Uncooled 100 GBd O-Band EML for Datacom Transmitter Arrays

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Abstract: 100 GBd is demonstrated from 30°C to 70°C with O-Band InP EML array chips. Modulation bandwidths are above 50 GHz, and an integrated SOA ensures 10 dBm, while a single active layer allows for cost effective manufacturing.

1. Introduction

High speed electroabsorption modulated DFB lasers (EMLs) are key components to handle the steadily increasing volume of fiber based data communications. Applied in intensity modulation / direct detection schemes, EMLs convince with superior modulation bandwidth, high extinction ratios and low footprint. Results in [1] demonstrate the potential of EMLs for 200Gb/s/λ, that fits well into the roadmap of beyond 400Gb/s Ethernet objectives [2] where, for example, parallel single mode (PSM) fiber links are envisioned to enable 800 Gb/s and 1.6 Tb/s operation.

Present development of O-Band transmitter components focuses on higher modulation bandwidth in combination with uncooled operation in order to reduce the overall power consumption and costs. Directly modulated DFB lasers could demonstrate here 112 Gb/s in a single lane with 56 GBd PAM4 signals and operating from 25°C to 85°C [3].

The EML device design for uncooled operation in general has to balance the change of detuning between DFB laser wavelength and absorption edge of the modulator with temperature. Solutions for uncooled EMLs that have been presented so far employed a design of different active layer stacks for DFB and electroabsorption modulator (EAM) sections, monolithically integrated via butt joint [4]. Standard EML solutions comprising a single, common active layer for DFB and EAM support 56 Gb/s in uncooled operation and 100 Gb/s at 45°C with NRZ signals [5]. This paper explores the potential of O-Band EML array chips with identical active layer design, which allows for reduced fabrication complexity and thus low cost devices. We present for the first time an identical active layer EML capable of operating at 100 GBd NRZ in a temperature range from 30°C to 70°C.

2. Device Structure

The device presented here is a ridge waveguide (RW) EML that operates in the O-band. It comprises a distributed feedback (DFB) laser, an electroabsorption modulator (EAM) and a semiconductor optical amplifier (SOA) (cf. Fig. 1).

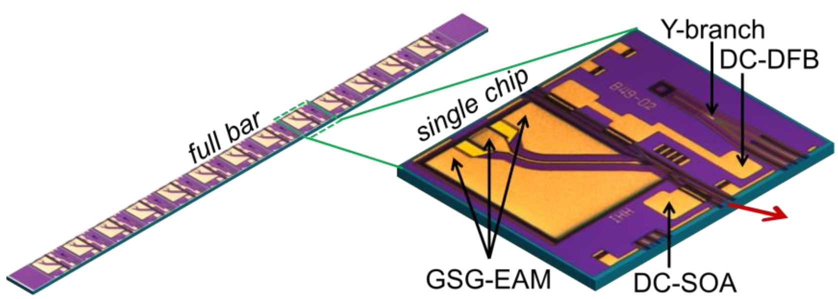


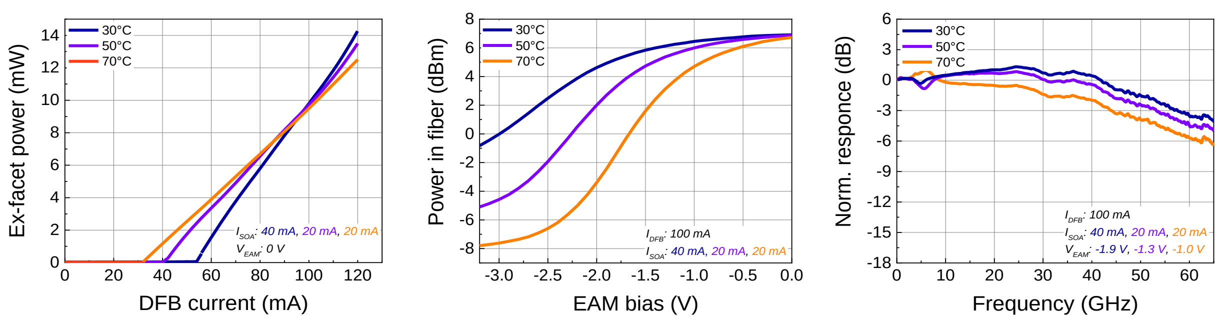
Fig. 1. O-Band EML array chip.

These functional parts share the same InGaAlAs based MQW stack as active layer and have a common ground n-InP substrate. The p-contacts of individual sections are electrically isolated by > 80 kΩ. The EML device layout is optimized for EML array applications. Figure 1 shows the picture of a full bar of EMLs of which monolithic arrays up to a maximum number of 13 elements can be generated. Here, individual EML chips feature identical designs.

On-chip RF transmission lines, as they are formerly described in [6], form GSG-EAM contacts at the rear side of the chip, which allows for a short RF connection to driver electronics. DC pads for driving the DFB and the SOA are located at the front of the chip. The back facet of the EML is anti-reflection coated against air to allow for the near 100 % single mode yield required in arrays. The front facet is tilted and anti-reflection coated against UV-glue (n = 1.5) to optimize coupling to polymer based optical waveguides as it is outlined in the POETICS project [7]. The EML device comprises an additional y-branch structure that acts as an optical alignment loop. Each EML element has a size of 750 µm x 620 µm.

3. Experimental Characterization

For the experimental characterization, a single EML device was mounted on a diamond heatsink and coupled to a lensed single mode fiber with around 3 dB coupling loss. The EAM GSG contacts were driven using an RF probe with integrated 50 Ω termination. The EML was tested under heatsink temperatures from 30 °C to 70 °C. Figure 2(a) shows the measured ex-facet output power versus DFB current for three heatsink temperatures. The threshold current decreases with higher temperature from 55 mA to 32 mA. This behavior can be explained by the large detuning between the lasing wavelength and DFB gain maximum that is required for EMLs with identical MQW layer stack. For uncooled operation, the large detuning of DFBs is beneficial, as it allows achieving a similar output power at different temperatures. By slightly adapting the SOA current between 20 mA and 40 mA, equal output power of around 10 mW is achieved for all temperatures at 100 mA DFB current (c.f. Fig. 2(a)). Figure 2(b) shows the optical power measured in fiber versus the EAM bias voltage. At 30 °C a static extinction ratio of up to 8 dB is achieved. At an elevated temperature of 70°C the static extinction ratio increases up to 14 dB. Figure 2(c) shows the measured frequency response at different temperatures. For each temperature, the EAM bias was adjusted so that the EAM operates in its linear regime. Over the whole temperature range, the device exhibits a high 3 dB bandwidth above 44 GHz. At 30°C a 57 GHz modulation bandwidth is achieved. The small ripple visible in the response curve at around 5 GHz is caused by optical feedback from the front facet, which is coated for UV-glue (n=1.5) but measured in air (see above).



(a) (b) (c)

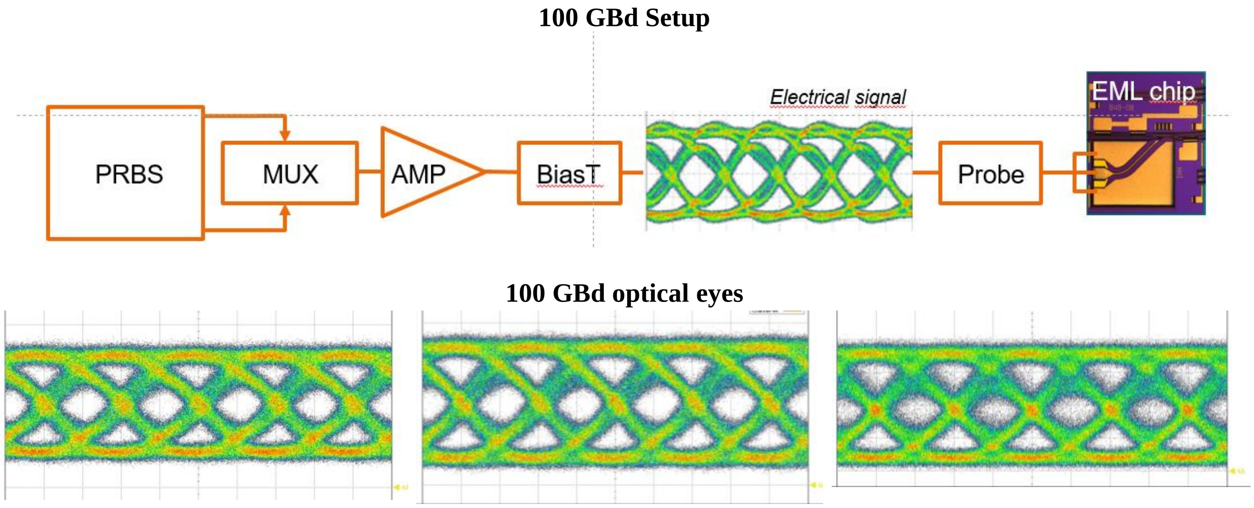
Fig. 2. Performance of O-Band EML array chip at temperatures of 30°C, 50°C and 70°; output power vs. DFB current (a), static transfer curves of EAM (b) and small signal modulation response of EAM (c).

Large signal modulation measurements are performed with 100 GBd NRZ signals. The setup is illustrated in Figure 3 (top). The test equipment involves a *SHF 12105 A* PRBS source, a *SHF C603 A* multiplexer (MUX) and a 66 GHz electrical amplifier (AMP) *SHF M804 B.* After the Bias-T, the electrical NRZ signal of a 2^{15}-1 sequence exhibits an eye amplitude of 2.1 V which has been kept constant in the experiments. The DC bias voltage of the EAM was changed from -1.9 V (at 30°C) to -0.9 V (at 70°C). Similar as in the small signal response measurements, an RF probe with 50 Ω matching impedance was used to contact the EAM. Further DC signals to drive DFB and SOA sections also have been supplied via contact needles directly on chip. The optical output was coupled to a lensed SMF fiber. The eye diagrams are directly detected using a digital scope (*Agilent DCA – X 86100D)* with a 80 GHz electrical module and a 65 GHz optical module, respectively. Neither pre-compensation nor post-processing of signals have been applied, thus the optical eyes provide the unveiled response behavior.

Figure 3 (bottom) depicts the 100 GBd optical eye diagrams at three different temperatures where the chosen EAM bias voltages ensure a crossing of about 50 %. The dynamic extinction ratios (ER) varying from 4.1 dB at

30 °C to 6.0 dB at 70°C, a behavior, that is determined by the different slopes of transfer characteristics (c.f. Fig 2(b)). Open eyes are observed for all temperatures. A higher noise level is appearing at 70°C and needs additional investigations, in particular, for excluding instabilities originating from the setup.

Further studies and bit error measurements are necessary to fully acquire the potential of the presented EML array chip in uncooled 200 Gb/s single lane scenarios. With monolithic 4-fold and 8-fold arrays the developed approach is prepared to access 800 Gb/s and 1.6 Tb/s with a solitary InP transmitter chip.



30°C
1306.2 nm, EAM: -1.9 V, ER: 4.1 dB

50°C
1308.5 nm, EAM: -1.4 V, ER: 4.8 dB

70°C
1311.8 nm, EAM: -0.9V, ER: 6.0 dB

Fig. 3. Setup for 100 GBd EML measurements on chip (top) and b2b optical eyes at three different temperatures (bottom).

4. Conclusion

We successfully demonstrate the 100 GBd performance of an array-compatible O-Band InP EML in a temperature range from 30°C to 70°C. The EML chip utilizes a common active layer design, and a booster SOA increases the optical output power and equalizes it to 10 mW for all operation temperatures. High modulation bandwidth up to 57 GHz at 30°C provide the background for open 100Gb/s NRZ eyes in an uncooled operation regime. Further work will reveal the capability of the monolithic EML array chip in uncooled 200 Gb/s PAM4 modulation schemes that prepare for applications in future cost effective 800 Gb/s and 1.6 Tb/s transmitters by using four or eight fold arrays and parallel lanes.

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5. References

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