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Kinetics of local "magnetic" moment and non-stationary spin-polarized current in the single impurity Anderson-model

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The creation, diagnostics and controlled manipulation of charge and spin states of the impurity atoms or quantum dots (QDs) are one of the most important problems in nano-electronics now a days [1–3]. Modern ultra small size electronic devices design with a given set of electronic transport parameters requires careful analysis of non-stationary effects, transient processes and time evolution of electronic states prepared at the initial time moment [4–9]. So, it is necessary to investigate the time dependent dynamics of initial spin and charge configurations of correlated impurity or QD. Moreover, the characteristics of stationary state of single impurity interacting with the reservoir in the presence of strong Coulomb correlations are not completely understood [10–12].

The possibility of the localized non-zero magnetic moment existence on the single impurity or single-level QD, interacting with the reservoir, in the absence of external magnetic field is still unclear. Results obtained in the mean-field approximation for the one-level Anderson model allowing the presence of magnetic state (electron occupation numbers with opposite spins have different values) for the single impurity with strong oncite Coulomb repulsion seems to be rather questionable.

The single-impurity Anderson model for a long time served as a basic one for the understanding of the nature of local magnetic moments in solids [13, 14]. For a single partly occupied impurity state, the correlation energy acts to prevent the appearance of a nonvanishing ground-state spin, while in low-density limit the Hartree-Fock theory still predicts a non-zero magnetic moment over a range of parameters [15]. As it was argued in [15] the magnetism is possible only when several degenerate orbitals are present on the impurity in the Anderson model. Local moment approach to the Anderson model has been applied for the case of half-filling in [16].

The most adequate approach for this problem analysis is based on the non-stationary kinetic equations for localized electron occupation numbers and their correlation functions, taking into account all high-order correlation functions for the localized electrons. The simplest way to obtain the system of kinetic equations is the Heisenberg approach. These equations can be also obtained by means of Keldysh diagram technique, but it is more cumbersome procedure [17].

In this paper we analyzed the localized state dynamics in the presence of interaction with the reservoir and Coulomb correlations by means of kinetic equations for electron occupation numbers with the different spins and second order correlation functions of the localized electrons. We demonstrated that the difference between "magnetic" and "paramagnetic" states in the single-impurity Anderson model appears only in the non-stationary characteristics of the system and in the second order correlation functions behavior. Localized state dynamics in the presence of interaction with the reservoir and Coulomb correlations has been analyzed by means of the kinetic equations for the electron occupation numbers with the different spins, taking into account high order correlation functions for the localized electrons.

We revealed that the stationary state of the single impurity with Coulomb correlations in the presence of interaction with the reservoir is always a "paramagnetic" one, even when interaction is weak. Electron occupation numbers with the opposite spin in the stationary case are equal for any value of the on-site Coulomb repulsion, contrary to the results obtained in the mean-field approximation. To reveal "magnetic" properties for the single-impurity Anderson model one has to analyze nonstationary system characteristics.

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We showed that typical times of the stationary state formation depend on the initial conditions. For the deep energy levels and strong Coulomb correlations, relaxation time for the initial "magnetic" state can be several orders larger than for the "paramagnetic" one. This fact reflects the "magnetic" nature of the single occupied localized state with the strong Coulomb correlations. Described relaxation times difference allows to distinguish the "magnetic" state on the localized impurity from the "paramagnetic" one.

For initially magnetic impurities non-stationary spin polarized currents flowing in the opposite directions for the different spins exist in the system in the particular time interval similar to the spin-Hall systems with the two types of the "edge" states with opposite velocities and spins at each boundary.

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