Spin-orbit qubits in low-dimensional semiconductor systems

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The proposed theoretical research pertains to the emerging domain of spin-orbitronics, and it focuses on the study of the spin-orbit mechanisms for quantum dots defined in semiconductor nanostructures. The spin-orbit coupling determines the spin lifetimes [1], the nature of the electronic states [2], and the possibility of controlling the spin via electric signals in spintronic devices [3].

The spin relaxation in doped semiconductor systems has been shown to be strongly dependent on the impurity concentration, and therefore related to the electronic transport properties. We propose to further develop the theoretical techniques originated from our team for the bulk case [1], in order to incorporate the effect of the dimensionality reduction characterizing the relaxation time in quasi-one-dimensional structures. The goal of this research will be to obtain reliable estimations of the spin relaxation times in different kinds of nano-wires that can be contrasted with those of the experimental literature.

The numerical determination of the one- and few-electron states of a quantum dot defined in a quantum wire, taking into account various spin-orbit coupling mechanisms, will be in turn undertaken. Such a research constitutes, together with the determination of spin relaxation times, necessary steps towards the understanding of spin-orbit qubits, like those developed by the Delft Quantum Nanoscience group [3].

Quantum master equations and non-equilibrium techniques will be used to study the spin dynamics, and thus model the electric dipole spin resonance and the spin echo in asymmetric nano-structures, in order to characterize spin-orbit qubits.

This study will allow to assess the potentialities and limitations of the spin-orbit qubit, contributing to the present quest for quantum technologies.

The PhD student will work within the international collaborations, established by Prof. R. Jalabert and Dr. D. Weinmann, with colleagues from the universities of Freiburg (Germany) [1] and Buenos Aires (Argentina) [2].

The candidate is expected to have a very solid background in condensed matter physics and numerical computations, as well as an excellent command of English.

[1] *Charge and spin diffusion on the metallic side of the metal-insulator transition: a self-consistent approach*; T. Wellens and R.A. Jalabert; Phys. Rev. B **94**, 144209 (2016).
[2] *Spin-orbit effects in nanowire-based wurtzite semiconductor quantum dots*; G.A. Intronati, P.I. Tamborenea, D. Weinmann, and R.A. Jalabert; Phys. Rev. B **88**, 045303 (2013).
[3] *Spectroscopy of Spin-Orbit Quantum Bits in Indium Antimonide Nanowires*; S. Nadj-Perge, et al.; Phys. Rev. Lett. **108**, 166801 (2012).