Modeling and simulation of strained quantum wells in semiconductor lasers

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Many modern optoelectronic devices, in particular semiconductor lasers, essentially rely on Quantum Well structures which need to be properly designed. Based on the Envelope Function Approach for heterostructured materials and the **kp**–theory, a model has been developed which allows to simulate such structures consistently. The model is based on matrix–valued **kp**–Schrödinger operators. Effects such as confinement, band mixing, spin–orbit interaction and strain can be treated for different material systems, e.g. cubic and wurtzite crystallographic structures. Important information provided by the model are the non parabolic band structure, the quantum confined states, their respective transition matrix elements, carrier densities and the optical response function, which is crucial for semiconductor laser modeling. The impact of prominent Coulomb effects has been considered by including the Hartree interaction via the Poisson equation and the bandgap renormalization via exchange–correlation potentials, resulting in generalized matrix–valued Schrödinger–Poisson systems. Based on these results, comprehensive device simulations have been performed. These simulations include the interaction between the electronic behaviour of the device and the optical field, i.e., they account for carrier transport, optical wave wave guiding, and generation and transport of thermal energy. The bandstructure information enters parametrically via the density of states, or alternatively by a capture–escape mechanism, and the optical response function. The simulation results are in good agreement with experiments, demonstrating their applicability for designing modern optoelectronic devices. Indeed, the described simulations of semiconductor lasers now can be routinely performed in an development environment. e.g. at the "Heinrich–Hertz–Institut für Nachrichtentechnik" (HHI), Berlin. where they are used for optimizing multi quantum well laser structures.

Publications within the Project

Publications in Journals and Books

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- Th. Koprucki. Efficient simulation of electronic states in semiconductor quantum wells. 16th GAMM–Seminar Leipzig on Numerical techniques for Schrödinger equations, February 3–5, 2000.
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- U. Bandelow. Lasermodellierung - Beiträge des WIAS zum Projekt "Terabit-Optics-Berlin". Talk at session of scientific committee of WIAS, WIAS, Berlin, oct 13 2000.
- Uwe Bandelow, Herbert Gajewski, Hans-Christoph Kaiser, Thomas Koprucki, and Joachim Rehberg. Modeling and simulation of strained quantum wells in semiconductor lasers. Statusseminar 2000 des BMBF–Förderschwerpunktes "Neue Mathematische Verfahren in Industrie und Dienstleistungen", Frankfurt am Main.
- U. Bandelow. Modeling of active optoelectronic components. Invited talk at Intel Corp., Santa Clara, CA, USA, march 25 2000.
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