50-Gbps EML CAN for 5G Base Stations

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The fifth-generation mobile communication system (5G) is spreading to satisfy the need for larger transmission capacity driven by the rapid increase in data traffic. Accordingly, there is demand for electro-absorption modulated lasers (EMLs) that operate with 26-Gbaud 4-level pulse amplitude modulation (PAM4) as optical devices with the transmission speed of 50 Gbps to be applied to midhaul of 5G base station networks. In this study, we optimized the transmission line on the flexible printed circuit (FPC) of 25-Gbps EML CAN(1) and driving conditions. The obtained characteristics conformed to 50GBASE-ER (26-Gbaud PAM4, transmission distance of 40 km), which is a standard for midhaul of 5G base stations.

1. Introduction

In order to satisfy the need for larger transmission capacity, 5G is spreading. Large-capacity communication systems are used for the base stations where the traffic concentrates and higher-speed optical devices are applied to each layer. For midhaul, optical devices with the transmission speed of 50 Gbps are applied and the transmission distance is 40 km.

As a general method to realize the transmission speed of 50 Gbps, EML elements are installed onto box packages consisting of ceramic and metal and are operated with 26-Gbaud PAM4. When CAN packages are applied, band limiting occurs due to impedance mismatch, making it difficult to obtain sufficient band for operation with 26-Gbaud PAM4.

In the present study, we optimized the transmission line on the FPC of 25-Gbps EML CAN and driving conditions. In the case of operation with 26-Gbaud PAM4, the extinction ratio was 7.0 dB and the transmitter and dispersion eye closure quaternary (TDECQ) was 2.0 dB. The electric power consumption of the thermoelectric cooler was 0.19 W when the case temperature was +80℃ and 0.20 W when it was −5℃. It could be reduced by 23% compared to 0.26 W for box packages. The low-cost low-power consumption CAN package that operates at C-temp (−5℃ to +80℃) provides characteristics that satisfy midhaul standard 50GBASE-ER (extinction ratio ≥ 6 dB, TDECQ ≤ 3.2 dB).

2. External Shape of the Package

The outside diameter of a CAN package for 50-Gbps EML CAN is industry-standard 5.6 mm. The characteristics of EMLs greatly change as the temperature changes and so a thermoelectric cooler and thermistor to detect the temperature near the EML are required to control the temperature of the EML at a certain level. In addition, in order to control the driving current of the laser diode, a photodiode to monitor the optical output from the EML back facet has been built in. The lens cap has the widely-used cylindrical shape.

3. Structure of the EML Element

At the laser section of the EML, a highly-efficient buried waveguide that functions well at high temperatures is used. For the electro-absorption (EA) modulator section, in order to realize low modulation voltage and high-speed operation, the size was extended and the width of the absorption layer was reduced. Because reducing the absorption layer width deteriorates the optical confinement factor, a high-mesa waveguide is used to retain a high factor.(2) Thus, the structure of the waveguide at the laser section differs from that at the EA modulator section, which enhances the characteristics of both sections. In addition, a spot-size converter installed at the end of the EA modulator section improves the efficiency of fiber coupling to single-mode fibers.

4. Impedance of the Transmission Line on the FPC and Frequency Characteristics

Band deterioration of a CAN package is caused by impedance mismatch between the driver IC that drives the EML and the EML element. In particular, electrical multiple reflection that occurs between the stemmed glass penetration section and EML element often causes band deterioration. Therefore, the impedance matching was improved including the transmission line in the CAN package.(1) In addition, the impedance of part of the transmission line on the FPC was adjusted so that unevenness of the gain is compensated by reflected waves according to the impedance mismatch at the stemmed glass penetration section. Figure 1 shows a schematic diagram. At the impedance adjustment section, reflected waves are superposed based on the frequency, compensating the frequency response characteristics. Figure 2 shows the frequency response characteristics when the impedance values were changed at the same section of the transmission line on the FPC. The results show that the provided impedance adjustment section can smooth the frequency response characteristics.

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5. Evaluation Results

Based on the results in Section 4, the transmission line on the FPC was optimized. As a result, the 3-dB cut-off frequency of the frequency response characteristics of the 50-Gbps EML CAN including the transmission line (e.g., on the FPC) was 19.4 GHz. Figure 3 shows the back-to-back optical waveforms. As the driving conditions, the case temperature (Tc) was 25°C, the EML set temperature (Tld) was 50°C, the LD driving current (Iop) was 100 mA, the modulation voltage swing of EA (Vpp) was 1.3 V, and the bias voltage of EA (Voff) was −1.5 V. As the evaluation results, the extinction ratio was 7.0 dB and TDECQ was 2.0 dB. Thus, the obtained characteristics conform to midhaul standard 50GBASE-ER.

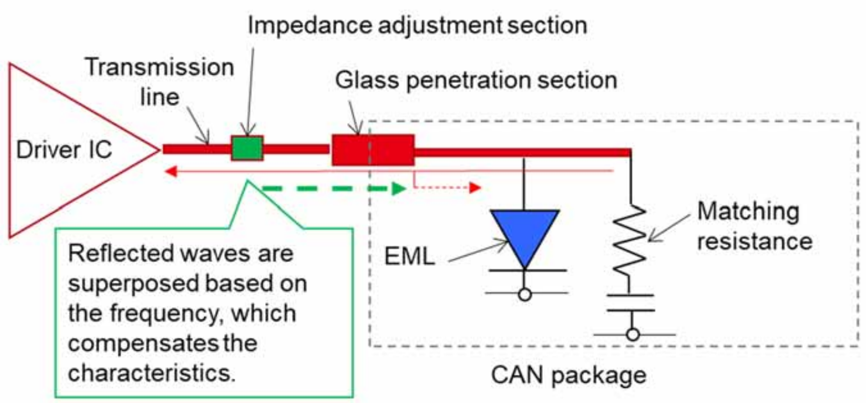

Fig. 1 Impedance adjustment compensating frequency response

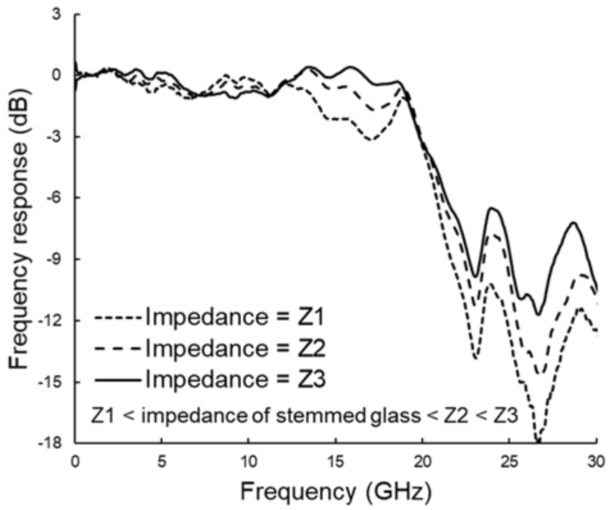

Fig. 2 Experimental results of frequency response

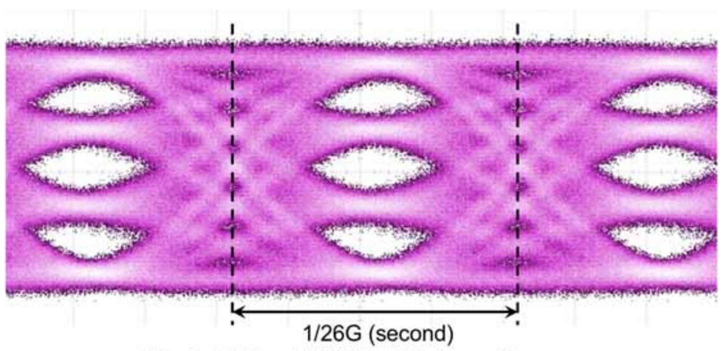

Fig. 3 26Gbaud PAM4 optical eye diagram

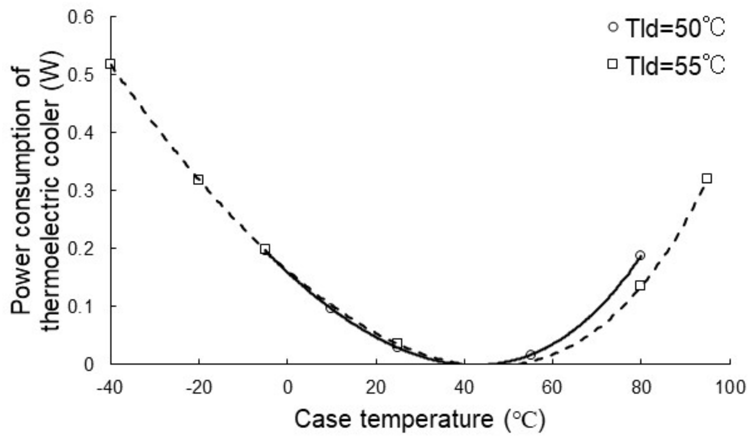

Fig. 4 Experimental results of power consumption of thermoelectric cooler

Table 1 Specifications and experimental results of 50-Gbps EML CAN

Item	Target specification	Evaluation result
Emission wavelength	1,304.5~1,317.5 nm	1,309.1 nm
Optical output(CW)@I_{op}=100mA	≥+10.9 dBm	+12.3 dBm
3dB cutoff frequency	-	19.4 GHz
Extinction ratio	≥6.0 dB	7.0 dB
TDECQ	≤3.2 dB	2.0 dB
Power consumption of thermoelectric cooler	≤0.70 W@-5℃ ≤0.42 W@+80℃	0.20 W@-5℃ 0.19 W@+80℃

For the 25-Gbps EML CAN developed for fronthaul, because the service temperature is I-temp (−40 to +95℃), Tld of the EML was determined as 55℃ considering the power consumption of the thermoelectric cooler. Meanwhile, because the service temperature of EML CAN for midhaul is C-temp, even if Tld is lowered to increase the EML output, the power consumption of the thermoelectric cooler can be kept low. Therefore, Tld of 50-Gbps EML CAN was determined as 50℃ so that the power consumption when the case temperature is −5℃ will be at the same level as that when it is +80℃. When Iop is 100 mA, setting the temperature to 50℃ can increase the optical output by +0.6 dB. Figure 4 shows the power consumption of the thermoelectric cooler when the case temperature was changed from −5℃ to +80℃. The power consumption of the thermoelectric cooler was 0.19 W when the case temperature was +80℃ and 0.20 W when it was −5℃, which shows that the model can be operated at C-temp.

Table 1 lists the target specifications of the 50-Gbps EML CAN and evaluation results.

6. Conclusion

We have realized 50-Gbps EML CAN that operates with 26-Gbaud PAM4 for midhaul of 5G base stations. The optical waveforms were evaluated and the obtained characteristics conform to standard 50GBASE-ER.

References

(1) Watanabe, Y., et al.: 25-Gbps Can-type EML for 5G Mobile Base Stations, Mitsubishi Electric ADVANCE Vol. 168 (2019)

(2) Yamatoya, T., et al.: Novel Hybrid-Waveguide EMLs for 100 Gb/s CFP2 Transceivers, 18th OECC/PS, MK1-2 (2013)