CURRENT CONTROL OF QUANTUM WIRES BY ATTACHED QUANTUM DOTS

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Recent progress in nanofabrication of quantum devices enables to study electron transport through quantum dots (QDs) in a rather controllable way. These structures are small semiconductor or metal structures in which electrons are confined in all spatial dimensions. As a consequence, discreteness of energy and charge arise. For this reason QDs are often referred to as artificial atoms. Two or more QDs can be coupled to form an artificial molecule sharing electrons. This analogy opens the way to look for new electronic effects that might resemble quantum optics [1]. In this way, it has been recently demonstrated that coupled QDs shows the electronic counterpart of Fano and Dicke effects that can be controlled via a magnetic Flux [2,3]

In this work we study electron dynamics and transport properties of a double QD side attached to a quantum wire (QW), as shown in Figure 1. We examine the linear conductance at zero temperature and obtain the associated density of states when the gate voltages of the QDs are slightly different. The density of states is the sum of two Lorentzians, namely a narrow one and a wide one. Thus, these states can be viewed as long- and short-living states. Afterwards, we consider the scattering by the QDs of a wide electronic wave packet moving in the QW. Depending of the chosen values of the parameters the wave packet can be split into two packets, one delayed with respect to the other. Such a complex scattering process is related to the interference in a rather peculiar way of long- and short-living states. Therefore, the device works as a quantum electron splitter.

To probe this claim, we modelled the system by a two impurity Anderson Hamiltonian. The resulting equation of motion was solved numerically for an initial Gaussian-shaped superposition of plane waves with mean wave number located at the center of the band. Then, the current density was computed in the standard way. Figure 2 shows the results for a typical simulation. The electron effective mass was set to $m^* = 0.067m$ (m being the free electron mass). The hopping at the QW was $v = \hbar^2/2m^*a^2$, where the lattice spacing is $a = 0.6$ nm. The Hubbard term was chosen as $U = v$ and the hopping between the QW and the QDs was $V_0 = 316$ nm. Moreover, the gate voltages were $V_{1G} = -V_{2G} = 47$ mV. The current present two peaks as a function of time, indicating the occurrence of electron splitting. The figure also shows the current then the Hubbard interaction is neglected. It becomes rather apparent that the electron-electron interaction is not responsible of the quantum electron splitting, which can be regarded as a one-electron phenomenon. By changing the gate voltages and the hopping (e.g. $V_0 = 158$ nm and $V_{1G} = -V_{2G} = 14$ mV) the current displays only only peak, thus allowing the control of the system response in a rather easy way.

References:

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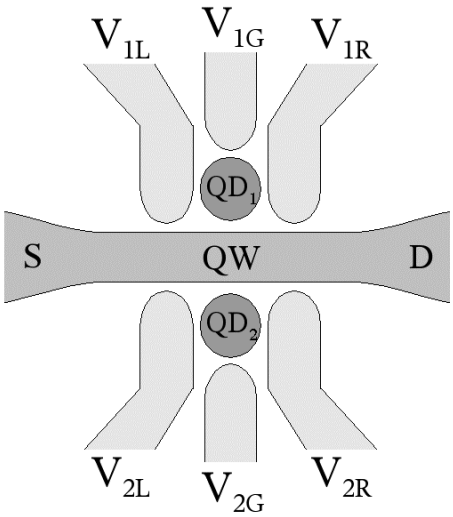

Figure 1: Schematic view of the two QDs attached to a QW. Current passing from the source (S) to the drain (D) is controlled by the gate voltages V_{1G} and V_{2G}.

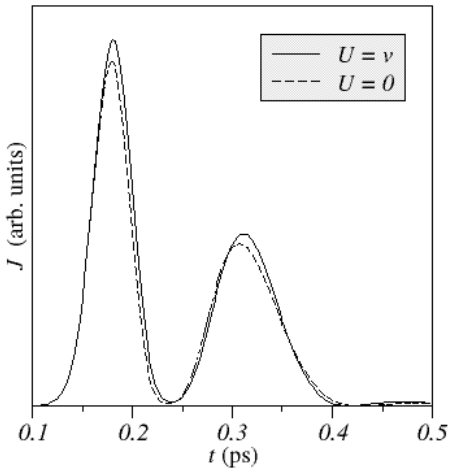

Figure 2: Current density at the drain in arbitrary units as a function of time, for the parameters given in the text. Solid (dashed) line is the current density when the Hubbard interaction is taken into account (neglected).