Ultrafast Electron Dynamics in a Silicon Quantum-Dot Single-Electron Pump

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A tunable-barrier single-electron pump [1] is a promising device for metrological current standards [2] and coherent single-electron sources for electron quantum optics [3] due to its capabilities of high-frequency (>GHz) operation and tunable electron emission energy; a single electron is captured into a dynamically gate-defined quantum dot (QD) via the entrance barrier and then ejected via the exit barrier. While it generates a DC current proportional to the pump frequency, the current can significantly reflect capture/ejection processes into/from the QD, which occur in a shorter time scale within a small fraction of the whole pump cycle. This provides us opportunities to perform ultrafast (on the orders of picoseconds) sampling of spatial and energy distributions of the single electron inside a dynamic QD, or electron dynamics in a QD such as quantum charge oscillation, energy excitation and relaxation.

In this talk we will introduce our recent work on fast electron dynamics in a silicon QD single-electron pump. We have demonstrated the detection of picoseconds coherent oscillation of a single electron in a QD by utilizing the electron ejection via a resonant trap level in the exit barrier [4]. We have also investigated temperature [5] and frequency [6] dependence of the electron capture process. We have found that electron dynamics such as thermal and nonadiabatic excitation, energy relaxation by electron-phonon scattering, and heat flow could play significant roles in the electron capture under high-frequency operation. These findings would be important for deeper understanding of ultrafast electron dynamics in a QD to realize precise control of charge and quantum states of single electrons for future metrology and quantum technology.

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