Quantum coherence in noise power spectrum in quantum dots

Bogdan R. Bułka[1]

[1] *Institute of Molecular Physics, Polish Academy of Sciences, ul. M. Smoluchowskiego 17, 60-179 Poznań, Poland*

In quantum optic experiments coherent properties of light are described by the coherent function of the first and the second order (or higher orders). In analogy interference of electron waves were studied in transport through nanostructures, for example the Aharonov-Bohm effect and the Fano resonance. These effects were observed in measurements of the differential conductance, which corresponds to the first order coherence function. The current correlation function (referred as noise power) describes fluctuations of the currents and it is related with the second coherence function. The problems of interference in the noise power spectrum have had little interest [1,2].
Here, we want to present studies of the noise power spectrum, in particular, dynamics of coherent intra- and inter-level current correlations in two quantum dots (2QD) in a T-shape geometry. Such the system seems to be a good choice, because the conductance shows the Fano resonance with a characteristic dip due to destructive interference of a travelling wave with an localized state. Using the nonequlibrium Green functions (NEGF) and neglecting Coulomb interactions we derived exact formulae for the current and the frequency dependent current-current correlation functions. For the high voltage bias the shot noise dominates and shows the particle nature of the electron transport. Performing the spectral decomposition we are able to separate the currents flowing through the bonding and the antibonding state. Therefore, we can distinguish between the intra- and inter-level current correlation contributions to the noise power spectrum. In particular, we show that for a weak coupling with the electrodes the noise spectrum has dips at frequencies characteristic to inter-level excitations and the corresponding current correlations are negative. When the coupling with the electrodes is larger than the separation between the states, the electron transport changes its nature. The dynamics of the current correlations is different: there are two coherently coupled relaxators with different relaxation frequencies. These two regimes of current dynamics are separated by a quantum critical point. The wave nature of the electron transport and the quantum interference can be observed in the noise power spectrum for equilibrium and in the linear response limit, where the current fluctuations on the same tunnel junction become relevant. In this limit the noise spectrum is related with the admittance by to the fluctuation-dissipation theorem.
Our theoretical predictions can be verified by measurement of noise power spectrum in an active quantum detector coupled via an on-chip resonant circuit to the quantum dot system [3].

References:

[1] O. Entin-Wohlman, et al. Phys. Rev. B 75, 193308 (2007).
[2] D. Marcos, et al., Phys. Rev. B 83, 125426 (2011).
[3] A. A. Clerk, et al., Rev. Mod. Phys. 82, 1155 (2010).

The research was financed by the National Science Centre, Poland - project number 2016/21/B/ST3/02160