Imaging of liquid - solid transition in two-dimensional quantum dots by scanning probe microscopy

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We consider mapping of the charge density distribution inside quantum dots by the scanning probe microscopy. The external perpendicular magnetic field polarizes the spins inside the quantum 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).

The MDD [1] decays at higher magnetic fields for which the filling factor drops below 1. The MDD decay is connected with a strong increase of the electron-electron correlation and formation of molecular electron distribution in the inner coordinates of the system. This electron distribution is called a Wigner molecule [2]. We consider detection of the Wigner molecules in the laboratory frame of reference by using the scanning gate microscopy technique (SGM) [3,4]. The potential of the charged probe changes the energy of the confined system in an extent which depends on the charge density in a specific location [5]. The conditions of the Coulomb blockade of the current flow through the quantum dot can be lifted [6]. Thus, the local charge density can be experimentally read out by energy measurement in function of the position of the probe driving the system in or out the Coulomb blockade of the current (so called Coulomb microscopy).

We solve the few-electron Schrödinger equation with the exact diagonalization method and produce the energy maps in function of the probe position. Then we solve the integral equation for the charge density given by the perturbation theory and compare the reproduced charge density with the original one. In the absence of the probe the charge density is rotationally-symmetric. We show that the probe perturbs this symmetry and pins the molecule in the laboratory frame. Nevertheless, since the molecule follows the movement of the tip, the molecule evades detection by the Coulomb blockade microscopy. The molecular distribution in the laboratory frame in the absence of the probe can be observed when the confinement potential is not precisely circular. We demonstrate that for perturbed circular symmetry of the confinement potential (due to a charged defect) the transitions to lower filling factors appear in a continuous manner in function of B. In these conditions the observation of the molecular electron distribution by the energy measurements is possible, but surprisingly it is least precise for B values when the nucleation of molecular density is the most pronounced.

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