NÉEL – SPINTEC – LNCMI, Grenoble

Fully funded Ph.D. position

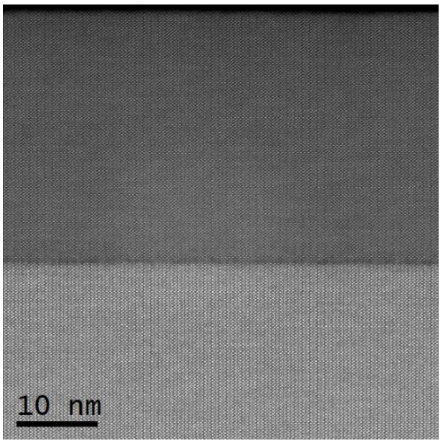
Topic: Sub-terahertz investigation of orbital momentum physics with antiferromagnets

Keywords: antiferromagnetic spintronics, magnetic oxides, THz physics, orbitronics

Context: The recent years have witnessed a renewed interest in the mutual coupling of condensed-matter excitations of different nature (incl. photons, phonons, magnons, etc.), aiming to build hybrid devices with new functionalities to be leveraged, for instance, in spintronics or in quantum engineering. In this context, the transfer of angular momentum between photons, phonons, magnons and electrons in antiferromagnets is a vast subject of fundamental research that could pave the way for the generation, manipulation and electrical conversion of chiral antiferromagnetic spin waves in the sub-THz to THz frequency range. The THz dynamics of the antiferromagnetic order parameter is directly related to the internal exchange interactions between the spin sub-lattices (~100T), which is several orders of magnitude larger than the internal fields involved in the GHz dynamics of ferromagnetic materials. Our experimental approach is supported by the tremendous progress made over the recent years in the synthesis of ultrathin (<100 nm) epitaxial films of antiferromagnetic insulators. While applications of antiferromagnets to room-temperature common electronics are now thoroughly investigated, there remains a largely unexplored potential for turning them into compact, cryogenic devices operating in the THz. They would present superior immunity to thermal fluctuations and thus be able to operate at temperatures of a few K, instead of the mK range. This investigation has potential to shape future key enabling technologies with quantum devices operating in the sub-THz to THz frequency range.

Project summary: The core of this Ph.D. work will be to explore the fundamental coupling mechanisms of ferrimagnetic and antiferromagnetic magnons in the sub-THz to THz frequency range. The project will span several classes of magnetic oxides to be grown in Grenoble as part of this Ph.D. work, and also obtained through external collaborations. You will benefit from the holistic knowhow in Grenoble covering from materials and spintronics to high fields and THz spectroscopies, in NEEL (W. Legrand, L. Ranno) [1], SPINTEC (V. Baltz and U. Ebels) [2,3] and LNCMI (A.-L. Barra) [4], and from national and international collaborations [5]. You will work with state-of-the-art techniques for oxide synthesis, cleanroom fabrication, characterization at the nanoscale under cryogenic temperatures, as well as experiments under strong magnetic fields (15 T) and large frequencies (600 GHz) developed in LNCMI.

Methods: Your approach will rely on the exploration of several growth recipes for oxides in our sputter deposition apparatuses, located at NEEL and SPINTEC, so as to obtain the desired static and dynamical magnetic properties in thin (<100 nm) epitaxial films of low-dissipation antiferromagnets and ferrimagnets. The sub-THz spectroscopy setup available at LNCMI will be available for the measurement of magnon-induced phenomena in this system, supported by a continuous experimental development. This main instrument will be complemented by magneto-transport and electronic pumping measurements. This will lead to experiments that exhibit the coupling mechanisms between magnons and electrons in the sub-THz to THz range, which we expect to be able to exploit in nanodevices.



A cross-sectional scanning transmission electron microscopy image (collab. M. Aguirre, U. Zaragoza) of a 30-nm-thick epitaxial film of yttrium-enriched iron garnet, hosting low-dissipation magnons [1].

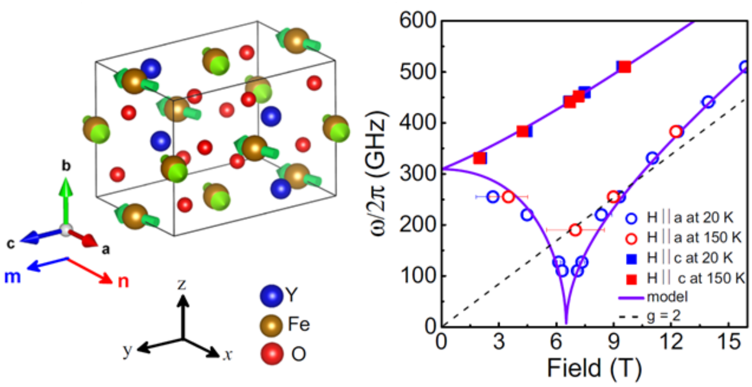


Illustration of the crystal structure and antiferromagnetic order in $YFeO_3$, exhibiting canted antiferromagnetism, and field-frequency diagram of its magnon modes measured under uniform sub-THz field excitation at LNCMI [5]. Yttrium-enriched iron garnet and $YFeO_3$ orthoferrite are two strong options for investigation in this Ph.D. work.

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Available facilities: NEEL and SPINTEC house their respective state-of-the-art cleanroom facilities with complementary or mirrored nanofabrication equipment. LNCMI operates a multi-frequency, continuous-wave sub-THz spectroscopy instrument with only few equivalents in Europe. NEEL and LNCMI are located on the CNRS campus and SPINTEC in the neighboring CEA campus, all within 1.5km distance inside the 'scientific polygon' in Grenoble.

International dimension: The three teams participating to this Ph.D. project are involved in numerous national and international research networks and projects, providing opportunities for scientific exchange and international collaboration. In addition, Grenoble hosts a very international and active scientific community, with around 100 Ph.D. students graduating in Physics every year.

Supervision: The Ph.D. thesis will be officially directed by the NEEL team (W. Legrand, L. Ranno), and is a collaborative project granted by UGA to the 3 teams at NEEL, SPINTEC and LNCMI, thus providing comprehensive guidance on this multi-faceted research topic.

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Required qualifications and skills: A Master's degree awarded at the latest by the starting date is demanded, and an excellent academic record is mandatory. Applicants should have a degree in Physics, good practical and coding skills, a commitment to teamwork and scientific communication, and the will to pursue work involving experimental physics, material science, and solid-state physics with a commitment to advanced instrumentation.

Funding: The doctoral contract with UGA offers a gross salary of 2100€ per month. The duration of the position is fixed to 3 years. More information is available at https://doctorat.univ-grenoble-alpes.fr/preparing-a-phd/the-doctorate/.

Starting date: A starting date before 01/10/2025 is requested by UGA.

Application procedure: Candidates should apply to this position by emailing the main contacts listed below with a brief message specifying their background, attaching an academic CV and a cover letter, and providing at least 2 contacts for reference. The closing date for applications is fixed to June 20th. Applicants shortlisted for an interview will be informed via an email containing further details.

Selection criteria: The following criteria will be evaluated during the selection process:
- the academic merit of the candidates and their ability to conduct research, as demonstrated in their Master's thesis or equivalent;
- their motivation to pursue a Ph.D. degree;
- their background and expertise in relation to the proposed thesis project;
- their demonstration of having the required skills

Main contacts:
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[1] W. Legrand et al., arXiv:2407.06850 (2024).
[2] V. Baltz et al., Rev. Mod. Phys. **90**, 015005 (2018); L. Frangou et al., Phys. Rev. Lett. **116**, 077203 (2016)
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[4] Y. Li, A.-L. Barra et al., Phys. Rev. B **92**, 140413 (2015).
[5] R. Lebrun et al., Nature **561**, 222 (2018); S. Das et al., Nat. Commun. **13**, 6140 (2022).