Extended Abstracts of the 1995 International Conference on Solid State Devices and Materials, Osaka, 1995, pp. 428-430 **D-4-2**

Beam Expander-Integrated Lasers Grown by Single-Step MOVPE

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Abstract

A new structure for a 1.3-μm-wavelength beam expander-integrated ridge-waveguide laser is demonstrated that dose not require regrowth step. A narrow beam divergence of 5.4° (lateral) and 18.9° (vertical) enables a laser diode to be coupled to a cleaved single-mode fiber with an efficiency as high as 33% with a 1-dB alignment tolerance of ±2.4 μm laterally and ±1.5 μm vertically.

1. Introduction

Highly efficient coupling of laser diodes to an optical fiber with a large alignment tolerance is essential for the low-cost transmitters used in subscriber optical links. However, the large optical mode mismatch between single-mode fibers and semiconductor lasers results in poor efficiency and a critical alignment tolerance. To overcome these problems, the integration of a beam expander (BEX) to lasers has been extensively studied [1-5]. However, most of these integrations require multi-step regrowth or complicated etching procedures. In this report, we propose a novel-structure 1.3-μm BEX-integrated laser that uses a laterally-constricted tapered ridge-waveguide (RWG), combined with a double-core structure created by only one-step metalorganic vapor phase epitaxy (MOVPE).

2. Device Structure

The structure of our BEX-integrated laser is shown in Fig. 1. The device consists of two sections: a laser section and a BEX section. Both have a layer structure composed of a 3-μm-thick underlying second core containing a 16-period InGaAsP (1.06 μm)/InP multilayer, a separate confinement heterostructure (SCH) strained InGaAsP multiple quantum well (MQW) active layer, a p-InP cladding layer, and a p^+-InGaAs contact layer formed on an (100) n-InP substrate. The MQW contains six 1.4 % compressively-strained InGaAsP wells separated by lattice-matched InGaAsP (1.15 μm) barriers. In the 200-μm-long BEX section, the ridge neck narrows from 2.4 to 0.8 μm towards the output facet, gradually transferring the optical mode field to the thick second core. This results in a adiabatic mode expansion in the lateral and vertical directions (Fig. 1(b)). Optical and carrier confinement are attained by a simple reversed-mesa (RM) RWG structure, which is suitable for wide-range temperature operation [6]. The RWG was formed using standard photolithography followed by wet etching. Non-tapered lasers were also fabricated on the wafers for reference. The device length was 400 μm ; the back facet was coated with a highly reflective (90%) film.

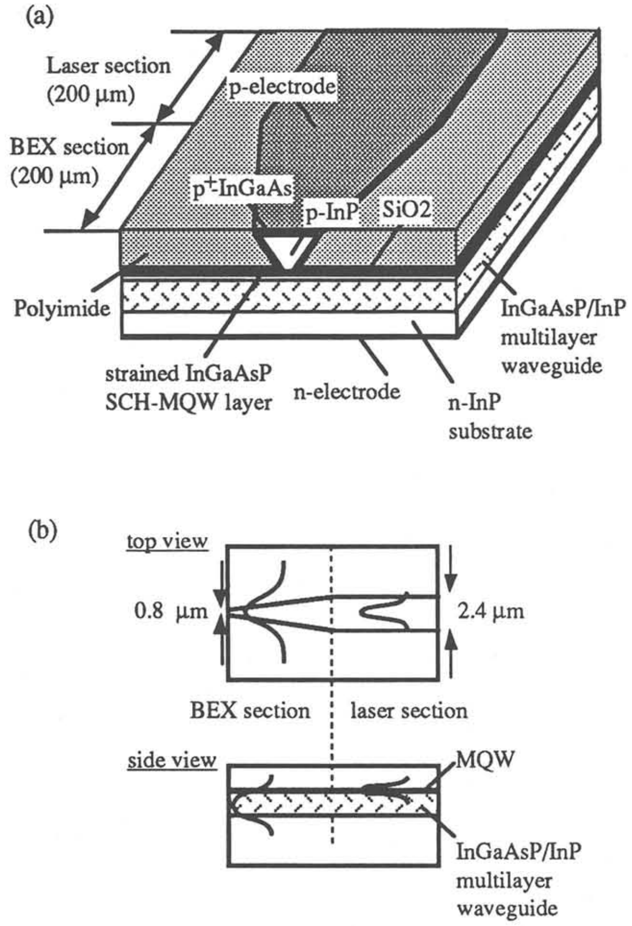

Fig. 1. Structure of beam expander integrated ridge-waveguide (BEX-RWG) laser (a) and principle of beam expansion (b).

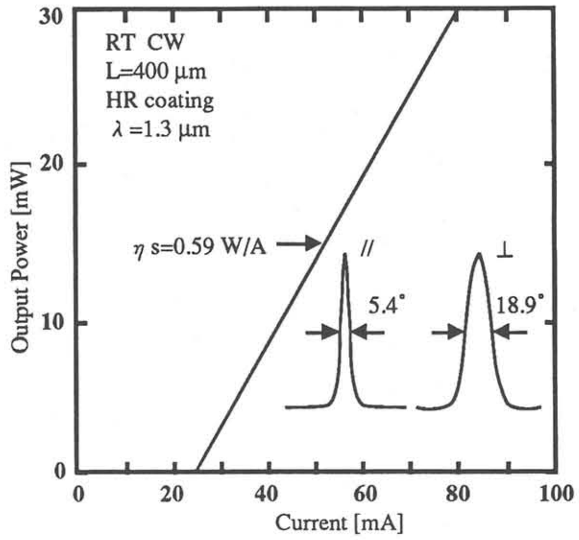

Fig. 2. Continuous wave oscillation light-current characteristics and far-field patterns for a 400-μm-long device with cleaved-HR facets.

3. Device Performance

Figure 2 shows a typical CW light-current curve at room temperature. A threshold current of 25 mA and a high slope efficiency of 0.59 W/A were achieved. The threshold current, in comparison to the non-tapered laser, was about 5 mA higher due to the optical loss in the BEX section, but the slope efficiency was almost the same. This high slope efficiency is due to the small amount of current leakage in the RM-RWG structure. The beam divergence parallel and perpendicular to the junction plane was 5.4° and 18.9° , respectively (Fig. 2). In contrast, the measured beam divergence of a conventional RWG laser without a BEX was 22.4° laterally and 35.1° vertically.

The narrow divergence increases the efficiency of coupling to a 10-μm-diameter silica fiber to 33%, which is more than four times larger than that obtained with the conventional device. As shown in Fig. 3, this also leads to large alignment tolerances of ±2.4 μm and ±1.5 μm in the parallel and perpendicular directions, respectively. While these results are a significant improvement over conventional RWG lasers, further improved performance is expected to be achieved by optimizing the second core structure. In particular, further mode expansion in the vertical direction should be possible by optimizing the second core structure.

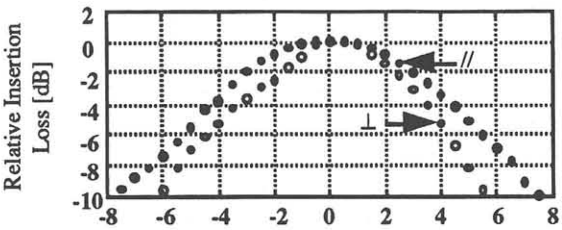

Fig. 3. 1-dB alignment tolerance for coupling to a 10-μm-diameter cleaved single-mode fiber

4. Summary

We demonstrated a 1.3-μm beam-expander integrated ridge-waveguide (BEX-RWG) laser that can be grown by single-step MOVPE. This device has a narrow far-field angle of 5.4° (lateral) and 18.9° (vertical). A high coupling efficiency of 33 % and large tolerances of ±2.4 μm laterally and ±1.5 μm vertically for 1-dB excess insertion loss were achieved. These results show the potential of this BEX-RWG laser as a practical light source for use in low-cost assembly technologies in the near future.

5. References

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