Multi-terminal Decoherent Quantum Transport: From Giant Magnetoresistance and SASERs to Dissipative Adiabatic Quantum Motors

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Quantum conductance in nano and mesoscopic systems is often affected by decoherence, which in turn, becomes critical to obtain the semiclassical behavior. In spite of this, just a few works include these effects [1-3]. Here, we present a Green's functions based model which generalizes the previous work of D'Amato and Pastawski to multi-terminal structures [4]. There, the Keldysh integral equations are derived, in a linear response regime. The observables are evaluated through simple recursive algorithms which are applicable in a discrete space, i.e. in a matrix representation.

As a first application, we present a Hamiltonian 1-D model for the Giant Magnetoresistance (GMR). Starting from a quantum description, we recover the semiclassical regime of the standard two resistor model for the GMR. This is achieved by increasing the decoherence strength controlled by the mean free path. We show how the spin-flip rate and mean free path, which are Hamiltonian parameters, determine the semiclassical transport observables. In a length scale lower than the mean free path, there are interferences that depend on the domain wall size identified with Rabi oscillations [5]. At the metal-ferromagnet interfaces and abrupt domain walls the interferences are identifiable with Friedel oscillations.

By considering a simple model of a phonon-laser (SASER) based on the electron-phonon interaction in a quantum dot [6] we assess the role of decoherence in the SASER efficiency. Besides of the smoothing out of the resonances, we found that it leads to the degradation of the contrast mainly from the suppression of the antiresonances.

We also study the role of decoherence and dissipation on adiabatic quantum motors [7]. Their working principle relies on reverse quantum pumping. Consequently, it is expected a strong dependence of their properties on electronic decoherence. We study two different models: a quantum-dot based motor and a reverse-Thouless-pump motor. The first case shows that the optimal efficiency is obtained for a given amount of decoherence/dissipation. We model the reverse Thouless-pump motor, a 1-D wire with a gap inducing cosine potential where cycling phase allows the pumping, with a tight binding Hamiltonian. This allows to include the effect of decoherence and to analyze the deviations from the approximations used in previous works [7]. On both cases we study the effect of decoherence on the maximum work performed per cycle, the friction coefficient, and the efficiency of the motor.

[1] J. L. D'Amato and H. M. Pastawski, Phys. Rev. B 41, 7411 (1990).
[2] S. Datta, J. Phys.: Condens. Matter 2, 8023 (1990).
[3] C. J. Cattena, R. A. Bustos-Marún, and H. M. Pastawski, Phys. Rev. B 82, 144201 (2010).
[4] C. J. Cattena, L. Fernández-Alcázar, D. Nozaki, R. A. Bustos-Marún, and H. M. Pastawski, J. Phys. Condens. Matt. in press (2014).
[5] L. Fernández-Alcázar and H. M. Pastawski, Europhys. Lett. (2014).
[6] L. E. F. Foa Torres, H. M. Pastawski, and S. S. Makler, Phys. Rev. B 64, 193304 (2001); W. Maryam, et.al, Nat. Commun. 4 (2013).
[7] R. Bustos-Marún, et. al Phys. Rev. Lett. 111, 060802 (2013).