Ultrafast magnetization dynamics: a phase-space approach

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The interaction of a femtosecond electromagnetic pulse with the electronic spins in a ferromagnetic nanostructure has been the object of intense investigations, both theoretical and experimental, over the past two decades. Experimentally, the main effect to be observed, although not yet fully elucidated, is the quick loss of magnetization following the excitation by the laser pulse. In order to tackle this complex problem, we have recently developed an original approach based on the phase-space representation of quantum mechanics due to Wigner [1, 2]. This phase-space approach appears to be a powerful tool to investigate the combined charge and spin dynamics in ferromagnets and was tested successfully in a recent study of spin current generation in thin nickel films [3].

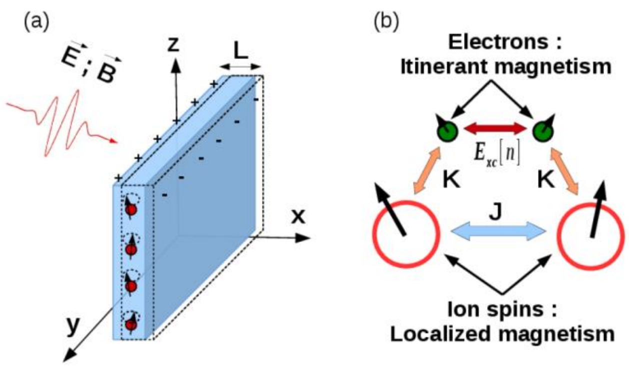

Figure 1: (a) Geometry of a ferromagnetic thin film; (b) Schematic view of the various magnetic exchange interactions between the ion and electron spins. K and J are, respectively, the electron-ion and ion-ion coupling constants. From Ref. [3].

The purpose of the present PhD project is to extend the scope of this method in several ways, in order to tackle more realistic situations. Specifically, we aim at: (i) extending the approach to 2D and 3D nano-objects, (ii) including the orbital magnetism and spin-orbit coupling, (iii) incorporating dissipative effects that originate from electron-phonon and e-e scattering processes. The model will be used to investigate experimentally-relevant magnetic nano-objects such as multilayer structures, and novel types of excitations such as hot electron currents.

The project will profit from existing local collaborations, both with mathematicians specialist in the numerical solution of Vlasov equations and with experimentalists who synthetize and characterize the magnetic nano-objects.

References

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2. J. Hurst, O. Morandi, G. Manfredi, and P.-A. Hervieux, *Semiclassical Vlasov and fluid models for an electron gas with spin effects*, Eur. Phys. J. D **68**, 176 (2014).
3. J. Hurst, P.-A. Hervieux, G. Manfredi, *Spin current generation by ultrafast laser pulses in ferromagnetic nickel films*, Phys. Rev. B **97**, 014424 (2018).