400-Gbps Compact Integrated EML-TOSA

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1. Introduction

To meet the rapid increase in traffic along with higher speed and larger capacity of optical transmission devices, a transceiver that can handle larger-capacity communication is required by changing the conventional optical transceiver with transmission capacity of 100 Gbps [(1)]. To meet such requirements, two TOSA, one with a short-wavelength bandwidth and the other with a long-wavelength bandwidth, were combined (8 wavelengths) based on the 100-Gbps small integrated EML-TOSA. A product conforming to a transceiver with a transmission capacity of 400 Gbps was thus developed for operation in the newly employed PAM-4 modulation system.

2. Device Specifications

The newly developed 400-Gbps small integrated EML-TOSA meets the specifications of 400GBASE-LR8 which is 8 wavelengths and a transmission distance of 10 km standardized by IEEE. The TOSA size conforms to CFP8 which is the package standard of the 400-Gbps optical transceiver. The operating temperature range is −5°C to 80°C for the temperature of the case. If operated in the PAM-4 modulation system, it can operate at a maximum bit rate of 53.125 Gbps.

3. Device Design

Figure 1 shows a photo of the appearance. The package integrates both metal and ceramics. For the interface of electric signals, two FPC for the RF connection which sends modulating signals and for the DC connection which supplies power to LD, PD and TEC were used for connection. The FPC was directly connected to the metal pattern with narrow spacing on the ceramic to make the package small. The FPC for RF connection used a three-layer structure. The layout of the signal wire in the internal layer of the FPC widened the space between electrodes at the connection, and by maintaining the electrode distance to avoid shorting, ideal impedance matching was achieved [(2)].

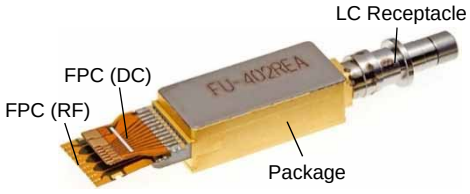

Fig. 1 400-Gbps compact integrated EML-TOSA

The size of the package area for one unit is 15.0 × 6.5 × 5.4 mm, which allows two units to be mounted on the CFP8 transceiver [(3)].

4. Optical System and Mechanism Design

Figure 2 shows a conceptual diagram of the optical system inside the TOSA. Inside the package, four EMLs, a lens and a spatial optical multiplexer are integrated. The optical multiplexer consists of three BPFs and one mirror, and they are fixed to a block member. This product uses the two-lens optical system. The first lens is mounted inside the package and the second lens is mounted outside the package. The collimated light through the first lens enters the spatial optical multiplexer and four wavelengths of lanes 0, 1, 2 and 3 are combined by multiple reflection between the BPFs and the mirror [(4)].

The difference between the two TOSAs (one for short wavelength and one for long wavelength) is the wavelength only. Since the internal structure is identical, they can be assembled in the same process.

5. PAM-4 (Pulse Amplitude Modulation 4)

Figure 3 shows the outline diagram of the optical waveform in PAM-4 modulation. This modulation system

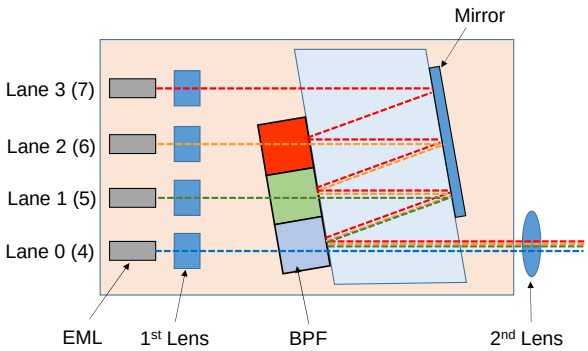

Fig. 2 Conceptual diagram of optical system

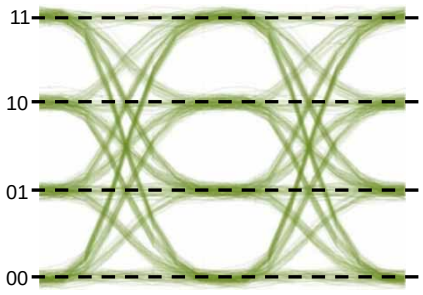

Fig. 3 Eye diagram by PAM-4 (Simulation)

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(4-level modulation) modulates and transmits the bit row consisting of “0” and “1” as the pulse signal of four voltage levels of “00,” “01,” “10” and “11.” The transmission capacity per hour is twice that of the NRZ modulation system which uses 2-level.

For the PAM-4 modulation system, TDECQ is a particularly important evaluation parameter which shows the degree of three eye openings equivalent to the eye mask test of NRZ. The signal error rate is obtained from two elements of the signal distribution: the specified UI and the optical output threshold, and TDECQ is the value obtained from the signal error rate. Although the definition is different, TDECQ means evaluation of the error rate and communication quality, similarly to the eye mask test for the NRZ modulation waveform. The standard for this TDECQ specifies 3.3 dB or less in the Institute of Electrical and Electronics Engineers (IEEE) which performs standardization activities [5].

6. Evaluation Results

Figure 4 shows the measured optical waveform (shortwave length side). EML modulates all lanes in PAM-4 simultaneously. All lanes obtained good eye-opening characteristics with the extinction ratio of 8 dB or more and TDECQ of 2.7 dB or less under the conditions of the EA modulator voltage amplitude of 1.40 V.

Figure 5 shows the relationship between the total TEC power consumption of two TOSAs and the case temperature when the chip drive temperature is set to 60°C.

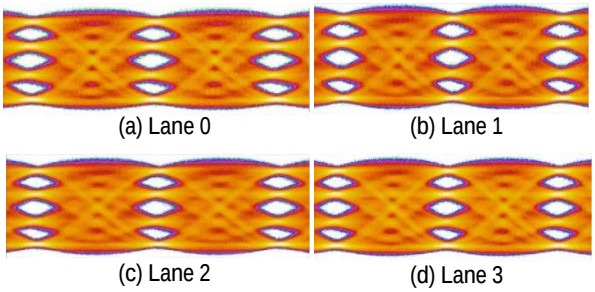

Fig. 4 Eye diagram by PAM-4 (Measurement)

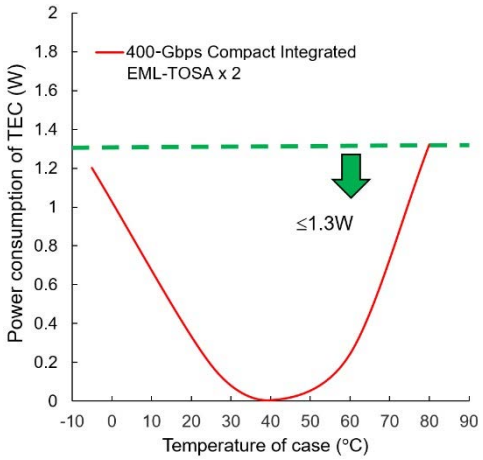

Fig. 5 Power consumption of TEC (LD current: 100 mA)

The TEC power consumption for one TOSA is equivalent to the 100-Gbps small integrated EML-TOSA. The TEC power consumption is controlled to 1.3 W or less for two units in the operating temperature range from −5 to 80°C. This system supports higher transmission capacity and yet suppresses an increase of power consumption.

7. Conclusion

We have developed a small integrated EML-TOSA which supports large-capacity high-speed transmission of 400 Gbps with two TOSAs, which can be mounted on CFP8.

This product will contribute to the spread of optical transceivers in 400-Gbps networks, a market which is expected to expand rapidly in the future. We will leverage the knowledge gained with this product and the PAM-4 modulation system to develop a smaller TOSA which can be mounted on the QSFP-DD platform, enabling the transceiver to be made more compact.

8. References

(1) M. Birk, et al., “First 400GBASE-LR8 interoperability using CFP8 modules,” OFC 2017, Th5B.7.
(2) Shirao, M., et al., “A miniaturized 43 Gbps EML TOSA employing impedance matched FPC connection,” OSA 2013, OTh4H.6.
(3) CFP-MSA: http://www.cfp-msa.org/
(4) Murao, T., et al.: “Integrated Spatial Optical System for Compact 100GbE Transmitter Optical Sub-Assemblies Using Lens Positional Control by Laser Irradiation,” 2015 preliminary draft of Technical Committee on Lasers and Quantum Electronics, Institute of Electronics, Information and Communication Engineers
(5) IEEE Std 802.3bs