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Non-stationary spin-polarized tunneling through a quantum dot coupled to noncollinearly polarized ferromagnetic leads

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Physics of spin-polarized electron transport in semiconductor nanostructures (quantum dots (QDs) and impurity atoms) is stimulated by their possible application in nanoelectronics and spintronics devices [1]. One of the main tasks of spintronics is precise initialization and controlled manipulation of charge and spin states of the impurity atoms or QDs [2]. Control under the spin states in the semiconductor nanostrucutres can be achieved by detection of spin-polarized currents [3]. Moreover, generation and detection of spin-polarized currents is the key problem in the spintronic devices itself, as it is promising for application in semiconductor spin lasers, in which spin polarized carriers can be injected by circularly polarized light or by electrical injection [4]. A significant progress has been made in stationary spin transport in magnetic [5, 6] and nonmagnetic tunnel junctions in the presence of spin-orbit and exchange interactions [7, 8] and in QD systems [9, 10] in magnetic field. Moreover, spin-filter devices, which can generate a spin-polarized current without using magnetic properties of materials were proposed in [11, 12]. For charge and spin control in small devices time dependent effects and transient processes are essential [13–16]. Thus, time evolution of spin and charge configurations in correlated low-dimensional systems is of great interest both from fundamental and technological points of view. Among the most promising objects for spin initialization are QDs [17]. Spin states in self assembled QDs can be initialized without magnetic fields by means of optical pumping [18, 19], while in the electrostatic QDs the Pauli blockade starts to play the main role [20, 21]. Recently, experimental realizations of QDs localized between the ferromagnetic leads were presented. Different magnetic materials, such as ferromagnetic metals [22] or diluted magnetic semiconductors [23] have been applied as a spin injection sources and drains. Most of the theoretical works devoted to the analysis of stationary transport properties through QDs localized between ferromagnetic leads deals with parallel or antiparallel magnetic configurations [24–26]. Stationary electronic transport through the nanostructures coupled to the leads with non-collinear magnetizations was analyzed in [27, 28]. Non-stationary spin initialization in QDs was theoretically analyzed in [17, 29]. Spin initialization and manipulation occurs due to the electric field induced Rashba spin-orbit interaction. Modulation of coupling between the electron spin and momentum opens the possibility to set an electron in motion in the spin-dependent direction [30, 31]. Spin-orbit effect in this case can be applied to achieve spin-polarization via resonant tunneling without external magnetic leads or application of ferromagnetic materials. As creation, diagnostics and controlled manipulation of charge and spin states of the QDs or impurity atoms, applicable for ultra small size electronic devices design requires careful analysis of non-stationary effects and transient processes, time dependent dynamics of initial spin and charge configurations of correlated nanostructures is an area of great interest both from fundamental and technological point of view. In the present paper we analyze a situation when non-stationary spin-dependent tunneling currents appear when a single-level QD is coupled to ferromagnetic leads with non-collinear magnetizations and at the initial time point a non-zero magnetic moment is present in the dot. We extend the previous descriptions of stationary electron transport through the tunneling contact with non-collinear magnetization of the leads and correlated QD by careful analysis of non-stationary spin-polarized transport in the frame of theo-

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retical approach based on kinetic equations for the electron occupation numbers with different spins. We revealed that spin polarization of the non-stationary current could be changed by tuning only the relative directions of the magnetic moments in the leads. This finding opens the possibility to create an effective spin-valve in a very simple system without modulating transparency of tunneling barriers or changing applied bias voltage.

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