

## Foreword

Semiconductor lasers are very small and cost efficient optical light sources that already entered into numerous parts of our daily lives. For the past 30 to 40 years, they have been used as experimental platforms for investigating new and interesting phenomena in physics and mathematics, and on the other hand as easy-to-handle test-beds for nonlinear dynamical phenomena occurring in a much wider context.

This thesis deals with the light emission characteristics of quantum-dot lasers, i.e., semiconductor lasers that contain pyramid-shaped nanostructures (quantum dots) coupled to a surrounding 2-dimensional layer of semiconductor material. Due to their multiple confined states these lasers can show multimode emission which is interesting for two reasons. At first it allows to study fundamental aspects of complex nonlinear dynamical system and second it may lead to technological applications in modern telecommunication where there is a need for multi-wavelength data transmission.

The microscopic modelling approach used within the thesis contains sophisticated microscopic modelling of the internal scattering processes and thus allows to quantitatively describe the light emission from the ground and the first excited state. As also observed in experiments, different operation modes are possible ranging from single mode operation to simultaneous two-state lasing or to a current depending ground state quenching. Especially the last phenomena, i.e., a shutdown of the ground state emission during an increase of the electric pump current, crucially depends on the internal scattering processes and is discussed in depth in the thesis. Supported by analytic approximations it is possible to predict the parameter regimes for ground state quenching and to identify the asymmetry in the electron and hole charge carrier populations as the driving force for the quenching.

The electrical modulation properties of a two-mode device can be significantly better than those of purely ground state emitting quantum-dot lasers. It is shown that an abrupt improvement is observed shortly behind the excited state emission threshold.

The thesis presents new results on the light emission characteristics of two-mode quantum dot lasers and suggests operation conditions for innovative and fast devices. This has considerable application potential, since quantum-dot lasers are very promising candidates for telecommunication applications and high-speed data transmission. Further the thesis gives new fundamental insights into the interplay between internal carrier scattering timescales and optical modulation properties by combining numerical solutions of nonlinear laser differential equations and analytical approximations methods.

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