Low chirp RSOA using multi-sections devices for optical access networks

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Abstract—**Optimized bi-electrode reflective semiconductor optical amplifier is used as remote modulator. It is demonstrated both theoretically and experimentally that multi-sections devices reduce the chirp, enabling only 4.5 dB penalty for transmission on standard fibre at 2.5 Gbit/s over 50 km.**

Keywords-Access control; Modulation; Optical fiber communication; Semiconductor optical amplifiers

I. Introduction

Today, high speed connectivity is required to fill users demand. Wavelength division multiplexed (WDM) passive optical networks (PONs) is one of the possible scenario for the next generation of access network. Colorless remote modulator such as injection-locked Fabry-Perot lasers [1], reflective electro-absorption modulator (EAM) [2] and Reflective EAM-semiconductor optical amplifier (SOA) [3] are considered as potential candidates. However, in order to develop large scale commercially available services, low cost solutions have to be investigated. Its large optical bandwidth, high gain and large electro-optic bandwidth make RSOA an ideal candidate fullfilling most requirements [4]. Recently, the first commercial service with R-SOA based hybrid PON has been announced for 1024 subscribers at 1.25 Gbps over 20 km[5]. However the performance of SOAs is still to be improved for higher bit-rate and longer transmission distance. In particular, the chirp due to direct modulation of the RSOA becomes a limiting factor for transmission distance approaching 50 km and bit rate up to 10 Gbit/s. In this paper, we demonstrate, for the first time, both theoretically and experimentally the chirp reduction by using adequate RSOA electrodes configuration. The penalty introduced over a 50 km transmission at 2.5 Gbps is reduced to 4.5 dB, corresponding to 1.5 dB of improvement compared to the single electrode RSOA configuration.

II. Multi-electrodes model and carrier density simulation

In SOA devices, the modulation of refractive index, upon carrier density modulation, introduces a phase change of the incoming continuous wave signal, commonly called chirp. Because the carrier density along a RSOA is not homogenous, the location where is applied the current modulation strongly affect the device behaviour. A time domain model for RSOAs was developed based on the carrier rate and wave propagation equations. In this model, the non linear gain saturation effect and the amplified spontaneous emission on carrier density have been included. The analytical approach follows the same analytical formalism of Connelly static model [6]. The active zone thickness and width are 0.5 µm and 0.6 µm respectively. A constant DC current of 30 mA with ± 20 mA modulation is used with bi-electrode devices as in the experimental set up. A DC current of 35 mA is applied on the input electrode when modulating the mirror electrode (SOA2) and a DC current of 100mA is used in the other case (modulation of the input section: SOA1). Both current values correspond to optimized conditions in order to obtain low penalties. In classic SOA, strong carrier depletion at the input section is observed, due to the high amplified spontaneous emission (ASE) power in the RSOA at ON state, and this effect is reduced at OFF state. Due to spatial hole burning (SHB), both electrodes are not independent in the different configuration and the modulation of one electrode strongly affects the carrier density level of the

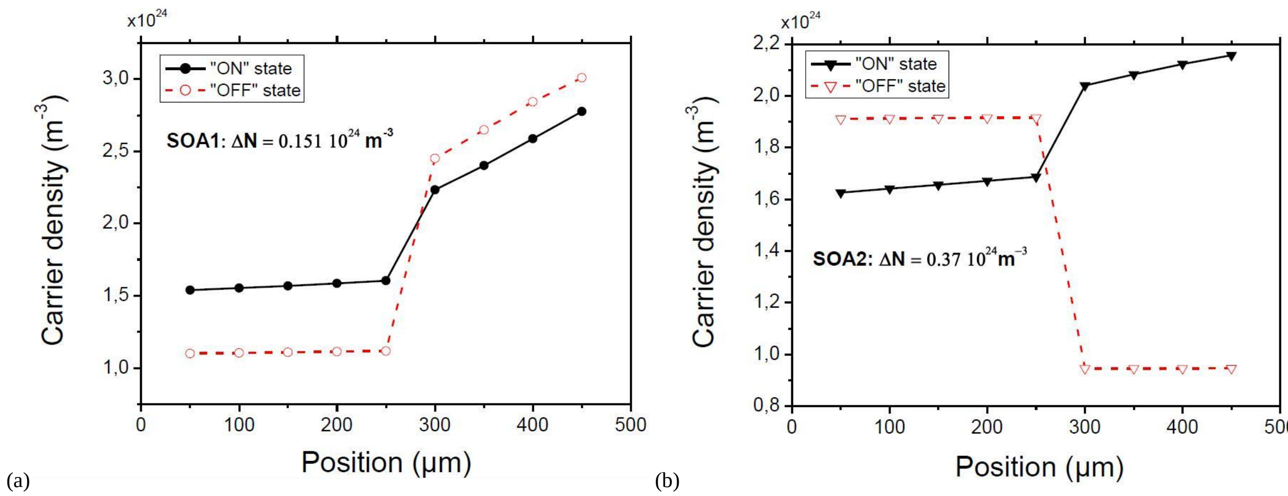

Figure 1. Simulated carrier density along bi-electrode RSOA with input (a) and mirror (b) electrode modulation for "ON" and "OFF" state

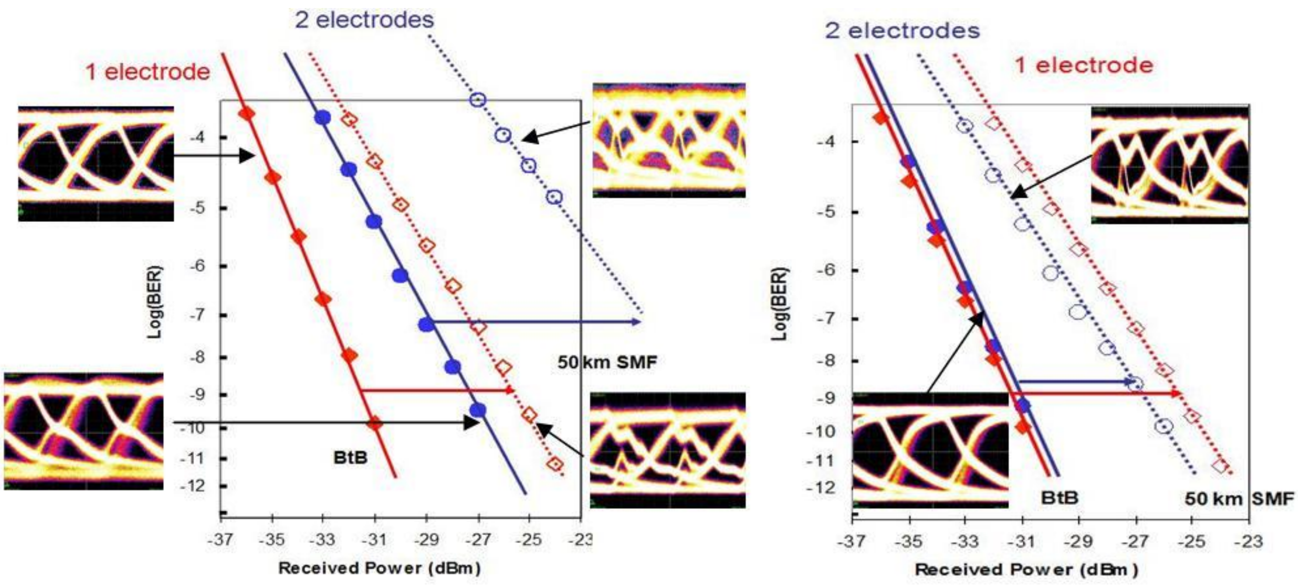

Figure 2. BER curves as a function of the received power in Back-to-Back and after 50 Km transmission for one and two electrodes configurations. In bi-electrode configuration, the modulation I_{HF} is applied to the mirror section and DC current I_{DC} to the input section (left) or inversely (right)

second one. As a result, large carrier density variation is observed in the input section when modulating the mirror section (SOA2, Fig. 1 (b)), which explains the limitation of this configuration. On the contrary, modulating the input section mainly affects this section (SOA1, Fig. 1 (a)), since in the mirror region carrier density is less impacted by photon density distribution variations.

III. Device characteristics and experimental results

The RSOA structure consists of thick tensile-strained InGaAsP active zone with high optical confinement value (around Γ~80%) and polarization independent gain. We minimize internal reflections using 7° tilted facet and AR coating. Coupling losses lower than 2dB and gain values up to 25 dB have been measured. The gain peak and gain bandwidth values were respectively 1510 nm and 50 nm. Proton implantation was used in order to isolate electrically the two electrodes. A standard reflective scheme is used including a transmission link over 50 km of fiber. An external cavity laser or a standard DFB is used to launch a CW signal into the system at λ = 1540 nm through an optical circulator (OC). The CW signal is coupled into the RSOA whose current is modulated to generate the upstream signal. The RSOA is biased with a 2^{31}-1 pseudo-random bit sequence (PRBS) at 2.5 Gbps, and the output of RSOA is coupled back into the OC. The modulated signal propagates through a 50 km long Single Mode Fiber (SMF). A variable optical attenuator is placed before the receiver in order to analyze the performances of the transmission. Bit-error-rate (BER) measurements were performed using an error analyzer. A back-to-back and transmission through 50 km SMF at 2.5 Gbps has been achieved using RSOA with one and two electrodes. Fig. 2 displays BER measurements and unfiltered eye diagrams performed at 1540 nm and 2.5 Gbps as a function of the received power for one electrode and bi-electrode RSOA. The penalty due to the transmission with a single electrode device is equal to 6 dB. With the bi-electrode device, penalties of 8 or 4.5 dB are obtained respectively for configurations SOA1 and SOA2. These transmission results clearly show the correlation between the penalty and the chirp: higher is the SOA chirp, larger is the transmission penalty. The minimum transmission penalty is achieved using an adequate bi-electrode configuration. However, the configuration SOA1 corresponds to a moderate average current in the input section, and leads to a degradation of the noise factor. This drawback can be overcome with a tri-electrode configuration.

IV. Conclusions

We demonstrate that penalties due to the transmission over 50 km SMF at 2.5 Gbps are reduced from 6dB to 4.5dB using an optimized multi-electrodes device. However the use of a non adequate bi-electrode configuration increases transmission penalties up to 8 dB. We believe this effect will be even more pronounced when 10 Gbps RSOA will be used. Further works are underway to study more complex, optimized multi-electrodes schemes (Tri-electrode and more).

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