Nonequilibrium quantum cellular automata effect in a three-terminal triple quantum dot

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Proposals on the exchange-only spin qubit [1] and electron spin entangler [2] have triggered growing interest in triple quantum dots (TQDs) for the exploration of new functionalities that exceed those of single and double quantum dots (DQDs). Recent studies indicate that TQDs are not only a promising candidate for applications to these quantum devices but also a platform for various correlation phenomena such as the quantum cellular automata (QCA) effect [3,4]. In this presentation, we report three-terminal transport measurements of a TQD. Detailed transport spectroscopy reveals a QCA effect, i.e., rearrangement of the ground-state charge configuration within the TQD that accompanies charge addition. Furthermore, we find that a transient charge configuration that occurs during transport through one channel dynamically induces a charge rearrangement and subsequent transport in the other channel, a phenomenon that can be termed a nonequilibrium QCA effect.

The TQD was defined in a GaAs/AlGaAs heterostructure by Ti/Au gates (Fig. 1). Each quantum dot (QD) has a separate electrical lead, which allows for the independent measurements of current I_L (I_R) through the left (right) DQD consisting of center and left (right) QDs and their sum $I_C = -I_L - I_R$. The upper panels in Fig. 2 show I_C measured in the few-electron regime for four different values of gate bias V_C, plotted as a function of gate biases V_R and V_L. Two sets of bias triangles, reminiscent of transport through DQDs, are observed. These triangles, which are separate at $V_C = -1.734$ and -1.814 V, merge to form complex features at intermediate V_C. The simultaneously measured I_R spectra (lower panels) allows us to clearly identify which DQD each bias triangle belongs to, revealing the existence of duplicated triangles at $V_C = -1.786$ V. Duplications of a bias triangles are explained by a QCA effect [3,4] as a consequence of the difference in the electrostatic coupling between the left and right QD pair and other pairs. Furthermore, we observe finite current flow outside the triangles. These signals originate from a QCA effect induced by transient occupations of the left (right) QD in the transport process through the left (right) DQD. Such a dynamic effect is specific to the nonequilibrium regime of three-terminal transport through a TQD.

[1] D. P. DiVincenzo et al., Nature **408**, 339 (2000).
[2] D. S. Saraga et al., Phys. Rev. Lett. **90**, 166803 (2003).
[3] L. Gaudreau et al., Phys. Rev. Lett. **97**, 036807 (2006).
[4] M. C. Rogge, R. J. Haug, Physica E **42**, 902-905 (2010).

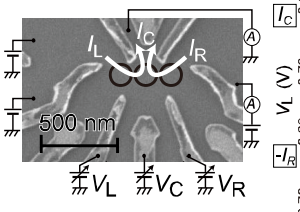

Figure 1: SEM image of the TQD sample.

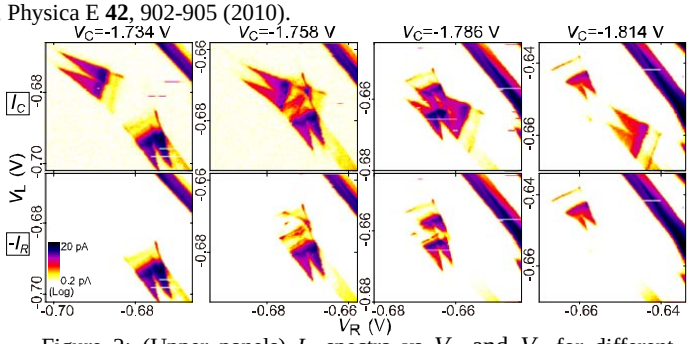

Figure 2: (Upper panels) I_C spectra vs V_R and V_L for different values of V_C. (Lower panels) simultaneously measured I_R spectra.