Butt-Joint Monolithically Integrated DFB-LD/ EA-MD Light Source for 10 Gbit/ s Transmission *

Li Baoxia, Hu Xiaohua, Zhu Hongliang, Wang Baojun, Bian Jing, Zhao Lingjuan, and Wang Wei

(National Research Center for Optoelectronics Technology, Institute of Semiconductors, Chinese Academy of Sciences, Beijing 100083, China)

Abstract: This paper reports on the design, fabrication, and performance of an integrated electro-absorptive modulated laser based on butt-joint configuration for 10 Gbit/ s application. This paper mainly aims at two aspects. One is to improve the optical coupling between the laser and modulator; another is to increase the bandwidth of such devices by reducing the capacitance parameter of the modulator. The integrated devices exhibit high static and dynamic characteristics. Typical threshold current is 15mA, with some value as low as 8mA. Output power at 100mA is more than 10mW. The extinction characteristics, modulation bandwidth, and electrical return loss are measured. 3dB bandwidth more than 10 GHz is monitored.

Key words: integrated optoelectronic device; electro-absorptive modulator; distributed-feedback lasers; butt-joint; 3dB-bandwidth

EEACC: 4270; 4320J; 2530C

CLC number: TN365 **Document code:** A **Article ID:** 0253-4177(2005)06-1100-04

1 Introduction

With the rising demands of higher bit rate for long-haul data-transmission, multi-quantum well (MQW) distributed feedback lasers integrated monolithically with an electro-absorptive modulator (EML) have been intensively investigated as suitable light sources for long-haul and high-bit-rate fiber-optic communication systems. Among various integration schemes such as selective area growth (SAG)[1], butt-coupling[2], quantum well intermixing (QWI)[3], identical active layer (IAL)[4], double stack active layer (DSAL)[5], and twin-guide structure (TGS)[6], etc., the butt-joint integration is a most potential one to reach a perfect performance level, since this approach allows independent optimization of the laser and the modulator sections. However, rigorous fabrication technologies (overcritical etching and re-growth steps) are required for this integration approach. In the previous paper, we have demonstrated an improved butt-joint method, which can successfully realize efficient coupling between the distributed feedback laser diode (DFB LD) and electro-absorptive modulator (EAM)[7,8]. In this paper, we focus on the modulation performance of such a monolithically integrated DFB LD and EAM using the butt-joint

* Project supported by the State Key Development Program for Basic Research of China (No. G20000683-1), the National High Technology Research and Development Program of China (No. 2001AA312050), and the National Natural Science Foundation of China (No. 90101023)

Li Baoxia female, was born in 1977, PhD candidate. Her research interest is in InP-based photonic integrated circuits, especially in the monolithic of DFB laser and high speed EA modulator.

Hu Xiaohua male, PhD. He is working in InP-based semiconductor optoelectronic devices.

Zhu Hongliang male, professor. His research interest is in semiconductor optoelectronic devices.

Received 18 November 2004, revised manuscript received 14 January 2005

technique.

2 Device structure

Figure 1 shows a schematic cross-sectional view of the ridge-waveguide integrated light source. First, the lower-SCH-layer and active layers of the laser on a planar n-InP substrate were grown by LP MOCVD. The active layers of the laser consist of 5 compressive-strained InGaAsP quantum wells. After the active layers on the modulation region were partially etched off, the active layers of the modulator, consisting of 9 tensile-strained In-

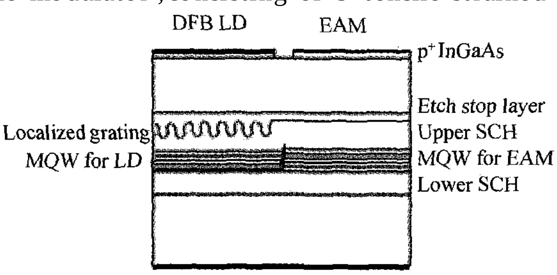

Fig. 1　Schematic cross-sectional view of the integrated DFB laser and modulator with two different MQWs

GaAsP quantum wells, were selectively grown over it. Then an upper-SCH-layer was grown over the entire surface. The grating, which is localized in the laser section, is realized by convenient holographic lithography, dry and wet etching. p-InP confining layer and p^+-InGaAs contact layer was then performed over the whole wafer. The ridge-waveguide (RWG) configuration is shown in Fig. 2. The length of the laser, trench, and EAM is set to be 250, 50, and 150μm, respectively. As for the waveguide structure, we adopt low-mesa ridge structure for the laser, in which the ridge etching is stopped just above the InGaAsP waveguide layer, and a combination of low- and deep- mesa is employed for the EAM section to gain the low capacitance. The width of the top and bottom mesas is 3 and 7μm respectively. Electrical isolation between the laser and modulator is over 50kΩ. The modulator facet is coated with an anti-reflection film and with a high-reflection film for the DFB laser. To reduce the electrical capacitance of the EAM, the EAM-RWG is wrapped in 3～4μm polyimide with a low dielectric constant of 3.5, and the bonding pad (70μm diameter) is fabricated on polyimide as well.

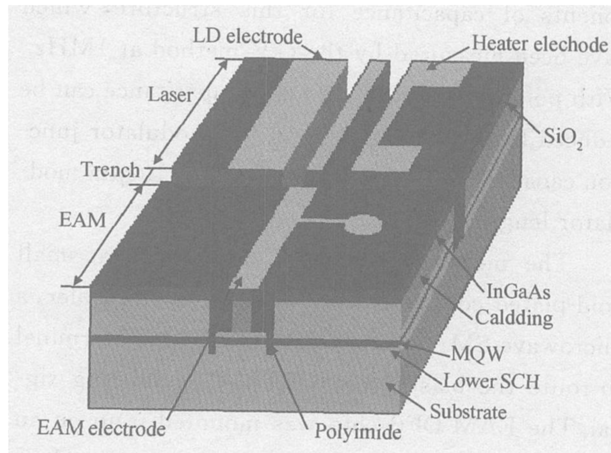

Fig. 2　Ridge-waveguide configuration of the integrated laser-modulator

3 Device characteristics

At room temperature, the typical threshold current of EML is 15mA, with some value as low as 8mA. The optical output is about 10mW at a DFB current of 100mA and a modulator voltage of 0V at 25 ℃. As shown in Fig. 3, a static extinction ratio as large as 28dB is obtained at an applied reverse voltage of - 4V, with 150μm modulator. All these static characters of such a device have been reported previously.

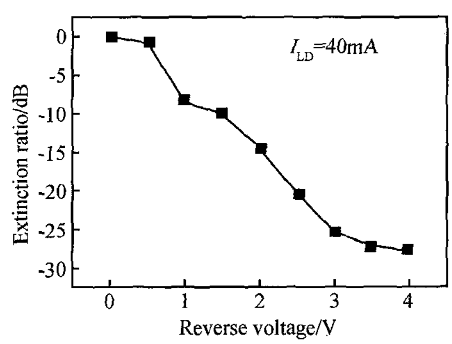

Fig. 3　Extinction ratio of the EML

The modulation bandwidth of the EA modulator is primarily RC limited. A short EAM offers high response frequency. Unfortunately, as the device length is reduced the extinction ratio decreases simultaneously. Much effort is made to reduce EAM capacitance without compromising the extinction ratio. There are two basically parallel components of capacitance for this structure, which have been measured by the C-V method at 1MHz. With polyimide the bonding pad capacitance can be reduced to below 0.04pF, and the modulator junction capacitance is less than 0.4pF per 100μm modulator length.

The measuring module consists of a small gold-plated copper case, a thermoelectric cooler, a microwave SMA connector as a RF input terminal to route the bias voltage and the modulating signal. The EAM-DFB chip was mounted p-up on an AlN submount with a coplanar waveguide and an integrated 50Ω TaN termination matching load. Figure 4 shows the electrical return loss (S_{11}) which is lower than -10dB up to 15GHz. The small-signal E/O frequency response is measured using an Agilent 71400 lightwave signal analyzer at a DFB incident current of 100mA, a DC bias of -2.5V and a 0dBm RF signal. A 10GHz 3dB bandwidth has been monitored (Fig. 5), which greatly reaches the required bandwidth for a 10Gbit/s transmission system.

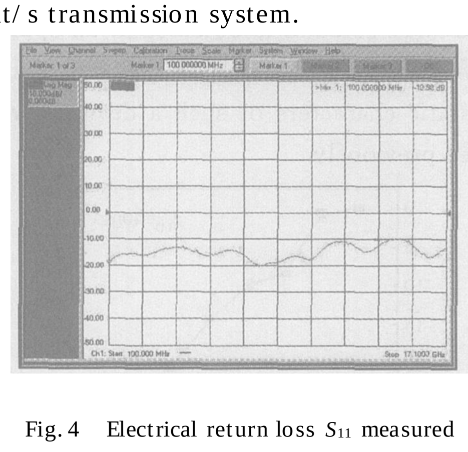

Fig. 4 Electrical return loss S_{11} measured

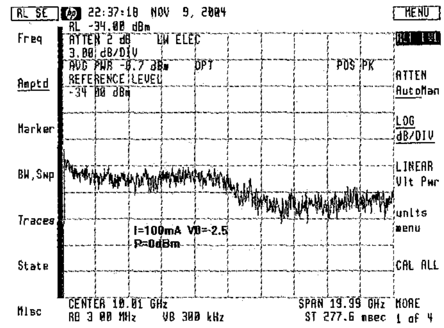

Fig. 5 Small-signal response measured I_{LD} = 100mA, V_{EA} = -2.5V, 0dBm modulating signal power

4 Conclusion

Through optimizing the EML structure and fabrication process, minimizing stray capacitance of the modulator, we have gotten a low threshold current, a high output power, and an over 10GHz 3dB bandwidth butt-joint integrated electro-absorptive modulated laser. Compared with the modulator junction capacitance, the modulator pad capacitance becomes negligible. Therefore, to further improve modulation speed of an EML, we should intensively decrease the area of modulator junction.

References

[1] Aoki M, Suzuki M, Sano H, et al. InGaAs/InGaAsP MQW electroabsorption modulator integrated with a DFB laser fabricated by band-gap energy control selective area MOCVD. IEEE J Quantum Electron, 1993, 29(6): 2088

[2] Takeuchi H, Tsuzuki K, Sato K, et al. Very high-speed light-source up to 40Gb/s containing an MQW electroabsorption modulator integrated with a DFB laser. IEEE J Sel Topics Quantum Electron, 1997, 3(2): 336

[3] Thornton R L, Mosby W J, Paoli T L. Monolithic waveguide coupled cavity lasers and modulators fabricated by impurity induced disordering. J Lightwave Technol, 1988, 6(6): 786

[4] Pallec M L, Kazmierski C, Vergnol E, et al. New integrated buried laser-ridge modulator with identical active layer. IEEE Photonics Technol Lett, 2003, 15(3): 362

[5] Stegmueller B, Baur E, Kicherer M. 15-GHz modulation performance of integrated DFB laser diode EA modulator with identical multiple-quantum-well double-stack active layer. IEEE Photonics Technol Lett, 2002, 14(12): 1647

[6] Sahlen O, Lundqvist L, Funke S. Zero-bias and low-chirp, monolithically integrated 10Gbit/s DFB laser and electro-absorption modulator on semi-insulating InP substrate. Electron Lett, 1996, 32(2): 120

[7] Li Baoxia, Hu Xiaohua, Zhu Hongliang, et al. Integrated electroabsorption-modulated DFB laser by using an improved butt-joint method. Chinese Optics Letters, 2004, 2(4): 226

[8] Hu Xiaohua, Wang Wei, Zhu Honglian, et al. A novel LP-MOCVD butt-joint growth method on MQW electroabsorption-modulated DFB lasers. Chinese Journal of Semiconductors, 2003, 24(8): 841 (in Chinese) [胡小华, 王圩, 朱洪亮, 等. 多量子阱电吸收调制 DFB 激光器的一种新型 LP-MOCVD 对接生长方法. 半导体学报, 2003, 24(8): 841]

用于 10 Gbit/ s 传输的对接集成 DFB-LD/ EA-MD 光源*

李宝霞　胡小华　朱洪亮　王保军　边　静　赵玲娟　王　圩

(中国科学院半导体研究所 光电子技术国家研究中心, 北京　100083)

摘要: 报道了用于 10 Gbit/ s 传输的 DFB 激光器和 EA 调制器对接集成器件的设计、制作和器件特性. 工作主要集中于两个方面:提高激光器和调制器间的光学耦合;通过减小调制器电容提高调制带宽. 集成器件显示出了良好的静态和高频特性:阈值电流典型值为 15mA,最小值为 8mA;100mA 激光器偏置电流下,输出功率大于 10mW;对消光比、电学回波损耗和调制带宽进行了测试,3dB 带宽的测量值超过 10 GHz.

关键词: 集成光电器件; 电吸收调制器; 分布反馈激光器; 对接集成; 3dB 带宽

EEACC: 4270; 4320J; 2530C

中图分类号: TN365　**文献标识码**: A　**文章编号**: 0253-4177(2005)06-1100-04

* 国家重点基础研究发展计划(批准号: G20000683-1),国家高技术研究发展计划(批准号:2001AA312050)和国家自然科学基金(批准号: 90101023)资助项目

李宝霞　女,1977 年出生,博士研究生,主要从事 InP 基光子集成电路,特别是 DFB 激光器和 EA 调制器单片集成的研究.

胡小华　男,博士,主要从事 InP 基半导体光电器件的研究.

朱洪亮　男,研究员,主要从事半导体光电器件的研究.

2004-11-18 收到,2005-01-14 定稿