Single spin dynamics control and spin readout in single atoms by electrical means with spin-polarized STM

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Our aim is find a theoretical description to evaluate the conditions and results of modern experiments directed to electrical control of single spin dynamics in presence of noncollinear magnetic electrodes or spin-polarized STM in quantum dot (QD) and single atoms on surface. Despite the fast-growing number of experimental works in this field, the fundamental principles remain unclear. In the such system we can observe the nonequilibrium accumulated spin on the QD (or atom), and virtual spin-dependent exchange processes between the QD and the ferromagnetic electrodes resulting in an effective exchange field [1, 3], that can be controlled by the gate and bias voltages. Using the real time diagrammatic technique and the Lindblad equation approach we define effective Lindblad jump operators for noncolinear systems and find a general Bloch equation [2, 3], which describe the complex spin dynamics in the presence of spin polarized current, and its solutions for various useful and important limits both in the sequential and the cotunneling regime. We derive effective relations describing the effect of the spin accumulation on the dc current flowing in the analyzed systems. We demonstrate that the dc current is related to distinct projections of the induced spin that allows for a single spin read-out locally by means of the electric transport measurements. Thus, the ferromagnetic electrodes can act effectively as spin detectors, that translate a spin information into a charge signal, while the readout direction can be controlled electrically. These findings allow us to explain the tunnel magnetoresistance characteristics from the recent experiment [4], where the nonequilibrium spin transport in the canted quantum dot spin valve was studied and signatures of out of equilibrium spin precession, that are electrically tunable, were observed. We also predict a new type of the zero-bias anomaly that is related to both the switching of the spin detection direction at the zero bias and to the spin dynamics due to the exchange field. Moreover, using our model with a compact equations we can explain analytically experimental results [5,6] related to recent breakthroughs in spin-polarized STM that makes it possible to probe and control the spin dynamics of individual atoms. We also propose further experiments in the analyzed systems.

References:

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Authors received support from National Science Centre, Poland, grant No. 2020/36/C/ST3/00539.