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Tapered Thickness Waveguide Integrated BH MQW Lasers

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1.3 μm tapered thickness waveguide spot-size transformer integrated BH MQW lasers were designed and fabricated successfully. Fabricated integrated lasers utilizing a selective area growth technique exhibited a narrow beam divergence of ~10° with a low threshold current of 6.5 mA and a high efficiency of 0.4 mW/mA. A butt-coupling loss into a single-mode fiber and -1 dB tolerances was improved to be 3.8 dB and ±2 μm by use of our new laser.

1. Introduction

Optical alignment in laser modules represents major cost barriers for subscriber systems. New approaches are needed to enable us the passive fiber alignment with large position tolerances and reduce the number of the optical components. The spot-size mismatch between the laser and the fiber mainly leads this barriers. Then the transformation of the output laser beam is expected to be most attractive. From the point of high volume production and low cost views, integration of the laser and the spot-size transformer is desirable [1-5]. Recently we have demonstrated a narrow beam divergence tapered thickness MQW spot-size transformer integrated Fabry-Perot BH MQW lasers using a selective area growth technique. Our tapered thickness waveguide MQW spot-size transformer is fully compatible for the laser fabrication process so that an increase in the fabrication cost will be minimized. Here we introduce our structure and lasing performance.

2. Structure and Design

Figure 1 shows a schematic structure of a tapered thickness spot-size transformer integrated BH MQW laser. By using the selective area growth technique [6] we gradually reduced the thickness of MQW and guide layers along the laser axis in the spot-size transformer. Thinner MQW layers can realize the low-loss transformer in a Fabry-Perot resonator because an absorption edge in the spot-size transformer shifts to the shorter wavelength than the lasing wavelength. For the uniform region we used the well-established laser structure having five 60 Å unstrained InGaAsP (λ_{PL} = 1.32 μm) wells, 150 Å InGaAsP (λ_{PL} = 1.10 μm) barriers and 100 nm guide layers (λ_{PL} = 1.10 μm). A conventional p-n blocking BH structure is used to obtain a low threshold current and stabilize a transverse mode. To design the tapered thickness spot-size transformer, it is necessary to evaluate a spot-size expansion and a coupling loss for one round trip. We simulated the beam propagation using a finite difference

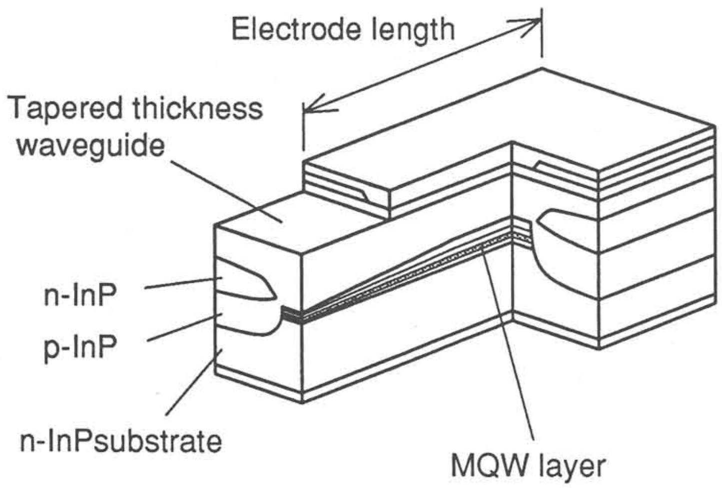

Fig.1. Device structure of a tapered thickness waveguide integrated BH MQW laser

beam propagation method [7]. For practical production it is required to shorten a length of the spot-size transformer. Then we fixed a 200 μm long spot-size transformer. Figure 2 shows the calculated thickness ratio dependence of the spot-size and radiation loss for such a transformer. The

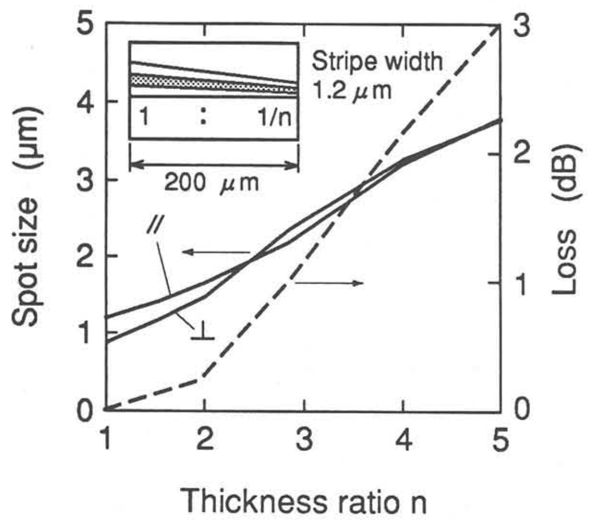

Fig.2. Calculated thickness ratio dependence of the spot-size and radiation loss

parallel and perpendicular spot-size are increased monotonically as increasing the thickness ratio. The spot-size expands to be 2.5 μm for the thickness ratio of 3, while the loss is estimated to be 1.1 dB. Thus we can expect the narrow beam divergence of about 10°.

Figure 3 shows a distribution of a measured total thickness of MQW and guide layers in one chip. The 3 : 1 maximum thickness ratio and flat thickness profile in the uniform region were attained by adjusting

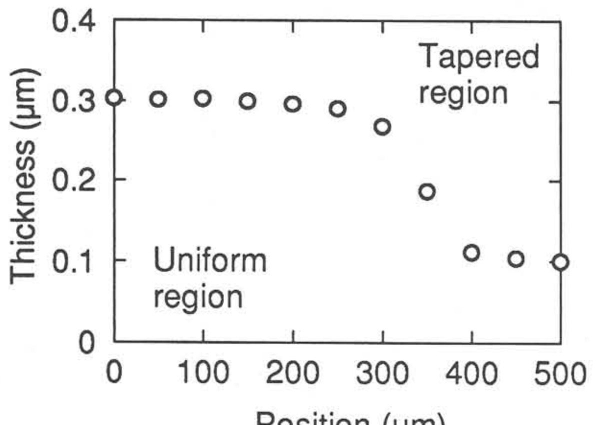

Fig. 3. Measured total thickness ditribution of MQW layers and guide layers

the selective mask pattern. The uniform region and the transformer region lengths were 300 and 200 μm. It was found that the lasing performances depended on the electrode configuration. The current injection is necessary to reduce an absorption loss of the thicker transformer region because of an absorption edge locates near the lasing wavelength as shown in Figure 4. On the other hand, the current injection at the thin transformer region induces the loss and reduces seriously the efficiency. Then an optimization of the electrode length is important to

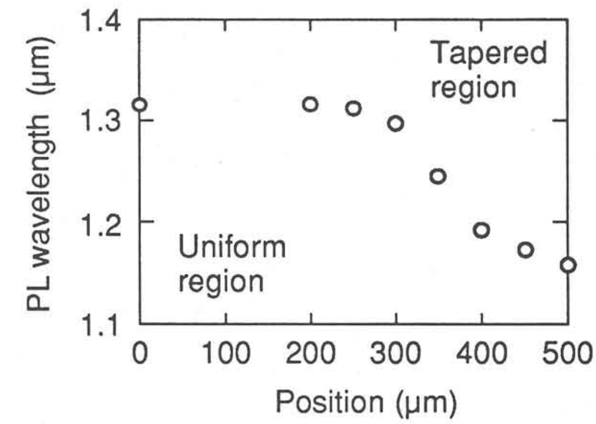

Fig. 4. Measured PL wavelength distribution

get high lasing performance for a wide temperature range [8]. Here we selected 350 μm long electrode.

3. Characteristics

Figure 5 shows the typical light output versus current characteristics of the device. The threshold current is 6.5 mA, and the slope efficiency is as high as 0.4 mW/mA with a cleaved facet and a high reflectivity facet. We

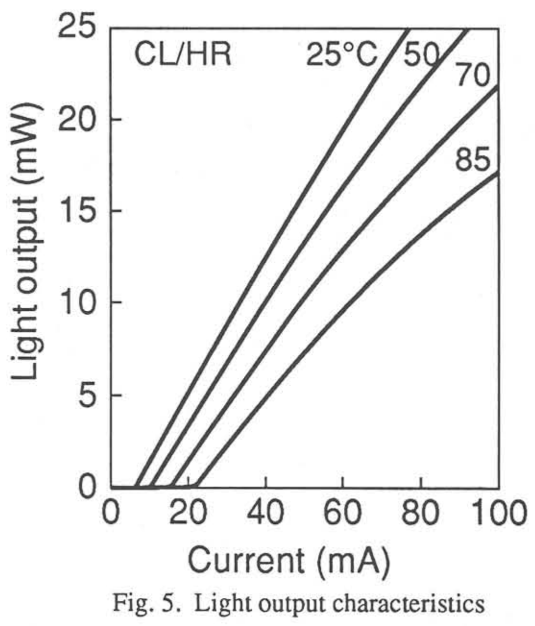

Fig. 5. Light output characteristics

observed no kink up to about 25 mW. Even at 85°C, the threshold current was only 22 mA by the electrode length optimization. Figure 6 shows measured far-fields from

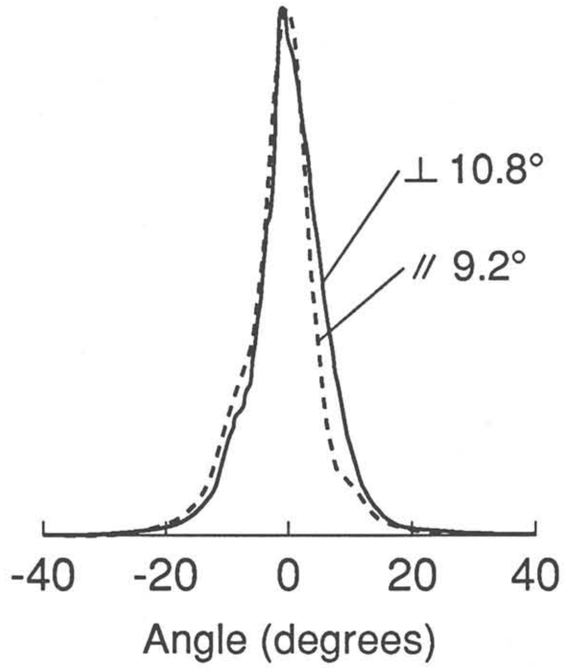

Fig. 6. Measured far-field patterms

the front facet. We obtained perpendicular and parallel front far-field FWHM of 10.8° and 9.2°. These measured values are in good agreement with the calculated values. In contrast with the far-field angle of conventional lasers, the spot-size transformer is found to be effective to reduce drastically the far-field angle. Next we have investigated butt-coupling to a flat single-mode optical fiber. The

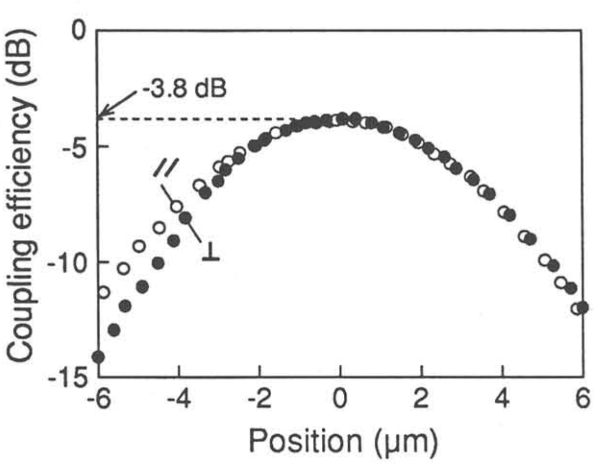

Fig. 7. Measured fiber coupling characteristics

coupling loss was 3.8 dB when the separation of the laser and the fiber was 10 μm. Figure 7 shows alignment tolerances in this coupling case. We obtained -1 dB tolerances of ±2 μm for alignment parallel and perpendicular to the junction. Such large tolerances enable us to make simple and low-cost laser modules.

4. Conclusions

1.3 μm BH MQW FP lasers monolithically integrated with a tapered thickness MQW waveguide were reported. Our new laser exhibited the perpendicular and parallel far-field FWHM of 10.8° and 9.2° with low threshold current of 6.5 mA and high slope efficiency of 0.4 mW/mA. We confirmed our spot-size transformer integrated lasers were suitable for future low-cost and compact laser modules.

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