A Cost Effective Hermetically Sealed 106 Gbit/s PAM4 EML TO-CAN For Beyond-5G Mobile Fronthaul

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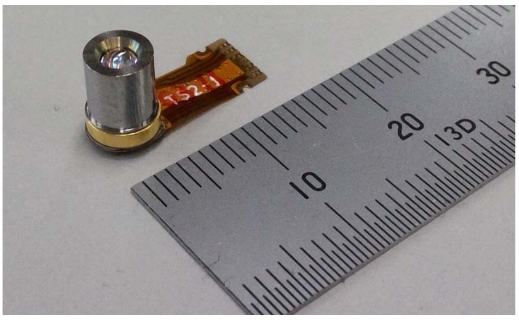
Abstract *We demonstrated 106 Gbit/s PAM4 signal transmission using a low cost hermetically sealed EML TO-CAN employing a metal plate to suppress resonance by providing a common ground between the TO-header and the FPC. A 3dB bandwidth of 35.9 GHz and TDECQ of 2.51dB were achieved.*

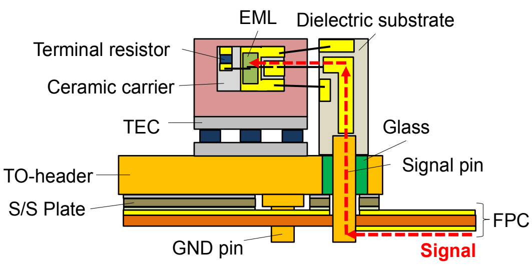
Introduction

Mobile user data rates are expected to increase gradually in the future with the spread of fifth generation (5G) mobile services. The mobile fronthaul (MFH) link speed per antenna increase dramatically and over 100 Gbit/s is expected to be required in Beyond-5G (B5G) era[1]. The demand for high-speed, low-cost transceivers will increase for 5G or B5G MFH. To cope with this trend, a single-lambda 100 Gbit/s transceiver using 53 Gbaud four level pulse amplitude modulation (PAM4) has gathered attention. An electroabsorption-modulator-integrated laser (EML) has been regarded as more promising for the optical transmitter device for 100 Gbit/s transceiver than a directly modulated laser diode (DML) [2] and a silicon photonics Mach-Zehnder modulator[3], because it attains high optical output power and wide modulation bandwidth simultaneously. We have been developing an EML for 53 Gbaud PAM4 and have obtained a 3dB bandwidth of 42.0 GHz using Chip-on-Carrier (CoC) with the EML chip mounted on a ceramic carrier[4]. We have demonstrated 53 Gbaud PAM4 transmitter optical sub-assembly (TOSA) with a BOX type package[5]-[7]. Although EML-TOSA with a temperature control mechanism suitable for temperature-sensitive EML chip is a promising approach to obtain best frequency response performance, it involves high package costs. This leads us to develop EML TO-CAN for 53 Gbaud PAM4 operation, and we have reported an uncooled EML TO-CAN with non-hermetic sealed package[8]. The most important advantage of TO-CAN over BOX-TOSA is cost effectiveness. The most crucial challenge of 106 Gbit/s EML TO-CAN for 5G and B5G application where optical transceivers are operated mainly outdoors is to carry a temperature control mechanism inside TO-CAN with hermetically sealed package. The hermetically sealed TO-CAN package is employed glass-sealed signal pin as transmission line, it is difficult to match the impedance of the connection point between the TO-header and the flexible printed circuit (FPC). Attaining the optimum frequency response of EML TO-CAN requires suppressing the multiple reflections of the connection point between the TO-header and the FPC.

In this paper, we propose and demonstrate a cooled EML TO-CAN with hermetically sealed package employing a stainless steel (S/S) plate to suppress resonance by making the ground between the TO-header and the FPC common. A high performance EML in this TO-CAN package demonstrated a 3 dB electrical bandwidth of 35.9 GHz and a transmitter and dispersion eye closure (TDECQ) for PAM4 of 2.51dB at an extinction ratio of 5.8dB.



(a) Photograph of external structure



(b) Schematic view of internal structure

Fig. 1: Photograph and schematic of the proposed TO-CAN

Design of a 106 Gbit/s PAM4 EML TO-CAN

Fig.1 shows the schematic diagram of the proposed 106 Gbit/s PAM4 EML TO-CAN. A 1310-nm wavelength EML chip is mounted on a ceramic carrier. The ceramic carrier and thermistor are mounted on a TEC (Thermoelectric cooler) which is placed on the TO-header for temperature control. By employing a hermetically sealed structure with a lens cap, it can be used in an outdoor environment such as a mobile base station. The EML is supplied with a 53 Gbaud PAM4 input signal from the FPC via a glass-sealed signal pin and a dielectric substrate. The FPC connection is not impedance matched, so it affects the electrical performance. Therefore, the high frequency performance of the EML TO-CAN was optimized by adjusting the electrical characteristics of the plate. If there is a step on the GND pin by welding, it is difficult to contact between the FPC and the TO-header. Therefore, a plate is used to flatten the FPC contact surface.

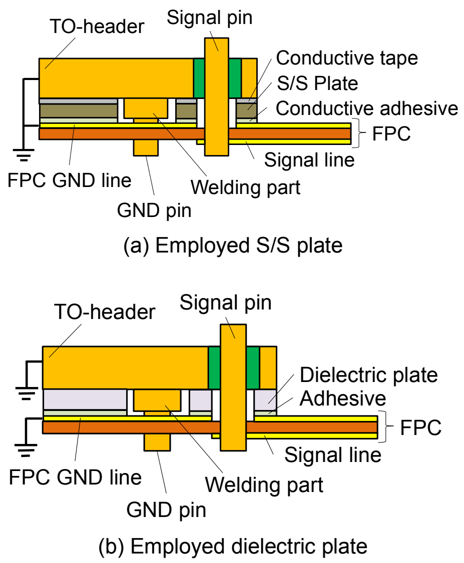


Fig. 2: Schematic view of the FPC structure

Fig. 2 shows the structure of the FPC. The S/S plate is attached to the 50Ω FPC transmission line. With the plate material isolated by the dielectric, resonance may occur between the TO-header and the FPC due to the separation of the TO- header ground and the FPC ground. The S/S plate is therefore bonded to the FPC ground with conductive adhesive and fixed to the TO- header with conductive tape. By adopting this configuration, a common ground connection is made between the TO-header and the FPC, and any resonance is suppressed.

Fig. 3 shows the results of simulations of the E/O response of the proposed structure and a conventional structure. The RF connector and the printed circuit board (PCB) were included in the simulation models. The ripple in the frequency response due to multiple reflections between the TO-header and the FPC was reduced, and the 3 dB electrical bandwidth of the proposed structure was improved.

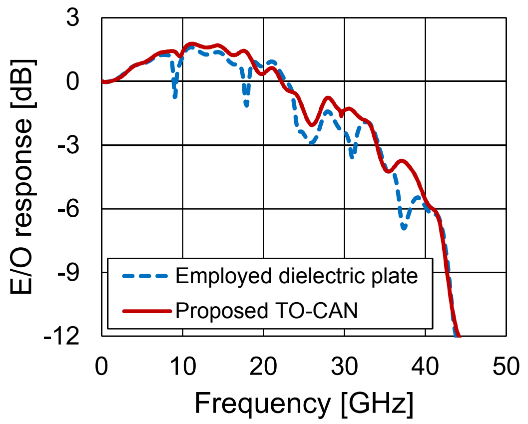


Fig. 3: Simulation of E/O response

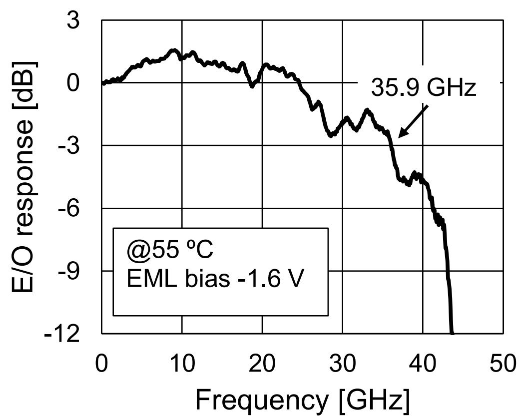


Fig. 4: E/O response of 106 Gbit/s EML TO-CAN

Fig. 4 shows the measured E/O response of the proposed 106 Gbit/s EML TO-CAN. The measured frequency response agrees well with the simulation shown in Fig. 3. The measured 3dB electrical bandwidth was 35.9 GHz, which is sufficient for 53 Gbaud PAM4 modulation.

PAM4 test results

The optical eye diagrams and the TDECQ were measured by using a commercially available digital signal processor (DSP) integrated with the EML driver. Fig. 5 shows the block diagram of the measurement setup for the optical eye diagrams and the TDECQ. The 53 Gbaud PAM4 signal in a short stressed pattern random quaternary (SSPRQ) format was generated by the DSP, and was supplied to the EML TO-CAN via coaxial cable and the PCB. The optical output was input to a digital communication analyser (DCA) via 1 m of standard single mode fibre (SMF).

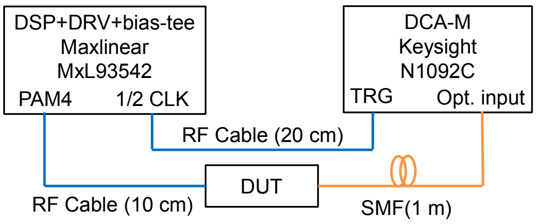
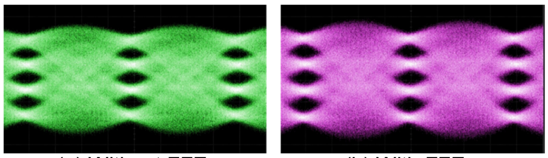


Fig. 5: Measurement setup for PAM4 optical eye



(a) Without FFE (b) With FFE

Fig. 6: 53 Gbaud PAM4 eye diagrams for back-to-back configuration

Fig. 6 shows the measured 53 Gbaud PAM4 optical eye diagrams with and without a T-spaced 5-tap feed forward equalizer (FFE). The electrical signal was pre-distorted by the DSP, and the drive voltage swing was 1.47 Vpp. Clear eye openings were obtained and the measured extinction ratio was 5.8dB. The maximum TDECQ value is specified to be 3.4dB in the standard[9],[10]. The measured TDECQ was 2.51dB, below the target value of 3.4dB. In addition, TDECQ-10*log(Ceq), which represents inherent noise penalties such as relative intensity noise (RIN) and multiple reflections, was 2.23dB, and has a margin within the 100G Lambda MSA specification. Note that the PCB, the RF connector and the coaxial cable can affect the TDECQ performance, and better TDECQ performance would be obtained in an actual transceiver configuration in which the EML TO-CAN is close to the DSP.

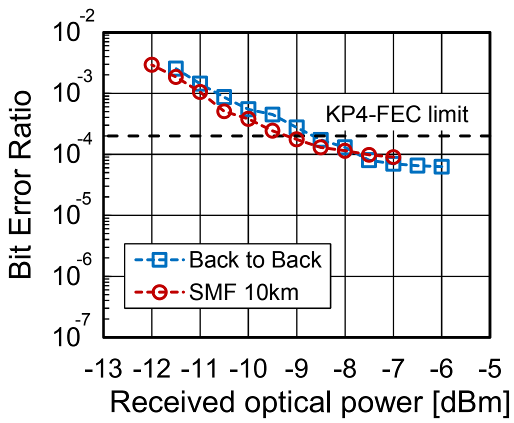


Fig. 7: Measured BER characteristic in back-to-back and after 10 km of SMF.

Fig. 7 shows the measured bit error ratio (BER) characteristic for 106 Gbit/s PAM4 transmission after 10 km of SMF. The 53 Gbaud PAM4 signal with a 2^{31}-1 pseudo-random bit sequence (PRBS) pattern was generated by the DSP. The output optical signal was received by a PIN PD module with a 3dB electrical bandwidth of 40 GHz for the measurement. The electrical signal from the PIN PD module was again captured by the DSP. The minimum receiver sensitivity at the KP4-FEC limit of 2.0×10^{-4} in back-to-back and after 10 km of SMF were -8.6 dBm and -9.1 dBm, respectively. The transmission penalty for 10 km of SMF against back-to-back configuration was -0.5dB. The transmission penalty was caused by the chromatic dispersion of SMF and positive chirp parameter of the EML.

These results show that our EML TO-CAN offers a cost effective alternative for a hermetically sealed package most suitable for 100G/λ applications.

Conclusions

We have developed a high-speed hermetically sealed EML TO-CAN suitable for 100 Gbit/s transceivers for the mobile fronthaul CPRI of Beyond-5G mobile base stations. We demonstrated a 3dB electrical bandwidth of 35.9 GHz. Thanks to the proposed stainless steel plate placed on the FPC, multiple reflections between the TO-header and the FPC were reduced. The TDECQ was 2.51dB at an extinction ratio of 5.8dB with a modulating voltage of 1.47 Vpp in a back-to-back link. Furthermore, the measured receiver sensitivity was -9.1 dBm. We believe that the EML TO-CAN is the best solution for 5G and Beyond-5G mobile fronthaul achieving both performance and cost effectiveness.

References

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