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Quantum Monte Carlo Studies of Interaction-Induced Localization in Quantum Dots and Wires

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We investigate interaction-induced localization of electrons in both quantum dots and inhomogeneous quantum wires using variational and diffusion quantum Monte Carlo methods. Quantum dots and wires are highly tunable systems that enable the study of the physics of strongly correlated electrons. With decreasing electronic density, interactions become stronger and electrons are expected to localize at their classical positions, as in Wigner crystallization in an infinite 2D system. (1) Dots: We show that the addition energy shows a clear progression from features associated with shell structure to those caused by commensurability of a Wigner crystal. This cross-over is, then, a signature of localization; it occurs near $r_s \sim 20$. For higher values of r_s, the configuration symmetry of the quantum dot becomes fully consistent with the classical ground state. (2) Wires: We study an inhomogeneous quasi-one-dimensional system – a wire with two regions, one at low density and the other high. We find that strong localization occurs in the low density quantum point contact region as the gate potential is increased. The nature of the transition from high to low density depends on the density gradient – if it is steep, a barrier develops between the two regions, causing Coulomb blockade effects. We find no evidence for ferromagnetic spin polarization for the range of parameters studied. The picture emerging here is in good agreement with the experimental measurements of tunneling between two wires. Collaborators: C. J. Umrigar (Cornell), Hong Jiang (Fritz Haber Institut), Amit Ghosal (IISER Calcutta), and H. U. Baranger (Duke).