Concentric-Circle-Grating, Surface-Emitting Semiconductor Lasers

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It is possible to make use of a concentric-circle grating (CCG) to define a novel Bragg resonator for a semiconductor laser. This fundamentally unique, two-dimensional optical resonator confines the propagation of circular waves through a distributed feedback (DFB) process. Such a laser, when operated in the second Bragg order, offers the prospect of surface emission from a broad area, circularly symmetric aperture. As a result, this laser can emit a low divergence, spectrally narrow beam that is circular in cross section. In addition, as in typical semiconductor laser configurations, the concentric-circle-grating, surface-emitting (CCGSE) laser makes use of waveguide mode propagation parallel to the active-layer plane, in contrast to the transverse propagation axis of a vertical cavity, surface-emitting laser. This feature, coupled with the broad area emission aperture, suggests that such a laser is capable of very high output powers. These emission properties make the CCGSE laser an attractive candidate for a number of applications, including fiber and free-space communications, optical recording, laser printing, and optical interconnection.

In the past year, lasing has been reported by several research groups in both optically pumped[1,2,3,4] and electrically pumped[5] CCGSE lasers. For low-divergence, circularly symmetric emission to be possible in a CCGSE laser, the laser must oscillate in a single radial (longitudinal) and azimuthal mode in a resonator that is much larger than an optical wavelength in two dimensions. To date, only one reported experiment has demonstrated single-mode lasing.[3,4] In these lasers, the emission was found to be spectrally narrow (width$\sim$1Å), and showed no evidence of filamentation despite the broad area of the lasers (grating diameter = 150 μm). The lasers consisted of an AlGaAs/GaAs quantum-well structure grown by molecular-beam epitaxy. Concentric circle gratings of period 0.25 μm were defined by electron-beam lithography, and subsequently transferred into the semiconductor via chemically assisted (chlorine) ion-beam etching. The figure shows a scanning electron micrograph of the center portion of a typical grating (a).

A cross section of the circularly symmetric beam emitted by a CCGSE laser is also shown in the figure (b). The total angular divergence of the beam is less than 1°. The beam is azimuthally polarized, making this laser a natural source of "scrambled" polarization. In addition, the beam cross section resembles a "doughnut," with a null in the center. Intuitively, this profile might be thought of as the circularly symmetric analog of the double-lobed far-field pattern emitted by a one-dimensional, grating-surface emitting DFB laser operating without end-facet reflections. While a substantial portion of the light is emitted in a direction normal to the plane of the laser, some of the emission also propagates radially away from the grating in a circular guided mode. This leakage might be useful for the formation of a two-dimensional, symmetric, phase-locked array of CCGSE lasers.

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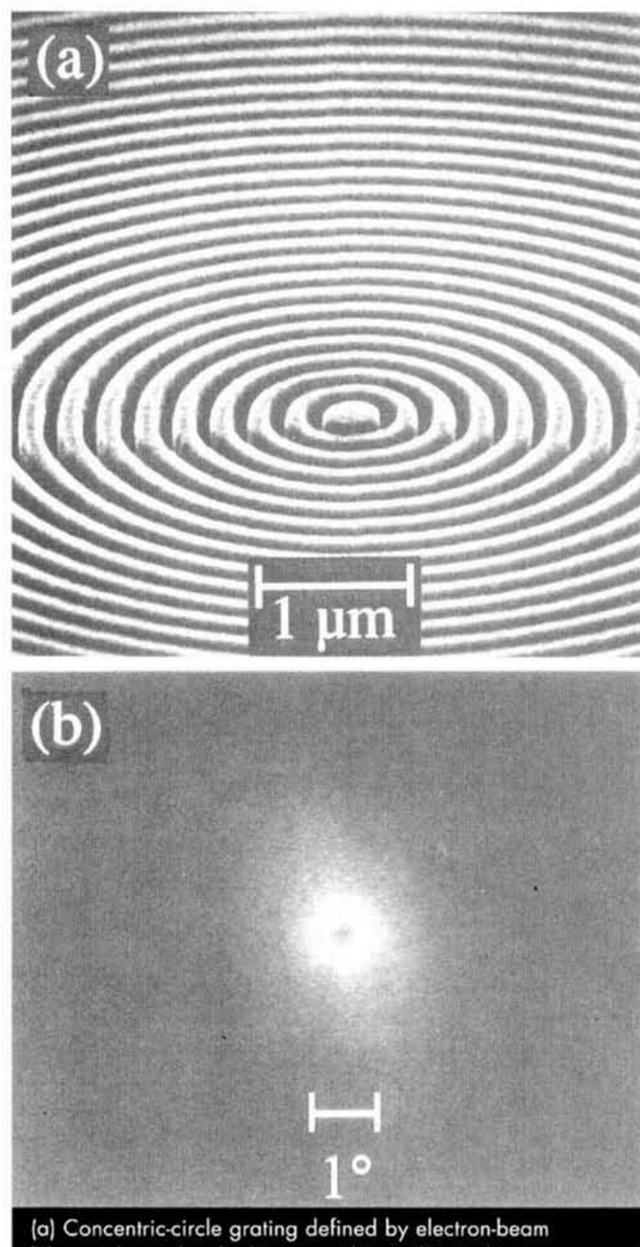

(a) Concentric-circle grating defined by electron-beam lithography and etched into an AlGaAs/GaAs laser structure; (b) Cross section of the surface-emitted laser beam.