High Efficiency Oxide-Confined High-Index-Contrast Broad-Area Lasers with Reduced Threshold Current Density and Improved Near-Field Profile

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With the advance of crystal growth technique, high power diode lasers have become a highly favorable light source for solid-state laser pumping, direct material processing and medical applications. A gain-guided or weak index-guided broad-area laser structure with an aperture size of w=50 μm-200 μm is normally employed to maximize the output power while minimizing the waveguide scattering loss and non-radiative recombination. The poor lateral electrical and optical confinement, however, make current spreading unavoidable and lead to filamentation, a nonlinear effect, limiting the maximum output power achievable while keeping the facet load below the threshold of catastrophic optical damage.

We have recently developed a simple, self-aligned ridge waveguide laser fabrication process for high-performance GaAs-based narrow-stripe devices [1]. A high-index-contrast (HIC) structure is formed by deep etching (through the waveguide core layer), followed by non-selective O_2-enhanced wet thermal oxidation [2] to grow a uniform thickness layer of high-quality native oxide (200~300 nm) at the sidewalls of the etch-exposed high Al-composition cladding layers and low Al-composition core layer and active region. As shown by the schematic inset in Fig. 1, the oxide-confined waveguide sidewall totally eliminates the lateral current spreading while simultaneously providing a strong lateral index step of $\Delta n\sim1.7$. All devices in this work are fabricated in an 808 nm single quantum well graded-index separate-confinement heterostructure (GRINSCH) with no facet coating or heatsinking employed, and are tested p-side up with 1% duty cycle current pulses at room temperature. A high average slope efficiency of 1.32 W/A (corresponding to a differential quantum efficiency of η_d=86%) is demonstrated (Fig. 1) in a 490 μm long bar length for aperture sizes w ranging from 40 μm to 120 μm. Conventional weak index-guided broad-area devices are also made from the same material to comparatively study the benefit of good lateral electrical and optical confinement in our HIC oxide-confined devices. Fig. 2 compares the laser threshold current densities versus aperture size for similar cavity length structures, and shows a reduction of up to 1.74X at w=40 μm.

Good thermal dissipation is also found in oxide-confined devices primarily because the deeply etched structure and thin native oxide place the high-conductivity deposited p-side metallization in close proximity to the active region sidewall. This is evident from the data of Fig. 3 which shows that the heat dissipation enables a steady output power increase without thermal roll-over up to 5.4X above threshold (I_{th}=74 mA) in a w=40 μm oxide-confined device under a fast-dc sweep, while a shorter weak index-guided device with the same aperture size starts rolling over at 4X threshold and ceases lasing. Fig. 4 shows near-field images for the same two devices under cw operation. The near-field profile in Fig. 4(a) clearly exhibits filamentation due to the spatial-hole burning effect for the conventional device at injection currents of 120 mA and 130 mA. Fig. 4(b), however, shows a much more uniform near-field profile, indicating that a better beam quality can be achieved in HIC broad-area laser structures.

[1] D. Liang, J. Wang, and D. C. Hall, *Electron. Lett.* **42**, 349-350 (2006).

[2] Y. Luo and D. C. Hall, *IEEE Journal of Selected Quant. Electron.* **11**, 1284-1291, (2005).

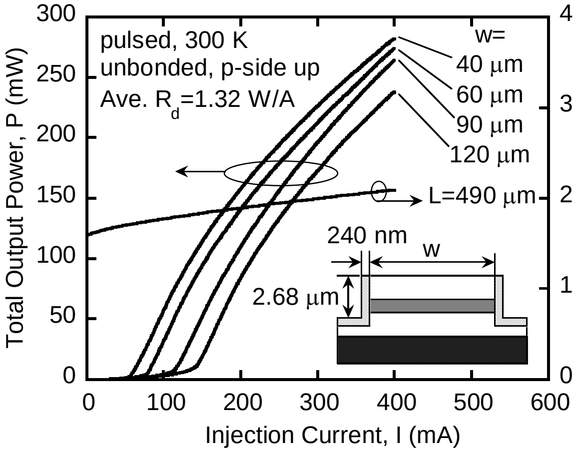

Fig. 1. Pulsed light-current (LI) characteristic and current-voltage relationship of high-index-contrast (HIC) broad-area lasers with aperture size varying from 40 μm to 120 μm and a cavity length of 490 μm, showing an average slope efficiency of 1.32 W/A.

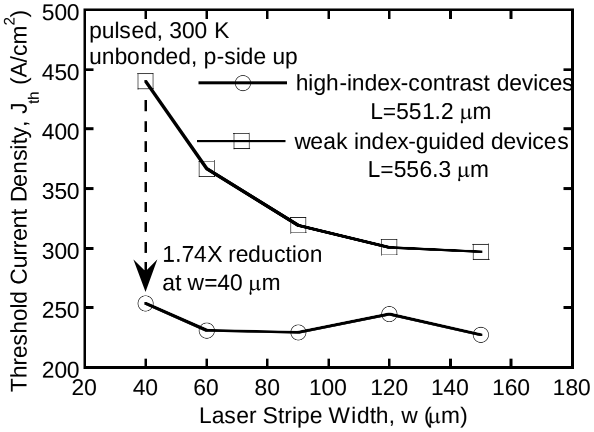

Fig. 2. Threshold current density vs. laser stripe width for HIC and conventional weak index-guided devices with similar cavity length. Up to 1.74X threshold current density reduction is achieved at w=40 μm.

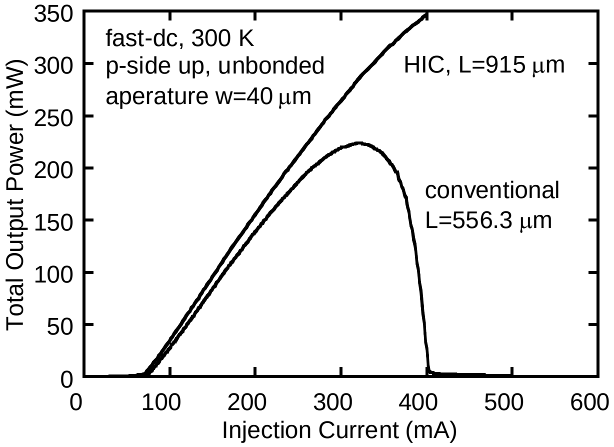

Fig. 3. Fast-dc LI characteristic of a HIC laser and a weak index-guided laser with the same 40 μm aperture size.

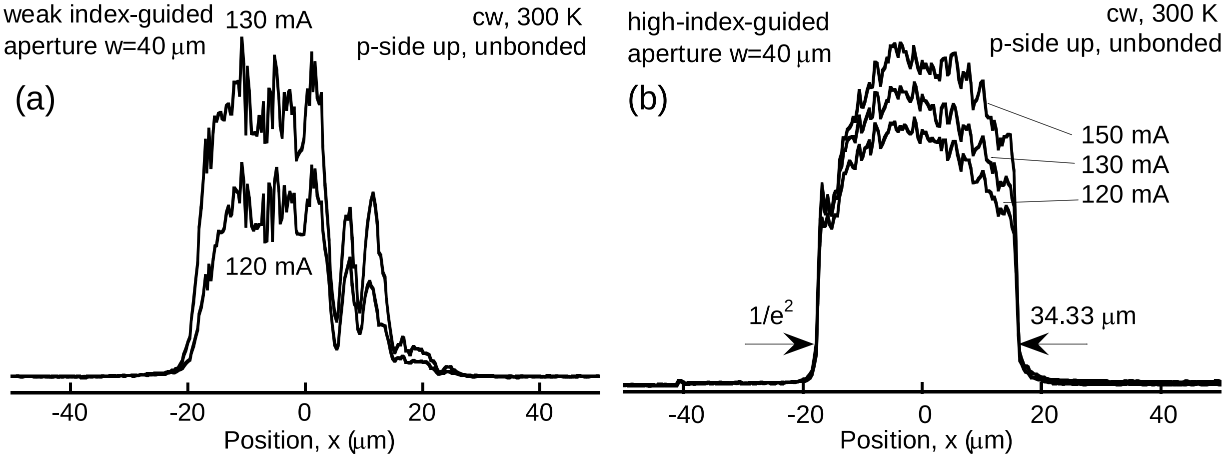

Fig. 4. Continuous wave (cw), 300 K near-field patterns of (a) weak index-guided and (b) HIC devices.