Master Matière Condensée et Nanophysique

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Title: Magnetization dynamics in single-domain nanoparticles

The fast and reliable control of the magnetization dynamics in magnetic materials has been a topical area of research for the last 10-15 years. The main driving force behind this growing interest is the development of practical devices that store and process information on an ultrafast timescale. Other promising applications include the use of magnetic nanoparticles as diagnostic or therapeutic use, for instance in cancer treatment (hyperthermia) [1].

A magnetic nanoparticle carries a magnetic moment (macrospin) resulting from the internal interactions that align all its atomic spins along the same direction. The simplest hypothesis is to suppose that the atomic spins form one single magnetic domain (which is only possible for small enough particles, with a diameter below 50 nm) and that the nanoparticle has a preferential axis of magnetization (known as the anisotropy axis or the ``easy axis"). The macrospin of an individual particle then evolves under the action of external (applied) and internal (due to magnetic anisotropy) magnetic fields, thermal fluctuations, and dipole-dipole interactions with other macrospins.

The magnetization switching was studied in several recent works by our group [2, 3]. In these earlier works, the nanoparticles were supposed to be distributed on a fixed spatial lattice.

In the present project, we want to investigate the dynamics of magnetic nanoparticles that are free to move in space, thus coupling the mechanical motion with the magnetization dynamics. The simulations will be based on a molecular dynamics approach that will be extended to include the macrospin evolution. The interaction of the particles with their environment (typically, a viscous fluid) will also be simulated, thus allowing us to describe thermal exchanges between the nanoparticles and the fluid substrate.

The project is theoretical/numerical, but will involve discussions with experimental physicists and chemists who synthetize and measure the properties of such systems.

References

[1] G Vallejo-Fernandez et al., *Mechanisms of hyperthermia in magnetic nanoparticles*, J. Phys. D: Appl. Phys. **46** (2013) 312001.

[2] H. Kesserwan, G. Manfredi, J.-Y. Bigot, P.-A. Hervieux, *Magnetization reversal in isolated and interacting single-domain nanoparticles,* Phys. Rev. B **84**, 172407 (2011).

[3] G. Klughertz, P.-A. Hervieux, G. Manfredi, *Autoresonant control of the magnetization switching in single-domain nanoparticles*, J. Phys. D: Appl. Phys. **47**, 345004 (2014).