Electronic Structure of Single Quantum Dots investigated by Electrostatic Force Microscopy at 4.5K

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Electrostatic force microscopy (EFM) is a powerful tool to investigate the electrical properties of nanometer-scale electronic devices. We apply the EFM for investigating the electronic structure of a single quantum dot (QD). We successfully observed the single-electron charging in epitaxially grown self-assembled InAs quantum dots by the force measurement. More elaborate experiments will reveal the internal energy level structure of such a single QD. The technique is also applied to investigate the spatial and temporal charge fluctuations in nanometer-scale electronic devices.

Quantum dots (QDs) are often referred to as ‘artificial atoms’ as they exhibit the discrete energy levels in their electronic structure as atoms do due to their small size. It is important to understand how the structure of QDs such as shape and size is related to their electronic structure as the variation of the energy levels is technically relevant in such applications as semiconductor lasers and quantum cellular automata.

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Theoretical predictions by Prof. A. Clerk show that the damping data as a function of temperature will yield the internal energy levels of a QD. Experiments under the magnetic field should also enable to yield the same information. Our cryogenic AFM equipped with a 8T superconducting magnet is capable of both experiments. In this way, we can systematically investigate a number of QDs with different size and shape.

This technique allows us to measure the spatial and temporal fluctuation of the electrostatic field and is applied to study such fluctuations in nanometer-scale electronics devices, which is also of great technological relevance.

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