Abstract

The coherent state manipulation of single quantum systems is a fundamental requirement for the implementation of quantum information devices. In the past, many different qubit implementations have been proposed, and basic coherent control has been demonstrated. Concerning the interaction with photons, exciton qubits are of particular interest for coherent optoelectronic applications. Until now, coherent manipulations of exciton qubits in semiconductor quantum dots have been performed mostly by ultrafast laser pulses. In particular, single quantum dot photodiodes have been used for a variety of coherent experiments, for example Rabi-oscillations, Ramsey fringes, and CROT quantum gate operation.

In this work, a new scheme for the coherent optoelectronic manipulation of an exciton qubits is developed. The scheme employs an optical clock signal and a synchronous electric gate signal, which controls the coherent manipulation. The experimental realization combines state of the art picosecond laser techniques with synchronous electric operation in the coherent regime. The experiments are performed using a single exciton, confined in a InGaAs QD in a GaAs photodiode.

To verify the experimental data, a detailed theoretical model is developed. The model is based on the optical Bloch equations and includes a two-step relaxation mechanism, which is characteristic for the tunneling of the quantum dot exciton in a photodiode. To confirm the model, results from previously developed experiments are compared to the model. Thereby, the model allows a more detailed analysis of the previous results. In particular, the evaluation of the heavy-hole tunneling time from the cw saturation spectroscopy is now more reliable. Furthermore, detailed analysis of the excitation dependent damping of the Rabi-oscillations at low temperature is given in the context of the theoretical model.

In this thesis, also CdSe/ZnSe QD photodiodes are introduced. This material system provides higher confinement and Coulomb correlation energies than the InGaAs/GaAs system and therefore is a candidate for coherent operation at elevated temperatures. The results of the voltage dependent photoluminescence measurements indicate, that it is possible to provide working CdSe/ZnSe QD photodiodes for future coherent photocurrent experiments.