The controlled electrical manipulation of the quantum dot spin detectable in the dc electron transport.

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The possibility of a controlled manipulation of the quantum dot spin, detectable in the electron transport is a very promising challenge, especially from point of view of application in information storage and processing technologies. To this aim we develop the theory of the electron transport through quantum dot weakly coupled to ferromagnetic leads with noncollinear magnetizations, that can be obtained experimentally [1]. One can observe much richer transport behavior of quantum-dot spin valves, as compared to single magnetic tunnel junctions, that relies on the possibility to generate a nonequilibrium spin accumulation on the quantum dot, depending on system parameters such as gate and bias voltages, charging energy, asymmetry of the tunnel couplings, and external magnetic field. Our theory indicates that the interplay of spin-dependent tunneling and Coulomb interaction in quantum-dot spin valves gives rise to an interaction driven spin precession, due to an internal effective exchange magnetic field [2-5] and external magnetic field in the limit of weak dot-lead coupling. It is important that this complex spin dynamics can be induced and observed even in the dc electron transport. We proved that from the dc current-voltage characteristic we can extract information about spin dynamics. In addition we propose the FMR like experiment in the quantum dot and we show that the exchange field present in this system can be widely used in nano-spinelectronics, as a local field controlled by the gate or bias voltages also at high temperatures. Moreover, these particular geometries can be used to induce and detect electron spin resonance (ESR) from a single spin as it was recently demonstrated for the first time in the spin polarized scanning tunneling microscope - electron spin resonance (STM-ESR) experiment [6-7].

References:

[1] A. D. Crisan, S. Datta, J. J. Viennot, M. R. Delbecq, A. Cottet, and T. Kontos, Nature Communications 7, 10451 (2016).

[2] J. Martinek, Y. Utsumi, H. Imamura, J. Barnas, S. Maekawa, J. Konig, and G. Schon, Phys. Rev. Lett. 91, 127203 (2003).

[3] J. Konig and J. Martinek, Phys. Rev. Lett. 90, 166602 (2003).

[4] M. Braun, J. Konig, and J. Martinek, Phys. Rev. B 70, 195345 (2004)

[5] M. Braun, J. Konig, and J. Martinek, Europhys. Lett., 72, 294 (2005)

[6] S. Baumann, W. Paul, T. Choi, C. P. Lutz, A. Ardavan, and A. J. Heinrich, Science 350, 417 (2015).

[7] K. Yang, W. Paul, S.-H. Phark, P. Willke, Y. Bae, T. Choi, T. Esat, A. Ardavan, A. J. Heinrich, and C. P. Lutz, Science 366, 509 (2019).

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