Signature of Landau-Zener-Stückelberg interference in coherent charge oscillations of a one-electron double quantum dot

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Recently, Landau-Zener (LZ) transitions have received renewed interest as an alternative approach to control single-qubit states. LZ transitions occur when a system is passed through an avoided crossing that arises from quantum mechanical coupling of two levels, where the transition probability is determined by the velocity, or the rate at which the Hamiltonian is varied. A single passage can serve as a coherent beam splitter for the incoming state. Successive sweeps through the avoided crossing back and forth induce multiple LZ transitions and thus interference between the superposition states generated on the incoming and outgoing passages. In analogy to optics, the final state also reflects the phase evolution between the two beam splitters. The effect, known as the Landau-Zener-Stückelberg (LZS) interference, has been demonstrated for superconductor charge and flux qubits [1] and semiconductor two-electron spin qubits [2].

Here we report the observation of LZS interference in coherent charge oscillations of a one-electron double quantum dot (DQD). The dot state is manipulated using high-frequency voltage pulses applied to the drain electrode and the charge state of the DQD is read out using nearby quantum point contact (QPC) charge sensor [Fig. 1(a)]. In order to achieve a nearly 50:50 beam splitter and thereby maximize the interference amplitude, the effective rise/fall time of the dot potential was controlled by tuning the dot-lead coupling. The QPC charge detection signal obtained in this way shows a characteristic oscillation pattern as a function of pulse duration and detuning ε, suggesting LZS interference [Fig. 1(b)]. The oscillations appear only for $\varepsilon > 0$, that is, when the system is passed though the resonance. By comparing experiment and numerical simulations, we show that there is a significant enhancement in the oscillation amplitude of the final state probability due to LZS interference. We also show that the LZS interference is relevant even without intentional pulse shaping and is thus inherent to charge qubits, whose anticrossing gap is comparable to the pulse rising/falling time.

[1] For example, S.N. Shevchenko, et al., Physics Reports 492, 1 (2010).

[2] J. R. Petta, et al., Science 327, 669 (2010).

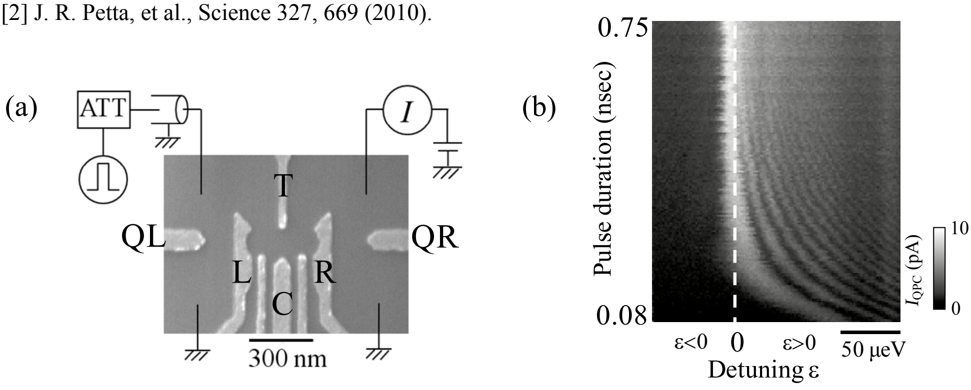

Fig. 1(a). Device structure and the experimental setup. The charge state of the DQD is measured by the QPC defined by the gates QR and R. (b) Pulse-induced QPC current I_{QPC} as a function of pulse duration and detuning ε.