Coupled Electro-Thermo-Optical 3D Simulation of Edge-Emitting Lasers

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Numerical Simulations of edge-emitting semiconductor lasers are usually restricted to one or two dimensions, assuming translational symmetry in the remaining dimensions. However, in cases where this assumption is not valid because of geometry variations in all dimensions, fully three-dimensional simulations might be required. In this work, the effect of unequal facet reflectivities on the performance of an edge-emitting laser diode is investigated. This is done by means of simplified two-dimensional and quasi three-dimensional laser device simulations. The device under investigation is an index-guided Fabry-Perot laser diode with a GaAs active layer between AlGaAs separate confinement layers. Its length is 400 μm. The reflectivitites are 20% and 80% at the front and back facet respectively.

For the device simulations, an extended version of a commercial device simulator is used [4]. In the framework of a hydrodynamic model [1], it solves the carrier drift-diffusion equations and the energy flux equations in fully self-consistent manner, together with the laser gain calculation, the photon rate equations and the Helmholtz equation for the optical field [2,3]. Thermionic emission at heterojunctions is considered, current and energy flux can be calculated in longitudinal and lateral direction. For the gain calculation a non-Lorentzian line broadening model is applied. Simulations are carried out on a transverse cross section of the device and on a quasi three-dimensional longitudinal device model [Fig.1]. The results are compared in order to see, if simplified simulations contain the essential physical information or if more advanced simulations are required.

Using the simulations, the effect of unequal facet reflectivities is studied. Unequal reflectivities lead to a strongly nonuniform optical intensity distribution. The optical intensity is higher at the facet with higher reflectivity, thus causing enhanced stimulated emission and spatial hole burning in this region. This leads to high injection currents and additional, nonuniform self-heating of the device near the highly reflective facet. Due to a inhomogenous carrier distribution also longitudinal current flow can be observed.

[1] K.Kells, “General Electrothermal Semiconductor Device Simulation”, *PhD Thesis*, ETH Zürich, 1994.

[2] B. Witzigmann, A. Witzig, W. Fichtner, “A Multidimensional Laser Simulator for Edge-Emitters Including Quantum Carrier Capture”, *IEEE Transactions on Electron Devices*, vol. 47, no. 10, pp. 1926-1934, October 2000.

[3] B. Witzigmann, “Design and Implementation of Three-Dimensional Edge-Emitting Quantum Well Laser Simulator”, *PhD Thesis*, ETH Zürich, 2000.

[4] DESSIS-ISE 6.1 by ISE Integrated Systems Engineering AG.

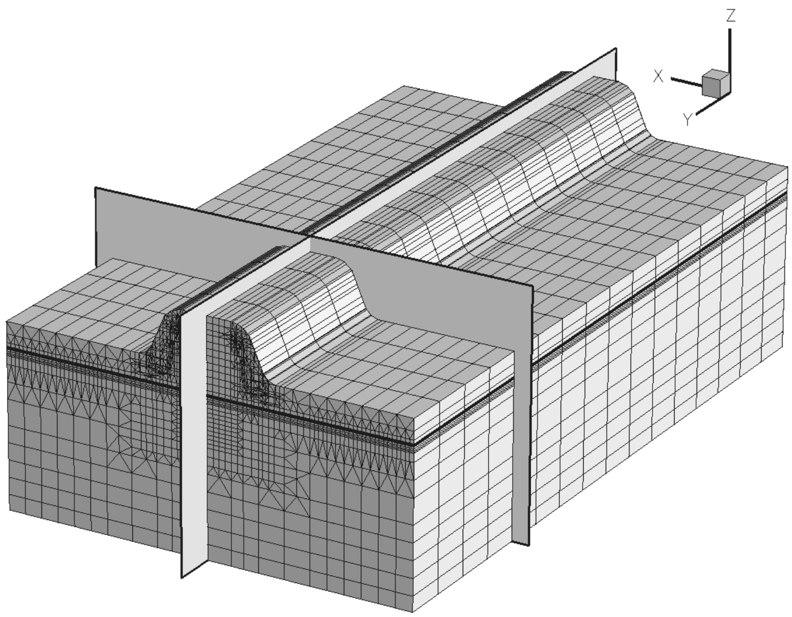

Fig.1: Simulations models for the laser simulation: cross sections and full 3-dimensional device model.

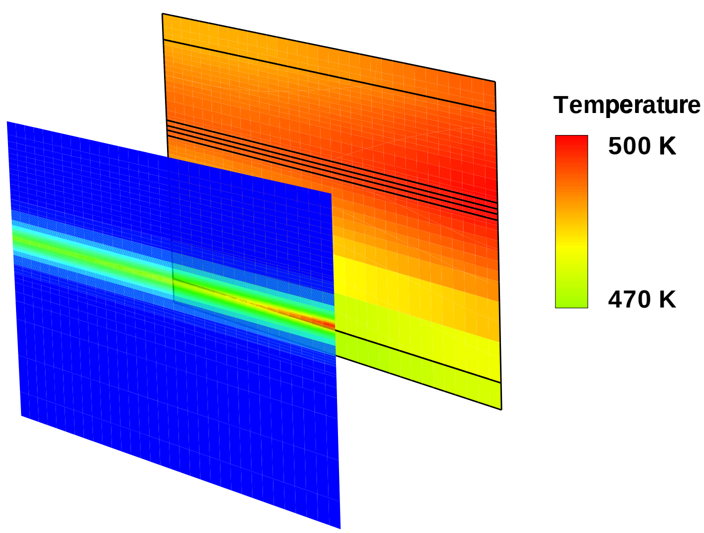

Fig.2: Longitudinal temperature (back) and intensity (front) profile. Result of a quasi-3D simulation on a longitudinal cross section of a device as shown in Fig.1. The cross section is a cut along the Y-direction. At the facet with higher reflectivity the optical intensity and the device temperature are higher than at the low reflective facet.

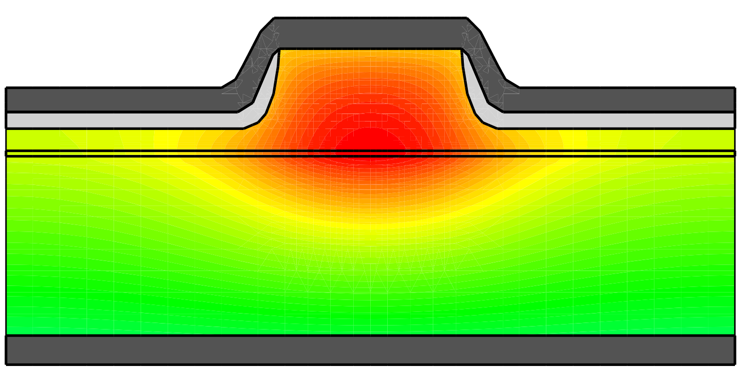

Fig.3: Transverse temperature profile at the highly reflective back facet of the same structure.