Abstract

The subject of this thesis are electronic properties of isolated quantum dots as well as transport properties of quantum dots coupled to two electronic reservoirs. Thereby special focus is put on the effects of Coulomb interaction and possible correlations in the quantum dot states.

First, the regime where the quantum dot is only weakly coupled to the reservoirs is investigated by using a master equation approach with tunneling rates obtained by Fermi's Golden Rule. It is shown that in case more than two quantum dot states participate in transport, the resonance positions in the differential conductance generally depend on temperature and the number of participating states. Therefore transport spectra generally cannot be interpreted in a straightforward manner by the energy levels of the isolated quantum dot. At the same time it is shown how this effect can be used to directly probe degeneracies in a quantum dot spectrum. In a spherical quantum dot occupied by two and three Coulomb interacting electrons, a mechanism is found which leads to a complete blocking of the quantum dot for transport. This blocking mechanism results in an enhancement of the Coulomb blockade regime where transport is exponentially suppressed and is explained by a cascade of transitions which ends in a state blocked for further transport due to spin-selection rules.

In the second part, the electronic structure of spherical quantum dots is calculated within a particle-in-a-sphere model for interacting electrons. In order to account for correlation effects, the few-particle Schrödinger equation is solved by an exact diagonalization procedure. It is shown that the calculated electronic structure compares to experimental findings obtained on colloidal semiconductor nanocrystals by Scanning Tunneling Spectroscopy. The electric field induced by the tunneling tip is studied and it is found that the resulting Stark effect can lead to a toroidal symmetry of the electronic ground state density which is in agreement with wave-function mapping experiments. For the five-particle ground state it is found that the symmetry depends on the nanocrystal radius. This is explained by a competition between exchange energy and the Stark energy.

Studying the excitation spectrum, it is found that Coulomb interaction can lead to a reduction of the low lying excitations for increasing number of electrons occupying the quantum dot which explains recent experimental findings on self-organized quantum dots.

In the last part, co-tunneling in the Coulomb blockade regime is studied. For this end the tunneling current is calculated up to the forth order perturbation theory in the tunnel coupling by a real-time Green's function approach for the non-equilibrium case. The differential conductance calculated for a quantum dot containing up to two interacting electrons shows complex signatures of the excitation spectrum which are explained by a combination of co-tunneling and

sequential tunneling processes. Thereby the calculations show a peak structure within the Coulomb blockade regime which has also been observed in experiment.