Simulations of imaging of the electron density in the planar quantum dots in transition to fractional quantum Hall regime

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In the scanning gate microscopy SGM [1] technique local properties of the semiconductor nanodevices are studied by measurements of the current flowing in the system in function of the position of the charged tip of atomic force microscope used as a floating gate electrode. For closed systems (i.e. quantum dots) operating in the Coulomb blockade regime the probe perturbs the confinement potential locally and changes the energy of the confined electron system in an extent which is determined by the charge density in a specific location [2]. Thus, the perturbation caused by the charged tip drives the system in or out the Coulomb blockade [3]. As a result, the charge density in the quantum dot can be read out experimentally.

We study imaging the electron density distribution in two-dimensional quantum dots by SGM. We solve few-electron Schrödinger equation with the configuration interaction method and simulate the SGM experiments. The method produces the energy maps as functions of the tip position. From the maps we reproduce the charge densities by solving the integral equation given by the perturbation theory and compare the obtained density with the original one.

We consider quantum dots of the different shapes (e.g. circular) in external magnetic field B which is oriented perpendicular to the plane of confinement. The magnetic field polarizes the electron spins inside the dot. The first spin-polarized energy level corresponds to quantum Hall liquid with the filling factor $\nu = 1$ and is called maximum density droplet (MDD) [4]. In higher magnetic fields the filling factor becomes less then unity ($\nu = 1$), the MDD decays and the electron-electron correlation strongly increases. This leads to the formation of Wigner molecules [5] (molecular electron distribution) in the inner coordinates of the dot. A charged defect (acceptor or donor ion) located outside the quantum dot symmetry axis pins the Wigner molecule at the high magnetic fields and therefore the molecular distribution appears in the laboratory frame. As a result of our numerical simulations we show that reproducing of the charge density and the observation of the molecular electron distribution by the energy measurements are possible.

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