Compact Optical Transmitter Module for XFP Transceivers

Atsushi Kanda†*, Akira Ohki, and Yuji Akatsu*

Abstract

We have developed a compact 10-Gbit/s cooled optical transmitter module applicable to XFP (10-Gbit/s small-form-factor pluggable) optical transceivers for 40-km transmission. The driver integrated circuit is mounted in the module package to reduce electrical crosstalk between the transmitter and receiver circuits. A pigtail-fiber optical interface improves the thermal conductivity without degrading the optical coupling efficiency. In addition, simplified optics reduce material and assembly costs.

1. Introduction

The optical transmitter module in an optical transceiver converts the input electrical signal to an optical signal. For 10-Gbit/s intermediate-to-long-distance (40–80 km) data links, the light source should have a wavelength of 1550 nm because loss in fibers is low at that wavelength. The light source should also have low-chirping properties. To meet these requirements, instead of a directly modulated laser diode (LD), a distributed feedback LD (DFB-LD) integrated with an electroabsorption (EA) modulator or a DFB-LD in combination with a lithium niobate ($LiNbO_3$) modulator is used as the light source.

The lasing wavelength, and hence the operating temperature of the EA DFB-LD, must be regulated because the EA modulator has strong wavelength dependency. This is done using a thermoelectric cooler (TEC), which can regulate the temperature of the LD using the Peltier effect to act as either a heater or cooler as required (in most cases, the device is cooled). Precise wavelength control of the EA DFB-LD by controlling its temperature is also necessary in wavelength division multiplexing (WDM) transmission systems. However, it is difficult to integrate a temperature control function into the limited space available in a small XFP transceiver [1] [2]. XFP transceivers normally use a can-type transmitter optical sub-assembly (TOSA) package. However, its small size and small number of pins prevent it from accommodating a TEC and temperature monitor. Our solution is to use a mini-DIL (dual-in-line) package [3]-[5]. As described in the previous paper in this issue [6], the mini-DIL accommodates a TEC and temperature monitor in a small transmitter module.

The market for 10-Gbit/s optical transceivers is expanding with the spread of high-speed optical communication systems for local area networks (LANs) and wide area networks (WANs). XFP transceivers seem to be most promising among those complying with 10-Gbit/s optical transceiver standards. However, they are expensive to build. Reducing the cost of the optical transmitter module should take priority because this module is the most expensive of the XFP's components.

2. Appearance

A photograph of our developed optical transmitter module is shown in **Fig. 1**. The pin layout of the module is based on mini-DIL. The ceramic-cavity-package area (12 mm × 7 mm) is also almost the same as that of a conventional mini-DIL package. The package height (less than 5 mm) is reduced to conform to the standard height for the XFP. The volume of the package is about one-fifth that of the conventional 14-pin butterfly-package transmitter module. We customized the TEC to make it small enough for our transmitter module and optimized its performance.

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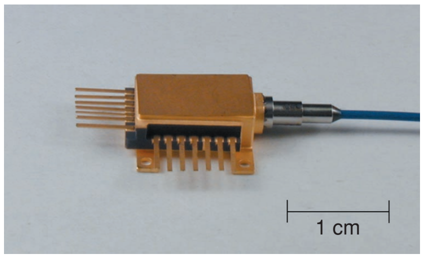

Fig. 1. Photograph of the optical transmitter module.

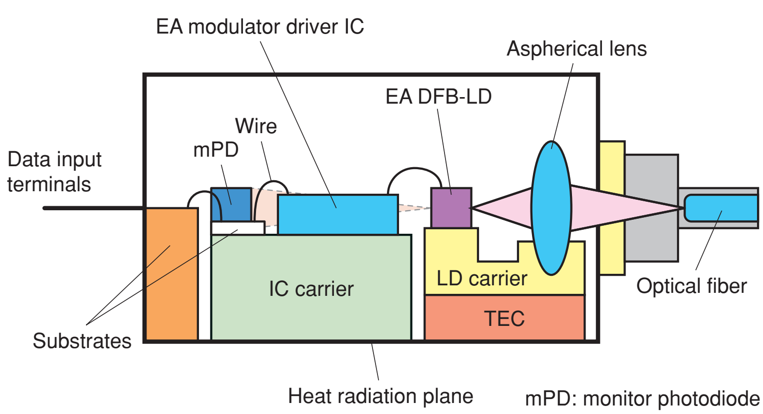

Fig. 2. Schematic of transmitter module structure.

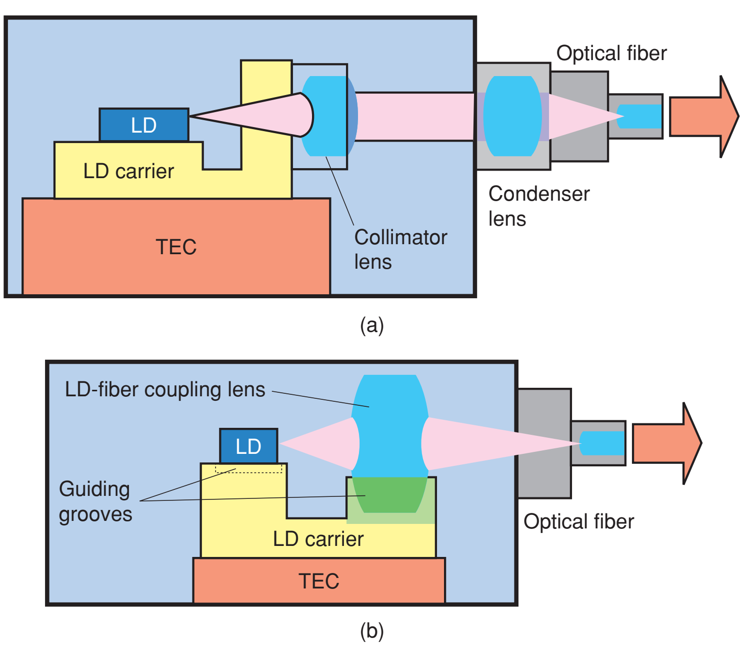

Fig. 3. (a) Conventional optics for LD-fiber coupling and (b) our simplified optics.

3. Configuration

The output voltage swing for the driver IC (integrated circuit) needs to be as large as 2–3 V to modulate the EA modulator. This large voltage swing causes electrical crosstalk from the transmitter to receiver circuits, and the noise from the crosstalk interferes with the weak photodiode output signals (less than 10 μA) of the optical receiver module. To reduce the effect of this noise, we mounted the driver IC in the optical transmitter module package. The module's structure is shown in **Fig. 2**. The module contains an EA modulator driver IC, 1550-nm EA DFB-LD, monitor photodiode, aspherical lens, and TEC. The TEC and driver IC are large heat sources, so it is important for the transmitter module to make good contact with the XFP chassis to transfer the heat to the chassis. Our transmitter module has a pigtail optical interface to provide better thermal conductivity between the heat radiation plane of the transmitter module and the XFP chassis than a conventional TOSA module with the receptacle optical interface.

4. Simplified optics

To reduce material and assembly costs, we simplified the optical coupling between the LD and the optical fiber. Our simplified layout is shown in **Fig. 3**, with a conventional layout shown for comparison. The LD and lens are aligned passively by being placed along the guiding grooves. Only the optical fiber has to be aligned actively. Once it is properly aligned, it is welded in place using a YAG (yttrium aluminum garnet) laser. This "semi-passive alignment" technique simplifies optical alignment to just a single procedure for active alignment of the module and fiber, whereas the conventional process involves three active alignment procedures for the LD, lenses, and fiber. As a result, assembly time is halved. The reproducibility of the optical coupling loss of the transmitter modules is shown in **Fig. 4**. An average coupling loss of 3.2 dB was achieved even using the semi-passive alignment.

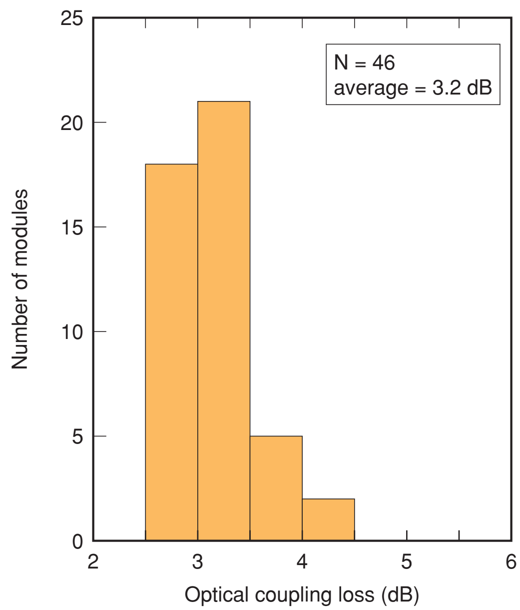

Fig. 4. Reproducibility of the transmitter module's optical coupling loss.

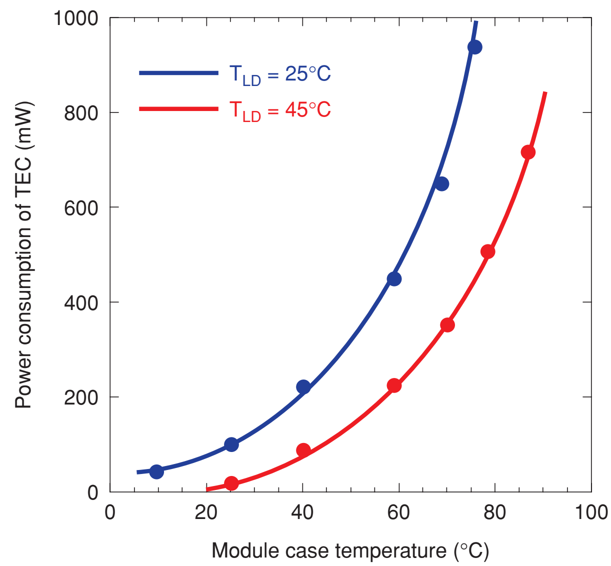

Fig. 5. Cooling capacity of the transmitter module.

5. Performance

5.1 Temperature characteristics

Since XFPs may be used under various ambient conditions, we examined how the power consumption depended on the temperature of the module's case. The cooling capacity of the transmitter module is shown in **Fig. 5**. The power consumption of the TEC increased as the case temperature rose because the temperature of the EA DFB-LD was regulated by the Peltier current of the TEC. However, the power consumption was less than 0.5 W even when the case temperature was as high as 75°C, when the LD chip temperature was set to 45°C. This will contribute to achieving total power consumption of less than 3.5 W specified for XFP transceivers [2].

5.2 Optical transmission performance

The transmission performance of the optical transmitter module was evaluated using a conventional single-mode fiber (SMF). The transmitter was modulated using 9.95328-Gbit/s or 10.3125-Gbit/s non-return-to-zero 2^{31}-1 pseudo-random bit stream data. The optical waveform measured by an optical-to-electrical converter is shown in **Fig. 6**.

The back-to-back eye pattern passed all the mask tests for 10-Gigabit Ethernet [7], SDH (synchronous digital hierarchy) STM-64 [8], and SONET (synchronous optical network) OC-192 [9] standards. The average optical output power and the extinction ratio were typically 0 dBm and 10 dB, respectively. The measured dispersion penalty (minimum sensitivity degradation due to the chromatic dispersion effect caused by SMF 40-km transmission) is shown in **Fig. 7**. At both module case temperatures, the dispersion penalty was less than 1 dB after the SMF 40-km

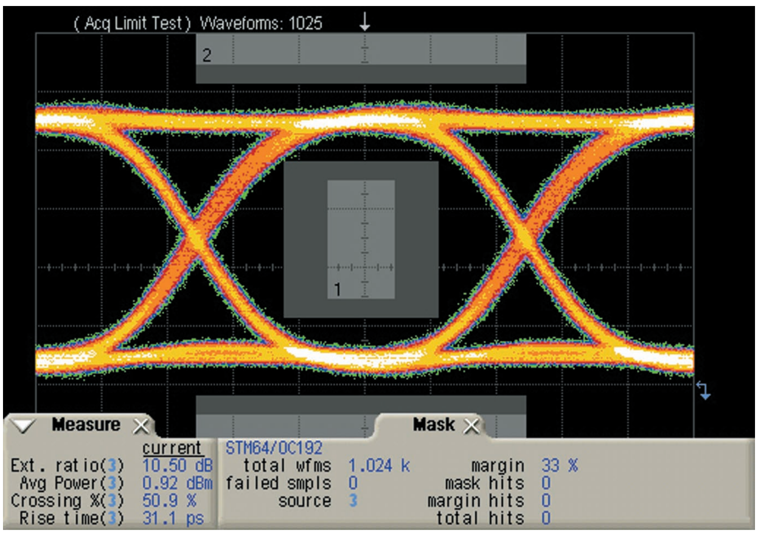

Fig. 6. Optical eye pattern of the transmitter module (back-to-back).

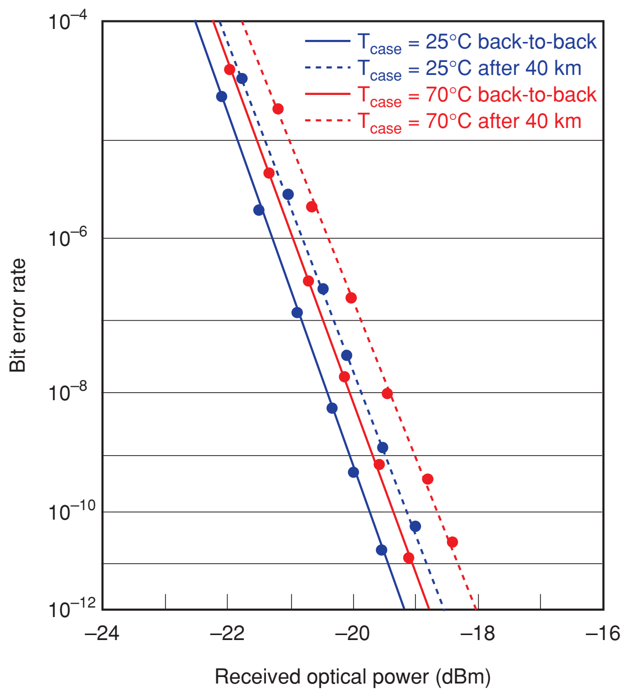

Fig. 7. Bit error rate performance of the transmitter module.

transmission. These results show that the developed transmitter meets the specifications for LAN and WAN systems with transmission distances of more than 40 km, such as 10-Gigabit Ethernet 10GBASE-ER/EW, SDH STM-64 P1S1-2D2b (S-64.2b), and SONET OC-192 IR-2.

6. Conclusion

We have developed a compact and cost-effective 10-Gbit/s cooled optical transmitter module. Its mechanical and electrical properties make it a very suitable component for 40-km-reach XFP transceivers. We plan to develop the transmitter and receiver modules best suited for XFP transceivers for long-distance-class (>80 km) and dense WDM data links.

References

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[7] IEEE 802.3ae standard.

[8] ITU-T Recommendation G.691.

[9] Telcordia GR-253.

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