Single-mode Large-aperture Vertical Cavity Surface Emitting Laser

BY C.J. CHANG-HASNAIN, Y.A. WU, AND R. NABIEV, E.L. GINZTON LABORATORY, STANFORD UNIVERSITY, STANFORD, CALIF.

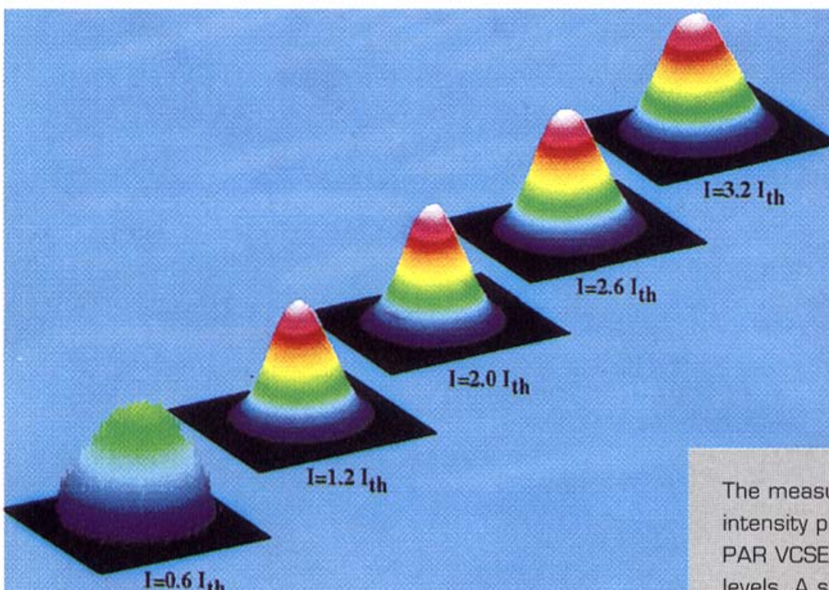
Vertical cavity surface emitting lasers (VCSEL) are promising for optical interconnects, communications, and signal processing. The most promising aspect lies in the prospect of eliminating low yield and high cost laser fabrication steps such as wafer lapping, cleaving, dicing, and facet coatings. Moreover, the topology of a vertical cavity facilitates on-wafer testing, pre-process screening, and the fabrication of large 2D arrays.

The most essential criteria for many applications include stable single-mode emission, fixed polarization, and low threshold currents. It is also desirable to obtain large-aperture VCSELs for high output power with low beam divergence. Though many efforts have been made, none can achieve single-mode emission at high currents.[1-3] Moreover, the single-mode laser aperture has been limited to ≤ 5 μm diameter. In this work,[4] we report a novel passive antiguide region (PAR) VCSEL, which exhibits all of the above-mentioned essential properties simultaneously. We achieved very low threshold currents of 0.8 and 1.2 mA with 8 and 16 μm diameter VCSELs, respectively, and a very low threshold current density of 490 A/cm^2 with a 32 μm VCSEL under pulsed operation at room temperature. The PAR VCSELs with diameters as large as 16 μm emit a single fundamental mode with a fixed polarization direction.

The PAR VCSEL is fabricated as follows. The vertical cavity heterostructure is first grown by molecular beam epitaxy. Laser posts are formed by a combination of dry and wet etching through the active region to obtain both electrical and optical confinement. The current-blocking $A1_{0.2}Ga_{0.8}As$ layer is grown surrounding the VCSEL posts by organometallic chemical vapor deposition. The equivalent refractive index of the Bragg reflectors is less than that of the regrown cladding region. Thus, a passive antiguide structure is formed effectively around the laser cavity in the transverse direction. The PAR structure introduces higher losses to the high order transverse modes and, thus, a single fundamental mode is selected. Additionally, the tapered shape formed by wet etching also acts as an aperture that suppresses further the high order modes.

Both 8 and 16 μm VCSELs show uniform spontaneous emission below threshold (Ith) indicating good current confinement and excellent regrowth interface. A stable, single TEM_{OO} mode emission is achieved up to 12 I_{th} for the 8 μm and ~4 Ith for the 16 μm VCSELs with constant near-field profiles as current increases. The TEM_{OO} mode is linearly polarized at $0\bar{1}1$ direction attributed to an anisotropic strain around the laser post.

In summary, we have demonstrated a novel PAR design that results in excellent mode selection for large-aperture VCSELs without compromising other laser properties. This structure is expected to be useful also for obtaining high-power and single-mode from a large aperture edge emitting lasers.



The measured near-field intensity profiles of a 16 μm PAR VCSEL at various current levels. A single fundamental mode is achieved up to four times threshold.

ACKNOWLEDGMENTS

The authors wish to acknowledge C. Caneau, L.T. Florez, G. Hasnain, and K.D. Choquette for their assistance in laser fabrication, and D. Botez for discussion on antiguides.

REFERENCES

1. K. Iga *et al.*, "Surface emitting semiconductor lasers," IEEE J. Quant. Elect. **24**, 1988, 1845-1855.
2. R. S. Geels *et al.*, "Low threshold planarized vertical-cavity surface-emitting lasers," IEEE Photon. Tech. Lett. **2**, 1990, 234-236.
3. C. J. Chang-Hasnain *et al.*, "Dynamic, polarization, and transverse mode characteristics of vertical cavity surface emitting lasers," IEEE J. Quant. Elect. **27**, 1991, 1404-1412.
4. C. J. Chang-Hasnain *et al.*, "Low threshold buried heterostructure vertical cavity surface emitting lasers," Appl. Phys. Lett. **63**:10, 1993, 1307-1309.