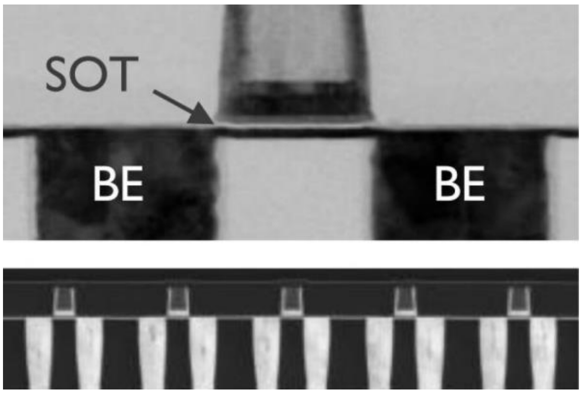
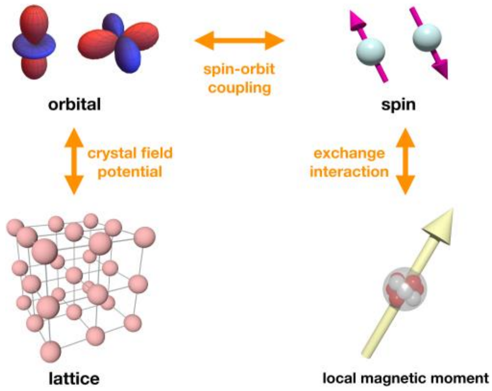
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Revisiting spintronics with orbitals

General Scope: Fundamental research in spin electronics has provided major contributions to our everyday technologies, among which hard disk drives or magnetic random-access memory chips. The latest generation of magnetic devices for memory applications features an electrical manipulation of the magnetization in nm-thin nanomagnets, by a phenomenon called spin–orbit torque. Whereas a widely acknowledged interpretation of spin–orbit torques has been established, which is only based on the spin character of electrons, recent research has unveiled a previously unsuspected, yet often dominant contribution from orbital currents and orbital magnetization instead [1]. Many 'classical' results in the field are questioned, opening a bright avenue for new discoveries and pushing further the technological prospects of spintronics. The groundbreaking nature of orbital transport in spintronics promises low-power information technology without the requirement of using any rare materials.





Left: Cross-sectional view of a spin-orbit torque (SOT)-MRAM memory component [© IMEC]. Right: Schematic of how lattice, orbital polarization, spin polarization and magnetization interact with each other to generate torques [Phys. Rev. Res. 2, 033401 (2020)].

Research topic and facilities available: Our team investigates the generation of spin and orbital electronic currents for spin–orbit torques in solid-state devices, made of light metals, metallic ferromagnets and insulating magnetic crystals [2,3]. In the electrical excitation of magnetization dynamics by torques, the different channels related to spin dynamics and orbital dynamics need to be disentangled, which we accomplish by experiments involving magnetic transport measurements and microwave spectroscopy of magnetization dynamics. As a Master thesis student, you will focus on the electronic measurement of magnetic oxides heterostructures subjected to microwaves, and image displacement of magnetic textures, to quantify their efficiency in generation of orbital currents. You will be invited to participate to the further understanding of the physics involved in these heterostructures and develop your experimental skills by contributing to the realization of new measurement procedures involving different kinds of electronic and microwave instrumentation.

Possible collaboration and networking: Our team is part of several national networks in spintronics, forming a strong and cohesive community of researchers in both France & Europe. Our different collaborations offer theoretical support and fertilize ideas to develop the offsprings of this research.

Possible extension as a PhD: Desired

Required skills: This topic and the subsequent PhD thesis requires a background in condensed-matter physics, motivation to actively learn a wide set of experimental techniques (nanofabrication, microwave electronics, magnetic microscopy), and a taste for solving technical challenges.

Starting date: Flexible, contact us.

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MNM team; Institut Néel – CNRS

[1] Jo, D., Go, D., Choi, G.-M. & Lee, H.-W. Spintronics meets orbitronics: Emergence of orbital angular momentum in solids. *npj Spintronics* **2**, (2024).
[2] Ding, S., Kang, M.-G., Legrand, W. & Gambardella, P. Orbital Torque in Rare-Earth Transition-Metal Ferrimagnets. *Phys. Rev. Lett.* **132**, 236702 (2024).
[3] Ding, S., Wang, H., Legrand, W., Noël, P. & Gambardella, P. Mitigation of Gilbert Damping in the CoFe/CuOx Orbital Torque System. *Nano Lett.* **24**, 10251–10257 (2024).