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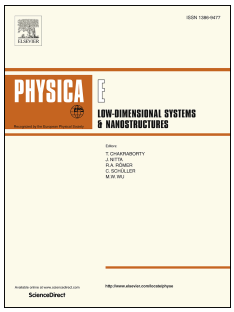

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Transport through capacitively coupled embedded and T-shape quantum dots in the Kondo range

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Abstract

Strong electron correlations resulting from spin and charge pseudospin fluctuations together with interference effects are discussed in asymmetric set of capacitively coupled dots: embedded and side attached (EDTD). Finite - U mean field slave boson approach is used. The many body resonance exhibits SU(4) Kondo character at the embedded dot and SU(4) Kondo-Fano in the T-shaped arm. For the deep dot levels characteristic temperatures of these resonances coincide with the temperatures of corresponding resonances in symmetric double dot systems, embedded or side attached respectively. Linear transport properties through embedded or side attached dots are identical with linear transport characteristics of corresponding symmetric dot systems. Breaking of spin symmetry in one of the arms or in both allows to a crossover to resonances of lower symmetries: SU(3) or SU(2). We also show the possibility of gate control of spin filtering in EDTD with polarized electrodes.

Keywords: quantum dots, Kondo effect, Fano effect
PACS: 72.10.Fk, 73.63.Kv, 85.35.Ds, 85.75.-d

1. Introduction

The advances in nanofabrication techniques opened a new path in studying correlation effects. Recently there is an increasing interest in the interplay of strong correlations and interference in multiply connected geometries [1–8], where due to tunability of couplings one can test different transport regimes. In this paper we study two capacitively coupled quantum dots differently coupled to the leads. One of the interacting dots (QD2) is tunnel coupled to a pair of electrodes (embedded dot - ED) and the second interacting dot (QD1) is attached to the wire indirectly via the open (noninteracting) dot OQD1 (TD). The single T- shaped junctions containing the additional mediating dot have been studied both experimentally [9] and theoretically [10–12]. The advantage of such arrangement is the possibility of independent electric control both of many body correlations and interference conditions. The former can be achieved by a change of gate voltage applied to interacting dots or by a change of voltage applied to the gates that define the tunnel barriers between open and interacting dots. Modification of interference conditions in turn is possible by a changes of gate voltage applied to an open dot. We call the setup consisting of embedded dot and T-shaped arm EDTD and schematically present it in the inset of Fig. 1a. We compare the conductance of strongly correlated EDTD system with conductances of analogous symmetric systems with one type of coupling: TDTD, where both dots are connected in T geometry or EDED, where dots are directly connected to the leads (the schematic drawings of these systems are shown in Fig. 2a). In TDTD geometry also interacting dot are tunnel coupled to the open dots and these in turn are embedded into the leads. For the weak symmetric couplings and equal values of intra and interdot Coulomb interactions SU(4) Kondo resonance is formed in EDED at low temperatures [13–15] and Kondo-Fano SU(4) resonance in TDTD [16]. The latter phenomena is the combined effect of interference and cotunneling induced fluctuations. The purpose of the present paper is to analyze the similar many-body effects in the asymmetric structure EDTD. When occupancies of both interacting dots are equal cotunneling processes through the interacting dots together with interference processes occurring in the lower arm lead to a novel many-body effect. The formed resonance resembles Kondo resonance at the embedded dot and Kondo-Fano resonance in the T-shape arm. Due to the asymmetry of the lower and upper arms strictly SU(4) resonance cannot be formed and the many body state is characterized by two characteristic temperatures, separately specifying the related processes in different arms. In a special case of symmetric resonance lines and for the deep dot levels Kondo and Kondo-Fano resonances are characterized by the same single characteristic temperature. Interestingly for the deep dot levels, the linear conductances of the arms are equal to the conductances of the corresponding symmetric systems linear conductance of T-shaped arm to the conductance of TDTD system, and similarly linear conductance of the upper arm to conductance of EDED. We call this behavior zero bias SU(4) Kondo - Kondo-Fano effect. We also extend the discussion by the analysis of the impact of spin polarization of electrodes. We demonstrate the spin filtering properties of EDTD and show that they can be controlled by gate voltage. A very interesting result is that an

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