# Research Internship for 2016

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## *Theoretical study of spin relaxation length in graphene*

### Context:

Thanks to high mobility and long spin relaxation times due to weak spin-orbit coupling, graphene is expected to be an excellent material for spintronic devices. Proposals of low power all-spin logic gates based on spin-transfer torque effect in graphene magnetic tunnel junctions are currently under investigation [1]. However, though long spin diffusion length in graphene has been already demonstrated, the experimental measurements of spin diffusion times remain several orders of magnitude lower than theoretically predicted. Additionally, the spin relaxation time does not seem to be clearly correlated to the mobility and the related sources for spin dephasing and scattering are still debated.

It is thus of high importance to reach a good understanding of the problem of spin relaxation in graphene. This may be achieved only by confronting a large range of theoretical calculations including appropriate sources of scattering with experimental measurements on graphene layers of different quality. It is the main goal of this collaboration between IEF (theory and simulation) and UMPhy (experiments)

### Scientific and technical work, prerequisites:

The student will implement a tight-binding (TB) model of graphene with random metallic adatoms within a non-equilibrium Green's function (NEGF) formalism of quantum transport. Such a tight-binding model has been recently used to analyze the time evolution of the spin polarization of wave packets [2]. It will be extended here to perform a statistical analysis of the space evolution of the spin polarization according to the density and distribution of adatoms, the electron density and the different coupling parameters.

A TB/NEGF simulation code has been developed in the group and used to investigate a wide range of transport problems [3]. It must be adapted to include the presence of non-magnetic adatoms randomly distributed on hollow positions of the graphene sheet, which is strongly thought to be a possible source of spin relaxation. This project will involve interactions with researchers at Unité Mixte de Physique CNRS (Pierre Seneor) who are leading state-of-the-art experiments of spin injection ad spin relaxation in graphene [4].

The project is adapted for a student with a background in condensed matter physics, quantum mechanics and transport physics. Prior knowledge of graphene and NEGF formalism is not necessary, though recommended. Strong taste for scientific programming and computational physics is essential.

### Skills to be learnt:

The student will develop skills in computational electronics and physics of quantum transport. The internship will ideally be extended into a collaborative PhD project on spintronic devices based on graphene and other 2D materials.

### References:

[1] L. Su, W. Zhao, Y. Zhang, D. Querlioz, Y. Zhang, J.-O. Klein, P. Dollfus, and A. Bournel, "Proposal for a graphene-based all-spin logic gate", Appl. Phys. Lett. 106 (2015) 072407.
[2] D. Van Tuan, F. Ortmann, D. Soriano, S. O. Valenzuela, and S. Roche, "Pseudospin-driven relaxation mechanism in graohene, Nature Phys. 10, 857-863 (2014).
[3] V. Hung Nguyen, A. Bournel, and P. Dollfus, "Spin-polarized current and tunneling magneto-resistance in ferromagnetic gate bilayer graphene structures", J. Appl. Phys. 109, 073717 (2011).
[4] B. Dlubak, M.-B. Martin, C. Deranlot, B. Servet, S. Xavier, C. Berger, W. A. De Heer, F. Petroff, A. Anane, P. Seneor and A. Fert, "Highly efficient spin transport in epitaxial graphene on SiC", Nature Phys. 8, 557-561 (2012).