10-Gb/s Floor-Free Transmission of a Hybrid III-V on Silicon Distributed Feedback Laser with Optical Feedback

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Abstract: A 10 Gb/s transmission by direct modulation of a distributed feedback semiconductor laser heterogeneously integrated onto silicon is studied with optical feedback. Its impact on the bit error rate and power penalty degradation is analyzed.
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1. Introduction
Photonic Integrated Circuits (PIC) are increasingly becoming more appealing due to the promising potential these devices can provide to a wide range of applications [1]. The tight integration of multiple optical and electrical components on one chip has gained significant attention and it is now considered one of the most promising technologies for optical applications [2]. Despite some efforts, no on-chip optical insulators with sufficient isolation ratio and low loss have been yet reported, therefore, investigating the effects of optical feedback on the laser performance remains of first importance for PIC integration. In fact, we have recently demonstrated that unintentional reflections originating from various possible interfaces (active/passive transitions regrowth interfaces, etc.) induce unwanted feedback into the laser [3]. In this paper, we analyze the sensitivity to optical feedback of a hybrid distributed feedback (DFB) semiconductor laser heterogeneously integrated onto silicon. The laser under study is directly modulated at 10-Gb/s and a floor-free transmission with a power penalty below 1.5 dB is demonstrated.

2. Laser structure
The device under investigation displayed in Fig. 1(a) is a 1-mm long hybrid III-V on silicon DFB [2,3]. Fig 1(a) depicts a top view of the structure composed of a 600 µm-long Bragg grating with a quarter-wavelength phase shift in the center etched on the silicon waveguide, below the III-V material. The period of the grating is 240 nm leading to a coupling strength coefficient of a few units. The light is coupled from silicon to the III-V material with adiabatic tapers, and outcoupled from vertical Bragg gratings on both sides of the device as shown below. Fig 1(b) presents the light-current (L-I) characteristics with a 40 mA threshold current measured at room temperature (20°C) whereas the optical spectrum inset confirms the single mode behavior with a side-mode suppression ratio (SMSR) > 50 dB at 141 mA.

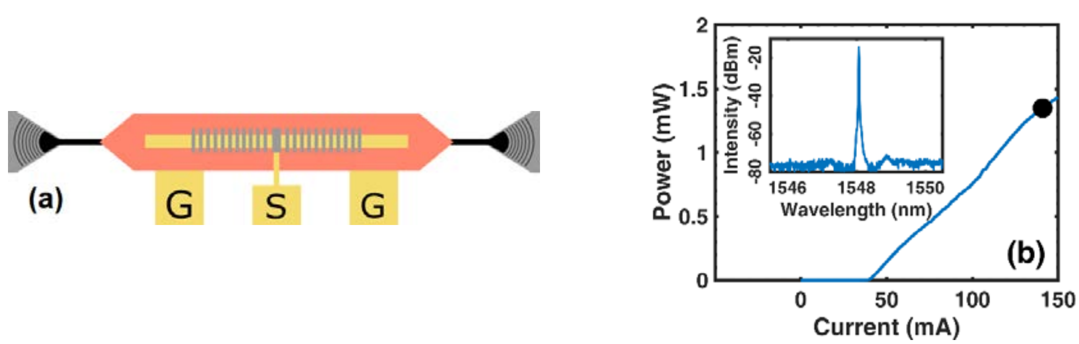

Fig.1: (a) Top view of the hybrid III-V/Si DFB laser. **(b)** L-I curve and optical spectrum (inset) of the hybrid III-v/Si DBF laser at I = 141 mA.

3. Experimental setup
Fig. 2(a) represents the test-bed experimental setup. A 50/50 splitter is used to send 50% of the light to the back reflector (BKR) to control the feedback strength and the remaining 50% is amplified with an erbium-doped fiber amplifier (EDFA) and analyzed by both the error detector and oscilloscope before and after transmission through a 10 km fiber coil. A pseudo-random bit sequence (PRBS) of 31 bits bit error rate (BER) transmission stress pattern is used with 2 V_{pp} amplitude to estimate the BER output at 10 Gb/s. Fig. 2(b) depicts a cartography of the feedback sensitivity in the optical domain as a function of the feedback strength. In this part of the experiment, the laser is not

modulated and the green dotted line at about -16 dB indicates the static critical feedback level at which the laser starts being destabilized. From this value and beyond, the laser exhibits undamping of the relaxation oscillations, which strongly affects the laser modulation performance [4].

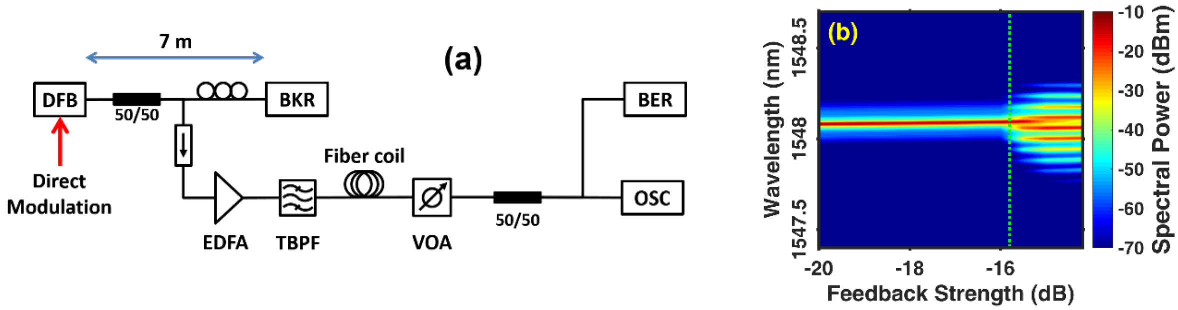

Fig.2: (a) Experimental set-up used for optical feedback investigation. (b) Feedback sensitivity cartography in the optical domain (without modulation). The green dotted line at about -16 dB indicates the static critical feedback.

4. Results and Discussion

Figs. 3(a) and 3(b) represent the eye diagrams of the directly-modulated DFB laser under solitary conditions (i.e. without optical feedback), before and after propagation through a 10 km fiber coil. Results show that the eye remains opened after propagation, and that the overshoots in the intensity output are well-suppressed. Fig. 3(c) displays the BER plots measured at different feedback strengths after transmission. The plot measured without optical feedback (red) is used as the reference and unveils a 10-Gb/s transmission without penalty and BER floor. While introducing the feedback to the stage (Fig. 2(a)), the BER increases due to the optical feedback induced noise into the laser cavity. At the maximum feedback level (-26 dB), an error-free transmission is still achieved with a power penalty below 1.5 dB at 10^{-9} BER. Note that -26 dB optical feedback strength corresponds to the critical level at which the transmission starts being degraded due to the enhanced relaxation oscillations. Certainly, the static critical feedback level originally estimated at -16 dB from Fig. 2(b) is actually decreased by the modulation down to -26 dB [5]. Finally, Fig. 3(d) illustrates the transmission result at a higher temperature (35°C) for an optical feedback level of -33 dB, which corresponds to the critical feedback level for this experimental condition. Results confirm that a 10 Gb/s floor-free transmission is still preserved with a power penalty still much below 1dB.

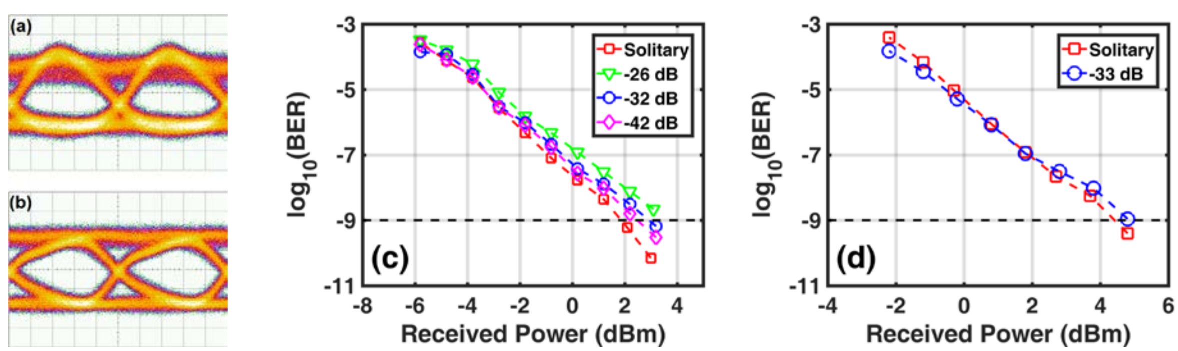

Fig. 3: Eye diagrams in **(a)** back-to-back (solitary) and **(b)** after 10 km transmission (solitary); BER plots after 10 km transmission distance at different optical feedback strengths for **(c)** T = 20°C and **(c)** T = 35°C.

5. Conclusion

This work investigates the performance of a 10 Gb/s directly modulated hybrid III-V/Si DFB laser with optical feedback. After 10 km transmission distance, the penalty is less than 1.5 dB making these transmitters very promising for isolator-free applications such as metro, access networks and PICs.

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4. References

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