LARGE TWO-DIMENSIONAL ARRAYS OF PHASE-LOCKED VERTICAL CAVITY SURFACE EMITTING DIODE LASERS

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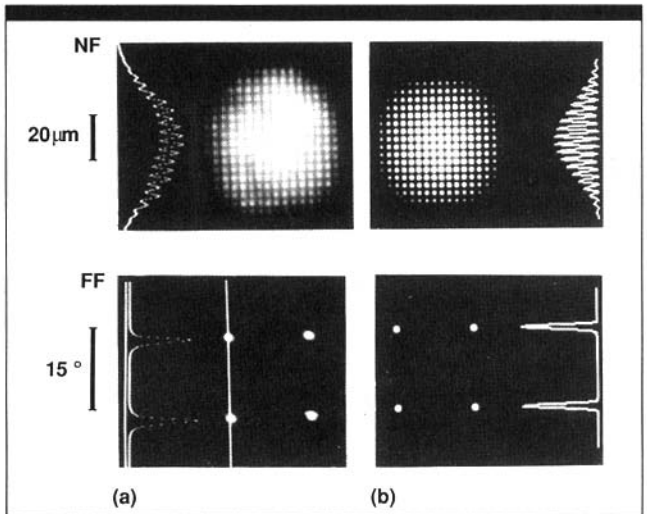
Coherent arrays of vertical cavity surface emitting lasers (VSCELs) are useful for applications involving high power coherent optical beams, *e.g.*, optical computing, multichannel optical interconnects, and free space communications. One of the unique properties of VCSELs is their low roundtrip gain, generated in active regions as short as ~10 nm, which requires high-Q optical cavities to achieve lasing in these structures. However, this feature makes it possible to define a VCSEL element simply by patterning one of the laser mirrors, which allows realization of high density, two dimensional (2D) arrays of VCSELs with high inter-element optical coupling.[1]

With this approach, a conventional VCSEL laser wafer grown by molecular beam epitaxy and incorporating two epitaxial Bragg mirrors is employed. The top mirror reflectivity is then patterned with a 2D array of Au reflectors to define the laser arrays. The optical coupling between adjacent lasers is accomplished via diffraction of the optical mode at the boundaries of each reflector.

This method of array-definition enables small inter-laser spacings (typically 1 μm), which leads to high optical coupling and efficient phase-locking. These structures also provide a built-in-mechanism for selection of a few supermodes (transverse cavity modes) out of the N^2 ones supported by a (weakly coupled) NXN array of single mode lasers. This spatial filtering is accomplished due to the higher cavity losses between the array elements, where the mirror reflectivity is low. The preferred supermodes are hence those with reduced near field intensity between elements, particularly the highest order supermode in which each laser is 180° out of phase with respect to all of its nearest neighbors.

The figure shows the measured and calculated near field (NF) and far field (FF) patterns of a 20 3 20 laser array. The four-lobed far field pattern indicates oscillation in the highest-order supermode, as confirmed by the corresponding calculated field patterns shown in Part (b). Remarkably, the 2D array oscillates in only one supermode out of the 400 supported by the laser cavity, which demonstrates the high spatial coherence of these structures. In fact, it has been shown[2] that the two-dimensionality of these arrays plays a crucial role in achieving such efficient, selective phase-locking. A 2D coupled system has an effectively higher inter-element coupling due to the larger number of nearest neighbors, compared to a 1D structure. It is also more immune to localization effects caused by inadvertent nonuniformities that can degrade the coherence. Phase-locked 2D-arrays incorporating up to 27 3 27 elements, lasing areas as large as 200 3 200 μm,[2] threshold currents as low as 0.95 mA per laser, and peak output powers as high as 310 mW have been demonstrated using this approach.[3] Scaling up of these devices to even larger arrays appears to be feasible.



MEASURED (a) AND CALCULATED (b) NEAR FIELD (NF) AND FAR FIELD (FF) PATTERNS OF A 20 × 20 TWO-DIMENSIONAL ARRAY OF INGAAS QUANTUM WELL VCSELS OPERATING IN A SINGLE SUPERMODE.

REFERENCES

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