50Gbps DFB Laser Diode for 5G Base Stations

Authors: *Go Sakaino** and *Masaaki Shimada**

1. Introduction

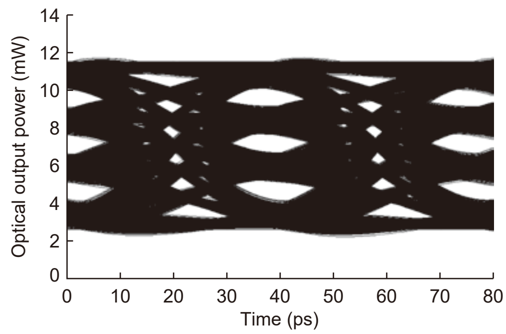
Migration to 5G is accelerating as the volume of data communication in mobile communications is increasing. Optical communication devices used in the fronthaul antenna base stations of 5G mobile communication networks are required to operate across a broad temperature range because they are installed outdoors. In addition, a Disributed Feedback (DFB) laser is used enabling direct modulation so that low power consumption operation is achieved without the need for a thermoelectric conversion element. In the 50GBASE-LR standard supported by the fronthaul, the Pulse Amplitude Modulation -4 (PAM4) modulation method in which the light intensity is changed from the conventional two-valued to four-valid is proposed. With this modulation method, even though the DFB laser's modulation speed is the same 25 Gbps as for conventional modulation, 50 Gbps transmission is possible. Here, we designed and developed a 50 Gbps DFB laser chip and industry-standard TO-56CAN package suitable for the PAM4 modulation method.

2. Device Design

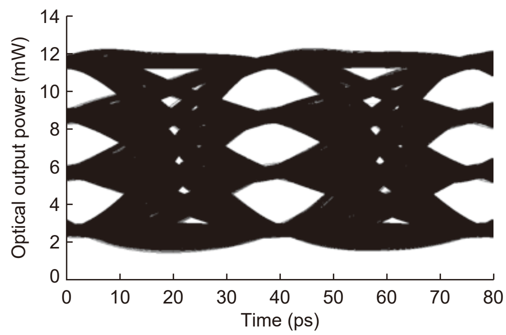
Until now, we have productized a DFB laser operating at 25 Gbps in a temperature range from –40°C to 90°C. With a direct modulation operation DFB laser, it is important to suppress the optical modulation waveform degradation due to the oscillation of the light intensity occurring as a result of the interaction of the electricity and the light. The frequency of this light intensity oscillation is referred to as the relaxation oscillation frequency and it is required to maintain a high value of the same order as the modulation frequency in the full temperature range of operation. For this reason, there is a remarkable loss of light and reduction in efficiency in injecting electric current into the active region at high temperatures in particular, and it is necessary to suppress the reduction in the light density in the active region. In addition, in a package equipped with a DFB laser chip, it is important to optimize the impedance in the design of the transmission line of the high frequency electrical signal to suppress the degradation of the high frequency characteristics.

In the use of 50GBASE-LR, the four-valued electrical signal which changes at 26.56 Gbaud is input into the DFB laser, and the DFB laser chip outputs the four-valued light signal. The index that determines whether this optical modulation waveform is good or not is stipulated in IEEE 802.3cd, and uses the Transmitter and Dispersion Eye Closure Quaternary (TDECQ) calculated from the optical modulation waveform with the waveform shaped by the Low Pass Filter (LPF) and Feed Forward Equalizer (FFE).

Because there is a four-valued signal in the PAM4 signal waveform, the eye opening is extremely small, so there is a tendency for the waveform quality to be reduced remarkably due to the effect of the DFB laser's relaxation oscillation. We conducted a simulation using a model based on the DFB chip model which takes into consideration this relaxation oscillation and the 25 Gbps DFB laser's package developed in 2018, and designed the DFB laser chip and package. The results are shown in Fig. 1.



(a) PAM4 before FFE



(b) PAM4 after FFE

Fig. 1 Simulated waveforms

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3. Device Structure and Characteristics

Figure 2 shows an outline photograph of the 50 Gbps DFB laser with an oscillating wavelength of 1310 nm developed here. The outline of the CAN package uses the industry-standard Φ 5.6 mm TO-CAN which makes it possible to secure compatibility with the previous product and to conform with the compact transceiver standard (SFP56).

The electric current and optical output characteristics are shown in Fig. 3. In the operating temperature range from a low temperature of –40°C to a high temperature of 90°C, the threshold current and the change in the slope efficiency are small, so we were able to achieve sufficient characteristics for 50GBASE-LR. At the high temperature of 90°C in particular, we achieved a threshold current of 20 mA or less, a slope efficiency of 0.22 mW/mA or more, and a maximum optical output of 12 mW or more.

Figure 4 shows the PAM4 transmission optical modulation waveform. The optical waveform is observed after applying the LPF and the FFE, and the TDECQ was calculated using a method conforming to IEEE 802.3cd. In addition, in order to correct the DFB laser's frequency response, the Pre-Emphasis which highlights the electrical signal's rising edge and falling edge in advance is used and the TDECQ can be improved. In recent years, driver ICs have been put into use with improved PE performance, and here, we also conducted a comparison with and without the PE applied. From the low temperature to the high temperature, whether the PE is applied or not, a large eye opening is achieved and, even after 20 km transmission, the optical modulation waveform is excellent with little disturbance.

Fig. 2 50Gbps DFB laser

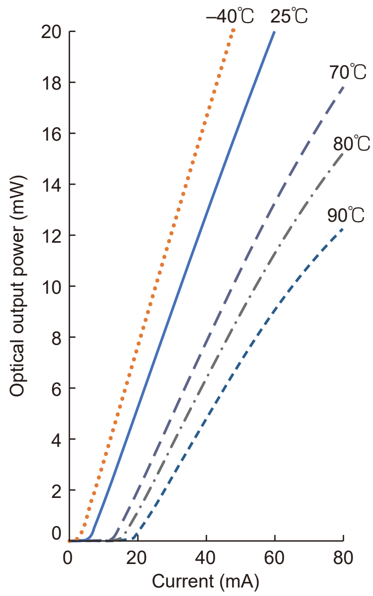
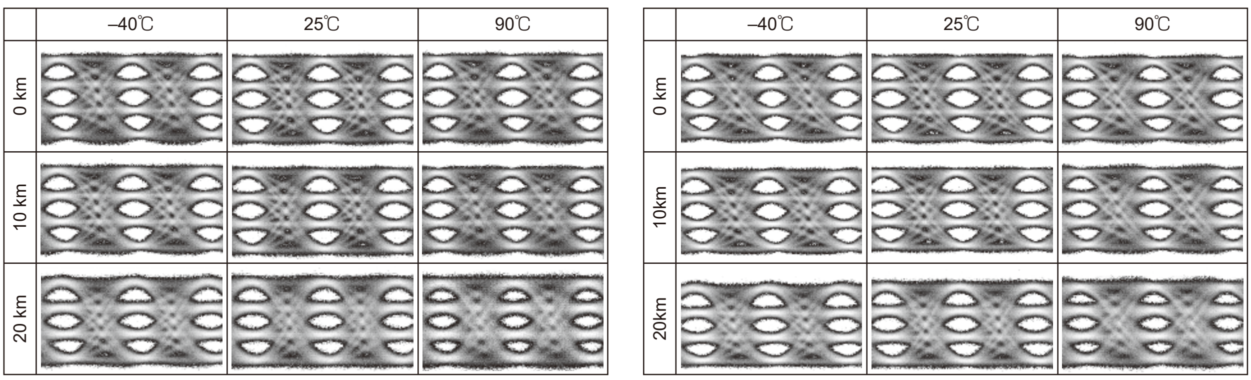


Fig. 3 I – L characteristics (–40, 25, 70, 80, 90°C)



(a) Without Pre-Emphasis

(b) With Pre-Emphasis

Fig. 4 Optical waveforms after transmission

Figure 5 shows the TDECQ transmission distance dependency. The TDECQ with no PE applied at temperatures of –40°C, 25°C, and 90°C are 2.3 dB, 1.8 dB, and 2.0 dB respectively before transmission (0 km). Furthermore, during the 10 km transmission required of 50GBASE-LR, the values are 2.1 dB, 1.7 dB, and 2.1 dB, which sufficiently satisfy the standard of 3.2 dB or less. In addition, when the PE is applied, the TDECQ after the 10 km transmission are 1.1 dB, 0.9 dB, and 1.3 dB, so that the effect of applying the PE is confirmed.

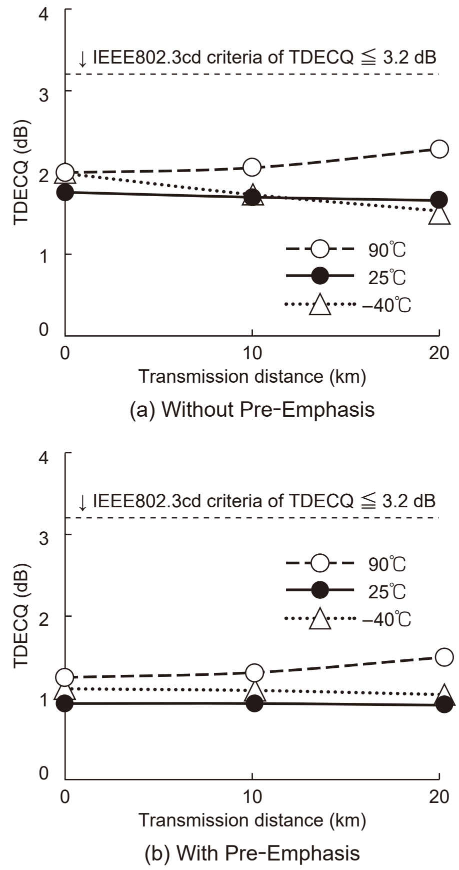


Fig. 5 Dependence of TDECQ on transmission distance

4. Conclusion

We developed a 50 Gbps DFB laser suitable for the PAM4 modulation method targeting the fronthaul of 5G mobile communication networks. Characteristics satisfying the standard 50GBASE-LR standard were achieved, the speed was doubled compared to the previous device to this one, and we were able to realize 5G high speeds and low power consumption.

References

(1) IEEE Standards Association : IEEE 802.3cd 50Gb/s, 100Gb/s and 200Gb/s Ethernet Task Force https://www.ieee802.org/3/cd/

(2) Sakaino, G., et al.: Direct Modulation DFB Laser for 25 Gbps Optical Transmission, Mitsubishi Electric ADVANCE Mar.2018 Vol.161, 2~4 (2018)