Formation of Fano resonance in double quantum dot system

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Nowadays, after applying short-time voltage pulses or other sudden changes in system parameters it is possible to experimentally observe dynamic of charge in nanostructures under the non-stationary conditions. The ultra-fast time-resolved spectroscopy techniques enable real-time observation of, among others, how the system returns to equilibrium from excited states. Just recently the Fano resonance buildups were monitored in optical experiments using the spectrally resolved electron interferometry and the atto-second transient absorption spectroscopy [1].
Here, transient electron dynamics and the Fano resonance formation in transport through a two-QD system (DQD) in a T-shape geometry are analysed (neglecting Coulomb interactions). Electrical currents are derived by means of nonequilibrium Green functions, where their time dependencies are found by inverting the Laplace transform in the wide band limit. We assume that initially only one QD is coupled to two metallic electrodes under bias, and then suddenly the second QD is attached. This strongly modifies coherent transport: currents and conductances. Time evolution of the transport characteristics and electron dynamics are different for a weak and a strong inter-dot coupling (t_{12}) with respect to the dot-electrode coupling (Γ). When the dot-dot coupling is weak, $t_{12} \ll \Gamma$, electrons tend to occupy dot levels. One level is strongly hybridized with the electrodes, while the other one (on the attached QD) is localized and only weakly coupled to a conducting channel. Interference between these two conducting channels leads to a Fano anti-resonance with a characteristic dip in the conductance. Periodic oscillations of conductance are found, which are related with charge transfers between the QD and the electrodes. The oscillation frequency is inversely proportional to the relative position of the QD level to the Fermi level and their amplitudes decrease with time and bias. In the opposite limit, $t_{12} \gg \Gamma$, one can treat DQD as an artificial molecule and observe the time evolution of the conductance from the single peak structure into the double peak structure, which corresponds with bonding and antibonding orbitals. Now the dot-electrode charge oscillations are more pronounced, which leads to a change in the direction of the current flow and, consequently, a change in the sign of the conductance. Apart from the aforementioned oscillations one finds also rapid Rabi oscillations caused by coherent electron transfer between the DQD states. For some bias voltages we have found the superimposed modulations of the conductance amplitude originating from beating of the Rabi oscillations with the dot-electrode charge oscillations. In the large time limit the stationary solutions of Fano resonance are recovered.

References:

[1] V. Gruson *et al.*, Science **354**, 734 (2016); A. Kaldun *et al.*, Science **354**, 738 (2016).

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