Non-adiabatic spin pumping driven by a rotating magnetic field

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The ever-growing demands for scaling electronic circuits and lower-power electronic devices have been predominant technological challenges during the last decades. Recent developments in fabrication techniques and material science allow the fabrication of electronic devices on the nanoscale, where the quantum effects dominate. An ambitious research field in this direction is nano-spintronics, which seeks to incorporate magnetic materials into nano-electronic devices. It aims to utilize the electron's spin degrees of freedom to give the electronic device new functionalities that could not be achieved by electronic charge alone.

In realizing nano-spintronic devices, the generation of spin-polarized electron current (spin current) is an important issue. In bulk systems, a typical method for the spin current generation uses the spin pumping effect in a ferromagnetic/normal metal heterostructure, where the spin current is induced to the normal metal layer by the precession of magnetization in the ferromagnetic layer. To date, numerous efforts have been made to realize spin pumping also in nano-systems (see [1] and references therein). While most of its theoretical studies are performed within the adiabatic approximation assuming slowness of the precession compared to the relaxation time of the conduction electron, the assumption is generically not valid for nano-systems because the relaxation time can be comparable to or longer than the precession period in actual experimental setups [2]. It motivates us to formulate a theory of spin pumping applicable to the non-adiabatic regime.

In this study, we theoretically investigate the spin pumping effect in a nano-system. The system under consideration consists of a single-level quantum dot tunnel coupled to a normal metal electrode; the quantum dot is subjected to a periodically rotating magnetic field (Figure 1). We analyze the spin-dependent electron transport between the dot and the electrode in terms of the full counting statistics with a quantum master equation approach. The periodic time dependence of the system Hamiltonian caused by the rotating magnetic field can be exactly eliminated by moving to a rotating frame; thus, the analysis is applicable to the non-adiabatic regime. In the presentation, I will discuss the dependence of the generated spin current on the frequency of the magnetic field and show a non-linear enhancement of the spin current in the non-adiabatic regime.

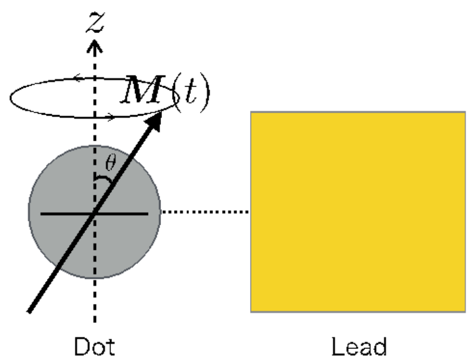

Figure 1 A schematic figure of the model for the nanoscale spin pumping.

[1] K. Hashimoto, G. Tatara, and C. Uchiyama, Phys. Rev. B **96**, 064439 (2017).
[2] L. Bogani and W. Wernsforfer, Nature Mater. **7**,179 (2008).