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Electronic and Photonic Quantum Devices

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Abstract

In this thesis various subjects at the crossroads of quantum mechanics and device physics are treated, spanning from a fundamental study on quantum measurements to fabrication techniques of controlling gates for nanoelectronic components.

Electron waveguide components, i.e. electronic components with a size such that the wave nature of the electron dominates the device characteristics, are treated both experimentally and theoretically. On the experimental side, evidence of partial ballistic transport at room-temperature has been found and devices controlled by in-plane Pt/GaAs gates have been fabricated exhibiting an order of magnitude improved gate-efficiency as compared to an earlier gate-technology. On the theoretical side, a novel numerical method for self-consistent simulations of electron waveguide devices has been developed. The method is unique as it incorporates an energy resolved charge density calculation allowing for e.g. calculations of electron waveguide devices to which a finite bias is applied. The method has then been used in discussions on the influence of space-charge on gate-control of electron waveguide Y-branch switches.

Electron waveguides were also used in a proposal for a novel scheme of carrier-injection in low-dimensional semiconductor lasers, a scheme which altogether bypasses the problem of slow carrier relaxation in such structures.

By studying a quantum mechanical two-level system serving as a model for electroabsorption modulators, the ultimate limits of possible modulation rates of such modulators have been assessed and found to largely be determined by the adiabatic response of the system. The possibility of using a microwave field to control Rabi oscillations in two-level systems such that a large number of states can be engineered has also been explored.

A more fundamental study on quantum mechanical measurements has been done, in which the transition from a classical to a quantum “interaction free” measurement was studied, making a connection with quantum non-demolition measurements.

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