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Standard mode 40Gbit/s performance analysis of the evanescent coupling “active-passive” Mach-Zehnder interferometers for all-optical regeneration

A. Labrousse, B. Dagens, R. Brenot, B. Lavigne, S. Squedin, B. Martin, S. Fabre, M.L. Nielsen, M. Renaud

This letter presents input data signal power dynamic range and noise tolerance measurements at 40Gbit/s on Mach-Zehnder Interferometers from the evanescent coupling “active-passive” integration scheme, working in standard mode. Influences of the device configuration and high bit rate constraints are emphasized.

Introduction: Data signal impairments, due to switching nodes [1] and optic fiber transmission links [2], make the all-optical 3R regeneration an essential data processing function for the future all-optical networks.

Cascaded all-active SOA (Semiconductor Optical Amplifier)-based Mach-Zehnder interferometers, with high Input Power Dynamic Range (IPDR) [3], have shown excellent regenerative capabilities in a recirculating loop up to 40Gbit/s in differential scheme [4]. New modular devices, from the evanescent coupling “active-passive” integration scheme, realize 40Gbit/s wavelength conversions in standard mode with a lower total consumption and without detectable bit error floor, thanks to structural modifications of their active zones [5]. A high IPDR is important to ease the insertion of those devices into the transmission systems and a high noise resistance prefigures important regenerative capabilities. Both parameters for those new devices are studied at 40Gbit/s in standard mode in this letter.

40Gbit/s data signal IPDR: The data signal IPDR was measured and compared at 40Gbit/s for two configurations of the evanescent coupling “active-passive” SOA-based MZI [5]: the two-SOAs device which includes only the two conversion SOAs, and the four-SOAs device which includes two more peripheral SOAs placed on the data signal entries. Only the standard working mode (the data signal is injected into a single branch of the MZI (no differential mode)), and the co-propagation scheme (the data and the continuous signal propagate in the same way) are considered (see Fig.1). The modulation and detection set up are identical to the ones described in [5].

The penalty was noted for a 10^{-10} BER (Bit Error Rate) of the converted signal and the input data signal power was varied from 0dBm to 9dBm, depending on the device. The threshold voltage and the delay of the optoelectronic receiver were unchanged for each measurement. For the device with peripheral-SOAs, conversions were realized from 1552nm to 1560nm with a 13dBm continuous input power, a 900mA injection current in the conversion-SOA, and for the device without peripheral-SOAs from 1552nm to 1555nm with a 9dBm continuous input power and a 750mA current. Results and the data signal peripheral-SOA current corresponding to each input data signal power for the device with the peripheral-SOAs are reported on the Fig.2. Without any control of the peripheral-SOA, the data signal IPDR corresponding to a 1dB excess penalty is close to 1.5dB for both devices. The optimal input data signal power of the four-SOAs device is 2dB more important than for the two-SOAs device, because of excess insertion losses possibly due to its two extra active-passive transitions. The data signal IPDR is attractively increased up to more than 8dB when the level of the peripheral-SOA current is adjusted, in order that its gain compensates for the input power fluctuations of the data signal. This is one great asset of the presence of the peripheral-SOAs.

Noise resistance and peripheral-SOAs current at 10Gbit/s: The noise resistance of the MZI with peripheral-SOAs was evaluated at 10Gbit/s, when varying the level of the data signal peripheral-SOA current from 50mA to 100mA. For each value of current, the power of the data signal was adjusted and the minimum input data signal OSNR (Optical Signal Noise Ratio), under which the BER floor of the converted signal was greater than 10^{-9} , was determined (see Fig.3). A 0.1nm resolution for the optical spectrum analyser was used to measure the OSNR. Conversions were realized from 1552nm to 1540nm with a 10dBm input continuous signal power. In order to control the OSNR of the input data signal, the latter was coupled with the ASE (Amplified Spontaneous Emission) of an EDFA (Erbium Doped Fiber Amplifier), which passed through a variable attenuator, thanks to a 50:50 coupler. The level of the coupled ASE power fixes the OSNR.

When the current of the peripheral-SOA differs from the range value 55mA-60mA (around its transparency point), the tolerated minimum input OSNR increases. Therefore, the noise resistance of the device decreases since a less noisy data signal is necessary to make the same error rate. When its peripheral-SOA current is increased, the ASE power propagating along the whole structure is more important. When it is decreased, the noise figure of the peripheral-SOA increases, that can mainly explain the signal impairment. This happens for instance when the peripheral-SOA current is changed to compensate the input data signal power fluctuations. So

the variation of the peripheral-SOA current, which allows to increase the IPDR of the device, induces a decrease of its noise resistance. Thus, there is a compromise to find between a high IPDR and a high noise resistance.

Noise resistance at 40Gbit/s: The excess penalty for a 10^{-10} BER of the converted signal against the data signal noise was measured at 40Gbit/s in the optimum conditions, with the 55mA peripheral-SOA current. Results are shown on the Fig.4.

The input data signal OSNR is measured with a resolution of 1nm in order to integrate all the data signal power. Anyway the presented results correspond to a 0.1 nm resolution in order to ease comparison with usual measurements. The same operating conditions as for the IPDR measurement at 40Gbit/s are applied, with a 1.9dBm input data signal power. The experimental set up used to degrade the input data signal OSNR is unchanged. The noise tolerance of the device is much less important at 40Gbit/s than at 10Gbit/s. A 1dB excess penalty is reached for a 29dB OSNR at 40Gbit/s, compared to only 20dB at 10Gbit/s. This degradation of the noise resistance is not due to the device itself, but is mainly inherent to the increase of the bit rate (four times). The noise receiver depends directly on it and the bit rate increase decreases the bit energy detected by the receiver. Thus, the noise resistance capability of a single device decreases with the bit rate. Nevertheless, 3R regeneration capabilities at 40Gbit/s have already been proved by cascade experiments via the use of a recirculating loop, with a regenerator formed by one SOA and one two-SOAs MZI [6]. Good regeneration capabilities at 40Gbit/s have been shown with those new devices, which turn out to be more attractive: they require less important injection currents and are more easy to handle.

Conclusion: Thanks to high bit rate capabilities, the IPDR and the noise resistance of evanescent coupling “active-passive” MZIs have been measured for the first time at 40Gbit/s in standard mode and without clock injection. The integration of peripheral-SOAs increases attractively their IPDR, at more than 8dB. Nevertheless, the existence of a compromise between a high IPDR and a high noise resistance has been established.

A decrease of their noise resistance is noted at 40Gbit/s, inherent to the bit rate increase between 10Gbit/s and 40Gbit/s. Nevertheless, the excellent regeneration capabilities at 40Gbit/s have been demonstrated with these new devices, including furthermore a reduced electrical consumption and an easier handling.

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Figure captions

Fig.1 MZI in standard working mode and co-propagation scheme. Conversion and peripheral-SOAs are illustrated. P_s, λ_s : data signal input power and wavelength, P_c, λ_c : continuous signal input power and wavelength.

Fig.2 Data signal input power dynamic range (IPDR) @40Gbit/s of evanescent coupling “active-passive” MZIs, and the corresponding current of the peripheral-SOA I'_4 .

■ : MZI without peripheral-SOA

★ : MZI with peripheral-SOA, without current control of the peripheral-SOA

☆ : MZI with peripheral-SOA, with current control of the peripheral-SOA

○ : Current control of the peripheral-SOA

Fig.3 Noise resistance @10Gbit/s against the peripheral-SOA current I'_4 .

Fig.4 Excess penalty @40Gbit/s against input data signal Optical Signal Noise ratio (OSNR)

Figure 1

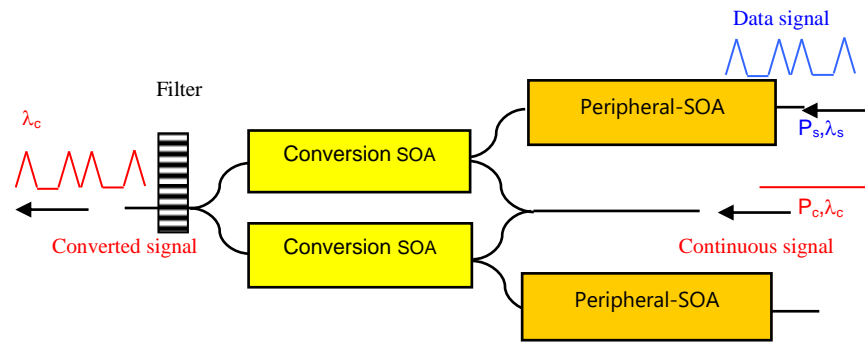


Figure 2

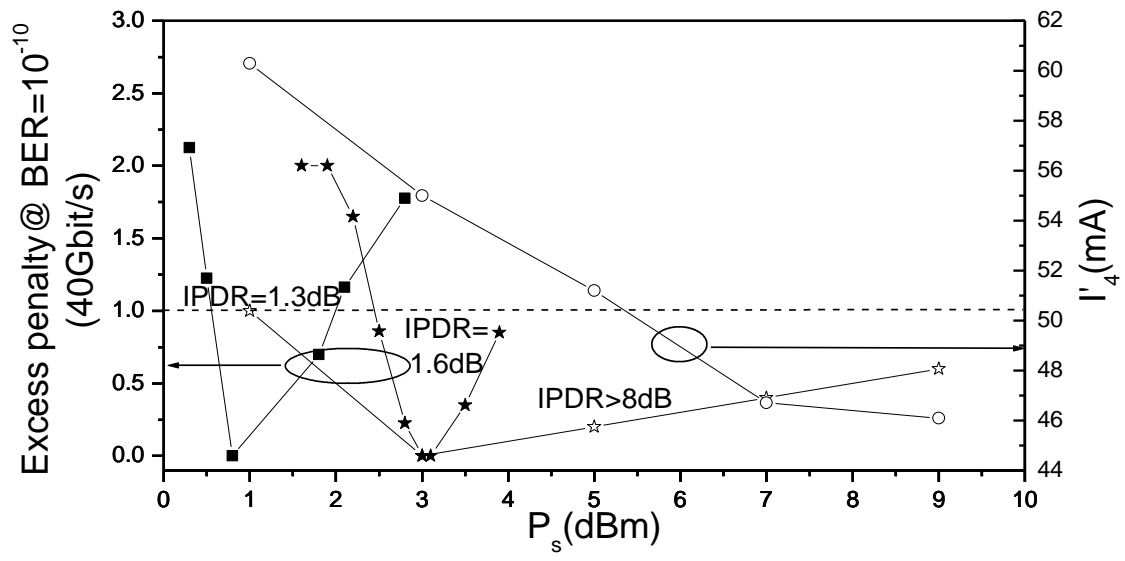


Figure 3

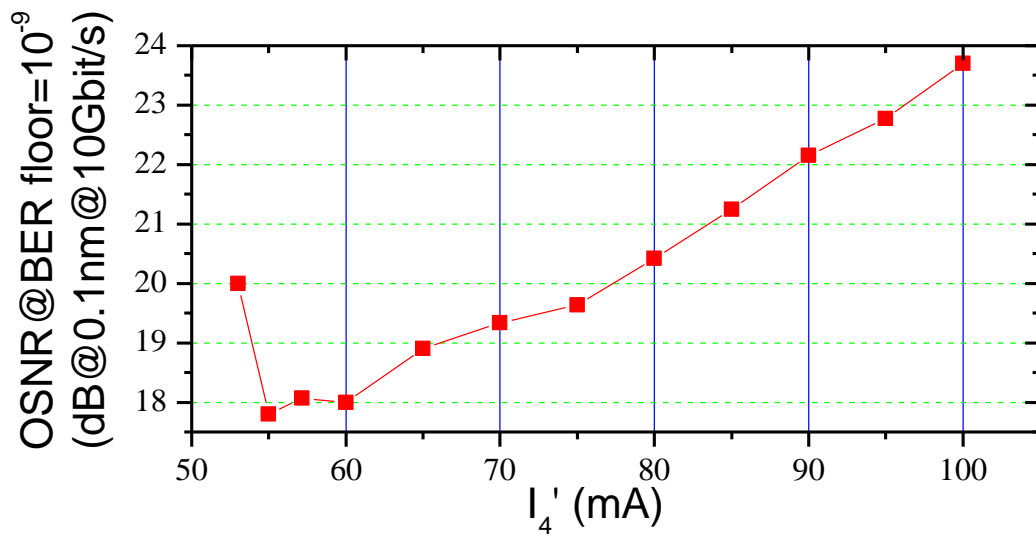


Figure 4

