60, 1999.