High Speed Laser Diode Packaging with Over 10GHz-Bandwidth

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***Abstract*— A high frequency laser diode module package with over 10GHz-bandwidth is presented. The package consists of a V-connector, heat sink, and L-shaped microstrip line (MSL) on a substrate and included an integrated impedance matching resistor. For evaluation, a 1.3μm Fabry-Parot laser was included as a load on the package and the frequency response was characterized. As a result, a large modulation bandwidth of up to 15GHz was obtained. Importantly, using an L-shaped MSL with integrated impedance matching resistor design, the assembling tolerance for various optical coupling systems has been improved and the assembly process and module design have been significantly simplified.**

Keywords-impedance matching; optoelectronics packaging.

I. Introduction

For increasingly large data rates, a laser diode module for over 10Gbps may be a key component for high bit rate optical communication systems. For the bit rate of 10Gbps, the modulation bandwidth of packaged laser module must exceed 10GHz [1]. This bandwidth can be a major requirement and is determined by the electrical return loss of the input signal. This return loss may occur from the mismatched impedance of each package element such as wire bonds and microstrip line (MSL) and parasitic effects of each element as well as the characteristics of a laser diode. There are several requirements for the high performance package [2]. Electrical requirements, such as a large bandwidth, can be achieved using impedance matching techniques. Impedance matching for the achievement of large modulation bandwidth can be attained using a 50Ω transmission line and interconnecting a resistor to the laser. Optical requirements are also required such as high coupling efficiency and low optical feedback. These requirements can be achieved by various optical coupling techniques. In addition, large assembly tolerances for adopting various optical coupling systems and a simplified module for cost reduction are required. Large assembly tolerance and simplified module design can aid the ease of production for high volume manufacturing, high reliability and low cost. In this paper, we demonstrated a high frequency laser diode package with large assembly tolerances using an integrated thin-film resistor with an L-shaped MSL.

II. Package Structure and Experimental Result

The package structure of the optical subassembly (OSA) consists of a heat sink made of Kovar as a ground plane, MSL on dielectric substrate with integrated thin film resistor, and a 1.3μm Fabry-Parot (FP) laser diode which is interconnected to the MSL via a wire bond as shown in Fig. 1. The required return loss must be less than −10dB. The return loss is mainly due to the parasitic effects of each element in the package. In particular, the inductance due to wire bonding is responsible for creating a large return loss. Generally, the length of the wire bond must be as short as possible to reduce the inductance. There are several methods to facilitate a reduction in the inductance such as using flip chip bonding which eliminates bond wires, multiple wire bonding, and ribbon wire bonding. Flip-chip is suitable for lasers with electrical transmission lines on the same plane, such as coplanar waveguide transmission lines on a laser. Flip chip bonding also has problems such as difficulty of forming solder bumps, removal of residual flux, and a reduction in the number of heat dissipation paths. For multiple wire bonding, the lasers bond pad may be small by design in order to minimize the parasitic capacitance. Among these techniques, we choose a ribbon bonding technique to reduce the inductance of a die attached laser.

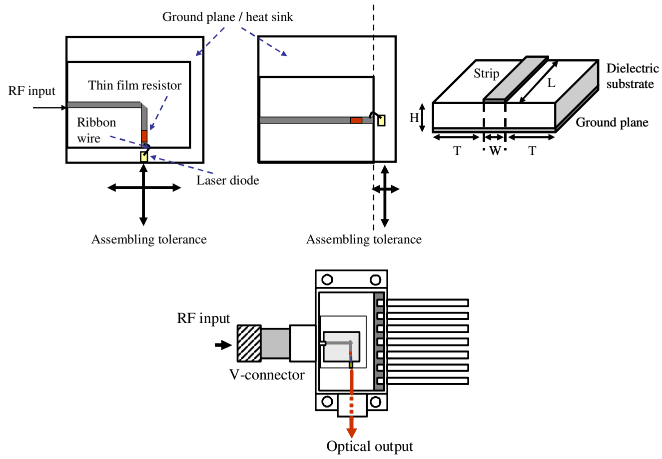

Figure 1. Microstrip line (MSL) geometry and schemetic of the package

Fig. 1 shows the comparison between using an L-shaped MSL and a conventional straight MSL. A thin-film resister integrated L-shaped MSL has been used in this experiment. The miter [3] of L-shaped design is 50%. The integrated thin-film resistor is based on a NiCr alloy and is laser trimmed to provide the required resistance value. The process used can provide a resistance of ±0.2Ω.

The working distance of an optical coupling system such as a micro lens [4] or lensed fiber [5], [6] is limited to few hundred microns or much less, respectively. As can be seen in Fig. 1, there is a large distance between the laser output facet and the edge of the ground plane due to the configuration of a

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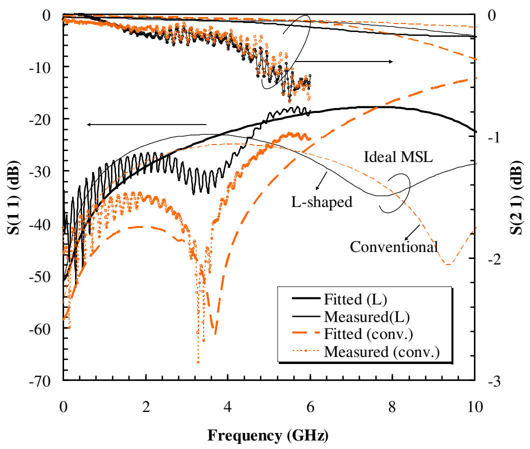

Figure 2. Convetional and L-shaped MSL measurements

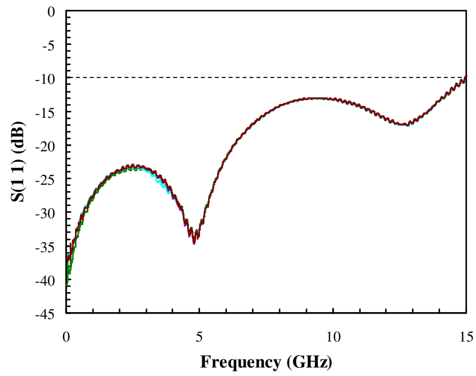

Figure 3. Reflection of frequency signal in the package with respect to various dc bias levels(40 to 70mA)

conventional MSL. This limits the alignment tolerance available when trying to achieve efficient optical coupling.

For an improved frequency response of the MSL, the conditions of T/W>2 and W/H>1 should be satisfied [7]. In the case of conventional MSL in Fig. 1, if the laser is to be aligned to the edge of the heat sink, the length of ribbon bond must be increased. However, the L-shaped MSL can overcome these limitations and can satisfy both conditions of the conventional MSL and the need for a short ribbon bond.

The fabricated MSL has the optimum width of 270μm for 50Ω impedance on the 254μm-thick Aluminum Nitride (AlN) substrate whose dielectric constant (ε) is 8.8. When W/H>1, the optimum width can be determined by equations in [8]. To investigate the frequency response of both the L-shaped and conventional MSLs, S-parameters have been measured using a vector network analyzer (VNA). Fig. 2 shows the measurement results of both MSLs. The estimated capacitances from the measurement are in the range of 0.05-0.15pF. These values of capacitance may be suitable for the package performance. The capacitance of the assembled package is an important parameter to consider because a high capacitance of the contact area would result in a large return loss when launching a high frequency signal and therefore a reduced modulation bandwidth. The results show that L-shaped and conventional MSLs have similar frequency response performance even when approaching near zero capacitance as ideal cases as shown in Fig. 2. However, the L-shaped MSL has significantly improved flexibility for adopting various optical coupling systems as mentioned previously. A 45±0.2Ω thin-film resistor has been integrated in the L-shaped MSL for impedance matching and to simplify the assembly process. The resistor integrated on the MSL is interconnected by a single ribbon bond to a laser using a K&S 4234 wedge bonder. The dimension of the gold ribbon bond was approximately 320μm×75μm×12μm which can help minimize the inductance. The measured resistance of the 1.3μm FP laser here is 4.5Ω. An entire package was assembled using a commercially available 7-pin butterfly package which included a heat sink, L-shaped MSL with impedance matching resistor and a sample laser interconnected by a ribbon bond and a V-connector. A high frequency input signal passes via a V-bead in the V-connector to the integrated impedance matched resistor on the MSL. The measurement setup for the package consists of a VNA, power meter, current source, and bias-tee. Fig. 3 shows the measurement results of our package with various injection currents. The results show that the reflection of the input signal was as low as −10dB for all signals up to 15GHz. This bandwidth is sufficient for a 10Gbps signal transmission.

III. Conclusion

We demonstrated a large bandwidth butterfly package for high speed laser diode modules. The package has relaxed assembly tolerances for coupling of the optical output. The package shows a large frequency bandwidth of up to 15GHz and higher flexibility for various optical coupling systems using impedance matching resistor integrated L-shape MSL. This packaging configuration is an attractive solution for high speed laser diode modules.

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