Correlation effects on transport through few electron quantum dots

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Coulomb interactions beyond the constant-interaction model can greatly influence transport properties of semiconductor quantum dots. In case of weak tunneling between dot and reservoirs, correlations generally lead to a suppression of differential conductance peaks. In linear transport, peaks occasionally disappear completely due to formation of a new groundstate which is blocked for transport by spin-selection rules. In non-linear transport a finite transport voltage is applied between both reservoirs. In this regime correlations can lead to additional effects as for example the appearance of transport channels forbidden in the non-interacting case or strong negative differential conductances. Next to a detailed understanding of this weak coupling regime it is of major interest to study how stable those correlation effects are against increasing coupling to the reservoirs.

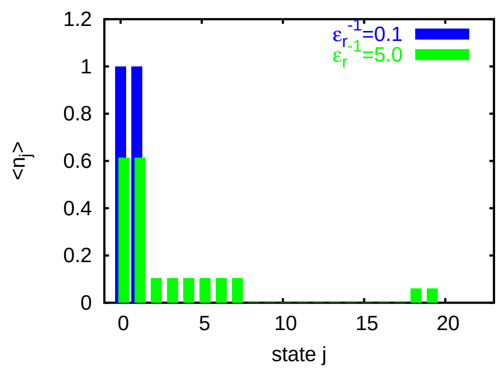

Figure 1: Single particle spin-orbital occupation of a correlated two electron state shown for weak and strong Coulomb interaction. The reduction of the first occupation number indicates a reduced conductance of the ground state channel between one and two electrons.

In order to study correlation effects on transport we theoretically investigate a spherical semiconductor quantum dot coupled to two reservoirs. Coulomb interaction within the quantum dot is fully taken into account by diagonalizing the dot Hamiltonian. In the weak coupling regime transport is dominated by sequential tunneling processes and tunneling rates are described by Fermi's golden rule. They essentially reproduce the spectral weights assigned to a particular transport channel. Strongly correlated quantum dot states are characterized by small spectral weights (Fig. 1) leading to reduced Coulomb-blockade peak heights in the linear conductance. In non-linear transport their occupation can lead to channel blocking and as a consequence to characteristic negative differential conductance (Fig. 2).

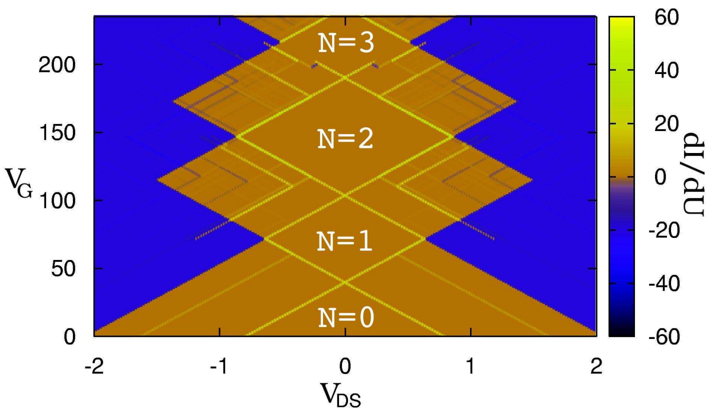

Figure 2: Charging diagram for weak coupling to the reservoirs where only sequential tunneling is considered (arbitrary units). Next to the excitation spectrum strong negative differential conductance is found in non-linear transport. Transport beyond single electron tunneling is not shown (dark blue area at the boundaries)

Whereas in the weak coupling regime correlations of dot states affect tunneling while those states stay unchanged, in the intermediate coupling regime the correlated states itself are changed due to co-tunneling events. This competition between tunneling and correlations will be presented in our contribution. We use real-time transport theory to calculate the differential conductance in linear and non-linear transport. In order to describe intermediate coupling co-tunneling processes are included.