High-power 10-Gbps EML CAN for Combo-PON

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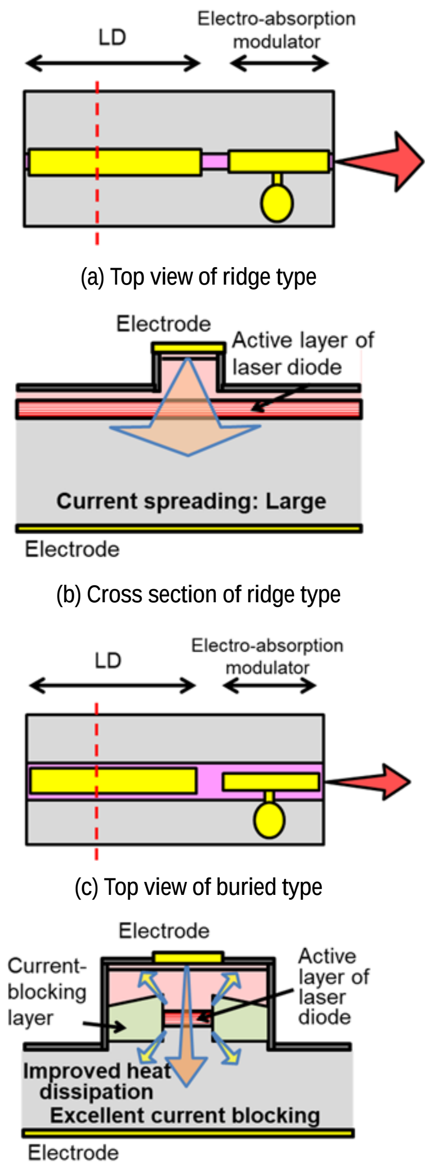
For Fiber To The Home (FTTH) systems, Combo-PON, which is compatible with 1-Gbps and 10-Gbps passive optical networks (PONs), has been spreading. For Combo-PON, there is demand for higher-power 10-Gbps electro-absorption modulated lasers (EMLs). In this development, the structure of EML elements was optimized to realize CAN EMLs that satisfy the Combo-PON (D1) standard.

1. Introduction

In a PON system, a single optical fiber connected to the optical line terminal (OLT) is branched out using a photocoupler and the branched lines are connected to multiple optical network units (ONUs). Currently, Gigabit-PON (G-PON) is being upgraded to 10-gigabit symmetric-PON (XGS-PON). However, both G-PON and XGS-PON are used on the end user side and so the structure needs to be designed to support both types. Under such circumstances, Combo-PON involving optical transceivers that are compatible with both G-PON and XGS-PON has been spreading. Because multiplexing of G-PON/XGS-PON is performed in optical transceivers for Combo-PON, the optical system tends to be complicated, which increases the optical loss. Accordingly, there is demand for higher-power CAN EMLs that are expected to be used as light sources for 10-Gbps systems. In this study, we reviewed the design of EML elements in detail to increase the optical output and improve the fiber coupling efficiency by narrowing the beam angle.

2. Higher Power Achieved by Changing the Element Structure

The conventional ridge-type EML element (Figs. 1(a) and 1(b)) cannot satisfy the needs for high optical output, high fiber coupling efficiency, and low power consumption that are demanded in Combo-PON. Accordingly, we have developed a new EML element that can satisfy such needs and has a high yield rate. To meet the Combo-PON (D1) standard, the optical output (PL) through the lens needs to be increased to 11 dBm from the conventional 9.5 dBm. To achieve this, the structure of the EML element was changed to the buried type (Figs. 1(c) and 1(d)) from the ridge type. To improve the efficiency of the current injection into the active layer of the laser diode, the active layer was buried within Indium phosphide (InP) to form a current blocking layer. In addition, a buried structure improves thermal dissipation around the current injection path. These improvements increased the optical output efficiency; the optical output when the LD current (Iop) was 109 mA, which is a typical driving condition, was increased by 1.2 dB to 11.7 dBm.



(a) Top view of ridge type

(b) Cross section of ridge type

(c) Top view of buried type

(d) Cross section of buried type

Fig. 1 Schematic structure of EML

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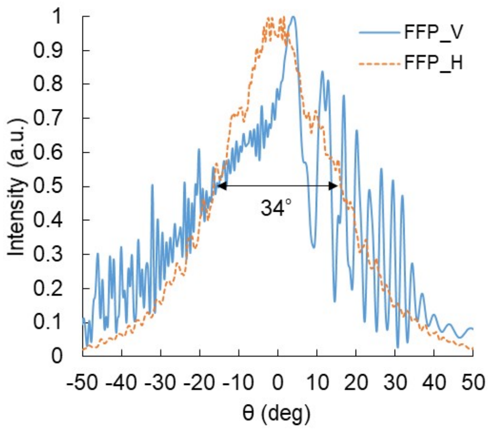
3. Narrower Beam Angle Realized by Changing the Element Structure

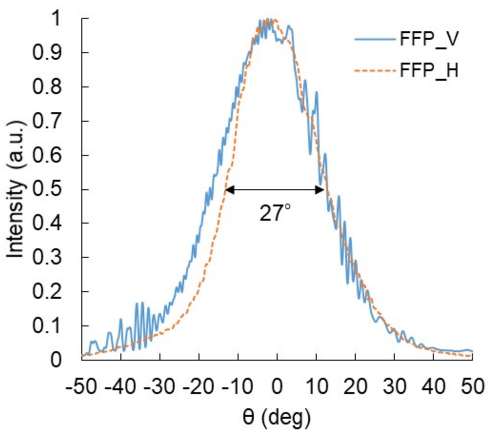
The shape of generated beams is determined based on the matching of the waveguide mode between the LD (light source) and the electro-absorption modulator (EAM, light-emitting side), as well as the shape of the waveguide mode of the EAM. The structure of the EAM was also changed to the buried type from the conventional ridge type as is the case with the structure of the LD to match the waveguide modes of the LD(1), and the angle of the generated beams was narrowed. This reduced ripples in the vertical beam shape (FFP-V) caused by mismatching of the waveguide modes between the LD and EAM. In addition, the diameter of the waveguide mode of the EAM was increased, which narrowed the beam emission angle from 34 degrees of the ridge type to 27 degrees (full width half maximum) (Fig. 2). As a result, the efficiency of fiber coupling to a single-mode fiber increased from 59% of the ridge type to 71%, and the output of the optical transceiver increased by 0.8 dB.

4. Stabilization of the High Frequency Characteristic

The application of the buried-type structure increased the optical output through the lens. However, it was found that the modulated optical waveform degraded because of insufficient high-frequency band, when the LD and EAM are buried within the same current blocking layer. These degraded waveforms are caused by an increase of capacitance, and we attributed the increase of capacitance to adoption of the same buried structure by the EAM as that of the LD.(2) To prevent this, we considered using a lower-capacitance structure for the buried layer (Fig. 3). However, it is necessary to match the waveguide mode between LD and EAM, when the structure of EAM is changed. Therefore, we developed the manufacturing process to remove a part of the current blocking layer from EAM. This developed process achieved a structure which reduces the capacitance, matching the waveguide mode. As a result, the lower-capacitance buried layer solved the problem of defective optical output waveforms and improved the mask margin (MM) from −20% to +30% or more.

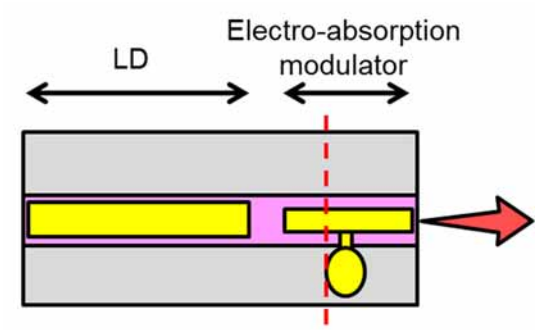


(a) Ridge type

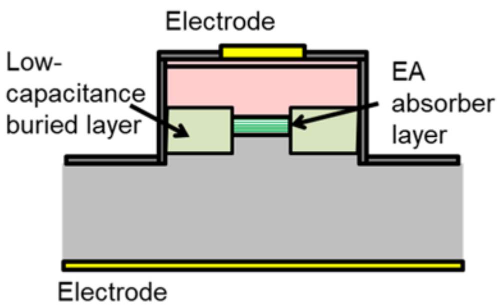


(b) Buried type

Fig. 2 Far field pattern



(a) Top view of buried type



(b) Cross section of EAM

Fig. 3 Schematic structure of EAM

5. Evaluation Results of EML CAN

The EML element designed as described above was installed onto a CAN package to evaluate the frequency response characteristic and optical output waveforms. Figure 4 shows the evaluated frequency response characteristic. The frequency is 9 GHz in the 3-dB band as the pass characteristic and is the same as that of the product with the conventional ridge type element. Figure 5 shows the back-to-back (BTB) optical output waveforms. As the driving conditions, the bit rate was 10.3 Gbps, the case temperature (Tc) was 25°C, the EML set temperature (Tld) was 45°C, the LD driving current (Iop) was 109 mA, the EML's modulation voltage amplitude (Vpp) was 2 V, and the EA offset voltage (Voff) was −0.6 V. For the evaluation, a flexible printed circuit (FPC) was connected to the CAN package. The evaluation results showed excellent optical output waveforms, with an extinction ratio of 10 dB and mask margin of 25%.

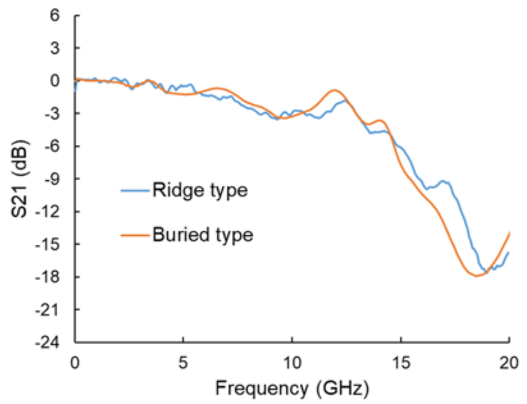


Fig. 4 Experimental results of frequency response

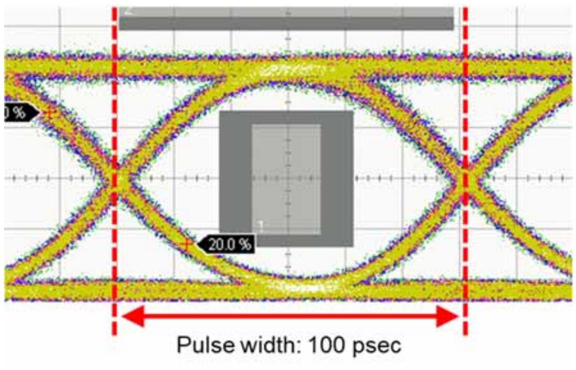


Fig. 5 10.3-Gbps eye diagram

6. Conclusion

We have developed a high-power 10-Gbps EML CAN for Combo-PON. The structure of the EML element was changed to the buried type, which improved the efficiency of the current injection to the active layer of the laser diode and heat dissipation. The optical output reached 11.7 dBm, which satisfies the Combo-PON (D1) standard of 11 dBm. The structure of the electro-absorption modulator was also changed to the buried type; while the waveguide modes were matched, the angle of generated beams was narrowed from 34 degrees to 27 degrees and the fiber coupling efficiency was improved by 0.8 dB. In addition, the structure of the electro-absorption modulator was changed to the buried type with lower capacitance, which eliminated defective optical output waveforms. The EML element was installed onto a CAN package. It was confirmed that the pass characteristic is the same as that of the ridge type and the obtained optical output waveforms were excellent, with an extinction ratio of 10 dB and mask margin of 25%.

References

(1) P. M. Asbeck, et al.: Lateral mode behavior in narrow stripe lasers, IEEE J. Quantum Electronics, QE-15, 727 (1979)
(2) N. H. Zhu, et al.: Electrical and Optical Coupling in an Electroabsorption Modulator Integrated with a DFB Laser, IEEE J. Quantum Electronics, 43, 535 (2007)