Measurement of 3db Bandwidth of Laser Diode Chips

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Abstract: An accurate technique for measuring the frequency response of semiconductor laser diode chips is proposed and experimentally demonstrated. The effects of test jig parasites can be completely removed in the measurement by a new calibration method. In theory, the measuring range of the measurement system is only determined by the measuring range of the instruments network analyzer and photo detector. Diodes' bandwidth of 7.5GHz and 10GHz is measured. The results reveal that the method is feasible and comparing with other method, it is more precise and easier to use.

Key words: bandwidth measurement; calibration; frequency response; semiconductor laser diode chips
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1 Introduction

In the last decade, the semiconductor laser diodes were significantly developed and became the key components for the high speed optical communication system due to their excellent electrical and optical characteristics as the sophisticated high speed sources.

First of all, the bandwidth and other parameters of the laser diode should be known clearly so that the optimization of packaging and modeling can be made.

There are three methods to measure the bandwidth of laser diodes. It is simple to use lightwave signal analyzers for checking the bandwidth[1], but the result is scalar quantity and it is not precise and comprehensive to reflect the performance of the diodes. To overcome the disadvantages of it, the correction methods[2] must be used. The other more precise method is to use vector network analyzers with a probe imposing signal on the chip[3]. We developed the third method. Our way is to use vector network analyzers with a microstrip imposing signal. And we used a new calibration method to remove the effects of test fixture.

After the description of the first method we present the last method developed by us in details and compare the result with that from the Vector Network Analyzers with a probe.

2 Measurement with vector network analyzers

Figure 1 shows the measuring setup we deployed. The cables have a corresponding calibration kit, and it can make the reference plane to locate at the end of the cable. But in order to get the chip's bandwidth, we must transfer the reference plane to the chip's weld pad. In order to do so we made a calibration kit (shown in Fig. 3) and calibrated the jig.

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The electrical and optical responses of the device under test are obtained by using an HP 8510C network analyzer with photo detector.

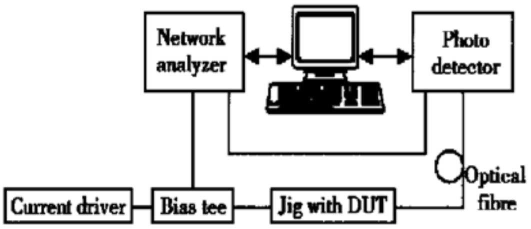

Fig. 1　Measurement setup

The jig, outlined in Fig. 2, consists of a small gold-plated copper case, a microwave SMA connector for routing the bias current and the modulating signal through a 50Ω microstrip (including an integrated 46Ω matching resistor) to the laser chip. The heat sink is melded on the case and as close as possible to the microstrip. The fiber with a coned lens is mounted on the positioning stage for collecting the laser radiation.

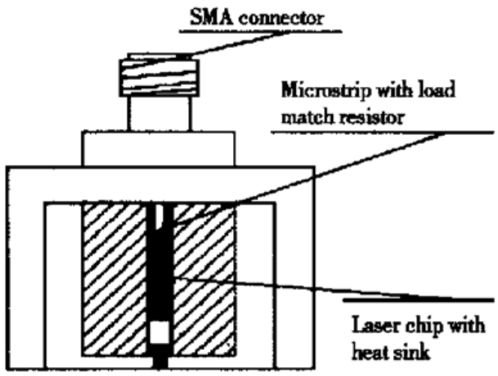

Fig. 2　Measurement jig

Figure 3 is the scheme of the calibration kit we made. Figure 3(a) shows that two jigs are placed head to head. Two microstrips are the same as each other and as the one used in measurement of the chip melded on the gold-plated copper case. For connecting them, a gold line is melded on the ends of the two microstrips. Figure 3(b) shows that one jig with a gold line connecting the microstrip with the ground. To calibrate the jig, we regard it as a tow-port network.

Figures 4(a) and (b) are the model of Figs. 3(a) and (b), respectively. The S represents scattering parameters of the two-port net, but the S' represents

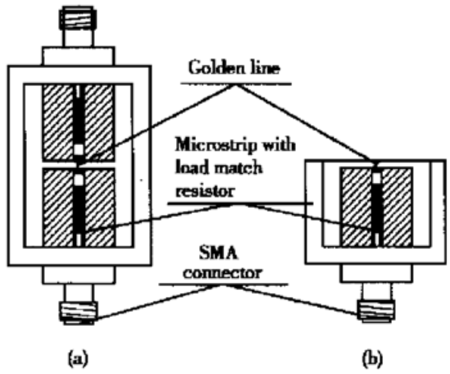

Fig. 3　Calibration kits

scattering parameters of the reversed two-port net. We got the scattering parameters of the combined two-port network S_m and s_{11} of the two-port net with network analyzer. Here S, S', and S_m are matrices. Then we calculated the scattering parameters S. Thus we avoided the tough work to calculate the impedances, capacitance, and inductance of the jig[4].

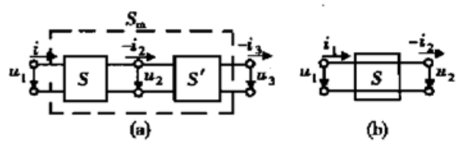

Fig. 4　Model of calibration kits

First, from the S_m we got the chain two-port parameters:

$$a_m = (1 + s_{m_{11}} - s_{m_{22}} + |s_m|)/2s_{m_{21}}$$

$$b_m = (1 + s_{m_{11}} + s_{m_{22}} + |s_m|)/2s_{m_{21}}$$

$$c_m = (1 - s_{m_{11}} - s_{m_{22}} + |s_m|)/2s_{m_{21}}$$

$$d_m = (1 - s_{m_{11}} + s_{m_{22}} - |s_m|)/2s_{m_{21}}$$

Also the input port of net S' is equivalent to the output port of net S and the output port of net S' is equivalent to the input port of net S. We supposed that the chain two-port parameters of S and S' are (A_1) and (A_2) respectively. From the definition of chain two-port parameters we got:

$$\begin{bmatrix} u_1 \\ i_1 \end{bmatrix} = \begin{bmatrix} a_1 & b_1 \\ c_1 & d_1 \end{bmatrix} \begin{bmatrix} u_2 \\ -i_2 \end{bmatrix} = (A_1) \begin{bmatrix} u_2 \\ -i_2 \end{bmatrix}$$

$$\begin{bmatrix} u_2 \\ i_2 \end{bmatrix} = \begin{bmatrix} a_2 & b_2 \\ c_2 & d_2 \end{bmatrix} \begin{bmatrix} u_1 \\ -i_1 \end{bmatrix} = (A_2) \begin{bmatrix} u_1 \\ -i_1 \end{bmatrix}$$

Here u_1 and $-i_1$ are equivalent to u_3 and $-i_3$

shown in Fig. 4(a). Then we got

$$\begin{bmatrix} a_1 & b_1 \\ c_1 & d_1 \end{bmatrix} \begin{bmatrix} a_2 & b_2 \\ c_2 & d_2 \end{bmatrix} =$$

$$\begin{bmatrix} \frac{-a_1d_1 - b_1c_1}{-a_1d_1 + b_1c_1} & \frac{-2a_1b_1}{-a_1d_1 + b_1c_1} \\ \frac{-2c_1d_1}{-a_1d_1 + b_1c_1} & \frac{-a_1d_1 - b_1c_1}{-a_1d_1 + b_1c_1} \end{bmatrix} = \begin{bmatrix} a_m & b_m \\ c_m & d_m \end{bmatrix}$$

We used the calibration kit shown in Fig. 3(b) to get s_{11}. So we got the group of equations

$$\frac{a_1 + b_1 - c_1 - d_1}{a_1 + b_1 + c_1 + d_1} = s_{11}$$

$$a_1d_1 + b_1c_1 = a_m$$

$$2a_1b_1 = b_m$$

$$2c_1d_1 = c_m$$

From these equations we can get a_1, b_1, c_1, and d_1. Finally, we got s_{21} parameter and the results are shown in Fig. 6 and Fig. 7.

Figures 5 and 6 show the results of measured response S_{21} of low-frequency (up to 7GHz) DFB-LD[6] chips, which were made from the same wafer (That means they have almost the same parameters). The results shown in Figs. 5 and 6 are got respectively by using vector network analyzers with a probe and vector network analyzers with a microstrip. The results are almost the same.

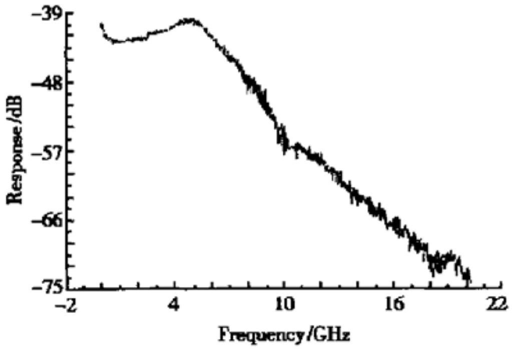

Fig. 5 Result of measured response S_{21}

Figure 7 shows the results of measured response S_{21} of high-frequency (up to 10GHz) DFB-LD chips.

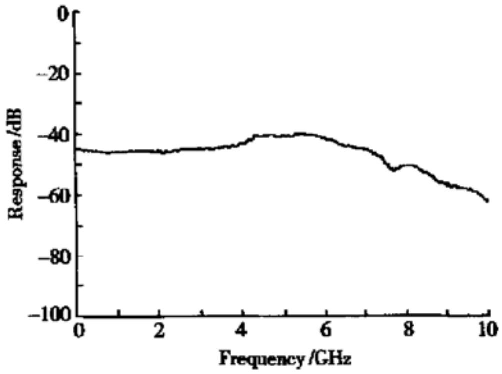

Fig. 6 Result of measured response S_{21}

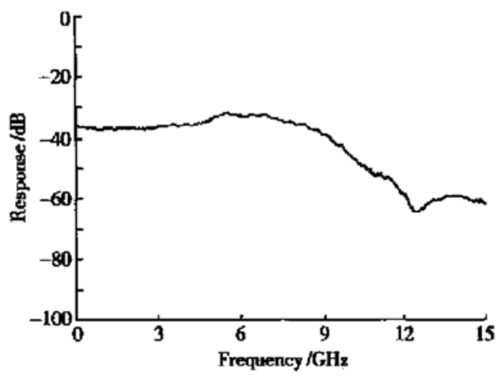

Fig. 7 Result of measured response S_{21}

3 Conclusion

Comparing to the results which are got by using the vector network analyzers with a probe, we found the results measured by vector network analyzers with a micro-strip imposing signal are the same in precise. And the method we used is much cheaper and easier because it can avoid using the expensive and frangible probe. An accurate and easy technique has been developed for measuring the real performance of the semiconductor laser diode chips. Furthermore, the case and microstrip are easy to be developed for packaging[4,5].

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半导体激光器芯片 3dB 带宽的测量

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摘要: 提出一种测量半导体激光器芯片频率响应的方法并建立了一套测试系统, 通过校准完全剔除了夹具的影响. 该方法简单、精确、实用性强. 在理论上, 该测试系统的测量范围只由测量仪器所决定. 在实验中, 测量了带宽为 7.5GHz 和 10GHz 的芯片, 并与其他方法的测量结果进行了比较, 表明该方法测量精度达到实用的要求, 同时具有简单、易于操作的优点.

关键词: 带宽测量; 校准; 频率响应; 半导体激光器芯片

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