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Quantum well DFB laser having a curved grating structure

G. S. Sokolovskii[†], *E. U. Rafailov*[‡], *A. G. Deryagin*[†], *V. I. Kuchinskii*[†],
D. J. L. Birkin[‡] and *W. Sibbett*[‡]

[†] Ioffe Physico-Technical Institute, St Petersburg, Russia

[‡] School of Physics and Astronomy, University of St Andrews,
 North Haugh, St. Andrews, Fife KY16 9SS UK

Abstract. Theoretical investigation of novel DFB laser with “curved-grooves” diffraction grating (c-DFB) is presented. Calculations show the proposed design provides spectral selectivity of conventional DFB resonator and output beam focusing in the plane of p-n-junction. The curved-grating DFB-laser design is predicted to be most attractive for the quantum well structures.

At present there is a great interest in high power single-mode single-frequency QW laser sources. Applications of these lasers ranges from medicine (e.g. NMR tomography) to telecommunication (pumping of Er-doped fibre amplifiers for fibre optical communication). Up-to-date single-element diode lasers based on a narrow index-guiding stripe are limited in power to less than 500 mW by either catastrophic optical damage or thermal overheating of the facet. Although higher powers may be achieved by increasing the stripe width, multiple lateral modes generally appear. Other approaches aimed at improving the diffraction-limited output power include arrays of antiguided narrow-stripe lasers, unstable resonators and master oscillator/power amplifier (MOPA) structures. Of these, only MOPA's have demonstrated diffraction-limited operation to output powers of >1 W, but the technology required to fabricate MOPA's is quite complex.

We present a novel type of distributed feedback laser with a “curved-grooves” diffraction grating (c-DFB), which is expected to give spectral and spatial output beams that are superior to those currently obtained from an angled diffraction grating (α -DFB). Figure 1 is a simplified schematic of the c-DFB laser [1]. The use of a c-DFB will combine not

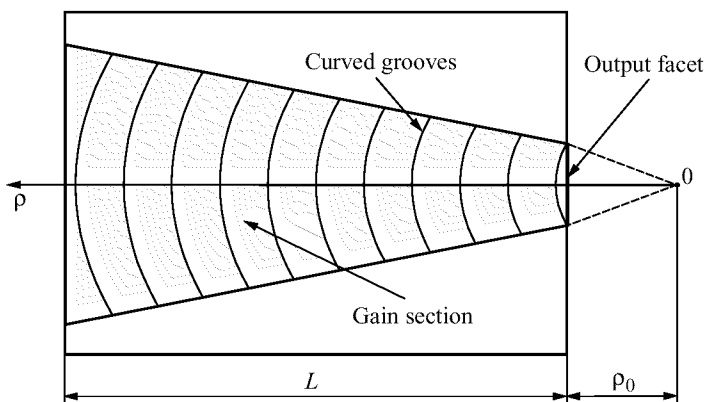


Fig. 1. A simplified schematic of the c-DFB laser.

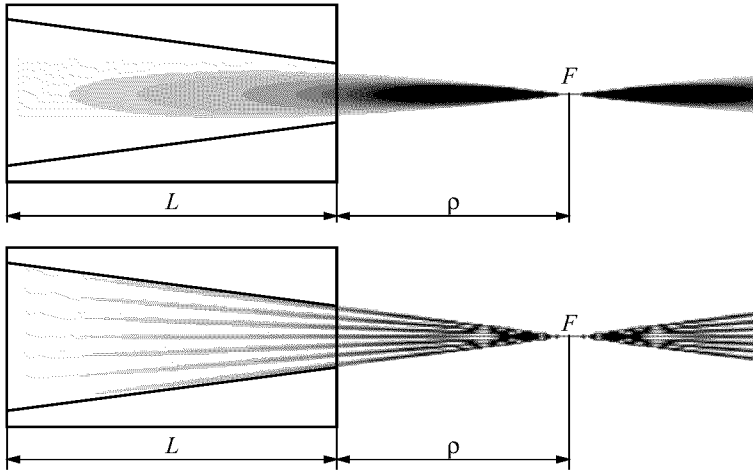


Fig. 2. The modelled performance of the c-DFB laser.

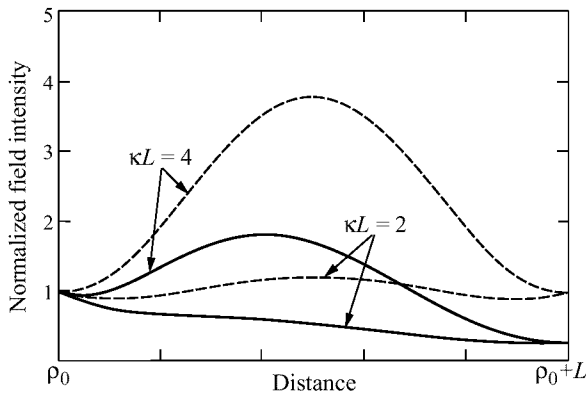


Fig. 3. Plot of the longitudinal intensity distribution for various coupling levels for c-DFB laser with $\rho_0 = L$ (solid lines) and conventional DFB laser (dashed lines).

only the high-power of a broad stripe device and spectral control provided by a diffraction grating but also output beam focusing in the plane of p-n-junction.

A diffraction grating with curved-grooves can be designed to concentrate the output emission to a focus determined by the curvature of the grating. Figure 2 shows the calculated c-DFB laser output field distribution in the plane of p-n-junction for a single transverse mode. Laser beam focusing in the direction orthogonal to the plane of p-n-junction can be simply obtained by a cylindrical lens mounted on the laser heat-sink.

The other advantage of the proposed c-DFB laser structure is the flat lateral intracavity intensity distribution, as it is shown in Fig. 3. The strongly non-uniform intensity distribution in the cavity of the conventional DFB laser causes the effect of spatial hole burning preventing high-power single-frequency laser operation. Spectral selectivity of c-DFB laser resonator is the same as that of a conventional DFB. These allow us to predict the improved spectral selectivity of the proposed c-DFB laser at high power compared to the conventional DFB laser design.

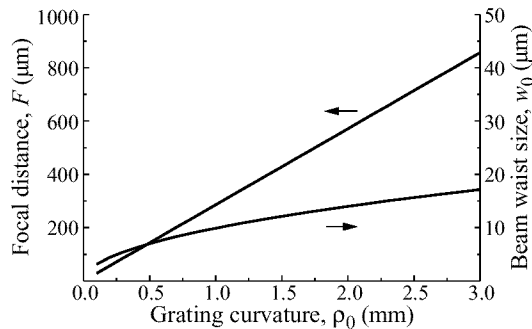


Fig. 4. Dependence of the focal distance and beam waist size on the grating curvature for the c-DFB laser in a paraxial approximation.

Figure 4 represents the calculated dependence of the focal distance and beam waist size on the grating curvature ρ_0 for a wavelength $1 \mu\text{m}$. The c-DFB laser design allows adjustment of the structural parameters to obtain the beam properties necessary for different applications: minimal beam waist size and short focal distance for coupling with single-mode optical fiber or long beam waist for pumping of nonlinear crystal.

In summary we have proposed the construction of a novel DFB laser with “curved-grooves” diffraction grating. The theoretical analysis shows that this laser can combine not only the high-power of a broad stripe device and the spectral control provided by a diffraction grating but also output beam focusing in the plane of p-n-junction. The maximum efficiency of the curved grating device is predicted to be achieved at the high-power operation (which imply high photon density) i.e. in QW lasers.

References

- [1] G. S. Sokolovskii, E. U. Rafailov, D. J. L. Birkin and W. Sibbett, *J. Opt. Quantum. Electron.* **31**, 215 (1999).