Unselective regrowth of 1.5-μm InGaAsP multiple-quantum-well distributed-feedback buried heterostructure lasers

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Abstract. Unselective regrowth for fabricating 1.5-μm InGaAsP multiple-quantum well (MQW) distributed-feedback (DFB) buried heterostructure (BH) lasers is developed. The experimental results exhibit superior characteristics, such as a low threshold of 8.5 mA, high slope efficiency of 0.55 mW/mA, circular-like far-field patterns, the narrow line-width of 2.5 MHz, etc. The high performance of the devices effectively proves the feasibility of the new method to fabricate buried heterostructure lasers.
[DOI: 10.1117/1.2355658]

Subject terms: buried heterostructure; regrowth; multiple quantum well; distributed feed back; laser.

Paper 060427LR received May 31, 2006; revised manuscript received Jul. 10, 2006; accepted for publication Jul. 14, 2006; published online Oct. 5, 2006.

1 Introduction

Buried heterostructures (BHs) have been widely used in discrete optical devices[1–3] and advanced integrated optical devices,[4–6] mainly because of the attractive advantages over the ridge structure, such as a lower threshold current, a circular-like and stable output beam, and lower thermal resistance.[7,8] The conventional BH is realized by two steps. First, a mesa including a SiO_2 dielectric mask and active region stripe is made by dry or wet etching. Then, the current blocking layers are formed by the selective regrowth method. The quality of these selectively grown blocking layers is heavily dependent on the mesa shape and the dielectric mask quality, which is inevitably worse than that of the blocking layers fabricated by the unselective regrowth method.

In this work, the unselective regrowth of buried heterostructures (BHs) is developed for InGaAsP multiple-quantum-well (MQW) distributed-feedback (DFB) lasers, which are independent of the mesa shape and the dielectric mask. The fabrication process of the lasers is first described amply in Sec. 2. Then, the characteristics of the InGaAsP MQW DFB BH lasers are demonstrated in Sec. 3.

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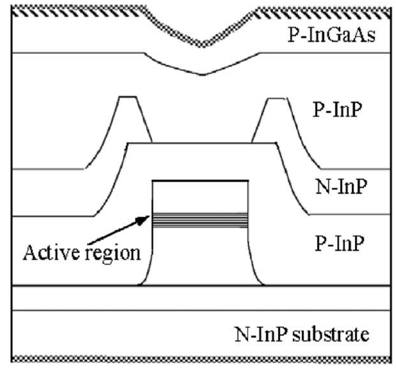

Fig. 1 Schematic structure of the InGaAsP MQW DFB BH laser fabricated by the unselective regrowth method.

2 Device Structure and Fabrication

The schematic structure of the multiple-quantum-well (MQW) distributed-feedback (DFB) buried heterostructure (BH) laser is shown in Fig. 1. The wafer was fabricated by three epitaxial growths using low pressure MOVPE. First, the strained-compensated InGaAsP MQWs sandwiched by two InGaAsP separate confinement heterostructure (SCH) layers were grown on (100) n-InP substrates. The photoluminescence (PL) spectrum of the active region is shown in Fig. 2. The peak wavelength of the PL spectrum is about 1560 nm with a small full width at half maximum (FWHM) of 53 nm. The grating was made on the upper InGaAsP SCH layer. To increase the differential gain of the DFB BH lasers, the negative detuning of the lasing wavelength from the material gain peak was adopted. After etching of a 1.2-μm-wide mesa stripe along the [110] direction, the p/n-InP current blocking layers were then grown on the whole area by the unselective regrowth method. A current channel was successively dug by etching the n-type current blocking layer just over the active region, which can be seen in Fig. 3(a). The alignment for this n-InP etching is not difficult, because a clear pattern correlated with the active region can be seen from the common light microscope even after the current blocking layers have grown on the wafer. Finally, after the growth of a 1.8-μm-thick p-InP cladding layer and 0.2-μm p-InGaAs contact layer,

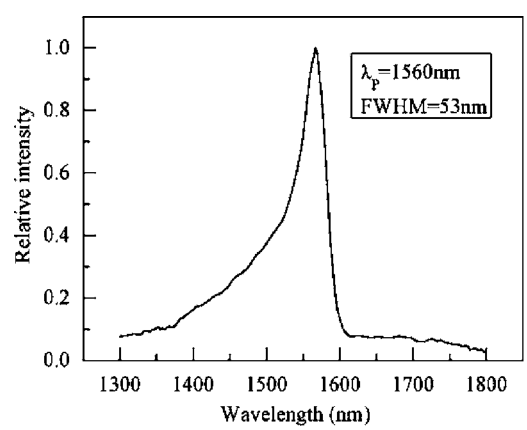

Fig. 2 PL spectrum of the strained-compensated InGaAsP MQW adopted as the active region of the laser.

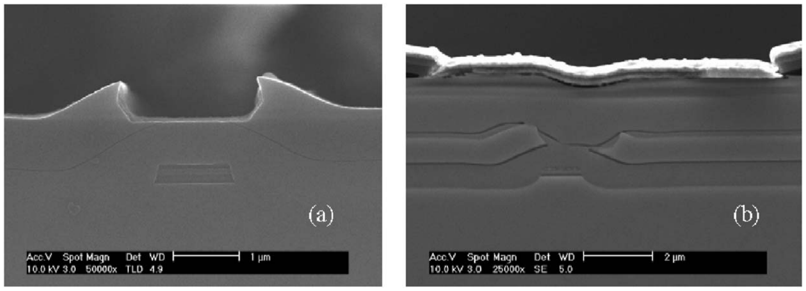

Fig. 3 SEM pictures of (a) a current channel that was dug by etching the n-type current blocking layer just over the active region, and (b) cross section of the DFB BH laser fabricated by the unselective regrowth method.

the electrode fabrication process was performed. The cross section of the fabricated DFB BH lasers is displayed in Fig. 3(b).

3 Results and Discussion

The fabricated wafer was cleaved into laser bars with different cavity lengths. The current dependence of the cw output power from one facet of the multiple-quantum-well (MQW) distributed-feedback (DFB) buried heterostructure (BH) lasers at room temperature is displayed in Fig. 4(a). The threshold current increases gradually with the increase of the cavity length. The 200-μm-long laser has a lowest threshold current of 8.5 mA and a largest slope efficiency of 0.55 mW/mA. Based on the data mentioned, the differential quantum efficiency (η_d), internal differential quantum efficiency (η_i), and internal loss (α_i) were extrapolated. Figure 4(b) shows the feature of the differential quantum efficiency (η_d) dependence on the cavity length (L). A high internal differential quantum efficiency (η_i) of 78% and internal loss (α_i) of 6.9 cm^{-1} were obtained by fitting the expression attached in Fig. 4(b). The as-cleaved lasers with a cavity length of 300 μm were then selected to test the far-field pattern and the linewidth of the lasers.

Figure 5 shows the far-field patterns in the vertical and horizontal directions for the DFB BH lasers. As can be seen in this figure, the laser emits in single transverse mode, and the divergence angles are 32×34 deg in the horizontal and vertical directions. The beam shape of the DFB BH lasers is shown to be more circular than that of ridge structure lasers, and thus more efficient optical coupling into a single mode fiber will be achieved with the DFB BH lasers.

Finally, the dependence of the linewidth on the output power is investigated for the DFB BH lasers fabricated by the unselective regrowth method. Stable output power and high differential gain of the strained-compensated MQW DFB BH lasers are the main factors to obtain a narrow linewidth. Figure 6 shows the linewidth of the DFB BH lasers under different output powers. The linewidth decreases rapidly with the increase of the output power from one laser facet. When the output power increases to 23.6 mW, the linewidth becomes as narrow as 2.5 MHz. The lasing spectrum of the laser under three times the threshold current is also plotted in the insert of Fig. 6. The side mode suppression ratio is as high as 51 dB with a lasing wavelength of 1542 nm.

4 Summary

A 1.5-μm InGaAsP MQW BH DFB laser formed by an unselective regrowth method is demonstrated. The current blocking layers are performed by the unselective regrowth method, which results in no deterioration of the quality of the BH layers. The P-I characteristics of the laser show superior features, such as a low threshold of 8.5 mA and a high slope efficiency of 0.55 mW/mA. The BH lasers provide circular-like far-field patterns with divergence angles of 32×34 deg in the horizontal and vertical directions. A narrow linewidth of 2.5 MHz is also obtained for the DFB BH lasers fabricated by the unselective regrowth method. The results suggest that the unselective regrowth method can be used to fabricate high performance DFB BH lasers.

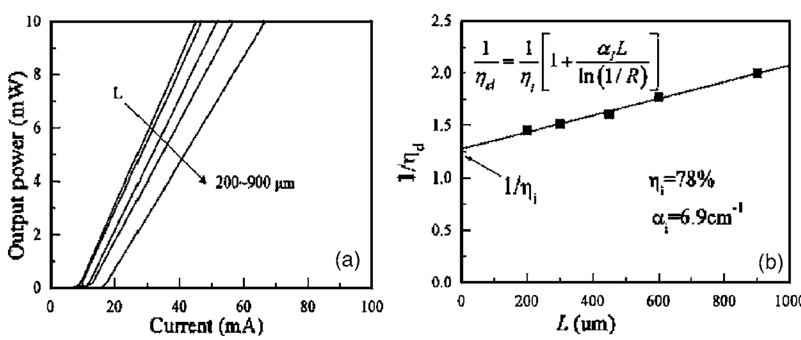

Fig. 4 (a) P-I characteristics of the DFB BH lasers with different cavity lengths and (b) differential quantum efficiency dependence on the cavity length.

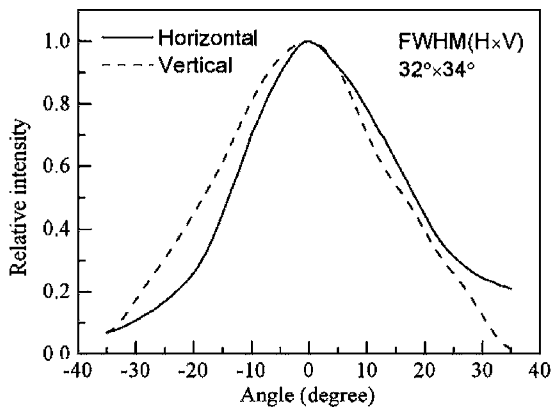

Fig. 5 Far-field patterns of the DFB BH laser with output power of 8 mW.

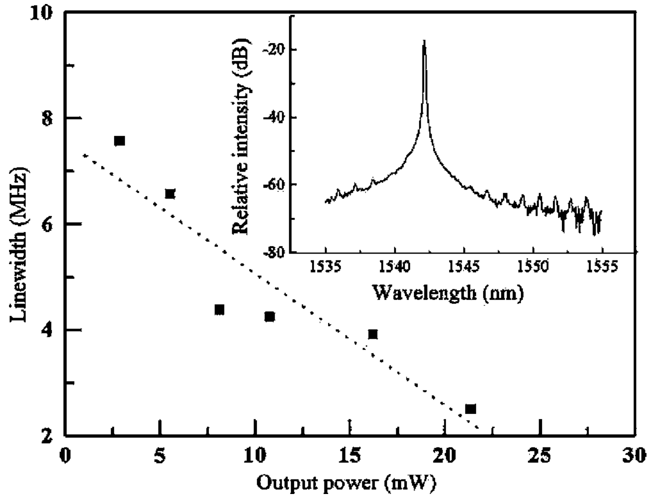

Fig. 6 Dependence of the spectrum linewidth on the output power for the DFB BH lasers. Inset shows the lasing spectrum of the device.

Acknowledgment

This work was partly supported by the National 973 (G2000068301) project, the National 863 (2002AA312150) project, and the National Natural Sciences Foundation (90401025, 90101023, 60176023, 60476009) of China.

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