Direct Modulation DFB Laser for 25 Gbps Optical Transmission

Authors: *Go Sakaino** and *Mizuki Shirao***

1. Introduction

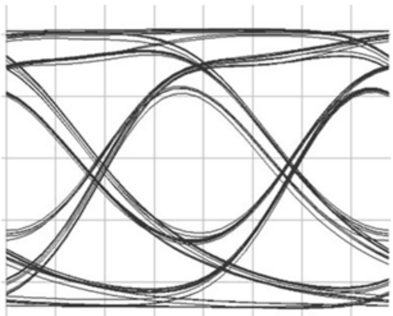
For the next-generation system defined by the Common Public Radio Interface (CPRI) standard for mobile communication systems, it is necessary to develop a high-speed transceiver (25 Gbps) for communication devices. In addition, operation at high temperatures is required for antenna base station communication devices installed outdoors. To meet these needs, we have developed a 25 Gbps distributed feedback (DFB) laser that operates over a wide temperature range (−20°C to 85°C) at high speed.

2. Device Design

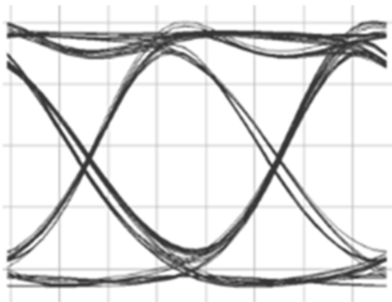
In the past, we developed laser chips that operate at 25 Gbps within the temperature range of −5°C to 75°C as uncooled direct modulation DFB lasers. To extend this range, it is necessary to minimize the decrease in optical output and the increase in operating current at high temperatures. To this end, it is important to suppress the deterioration of optical modulation waveforms caused by light oscillation resulting from the laser-inherent interaction between electricity and light. The frequency of this light oscillation is called the relaxation oscillation frequency (*fr*). To obtain a desirable optical modulation waveform, it is necessary to maintain *fr* at a high value at a high modulation signal frequency level. This can be achieved by suppressing the phenomena that are remarkable due to a high temperature, i.e., increased optical loss, reduced efficiency of current injection into the active region, and reduced optical density in the active region entailing a drop in *fr*. Based on a laser chip structure that operates at 25 Gbps within a temperature range of −5°C to 75°C, we redesigned the structure around the active region. As a result, we achieved a balanced structure between high-temperature, low-loss effective current injection into the active region even at 85°C, and stable high slope efficiency.

The package with the DFB laser also needs an increase in speed from 10 Gbps to 25 Gbps, i.e., 2.5 times. This involves two challenges: One relates to the modulation bandwidth of TO-CAN packages. Leads and inner gold wires for transmitting electrical signals inside a TO-CAN package can degrade the high-frequency properties of the entire package. By eliminating the inductance inside a TO-CAN package for 10 Gbps operation, the internal impedance was optimized. As shown in Fig. 1, the optical waveform quality was significantly improved for 25 Gbps operation, which has been difficult to achieve with a 10 Gbps TO-CAN package.

The other challenge involves deterioration of the waveform quality due to the multiple reflection of electricity. While a normal DFB laser has resistance of approx. 12 Ω, signal lines are designed using differential lines with characteristic impedance of 50 Ω. In this configuration, the inconsistent impedance is likely to make the reflection of high-frequency signals larger, involving waveform quality that is susceptible to deterioration due to multiple reflection to each connection point. The junction to a flexible printed circuit (FPC) as an electrical interface of a TO-CAN package in particular tends to be a multiple reflection point. Figure 2 shows the configuration at the junction between the stem, which is the main body of a TO-CAN package, and the FPC. In conventional 10 Gbps TO-CAN packages, an insulation sheet of approx. 0.1 mm thick is inserted between the FPC ground plane and the stem. With the interspace represented by G (gap), the simulation results for the small signal response properties of the TO-CAN



(a) TO-CAN for 10 Gbps

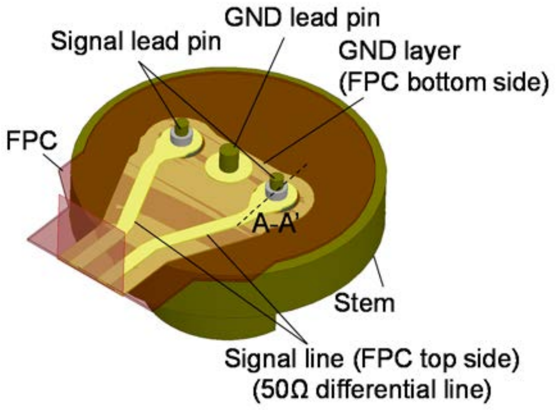


(b) Optimized TO-CAN for 25 Gbps

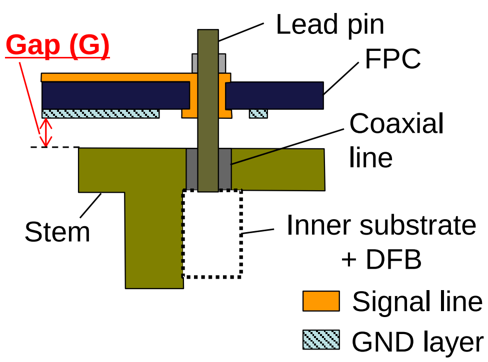
Fig. 1 Simulated waveforms of TO-CAN with the 25 Gbps DFB laser

**High Frequency & Optical Device Works **Information Technology R&D Center*

package with the 25 Gbps DFB laser are shown in Fig. 3; the simulation results for the optical waveforms are shown in Fig. 4. During the 25 Gbps operation, the properties to allow signal passage and the optical waveform quality were confirmed to have deteriorated even when the gap was small. Given the fact that the small discontinuous impedance and the inductance component increase due to the gap, causing property deterioration, configuration (a) without a gap was adopted for the prototype.



(a) Perspective view



(b) Cross-sectional view (A'-A)

Fig. 2 Simulation model of TO-CAN

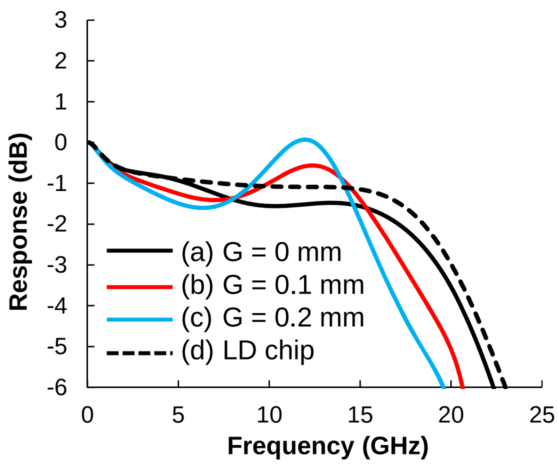


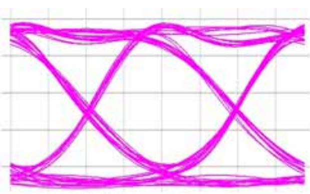
Fig. 3 Simulated frequency response of the 25 Gbps DFB laser

3. Device Structure and Characteristics

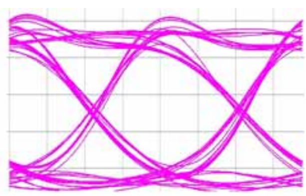
We produced a 25 Gbps DFB laser with the structure shown in Fig. 5, based on the design as described above. The DFB laser chip was mounted on the newly designed Φ 5.6 mm TO-CAN package described above. Via the internal substrate built into the TO-CAN package, the DFB laser chip was connected to external leads. A cap with a lens to link the emitted light to optical fiber, and to hermetically seal a laser chip was also mounted.

Figure 6 shows the current vs. optical output properties of the DFB laser. The threshold current and slope efficiency did not excessively depend on the temperature, and thus good characteristics were obtained. At a high temperature, e.g. 85°C, the threshold current did not exceed 16 mA, and the slope efficiency did not drop lower than 0.17 mW/mA. A maximum optical output of at least 10 mW was obtained.

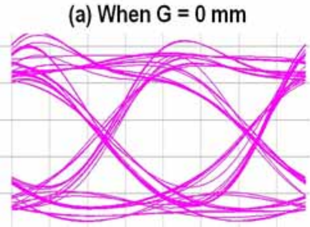
We evaluated 25.8 Gbps optical modulation waveforms in the temperature range of −20°C to 85°C. Through the FPC, pseudo-random NRZ signals (non-return-to-zero signal) of 25.78 Gbps were input from a PPG (pulse pattern generator). The obtained modulation waveforms are shown in Fig. 7. Clear shapes were obtained within the temperature range between −20°C and 85°C. When the CWDM4 mask was used, the mask margin (MM), which indicates the modulation waveform quality, had desirable values of 40%, 40% and 39% at −20°C, 25°C and 85°C, respectively. With the 100GBASE-LR4 mask, which requires higher waveform quality than CWDM4, the mask margin was high at 23%, 28% and 25% for each temperature. From these results, we confirmed that the DFB laser properties were sufficient for 25 Gbps optical transmission; the use of the DFB laser allowed us to perform low-current operation with the average current not exceeding 61 mA, and to obtain desirable mask margin values even at a high temperature of 85°C. We believe that these properties will be useful for mobile communication systems



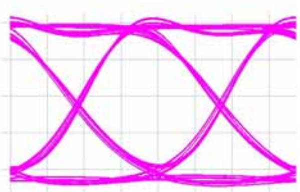
(a) When G = 0 mm



(b) When G = 0.1 mm



(c) When G = 0.2 mm



(d) When only the 25 Gbps DFB laser is used

Fig. 4 Simulated waveforms with 25Gbps modulation

Fig. 5 25 Gbps DFB laser

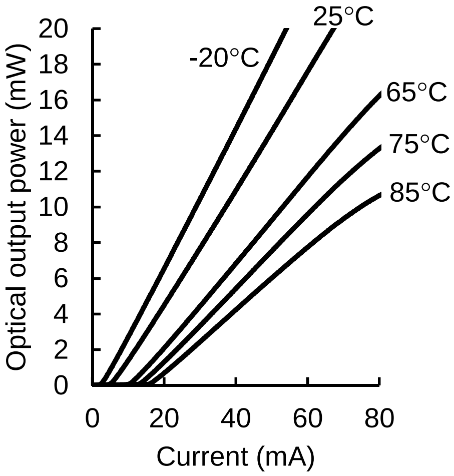
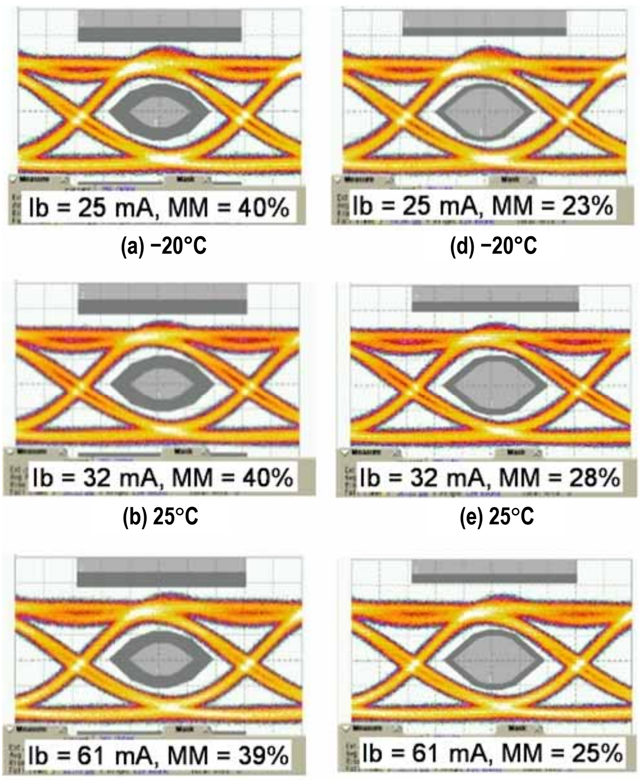


Fig. 6 I-L characteristics (−20, 25, 65, 75, 85°C)



(a) −20°C (d) −20°C

(b) 25°C (e) 25°C

(c) 85°C (f) 85°C

Ib: Average current
MM: Mask margin ((a) to (c): CWDM4, (d) to (f): LR4)

Fig. 7 25.78 Gbps waveforms
(Optical output power: 8 mW; Extinction ratio: 5 dB)

conforming to the 25 Gbps operation small transceiver standard (SFP28), and can play a significant role in increasing the speed and reducing the power consumption of mobile communication systems.

4. Conclusion

The developed product described here will contribute to the conformity of mobile communication systems to the 25 Gbps operation small transceiver standard (SFP28), as well as help increase the speed and reduce the power consumption of mobile communication systems by means of uncooled operation.