SOA-integrated High-power EML-CAN for 50G-PON Downstream

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Abstract: A high-power SOA-integrated EML was demonstrated for a 50G-PON downstream (20 dBm output power). An EML-CAN was developed using this chip and it could effectively satisfy the ITU-T standard, thereby demonstrating its remarkable characteristics. © 2024 The Authors

1. Introduction

Fiber-to-the-x (FTTx) access systems using passive optical network (PON) technology have been globally deployed. The bitrate of the PON communication must be increased to satisfy the demand of the continuous increase in Internet data traffic. Further, a next generation PON system with 50Gb/s speed (50G-PON) was standardized [1] in 2021 as the Higher-Speed PON recommendation in ITU-T. Consequently, device development is being actively conducted. In the ITU-T standard, extremely challenging high-output power is required for the downstream transmitter of an optical line terminal. Using a semiconductor optical amplifier (SOA) is considered a promising solution for increasing the output power, because of the possibility of monolithic integration of SOA and the lack of availability of optical fiber amplifiers for the downstream wavelength of 1342 nm. The fabrication of electroabsorption modulator (EAM)-integrated lasers (EMLs) with SOA monolithic integration and experimentally characterized results have been reported for 50G-PONs [2]-[4]. However, meeting the target specifications of 50G-PON such as the optical output power, extinction ratio, and transmitter and dispersion eye closure (TDEC) characteristics, is difficult owing to the optical waveform degradation caused by the gain saturation of the SOA [5] which inevitably occurs under high power operation conditions.

We recently developed high-speed EMLs for 50Gbaud modulation in the O-band wavelength [6], which can be used for 50G-PON applications. We are currently developing a high-power optical transmitter by monolithically integrating an SOA with an EML (EML-SOA). In this paper, we report the experimental demonstration results of a 20 dBm high output power, which has not yet been reported, and the waveforms of the 50G non-return-to zero (NRZ) format that satisfy the ITU-T standard by optimizing the SOA design. We further developed an EML-CAN module for 50G-PON wherein the proposed EML-SOA chip was embedded into the industry-standard ϕ5.6 mm TO-CAN package with wide bandwidth, thus rendering it suitable for low-cost production. We confirmed that the characteristics of EML-CAN satisfied the ITU-T standard, similar to the case of EML-SOA.

2. Device structure

A schematic of the developed EML-SOA is shown in Figures 1(a)-(c). The EML structure was the same as that reported in [6]; that is, a buried heterostructure distributed feedback laser diode (DFB-LD) for high optical output power and a high-mesa electro absorption modulator (EAM) waveguide for a high extinction ratio and high-speed operation were used. For the SOA, the input optical signal must be amplified to a very high output power and the waveform degradation caused by gain saturation under high power conditions must be reduced simultaneously. To address these requirements, we designed an SOA with a flared-taper shape and optimized its active layer structure. The spot-size converter (SSC) provided a good fiber coupling coefficient.

We embedded this EML-SOA chip into a ϕ5.6 mm TO-CAN package which is in accordance with the industry standard. A photograph of the transmitter optical sub-assembly (TOSA) using the EML-CAN is shown in Figure 1(d). The inner structure height of the CAN package was reduced to meet the extended chip length requirements owing to the SOA integration. The line impedance of the glass penetration of our TO-header was designed to be approximately 50 Ω by thinning a signal pin and applying glass with a lower permittivity [7].

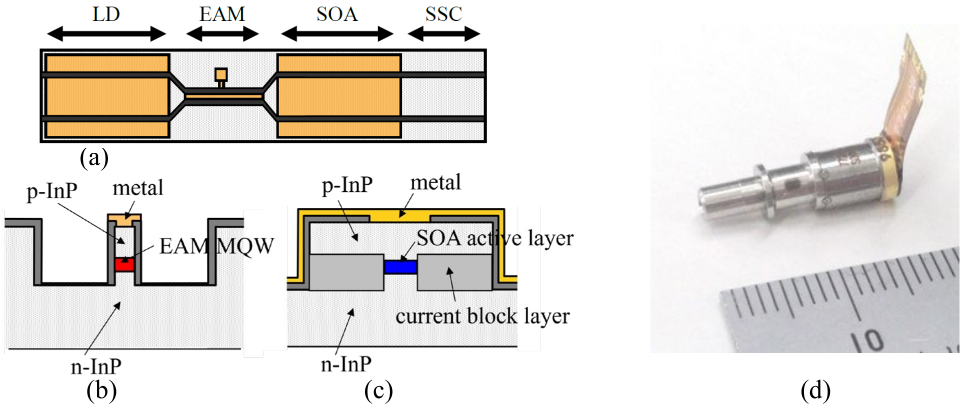

Fig. 1. Structure of SOA-integrated EML for 50G-PON. (a) Schematic top view of entire chip, (b) Cross-section of high-mesa EAM, (c) Cross-section of buried SOA, (d) Photograph of TOSA using EML-CAN

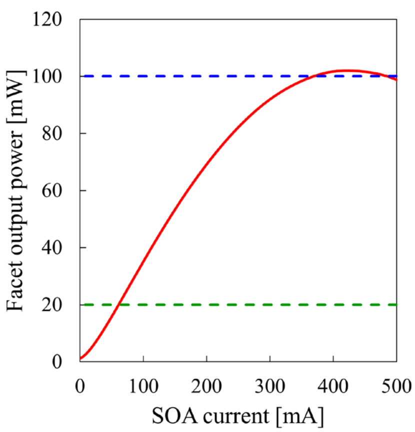

Fig. 2. DC output power as a function of SOA current

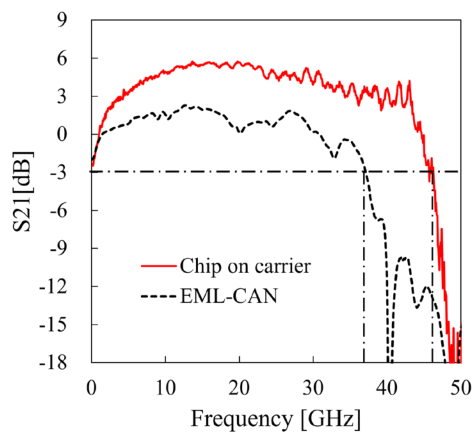

Fig. 3. Frequency response of EML-SOA in CoC and EML-CAN

3. Experimental results

We experimentally evaluated the facet output power of the EML-SOA chip as a function of the SOA current. The chip was assembled on a sub-mount and measurements were performed in a chip on carrier (CoC) form. Figure 2 shows the measurement results. LD current was adjusted to 100 mA, EAM bias voltage was set to 0 V and the chip temperature (Tc) was maintained at 55 ℃ using a thermo-electric controller. A facet output power of 100 mW (i.e., 20 dBm) was achieved at an SOA current of 400 mA. The measured high output power was attributed to the increase in the SOA saturation power by optimizing the flared-taper shape of the SOA. The SOA current was relatively high and improving the SOA current to reduce the power consumption will be a challenge in future.

Figure 3 shows the S21 high frequency responses of the EML-SOA in the CoC and the EML-CAN. An electrical signal was generated using an arbitrary waveform generator (AWG, Keysight M8196A) and amplified using a linear amplifier, including a bias tee (SHF, S807). An RF probe was in direct contact with the sub-mount in the CoC measurements. EAM vias voltage was set to -1.8 V and the SOA current was set to 400 mA. As shown by a dashed line position in the figure, a wide bandwidth of 46 GHz was confirmed for the CoC, which was sufficient for a 50G-NRZ signal. The S21 bandwidth of the EML-CAN was 37 GHz that was sufficient for the 50G-NRZ signal, indicating that the impedance of the signal line in the CAN structure was well optimized. In the very low frequency region below 2 GHz, a decrease in S21 was observed, which was attributed to the gain saturation of SOA caused by the depletion of the injected carrier in the case of a long sequence of high-level optical signal inputs. However, this decrease in S21 did not appear to significantly affect the optical waveform as shown in Figure 4.

We measured the optical eye diagrams of 50G-NRZ signal for both the EML-SOA chip and EML-CAN. The eye diagrams were captured using a sampling oscilloscope (Keysight, N1092C) and a 13-tap TDEC feed-forward equalizer. The optical waveforms of the back-to-back (BTB) and after 25 km transmission are shown in Figure 4. A standard single mode fiber was used for the 25 km transmission measurements. Measured characteristics of BTB extinction ratio of 8.5 dB, mask margin of 30.9%, and TDEC of 1.5 dB for EML-SOA chip, as shown in in Figure 4(a) and (b), sufficiently satisfied the ITU-T standard. The optical modulation amplitude (OMA) – TDEC value was 11.4 dBm with a sufficient margin compared with the target specification of 7.75 dBm. In addition, a clear eye-opening was observed after the 25 km transmission as shown in Figure 4(b). Eye diagrams of EML-CAN also exhibited a clear eye-opening for both BTB and after 25 km transmission as shown in Figures 4(c) and (d). The OMA-TDEC value was 10.2 dBm and satisfied the target specification of the ITU-T standard.

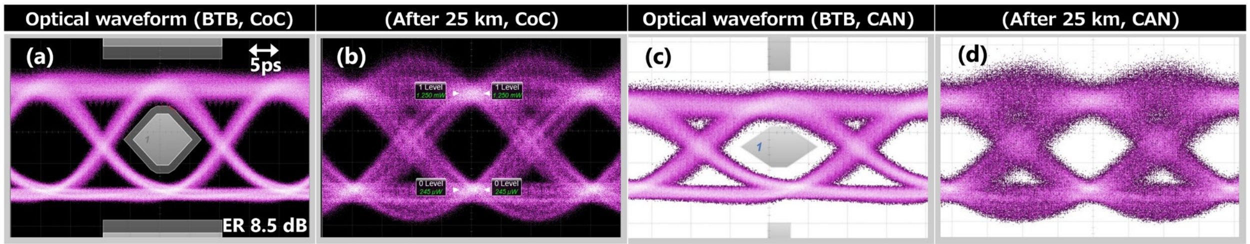

Fig. 4. Measured 50G-NRZ optical waveforms of EML-SOA CoC and EML-CAN. For (a) EML-SOA CoC under BTB, (b) EML-SOA CoC after 25 km transmission, (c) EML-CAN under BTB, (d) EML-CAN after 25 km transmission.

A comparison between the ITU-T major target specifications and the measured results of the EML-SOA chip and EML-CAN is presented in Table 1. The measured results satisfied the specifications for both EML-SOA and EML-CAN with a sufficient margin.

Table 1. ITU-T target specifications and measured results

Item	Target	EML-SOA measured	EML-CAN measured
Mean launch power	≥ 8.5 dBm	10.9 dBm	10.3 dBm
Extinction ratio	≥ 7 dB	9.2 dB	8.5 dB
TDEC	≤ 5 dB	1.5 dB	1.9 dB
OMA-TDEC	≥ 7.75 dBm	11.4 dBm	10.2 dBm

4. Conclusions

This study developed an SOA-integrated high-power EML for 50G-PON downstream at 1342 nm. We designed the SOA to balance high output power and efficient waveform by optimizing the SOA active layer and the shape of flared-taper SOA. Further, effective characteristics such as very high output power of 20 dBm at 55 ℃, extinction ratio exceeding 8 dB, OMA-TDEC value of 11.4 dBm, and clear waveforms of both at BTB and after 25 km transmission which satisfied the ITU-T standard were experimentally demonstrated. In addition, we developed an EML-CAN with ϕ5.6 mm TO-CAN package, specifically designed for 50G-NRZ signal. Additionally, the experimental results of EML-CAN satisfied the ITU-T standard.

5. References

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