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Spectroscopy of Collective Modes in Few-electron Quantum Dots[1]

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Quantum correlations among electrons confined in semiconductor quantum dots (QDs) are expected to lead to exotic states of matter, such as an electron molecule. In the limit of vanishing electron density, the distances between the confined electrons are rigidly fixed like those of nuclei in conventional molecules. The electronic excitations of such a molecule are quantized normal modes of roto-vibration, whose quanta have either a rigid-rotor or relative-motion character. Recent progress on the emergence of molecular roto-vibrational modes at experimentally attainable densities will be discussed. Signatures of the roto-vibrational spectrum are observed even if the localization in space of the electron wave functions is not yet fully achieved. I will present a joint experimental and theoretical investigation of the neutral electronic excitations of nanofabricated AlGaAs/GaAs QDs that contain four electrons. We use inelastic light scattering to probe electronic charge and spin excitations in an array of identical nanofabricated QDs. Spectra of low-lying excitations associated to changes of the relative-motion wave function -the analogues of the vibrational modes of a conventional molecule- do not depend on the rotational state represented by the angular momentum, which can be controlled by the application of a magnetic field. A theoretical model, based on full configuration-interaction method, offers an excellent quantitative agreement with the experimental findings. I will also demonstrate optical control of the number of electrons and lateral confining potential in our GaAs/AlGaAs QDs. This is achieved by illumination with a weak laser beam that is absorbed in the AlGaAs barrier. Precise tuning of the energy-level structure and number of electrons is manifested in the evolution of low-lying spin and charge excitations probed by inelastic light scattering. Our findings open a new venue towards the all-optical manipulation of single electrons in QDs.

[1]Work in collaboration with V. Pellegrini, C. P. Garcia, A. Singha, A. Pinczuk, M. Rontani, G. Goldoni, E. Molinari, L. N. Pfeiffer and K. W. West.

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