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Monolithic Electro-absorption Modulator/DFB Laser Lightsource with Semi-Insulating InP Burying Layers

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An optical intensity modulator monolithically integrated with a DFB laser with semi-insulating InP burying layer was developed. The coupled optical power into a single mode fibre was over 2.5 mW. An attenuation ratio was -13 dB under the modulator bias voltage of -5 V. The measured chirp width, the full width for half maximum was 0.1 Å, under 10 Gbit/s NRZ modulation.

1. Introduction

Bit-rate of optical communication systems is getting increasing higher. But the large chirp of directly modulated semiconductor laser bottle-necks an increase in the bit-rate and repeater span product. Accordingly a high-speed and low-chirp external optical intensity modulator has been studied extensively[1,2] . Until now several monolithic integration of modulator with a laser on a one chip have been reported[3,4] . Since it has a feasibility of high coupling coefficient and a good reliability. We previously reported a monolithic electro-absorption modulator / DFB laser light source with a simple mesa structure[5]. It was capable of high speed modulation of 5 Gbit/s. However there were problems caused by the mesa structure. The mesa structure was fragile, and the transverse mode was not stabilized because of the wide mesa width. Here we report a monolithic electro-absorption modulator / DFB laser light source with semi-insulating InP burying layers. The introduction of BH structure with semi-insulating burying layer improved the lasing and modulation performances remarkably.

2. Structure and fabrication

The integrated device structure is shown schematically in figure 1. For good optical coupling we introduced butt-joint waveguide structure. The both regions of the laser and the modulator were buried with a semi-insulating InP layer. The device was grown in three steps LPE growth and a MOVPE growth. First the DFB laser region was grown on an n-InP substrate with a partially formed 1st order corrugation. Next we selectively etched off

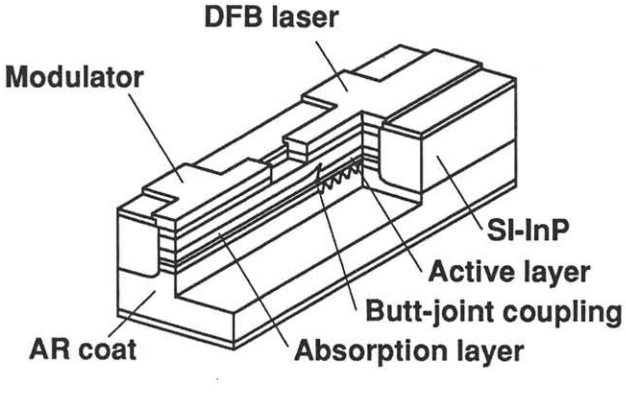

Fig. 1 Structure of monolithic EA modulator/DFB laser light source with semi-insulating InP burying layer

unnecessary cladding, anti-meltback and active layer. Then after we grew an absorption layer selectively using SiO_2 mask. In this selective growth process the butt-joint was formed due to a small step on regrowth face leaving waveguide layer. We used a GaInAsP absorption layer having photoluminescence wavelength of 1.40 μm for 1.55 μm wavelength operation. Then cladding and contact layers were grown entirely. Finally the waveguide was buried with semi-insulating InP layer by MOVPE, after forming a mesa stripe which contained the active region and absorption region. The waveguide width was typically 1.5 μm. A resistivity of 10^7 Ωcm was obtained. Figure 2 shows the sectional view SEM micrograph of the integrated light source. A fairly flat growth surface enabled easy processing. We introduced thick polyimide layer under the bonding-pads of the modulators to reduce the parasitic capacitance. The laser and modulator length were 300 μm and 200 μm, respectively. To isolate both region electrically we introduced a separation region with length of having 50 μm and removed contact layer there. The isolation resistance between the laser and the modulator was 2MΩ. A front facet was coated by a SiN film with well controlled deposition process to reduce the reflectively. The front facet reflectively was estimated to be about 0.5 % by other measurement. This value is small enough to obtain a flat frequency response.

Fig. 2 Cross sectional view of the fabricated devices

3. Characteristics

The output power-injection current characteristics of the fabricated device is shown in figure 3. The threshold current was 20 mA. At laser injection current of 150 mA and a modulator voltage of 0 V , the total output power was 17 mW, which was over three times of our mesa-type device. We also obtained the fundamental transverse mode. When we increase the bias voltage to -5 V, the output power was reduced to 4.5 mW, an attenuation ratio was -8 dB. The light output power of 2.5 mW was coupled into a single

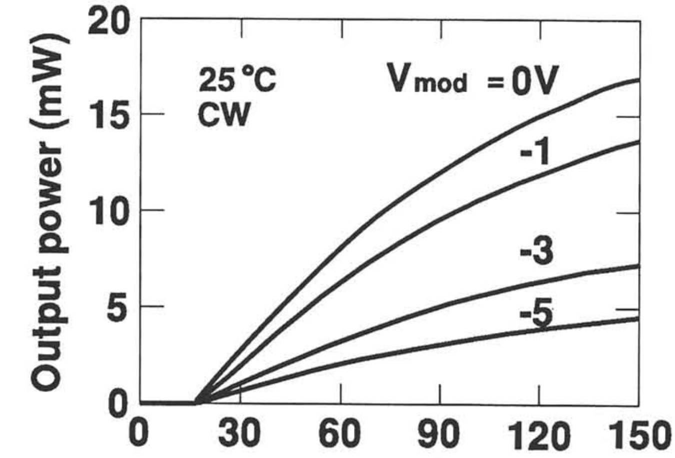

Fig. 3 Output power vs. current characteristics. Modulator bias from 0 to -5 V

mode fibre at a laser injection current of 150 mA and a modulator bias voltage of 0 V. An attenuation ratio of -13 dB was achieved at -5 V DC bias when we observed the fibre coupled light power. These characteristics of high-power, high attenuation ratio indicate that the light output from the DFB laser region is well guided into the modulator region. Figure 4 shows the small signal frequency response at an output power of 10 mW and a bias voltage of -1 V. The cutoff frequency was 10 GHz. This value agrees well with the calculated value using the measured parasitic capacitance of 0.55 pF. We tested the 10 Gbit/s large signal modulation characteristics. We used NRZ pseudorandom patterns with voltage of 0 V -5 V. The eye diagram detected by a high speed pin detector and a high speed amplifier is shown in the figure 5. The eye is clearly open with sufficient extinction ratio as expected. The chirp was evaluated by a Fabry-Perot interferometer. Figure 6 shows the observed spectrum of the modulated light under the same 10 Gbit/s NRZ modulation. The measured chirp width (FWHM) was 0.1 Å. When compared with a chirp of 5-8 Å for directly modulated semiconductor lasers, the drastic reduction in the chirp is attained.

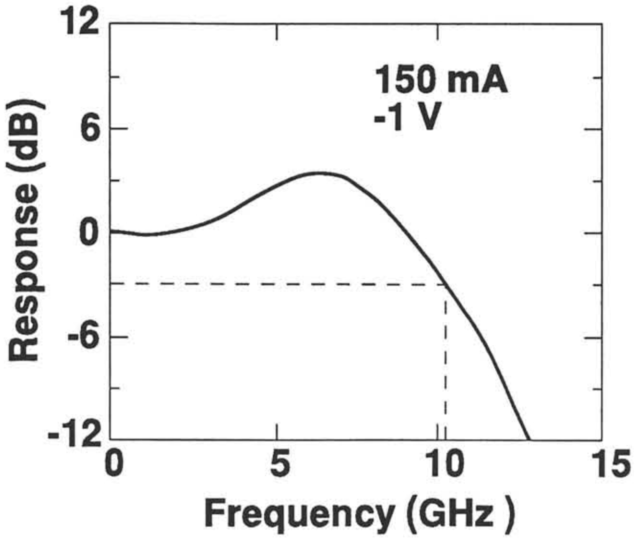

Fig. 4 Small-signal frequency response

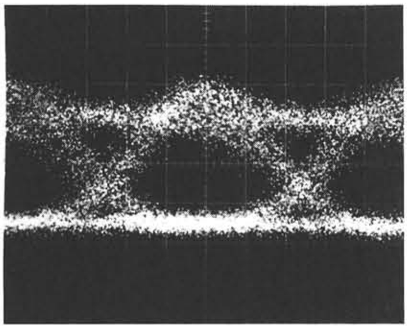
Fig. 5 Eye diagram under 10 Gbit/s NRZ modulation

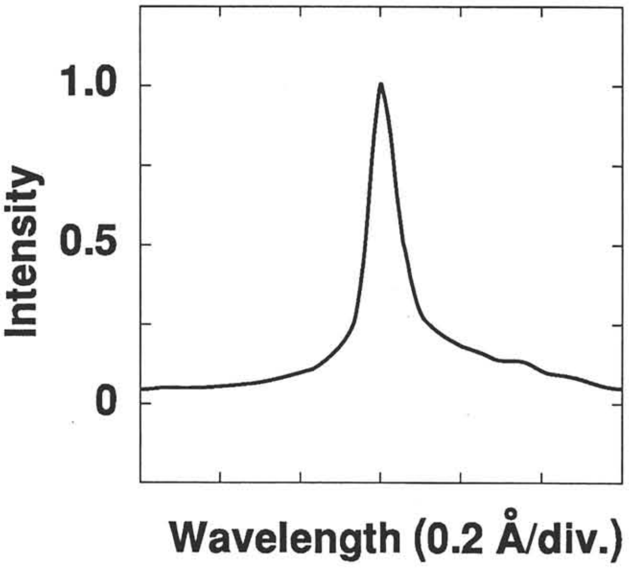

Fig. 6 Optical spectrum of output light under 10 Gbit/s NRZ modulation

4. Summary

We developed a high quality monolithic electro-absorption / DFB laser light source with semi-insulating burying layer. We obtained a high coupling power of 2.5 mW into a fibre with extinction ratio of -13 dB. Under 10 Gbit/s NRZ large signal modulation, a clearly eye opening and small chirping of 0.1 Å were attained.

5. Acknowledgments

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