

Development of a magnetic enclosure for microwave and THz studies of magnetic tunnel junctions

Développement d'une enceinte magnétique pour l'étude hyperfréquence et THz de jonctions tunnel magnétiques

Context: Magnetic materials exhibit ultrafast dynamics—on the picosecond timescale—accompanied by low energy dissipation, driven by spin-exchange interactions and spin-orbit coupling. These interactions, which dominate at the nanoscale, enable magnetization manipulation with remarkable energy efficiency, opening up prospects for critical industrial applications such as MRAM (based on the tunneling magnetoresistance effect) or 6G telecommunication systems (utilizing sub-THz frequencies). At high frequencies, numerous phenomena can be exploited: RF (Abbass, 2023) and THz (Mičica, 2024) emission, ultrafast THz wave modulation (Chen, 2026), RF connections between neural networks (Ross, 2023), and magnon activation (Rongione, 2023).

The collaboration between CROMA and SPINTEC will study layers of non-collinear chiral antiferromagnetic (NCAF) materials, such as Mn_3Sn and Mn_3Pt (Tsai, 2020). NCAFs have established a new paradigm, offering a promising alternative to ferromagnets for next-generation spintronic technologies. The chiral magnetic order in these materials breaks time-reversal symmetry and gives rise to properties traditionally associated with ferromagnets, such as spin-polarized transport, the anomalous Hall effect, tunneling magnetoresistance (TMR), and current-induced magnetic switching. NCAFs thus combine the advantages of antiferromagnets with efficient electrical readout and control mechanisms. These properties make NCAFs particularly attractive for future industrial RAM architectures. The high-frequency dynamics of NCAF devices will be studied at CROMA using instruments with real-time resolution down to the picosecond scale.

Objective: The objective of the FMNT internship is to design, fabricate, and test a magnetic enclosure for the ultra-fast (microwave or THz) characterization of NCAF samples. The intern will build a magnetic enclosure consisting of two or four electromagnets, a magnetic sensor, and a microcontroller. This enclosure must be compatible with our two characterization platforms: HYPER (probe station) and PLATERA (free-space THz). The components will be assembled using parts produced with 3D printing at the CROMA prototyping facility in Le Bourget-du-Lac. Once the enclosure is assembled, the intern will verify its proper magnetic functioning. Subsequently, initial measurements under a magnetic field—at microwave and THz frequencies—can be performed on test samples (such as Mn_3Sn films) provided by SPINTEC, as well as on the T-Spin2 commercial emitter.

Keywords: RF, THz, magnetic enclosure, NCAF, spintronics, MRAM.

Project Supervision: CROMA laboratory is represented by Pierre-Baptiste Vigneron (pierre-baptiste.vigneron@univ-smb.fr), Associate Professor at USMB, within the PHOTO team. His research focuses on the study of thin-film properties—particularly magnetic ones—in the THz range. Pietro M. FERREIRA (marisfep@univ-smb.fr), Full Professor at USMB. His research interests are design methodologies and microwave instrumentation techniques for ultra-low power integrated circuits in harsh environments. Recent projects aim the Internet of Things industry considering IA edge and reliability. SPINTEC laboratory is represented by Olivier Boule (olivier.boule@cea.fr), CR CNRS. His research is exploiting spin orbit interaction to manipulate magnetization in ultrathin films.

Candidate Profile: The candidate profile required for the project is a young professional pursuing a master's degree in Electronics, Photonics or Material Engineering, interested in the scientific field of spintronics and THz. He/She must be motivated, passionate about research in a multidisciplinary field and an organized person using scientific methods. He/She must justify good academic tracks in maths and applied physics; an experience in design flow; linguistic competence in English (B2 written and spoken); linguistic competence in French is a plus.

Intellectual Property: Being fundamental scientific research, this subject is not attached to any industrial project. Intellectual property will be promoted through scientific communications favoring the open science policy of the French government.

Bibliography: Abbass Hamadeh, A. *et al. Sci. Adv.* **9**, 1430 (2023) DOI :10.1126/sciadv.adk1430; Mičica, M. *et al. Nanophotonics* **13**, (2024) DOI : 10.1515/nanoph-2023-0807; Chen, X., *et al. ACS Photonics* **13**, 3519–3525 (2026) DOI : 10.1109/TMAG.2026.3657608 ; Ross, A. *et al. Nat. Nanotechnol.* **18**, 1273–1280 (2023) DOI : 10.1038/s41565-023-01452-w ; Rongione, E. *et al. Nat. Commun.* **14**, (2023); Tsai, H. *et al.* DOI: 10.1038/s41467-023-37509-6