Abstract

This thesis gives a theoretical treatment of how the electronic and optical properties in low-dimensional structures can be tuned by an external potential. The main theory we use is based on the quantum theory for few or many fermion problems, where one of the papers involves the theory of spin for few electron systems. The problem of optical transitions in low-dimensional structures is treated for both a single electron problem in a quantum dot as for an exciton which is polarized due to a split gate arrangement. In addition a model for diffusion in low-dimensional structures is obtained where we use a semi-classical approach due to the high temperature in the problem.

In Paper 1 we study spin and structural transitions of a three electron system in three dimensions. The three electrons are confined in a spherical parabolic potential and are treated using both the unrestricted Hartree-Fock method, using a Gaussian basis set and a path integral Monte Carlo simulation. Several interesting transitions are found and the two complementary theories agrees very well. The total spin and exchange for the three electron problem is fully analyzed.

In Paper 2 we have solved an exciton problem, which is solved numerical for a real three dimensional split gate setup. The exciton is found to be non-linearly polarized when the gate voltage exceed a certain threshold voltage. We use Hartree theory which treats the boundary condition dependent Hamiltonian problem numerically by coupling two Schrödinger with two Poisson equations. We also found that the lifetime of the exciton could be increased from nanosecond range to the millisecond range by the gate voltage. We have especially studied a few excited states in the exciton and the optical transitions including calculating the many-body oscillator strength.

Paper 3 deals with optical transitions for an electron in a quantum dot, controlled by an external parabolic potential. We found that the transition frequency could be tuned from the far infrared region to the ultraviolet region, depending on the parabolic strength and the size of the quantum dot.

In Paper 4 we have performed a charge neutral Schrödinger-Poisson calculation of the electronic structure in different doping profiles in a quantum well, as a function of an external parabolic potential strength. The doping profiles that was used in the calculation was predicted by Monte Carlo simulations.

Paper 5 deals with field-effect controlled diffusion in quantum layers, quantum wires and quantum dots. We study in this paper how we can control the diffusion profile by using an external parabolic potential, to δ-doping profiles. The theory is based on a self-consistent non-linear Poisson equation which takes into account for the concentration gradients, ionized impurities as well of the electrons. The role of the internal potential is extensively analyzed. In this paper the dependence of temperature, parabolic confinement strength, dimensionality, size and doping density are analyzed.