Abstract – Dissertation Patrick Ester – "Coherent Properties of Single Quantum Dot Transitions and Single Photon Emission"

After the discovery of the self organized generation, a new field in the area of semiconductor physics was initiated. Physicists worldwide have been inspired by the new possibilities which arise due to this discovery. The creation of self assembled quantum dots (QDs) takes place totally defect free. Thus, the quantum dots exhibit a very high optical quality. Due to an over-growth with a higher band gap semiconductor, a confinement potential for excitons can be created. The energy levels of a confined exciton are quantized, and therefore similar to an atom. However, this quantum system is fixed in space. Hence, it is fairly easily possible to study the properties of a single quantum system.

In this work, the properties and the different dephasing mechanisms of transitions of a single QD are analyzed. In addition, some applications are presented which arise due to the properties of the confined exciton. The isolation of a single QD out of the ensemble is achieved via a near field shadow mask, which restricts excitation and QD luminescence to a single QD. The integration of a QD-layer into a diode structure allows for an analysis of various dephasing mechanisms of a confined electron hole pair. The single QD is characterized regarding the energy of nearly all possible transitions, e.g. the ground state, excited states, charged states, multiple occupations, and phonon assisted absorptions. A very important issue in this content is the voltage dependence of the transition energy and thereby the ability of tunneling processes of charge carriers in and out of the QD.

The QD-transitions, which are subject of investigation here, are the single exciton ground state, the first excited state (*p*-shell), and the LO (longitudinal optical) phonon assisted absorption. By applying a suitable voltage, the resonantly excited ground state exciton is able to decay by a tunneling process, which reflects the transition energy in the photocurrent spectra. The *p*-shell transition decays by a relaxation process into the ground state, followed by an optical recombination process. The phonon assisted absorption differs from the *p*-shell transition. The resonant excitation energy fits to the exciton ground state energy plus the energy of a GaAs LO phonon. In this case, the single exciton (ground state) is generated as well as a GaAs LO phonon. These three transitions are investigated in different respects, such as different applied voltages, excitation polarizations, excitation intensities, and coherent properties. If a QD state can be treated as a quantum mechanical two level system, it must exhibit specific coherent and incoherent characteristics, such as occupation saturation (with increasing excitation intensity). In particular a coherent excitation must be possible. This is demonstrated for the single exciton ground state by photocurrent experiments and for the *p*-shell transition by photoluminescence experiments. The LO phonon assisted absorption shows also saturation behavior, but here coherent state preparation seems not possible with the available excitation conditions. The comparable long dephasing time of the single exciton ground state easily allows for two time separated interactions of laser pulses with the QD.

The exciton in the QD is able to interfere with the second laser pulse due to the storage of the phase information of the first laser pulse. The relative phase of the QDs exciton can be controlled externally via the bias voltage. This can be used for measurements of Ramsey-fringes, which are presented in this work.

The coherent manipulation of the *p*-shell is the basis for a novel excitation scheme for single photon emission. In this work it is shown, that the first excited state can be coherently manipulated, similar to the ground state. Due to this defined excitation of a single exciton in the *p*-shell, the resulting single photon emission (after the relaxation and recombination process) appears remarkably clean, as demonstrated by Hanbury-Brown and Twiss experiments.