2-D MONOLITHIC MULTIPLE-WAVELENGTH DIODE LASER ARRAY

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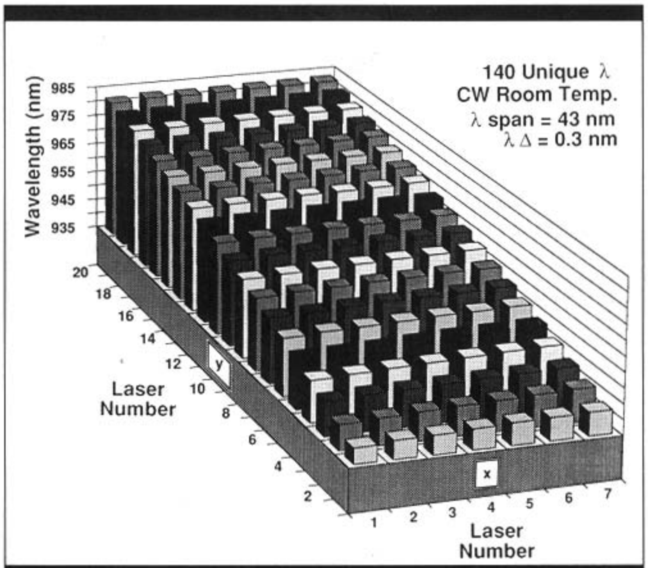
Optical sources capable of THz data rates are essential for applications ranging from optical fiber communications, to fully interconnected large computers, to real-time optical signal and image processing. The more conventional approach to achieve high data rate is to use a single high speed or mode-locked diode laser. However, their bandwidths are limited to a few tens to a hundred GHz. Moreover, the laser as well as its driver and packaging becomes very expensive as its speed increases.

A highly promising approach that has attracted considerable research efforts is to use a system that employs the laser wavelength as an additional parameter for multiplexing and coding—also known as wavelength-division-multiplexing (WDM).

One key component for a WDM system is a monolithic array of single-wavelength lasers emitting uniformly-spaced wavelengths (multiple wavelength laser array). Fabricating such an array using the conventional distributed feedback (DFB) edge-emitting lasers[1,2] has been very difficult and expensive because highly precise variation of the grating periods is required for the entire laser array.

In the previous reports, either x-ray[1] or e-beam lithography[2] were used to make multiple wavelength DFB laser arrays. In this work, we have taken a drastically different approach by implementing thickness graded layers in vertical cavity surface emitting lasers (VCSEL). We have achieved 140 uniformly-spaced, nonredundant, single-mode wavelengths from a 7 × 20 VCSEL array. Moreover, all the lasers exhibit nearly the same optical and electrical characteristics.

A VCSEL has its mirrors on the plane of the wafer and the laser beam emits in the direction normal to the wafer.[3,4] The VCSEL structure we used includes a top and bottom alternating quarter-wave GaAs/AlAs Bragg reflectors and a quantum-well active region.[3,4] The design principle of the multiple wavelength array is based on a unique property of VCSEL. Its cavity is so short that it can lase only at one particular wavelength, which is determined by the thickness of the Bragg reflectors. Hence, by implementing a thickness gradient in some layers of a VCSEL array, a multiple-wavelength array is obtained. Experimentally, we fabricated such a structure using the fact that the molecular sources are incident to the wafer at an angle off normal during the molecular beam epitaxy (MBE) growth. Keeping the wafer stationary during part of the growth yields the desired small but definite thickness gradient across the wafer.



Measured CW wavelength distribution of the 7 × 20 VCSEL array. Each laser emits a unique wavelength. The direction of increasing wavelength rasters through the 2D array in a predetermined manner.

The figure shows the experimentally measured CW (continuous wave) wavelengths as a function of laser numbers for a 7 × 20 VCSEL array. There are 140 unique wavelengths. All the lasers emit in a single fundamental transverse mode. The wavelength separation between two lasers in a row is 0.3 nm and the total wavelength span is 43 nm. The direction of increasing wavelength rasters through the 2D array in a pre-determined, well-behaved, and controllable manner.

The multiple wavelength VCSEL array should find numerous applications either as an array of independent sources or as a single wavelength-selectable source. The technique invented[5] here is both generic and flexible. It can be readily extended to other wavelength regimes, *e.g.*, 1.3~1.5 μm or 0.6~0.7 μm. The 2D N × M array can be made to have N × M wavelength or only M wavelengths, each with N redundancies for higher reliability and yield. The wavelength separation can be designed to range from 0.1-10 nm. In addition, there is high flexibility in the design of the physical dimension and number of elements of the laser array.

References

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