Long delay optical feedback sensitivity of Hybrid III-V/SOI Directly modulated DFB lasers

A. Gallet[1, 2], K. Schires[2], H. Huang[2], M. Song[2], A. Accard[1], D. Make[1], S. Olivier[3]
G.-H. Duan and F. Grillot[2, 4]
antonin.gallet@3-5lab.fr
(1) LTCI, Telecom ParisTech, Université Paris Saclay 46 rue Barreau, 75634 Paris Cedex 13, France
(2) III-V Lab, a joint lab of Alcatel-Lucent, Thales and CEA, 1 Avenue A. Fresnel, 91767 Palaiseau cedex, France
(3) CEA Leti, Minatec, 17 rue des Martyrs, 38054 Grenoble, France
(4) Center for High Technology Materials, University of New-Mexico, 1313 Goddard SE, Albuquerque, NM87106-4343, USA

Abstract: Hybrid III-V/SOI DFB lasers subjected to external optical feedback is analyzed. Its impact on optical spectrum, eye diagram and bit error rate (BER) is discussed.
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1. Introduction

Low-cost and efficient photonic integrated circuits (PICs) using silicon photonics are an attractive solution to meet ever-increasing bandwidth demands in access, datacom and metropolitan networks. In order to provide efficient light sources for silicon photonics, hybrid III-V/SOI lasers have been fabricated using wafer-bonding technique [1]. In particular, direct modulation of light with hybrid distributed feedback (DFB) lasers has been unveiled [2]. However, despite some efforts, no on-chip optical isolators with sufficient isolation ratio and low loss have been reported so far hence understanding the effects of optical feedback is of paramount importance for PICs. Indeed, optical feedback is known to alter modulation properties of directly modulated DFB lasers [3-4]. In this paper, we analyze the effect of a long delay optical feedback on the direct-modulation properties of a hybrid III-V/SOI DFB laser.

2. Hybrid laser chip description and basic characteristics

Fig. 1(a) displays a cross section of the λ/4 shifted DFB laser under study. Fig. 1(b) depicts the L-I-V curve from which the laser threshold is 40 mA at 20 °C. In the following, all measurements were performed at 110 mA where 1 dBm were coupled using an anti-reflection coated lens-ended fiber. The optical spectrum reported in Fig. 1(c) confirms the single mode behavior with a side mode suppression ratio (SMSR) higher than 40 dB.

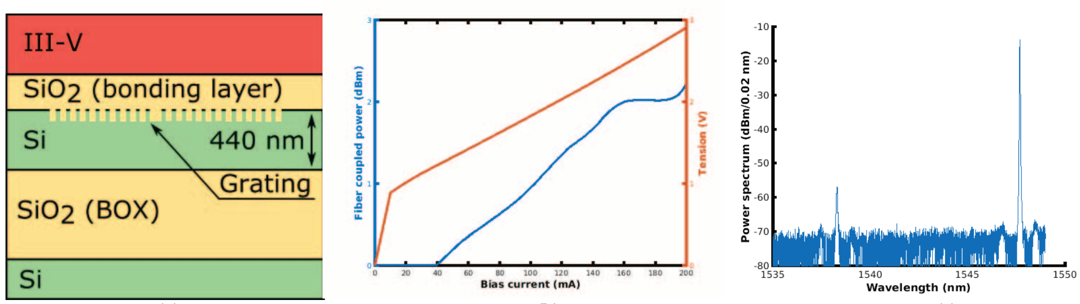
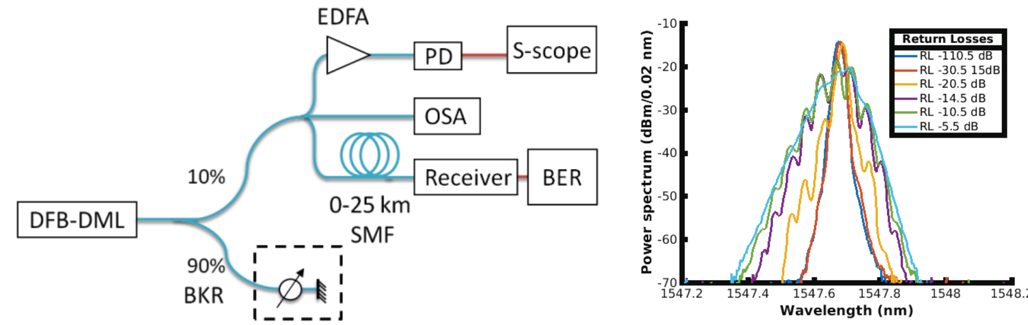


Fig. 1: (a) Cross section of the device. **(b)** Laser L-I-V curve. (c) optical spectrum at 110 mA showing SMSR superior to 40dB

3. Experimental set-up and main results

The experimental set-up is sketched in Fig. 2(a). A 90% /10% splitter is set to use both the variable back reflector (BKR, Yenista OSICS) that generates optical feedback and the measurement setup. The splitter is chosen to have sufficient feedback as well as enough power on the receiver. An erbium-doped-fiber-amplifier (EDFA) is used to record the eye diagram. The experiment consists in varying the attenuation on the BKR thus controlling the return loss (RL).

As can be seen on Fig. 2(b), varying the RL from -110.5 dB to -5.5 dB allows observing a typical route to chaos through self-sustained relaxation oscillation, hence leading to coherence collapse for which a broad optical spectrum is clearly observed [5]. Let us note that optical feedback doesn't affect side modes that can arise for bias currents greater than 130 mA. In the experiments, a bias current of 110 mA is chosen to have a large enough relaxation oscillation frequency in order to get a broader optical spectrum within the chaotic state.

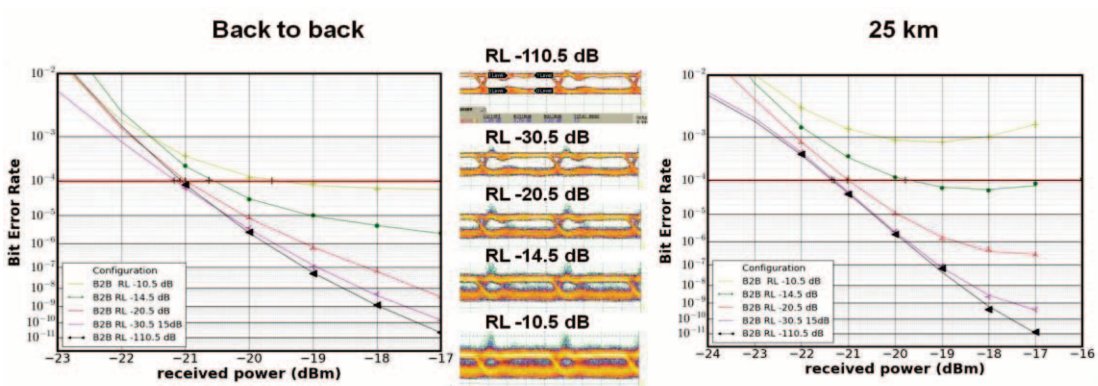


(a) **(b)**

Fig. 2: (a) Experimental set-up showing the feedback module and the receiver side. **(b)** Spectrum for different return losses showing spectrum enlargement due to self sustained relaxation oscillation.

Figure 3 shows back-to-back (B2B) eye diagram and BER measurement. A 2^{31} long pseudo-random bit sequence (PRBS) signal with 2 V_{pp} amplitude is applied to the laser corresponding to a 3.8 dB extinction ratio.

As the laser can be used in access networks, a 10^{-4} BER is chosen as forward error correction (FEC) reference in concordance to upstream NG-PON2 specification at 2.5 Gb/s. A full analysis of the transmission for several regimes is realized. As can been seen from BER plots the penalty degradation increases steeply above the optical chaotic state as reported in [4]. However, measurements show that the long delay optical feedback degrades the 10^{-4} B2B and 25 km penalty to less than 1.5 dB for return loss of more than -10.5 dB. For stronger feedback, BER is over FEC limit for 25 km propagation distance. Eye diagrams indicate that the strongest effect of the optical feedback in the laser is to increase noise on “ones” and “zero” levels. Further increase of the extinction ratio will reduce the optical feedback sensitivity.



(a) **(b)**

Fig. 3: BER measurements at 2.5 Gb/s **(a)**: back to back and **(b)** after 25km transmission. Back to back eye diagrams are also shown.

4. Conclusion

This work investigates the system performance of 2.5 Gbps hybrid III-V / SOI DFB DML operating under long optical. After 25 km transmission distance, the penalty is found to be less than 1.5 dB at the maximum feedback making these transmitters very promising for isolator-free applications such as access networks or PICs. Further work will consider 10 Gb/s test BER experiments under optical feedback.

5. References

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