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1.5μm Self-Aligned Spotsize Converter Integrated DFB Fabricated by Selective Area Grown MOVPE

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Abstract: High performance 1.57μm spotsize converter monolithically integrated DFB is fabricated by the technique of self-aligned selective area growth. The upper optical confinement layer and the butt-coupled tapered thickness waveguide are regrown simultaneously, which not only offeres the separated optimization of the active region and the integrated spotsize converter, but also reduces the difficulty of the butt-joint selective regrowth. The threshold current is as low as 4.4mA. The output power at 49mA is 10.1mW. The side mode suppression ratio (SMSR) is 33.2dB. The vertical and horizontal far field divergence angles are as small as 9° and 15° respectively, the 1dB misalignment tolerance are 3.6μm and 3.4μm.

Key words: spotsize converter; self-aligned; butt-joint; selective area growth

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1 Introduction

The single-mode fiber (SMF) coupling of semiconductor lasers has been a challenging topic in optoelectronic module packaging. The root of the problem lies in the highly divergent and elliptic mode of conventional semiconductor lasers that does not match the mode of SMF's in both the size and the shape. The development of the expanded-mode laser diode has been proposed as a solution to this problem. Large optical mode approach and integration of an adiabatic spotsize converter (SSC), commonly referred as taper, have been the main approaches to achieve a circularized lower divergence laser output beam. There are two kinds of methods of achieving vertically tapered waveguide monolithically integrated DFB lasers[1~4]. One is the all-selective MOVPE grown buriedheterostructure (ASM-BH) LDs, where the active region and the waveguide are selectively grown simultaneously[1,4]. The advantage of this type LD is the simplicity of selective growth. But the disadvantage lies in the lack of the separated optimization of the active region and the waveguide, which can induces excess absorption loss in the waveguide. The other method is the butt-joint spotsize converter integrated LDs[2,3]. The advantage of this method is the separated optimization of the active region and the waveguide, but its difficulty in selectively regrowth is obvious.

We have fabricated SSC integrated DFB lasers with

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ridge waveguide structure[5]. The vertical far field angle is reduced significantly. But the lateral far field angle is not improved due to the ridge waveguide structure. In this paper, we propose the technique of self-aligned selective area growth to fabricate the SSC integrated DFB, where the upper optical confinement layer and the integrated vertically tapered waveguide are selectively grown simultaneously by using twin masks. The active region and the integrated waveguide can be separately optimized. The difficulty of selecting over growth of the butt-joint integration between the waveguide and the active region is reduced significantly. Furthermore, the buried heterostructure is proposed, both the lateral and the vertical far field divergence angles can be improved.

2 Device structure and fabrication process

Figure 1 is the schematic structure of the device. The SSC region consisting of a bulk layer is self-aligned butt-jointed the strained MQW active layer. For the SSC structure, we proposed a taper waveguide with changing thickness in the vertical direction. This is selectively grown during the simultaneously growth with the upper optical confinement layer of the laser device. An exponential taper shape can easily obtained during selective growth. The slope provides low radiation loss in the SSC region[6].

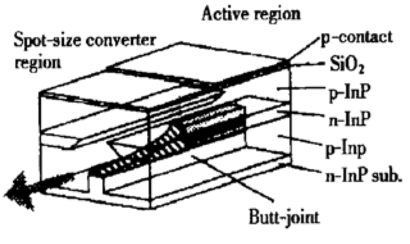

Fig. 1 Schematic structure of the SSC integrated DFB

The SSC integrated DFB was fabricated in four steps of MOVPE growth. N type InP buffer layer, 100nm InGaAsP lower optical confinement layer, strained multi-quantum well(MQW), which was optimized to the laser performance, were grown in the first step MOVPE. Then the MQW active layer was etched down to the buffer layer in the SSC region and the DFB mesa was formed. A dielectric thin film of 150nm SiO_2 was deposited on the wafer. The masks shown in Fig. 2 then were patterned to form the taper waveguide on the wafer. The forming of taper waveguide, the bulk waveguide and the upper optical confinement layer were selectively grown simultaneously in

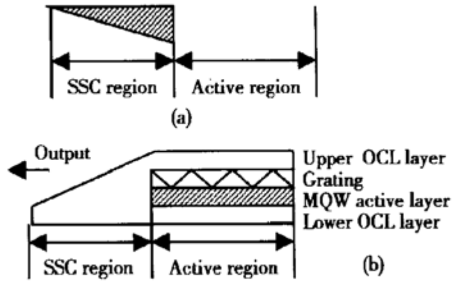

Fig. 2 (a) Mask shape of the SSC integrated DFB; (b) Lateral side view of the schematic structure of the device

the second step of MOVPE. The bandgap wavelength of the materials of the tapered waveguide and the upper optical confinement layer was set to around 1.2μm. The mask shape was designed to control the taper shape waveguide thickness for low-loss coupling to the active layer at the joint portion and to an optical fiber at the front tip. The SiO_2 masks were removed after selective area growth. The grating was formed by reactive ion etching (RIE) in the upper optical layer to form index coupling, while the SSC region was covered by SiO_2. A uniform stripe along the reverse mesa direction was formed by wet etching. PNPN current-blocking layer was grown in the third step of MOVPE. 1.5μm p-InP cladding layer and 0.2μm p^+-InGaAs contact layer were grown in the fourth step of growth. Au/Zn/Au alloy was deposited on the p side of the wafer to form the p electrode, and Au/Ge/Ni alloy was deposited on the n side of the wafer to form the n electrode after it was thinned to 100μm.

3 Characteristics

Typical *P-I* characteristics was shown in Fig. 3. The threshold current was 4.4mA at room temperature. The output power was 10.1mW at the current of 49mA. No

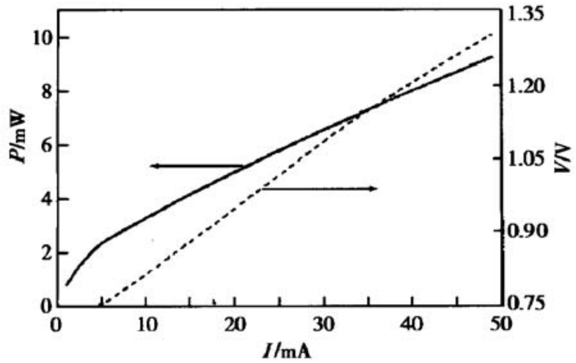

Fig. 3 Typical *P-I*, *I-V* curves of device

degradation of the threshold current characteristics was observed inside and outside the SSC region because of the low absorption in the SSC region buried by the PNPN current-blocking layer. The emission spectrum of the device is shown in Fig. 4. The suppression ratio of side mode was 33.2dB. The single mode yield of the integrated device was more than 85%, which meant the grating had high performance. The 3D

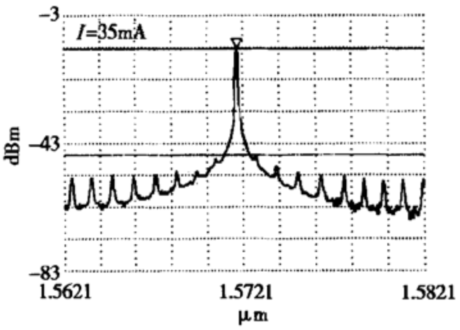

Fig. 4 Emission spectrum of SSC integrated DFB

view of the spot size of the SSC integrated DFB is shown in Fig. 5. The vertical and horizontal far field patterns were given in Fig. 6. The FWHM of the vertical and the horizontal angles of the device were as small as 9° and 15° respectively. The characteristics of direct coupling to a cleaved single mode fiber were given in Fig. 7. The 1dB misalignment tolerance was 3.6μm in vertical and 3.4μm in horizontal direction.

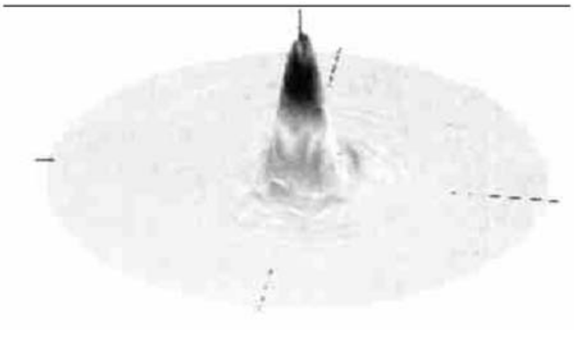

Fig. 5 3D view of the far field spot of the SSC integrated DFB

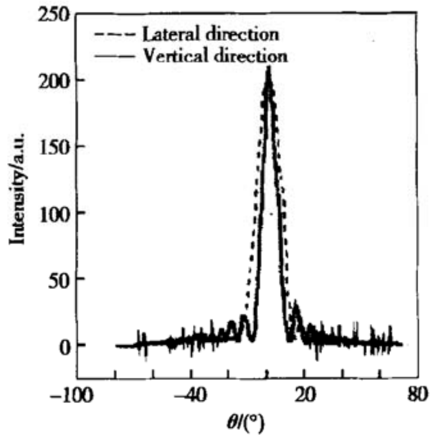

Fig. 6 Far field divergence pattern in vertical and horizontal direction

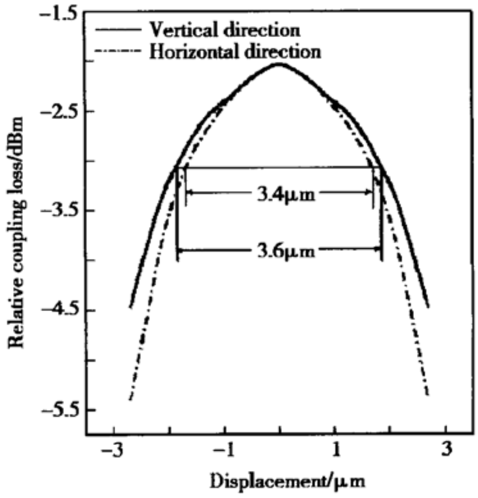

Fig. 7 1dB misalignment tolerance in vertical and horizontal direction

4 Conclusion

The self-aligned spotsize converter integrated DFB was fabricated by selective LP-MOVPE. The FWHM of the vertical and horizontal divergence angles were 9° and 15°. The 1dB misalignment tolerance was 3.6μm in vertical and 3.4μm in horizontal direction. The threshold current was as low as 4.4mA. The output power was 10.1mW at 49mA. The suppression ratio of side mode was 33.2dB.

References

[1] Furushima Y, Sakata Y, Sasaki Y, et al. 1.3μm spot-size converter integrated ASM-BH LDs with low operating current and high coupling efficiency. Electron Lett, 1998, 34(8): 767

[2] Vusirikala V, Saini S S, Bartolo R E, et al. High butt-coupling efficiency to single-mode fibers using a 1.55μm InGaAsP laser integrated with a tapered ridge mode transformer. IEEE Photonics Tech Lett, 1997, 9(11): 1472

[3] Wada M, Okamoto H, Kishi K, et al. Laser diode integrated with butt-jointed spotsize converter fabricated on 2-in wafer. Journal of Lightwave Technology, 1997, 15(3): 198

[4] Liu Guoli, Wang Wei, Zhu Hongling, et al. Strongly gain-coupled DFB laser monolithically integrated with a self-aligned spot-size converter. Chinese Journal of Semiconductors, 2001, 22: 832

[5] Qiu Weibin, Dong Jie, Zhang Jingyuan, et al. Selective area growth MOCVD and its application in fabrication of spotsize converter integrated DFB. Chinese Journal of Semiconductors, 2002, 23: 459

[6] Mitomi O, Kasaya K, Miyazawa H. Design of a single mode tapered waveguide for low loss chip to fiber coupling. IEEE Quantum Electron, 1994, 30: 1787

选择外延技术研制 1.5μm DFB 激光器和自对准模斑转换器集成器件

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摘要: 利用选择外延技术研制了 1.5μm DFB 激光器和自对准模斑转换器单片集成器件. 激光器的上限制层与垂直方向上楔型波导的模斑转换器同时选择性生长, 这样的方法不仅可以分别优化有源区和模斑转换器的材料, 同时可以降低选择性生长对接结构的难度. 所研制集成器件的阈值为 4.4mA, 在 49.5mA 下的输出功率为 10.1mW, 边模抑制比为 33.2dB, 垂直方向和水平方向上的远场发散角分别为 9°和 15°, 1dB 偏调容差分别为 3.6μm 和 3.4μm.

关键词: 模斑转换器; 自对准; 对接; 选择外延

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