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1.5-µm Directly Modulated Transmission over 66 km of SSMF with an Integrated Hybrid III-V/SOI DFB Laser

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Abstract: A hybrid III-V/SOI directly modulated DFB laser operating at 1.5 µm is fabricated, showing a side mode suppression ratio above 50 dB and a 3-dB bandwidth of 12 GHz. Error-free transmission (BER<10^{-9}) at 10 Gb/s over 66-km SSMF is demonstrated without dispersion compensation and FEC.

OCIS codes: (140.3490) Lasers, distributed-feedback; (200.4650) Optical interconnects; (060.4510) Optical communications

1. Introduction

The significant growth of internet traffic in recent years has been driving a strong research effort on low-cost high-speed solutions for access networks. In order to reduce the network cost and complexity, the focus has been directed towards finding integrated and compact solutions capable of reaching transmission distances above 40 km of standard single mode fiber (SSMF), which could still satisfy the stringent energy and cost requirements [1].

Among different platforms, silicon photonics has emerged as the most promising candidate for the integration of photonic and electronic integrated circuits [2, 3]. Furthermore, thanks to advances in integration of III-V materials on the silicon-on-insulator (SOI) platform [3, 4], high-speed transceivers have been demonstrated [4, 5].

Directly modulated lasers (DMLs) have been recognized as good candidates for short reach (≤ 10 km) applications thanks to their higher emitted power and lower power consumption compared to integrated externally modulated lasers (EMLs). EMLs can usually reach higher modulation speeds and are preferable for applications with a reach above 10 km that take advantage of their higher extinction ratio (ER) and lower frequency chirp compared to DMLs [6]. However, there is a trade-off between low frequency chirp and emitted power in such devices [7], which has an impact for achieving error-free performance over distances above 40 km and in high loss budget situations [8].

To extend the reach, either transmission in the O-band [9] or digital signal processing (DSP) [9, 10] is typically used. However, transmitting in the O-band will increase the losses, affecting the power budget for extended reach (> 40 km) applications, while DSP will increase the latency and power consumption. Therefore, DMLs that can transmit over such distances at 1.5 µm are highly desirable.

In this work, we report on an integrated 1.5-µm hybrid III-V/SOI DML operating at 10 Gb/s capable of transmitting over 66 km of SSMF without any dispersion compensation, equalization and FEC.

2. Fabrication and small-signal characterization

The hybrid III-V/SOI DFB laser was fabricated as described in [3] and its structure is shown in Fig. 1(a). First, the silicon waveguide was defined on the SOI wafer and a 50-nm-deep Bragg grating was etched with a period of Λ = 240 nm. Then the III-V material (InGaAlAs multiple quantum wells) was bonded on the SOI wafer and processed. A taper structure was used to couple light from the III-V material to the silicon waveguide and a vertical grating coupler is used to couple light off-chip. The optical spectra and the small-signal frequency responses ($|S_{21}|$ parameter) of the hybrid DFB measured for different bias currents are shown in Fig. 1(b) and (c), respectively.

The laser has a current threshold of 40 mA and good single mode performance with side mode suppression ratio well above 50 dB. The 3-dB modulation bandwidth is extracted from the S_{21} curves and is approximately 12 GHz at 140 mA bias current.

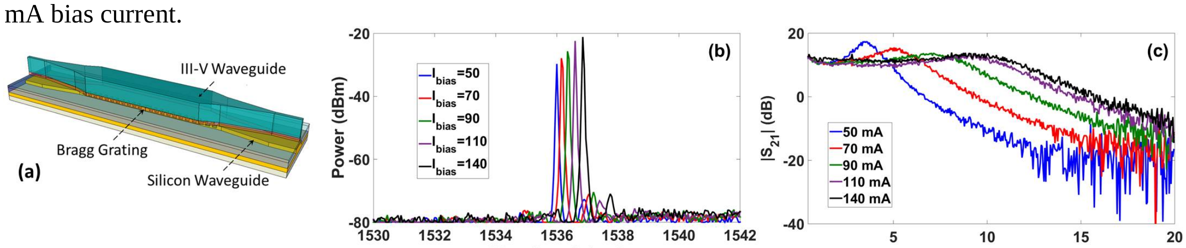

Fig. 1. a) Hybrid DFB structure; b) optical spectra of the DFB and c) small-signal amplitude modulation response for different bias currents.

3. Transmission results

The experimental setup for the transmission experiment is shown in Fig. 2.

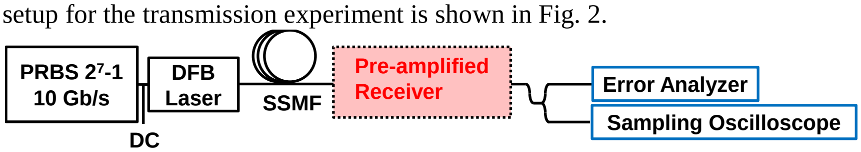

Fig. 2. Experimental setup for the DML-based transmission experiment.

The laser bias current is set to 140 mA, emitting 3.8 dBm of optical power, as measured after light collection in an SSMF after the vertical grating coupler, whose coupling loss is estimated to 7 dB. The laser is directly intensity-modulated at 10 Gb/s with a 2^7-1 pseudo-random binary sequence (PRBS) encoded into a non-return-to-zero signal with a peak-to-peak voltage of 2.4 V. After transmission over up to 66 km SSMF, the signal is received in a standard pre-amplified receiver connected to an error analyzer for bit-error ratio (BER) measurements and a sampling oscilloscope for eye diagrams recording. The results are shown in Fig. 3. The measured ER at the output of the DML is approximately 2.2 dB.

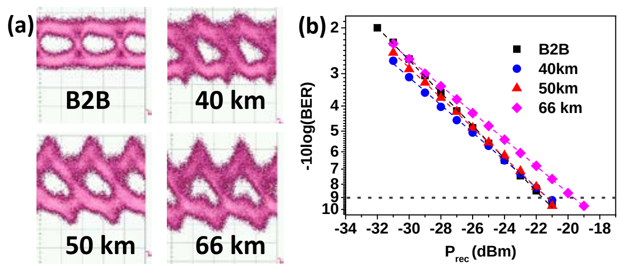

Fig. 3. a) Eye diagrams for back-to-back (B2B), 40-,50- and 66-km SSMF. b) Corresponding BER versus average received power curves.

The eye diagrams for back-to-back (B2B) and transmission over 40-, 50- and 66-km SSMF in Fig. 3 (a) clearly show the effect of dispersion on the modulated signal. Because of the intrinsic adiabatic chirp due to the direct modulation of the laser, the eye tends to close with increasing transmission distance, degrading the signal quality. However, even after 66 km a sufficiently open eye is still obtained and error-free performance (BER $< 10^{-9}$) is achieved. The BER curves as a function of the received power are reported in Fig. 3 (b). No power penalty compared to back-to-back is measured for distances up to 50 km. Increasing the transmission distance to 66 km induces a small penalty of 2 dB in receiver sensitivity.

4. Conclusions

We have demonstrated a hybrid III-V/SOI directly modulated DFB laser operating at 1.5 μm showing good single mode performance with a side mode suppression ratio above 50 dB. The 3-dB modulation bandwidth is measured to be approximately 12 GHz at a bias current of 140 mA. The laser is capable of achieving error-free performance at 10 Gb/s for transmission distances up to 50 km of SSMF with no penalty. Error-free transmission is also measured up to 66 km of SSMF with a small penalty of 2 dB in receiver sensitivity.

5. Acknowledgements

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