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Abstract. A bidirectional optical subassembly comprised of a 2.5 Gbps distributed feedback (DFB) laser diode (LD) directly modulated laser transmitter and a 10 Gbps positive intrinsic negative photodiode receiver was developed for an optical network unit of a 10 Gbps passive optical network. Here, a low-cost mini-dual-in-line package was modified to contain whole components of a transmitter and receiver in a single space while satisfying the requirements of 10 Gbps micro-device package standards. The transmitter was fabricated to achieve high optical output power by placing a micro aspheric lens very close to the DFB LD and reducing the thermal resistance between an LD chip and heat sink to bring down the DFB LD chip temperature. As a result, the transmitter output power was 3.5 dB higher than a conventional transistor outline can BOSA due to a high optical coupling efficiency of more than 70% and a low thermal resistance for heat dissipation. The receiver sensitivity was −21 dBm at a bit error rate of 10^{-3} and the sensitivity penalty of the receiver due to signal crosstalk was less than 0.3 dB. [DOI: 10.1117/1.OE.51.12.120501]

Keywords: passive optical network; direct modulation; optical network unit; bidirectional optical subassembly.

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1 Introduction

Passive optical network (PON) standards such as 10 Gbps gigabit capable PON and IEEE 802.3av PRX30 require a 10 gigabit per second (Gbps) downstream and a 2.5 or 1.25 Gbps burst mode upstream data rate for emerging broadband services such as Internet protocol televisions (IPTVs) and mobile convergence networks.[1,2] Besides the high bandwidth requirement, the link loss and power budget in the optical network unit (ONU) physical medium dependent layer are the greatest challenges to realize a 10 Gbps PON system due to longer reach extent and higher splitting ratio than previous Gbps PON systems.[3,4]

In a previous study, a 10 Gbps directly modulated laser (DML) bidirectional optical subassembly (BOSA) module for an ONU was constructed by combining a transistor outline can (TO-can) transmitter and receiver with a metal housing using a laser welding technique.[5] However, in general, the TO-can transmitter has high thermal resistance between a laser diode (LD) chip and an external heat sink, which brings up the distributed feedback (DFB) LD chip temperature. In addition, the optical coupling efficiency of a TO-can BOSA using a conventional bulk-type aspheric lens is typically less than 40% due to a large spherical aberration and a 1-mm-long coupling distance between the lens and the LD chip. In this study, we proposed a new compact DML BOSA package modified from a mini dual-in-line (mini-DIL) package to enhance heat dissipation of an un-cooled DFB LD and increase optical coupling efficiency.

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2 Structure and Fabrication of Single Package DML BOSA

Figure 1 shows a fully assembled single package DML BOSA (SPDB) using a modified mini-DIL package, 2.5 Gbps transmitter subassembly, and 10 Gbps receiver subassembly. The stems for integration of the transmitter and receiver are made of Kovar using a low-cost metal injection molding (MIM) process, and they are electrically well-insulated from each other by inserting a high resistance ceramic interposer between them using a metal blazing process as shown in Fig. 2. The transmitter feedthrough in the stem has ground(G)-signal(S)-signal(S)-ground(G) pins designed to have 25-Ω matching impedance for each signal line. For the receiver feedthrough, two lead pins were designed to have 50-Ω matching impedance, respectively. Flexible printed circuit boards (FPCBs) were soldered at the end of the transmitter and receiver lead pins separately.

The transmitter components such as the DFB LD chip, monitoring photodiode (mPD) chip, collimating lens, and wavelength multiplexing filter are integrated on a high resistive silicon (HRS) platform as shown in Fig. 1. In this study, a wavelength of 1310 nm DFB LD was integrated as a source. Even though it does not meet the wavelength requirement of the XG-PON1 standard, we can expect the same aspects of the transmitter performance except the result related with the wavelength.The assembled HRS platform is mounted on the transmitter stem to have large contact area with heat sink to reduce thermal resistance (R_{th}).

The length, height, and width of the single DML BOSA package are 6.5, 5.2, and 5.6 mm, respectively, which are compatible with XMD, the 10 Gbps package standard.

A V-groove was fabricated on a 6-in. HRS wafer that has 10 kohm cm resistivity by a 450 μm deep wet etching process to mount a collimating lens and a focusing lens passively. In the middle of the HRS platform, a 1.3 mm diameter hole through the optical input path was fabricated with a deep-reactive-ionized-etching (DRIE) process. A silicon dioxide (SiO_2) insulation layer was provided on the top side of the HRS using an oxidation process. On the SiO_2 layer, the signal lines and chip bonding pads were fabricated using under bump metallization (UBM) and a gold-tin (AuSn) solder coating process.

To guide the DFB emission beam to an optical fiber, a 1 mm diameter collimating lens was positioned on the V-groove at a distance (L1) of 160 μm from the DFB LD as shown in Fig. 2. The numerical aperture (NA) value of the micro lens was 0.4, and the vertical and horizontal divergence angles of the DFB LD at far-field were 27 deg and

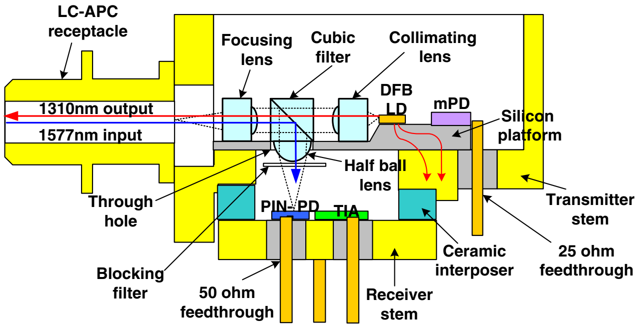

Fig. 1 The cross-section of the 10 Gbps single package DML BOSA.

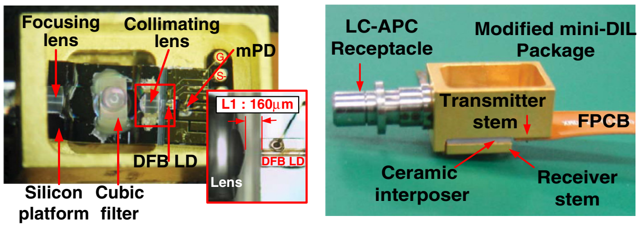

Fig. 2 The 10 Gbps single package DML BOSA assembled in a modified mini-DIL package.

24 deg, respectively. The focusing lens was positioned on another V-groove fabricated at the very end of the silicon platform. The silicon platform was mounted on the transmitter stem with a 4 deg angular tilt, which maximizes the coupling efficiency with a lucent-connector angled polished contact (LC-APC) receptacle that is aligned and welded on a package window with a monitor of maximum output power.

The receiver components such as a positive intrinsic negative photodiode (PIN-PD), trans-impedance amplifier (TIA) and capacitor were integrated on the receiver stem as shown in Fig. 1. An input beam at a wavelength of 1577 nm was collimated after passing through the focusing lens, entered the cubic filter which has a 45 deg coating layer angle, and was turned 90 deg to the PIN-PD on the receiver stem passing through the silicon through hole.

3 Experimental Results

To test the SPDB, we controlled the operating temperature at a Tc = 25°C and 85°C using thermal chamber and applied a threshold current (I_{th}) +20 mA to the DFB LD without modulation. The output power was 6.7 dBm at Tc = 25°C and 4 dBm at Tc = 85°C. To compare the performance with a TO-can based BOSA, we assembled a TO-can transmitter using a DFB LD chip which has the same light-current-voltage (L-I-V) characteristic with the DFB LD chip used in the SPDB. As shown in Fig. 3, the output power of the SPDB was at least 3.5 dB higher than that of TO-can BOSA at Tc = 25°C. The coupling efficiency of the SPDB was more than 70%, while that of the TO-can BOSA was 37%. The slope efficiency (SE) of the TO-can BOSA and the SPDB were 0.055 and 0.125, respectively at Tc = 85°C, and were 0.11 and 0.23 at Tc = 25°C. The SE ratio of the SPDB to the TO-can BOSA at Tc = 25°C increased by around 8% at Tc = 85°C, which meant the LD chip temperature of the SPDB was lower than that of the TO-can BOSA due to good heat dissipation.

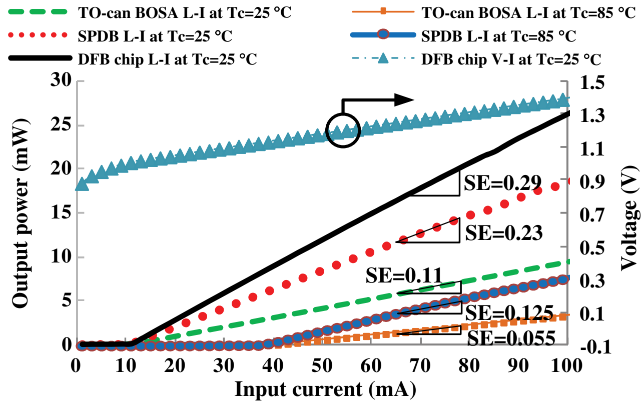

Fig. 3 Light-current-voltage (L-I-V) relation of the single package DML BOSA and TO-can BOSA according to the case temperature (Tc). Slope efficiency (SE) is indicated for each condition.

To compare the heat dissipation performance of the SPDB and TO-can BOSA, we evaluated the R_{th} which was defined by a ratio of a temperature change (dT) to a laser diode heat generation (Q_{LD}).[6] The temperature change was evaluated from the wavelength change of the DFB LD chip of which the wavelength-temperature coefficient was estimated as 0.09 nm/°C. The Q_{LD} was estimated by subtracting the optical output power from the electric power consumption. At the change of the input current from 10 mA to 100 mA, the wavelength change of the TO-can BOSA was 0.92 nm at Tc = 25°C and was 0.54 nm for the SPDB. Therefore, the R_{th} of the SPDB was 62.5°C/W, while that of the TO-can BOSA was 106.5°C/W, which meant the R_{th} was reduced by more than 40%.

The side mode suppression ratio measured with an optical spectrum analyzer showed over 37.5 dB at Tc = 25°C and 34.7 dB at Tc = 85°C. The rise and fall time were shorter than 150 ps and the extinction ratio was over 11 dB at a 2.5 Gbps modulation.

The sensitivity of the receiver was measured with the 10 Gbps modulated laser source. As shown in Fig. 4, we achieved a sensitivity of −21 dBm at a bit error rate (BER) of 10^{-3} without forward error correction (FEC). In addition, the sensitivity penalty of the receiver due to the signal crosstalk was less than 0.3 dB.

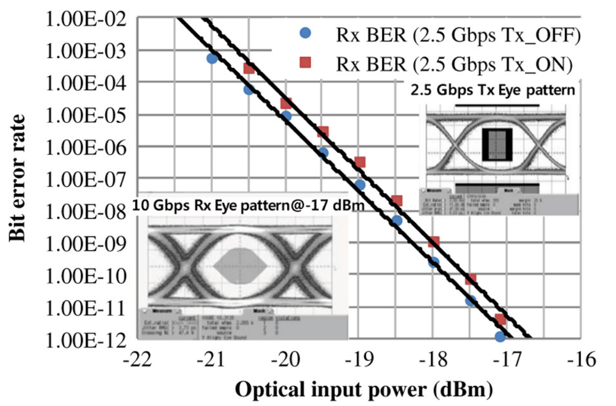

Fig. 4 Test result of PIN-PD receiver (Rx) sensitivity at a pseudo random bit sequence (PRBS) $2^{31} - 1$, 10.3125 Gbps with (blue circles) and without (red squares) a DFB transmitter (Tx) eye pattern at 2.5 Gbps modulation.

4 Conclusions

An XMD-compatible single-package DML BOSA for 10 Gbps PON applications was successfully fabricated and demonstrated by introducing a modified mini-DIL BOSA package in attempt to integrate the whole components of the transmitter and the receiver in a single package including micro aspheric lens which was placed very close to the DFB laser to minimize the optical coupling loss. In addition, the modified mini-DIL BOSA package reduced thermal resistance by 40% compared with typical TO-can BOSA, which brings down the DFB LD chip temperature more efficiently. The coupling efficiency of the transmitter was more than 70%, which was at least 3.5 dB larger more power compared with the typical TO-can BOSA.

References

1. ITU-T Recommendation G.987, July 2010, http://www.itu.int/rec/T-REC-G/en (2010).
2. IEEE 802.3av-2009, October 2009, http://ieeexplore.ieee.org/xpl/standards.jsp (2009).
3. K. Kim et al., “Low-cost, low-power, high-capacity 3R OEO-type reach extender for a long-reach TDMA-PON,” *ETRI J.* **34**(3), 352–360 (2012).
4. J. Kim, H. Bang, and C.-s. Park, “Design and performance analysis of passively extended XG-PON with CWDM upstream,” *J. Lightw. Technol.* **30**(11), 1677–1684 (2012).
5. T.-T. Shih et al., “High-performance and low-cost 10-Gb/s bidirectional optical subassembly modules,” *J. Lightw. Technol.* **25**(11), 3488–3494 (2007).
6. M. Funabashi et al., “Recent advances in DFB lasers for ultradense WDM applications,” *IEEE J. Sel. Topics Quant. Electron.* **10**(2), 312–320 (2004).