Topological electronics with ferrimagnetic insulators

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Project description:
The use of the spin of the electrons in devices is having a tremendous impact in our electronics and computing technologies. Tell-tale examples are found in the switching and reading of ferromagnetic layers, essential for the hard disk read head and the magnetic random-access memory technologies. Despite the enormous progress that has been made in the field, current devices are restricted to the use of metallic ferromagnets, which typically suffer from high losses and are limited in frequency.

Magnetic insulators (MIs), such as rare earth garnets ($R_3Fe_5O_{12}$; R=Y,Tm,..), have attracted a lot of interest because of their low damping and high-frequency dynamics. Interestingly, when coupled to heavy metal layers such as Pt or W, the magnetic state of MIs can also be controlled via electric currents, making thus possible to integrate these materials in electronic circuits. Very recently, our group has also demonstrated that chiral domain walls can be stabilized and manipulated by current pulses in $Tm_3Fe_5O_{12}$ (TmIG) thin films. This is an important step forward as the possibility to store information in mobile magnetic elements has the potential to overcome the memory capacity and the information processing speed of the current technologies. Remarkably, those devices based on MIs showed a lower current-threshold for wall motion and a higher wall mobility than those achieved with conventional ferromagnetic metals, thus pointing MIs as promising materials for memory and logic applications. In this TFM, the student will investigate the interfacial stabilization and electric manipulation of a different type of magnetic texture in MIs: skyrmions (continuous swirls of the magnetic moment that carry topological charge). Skyrmions are particularly interesting due to their enhanced stability, higher density memory storage capabilities, and the possibility to enable novel logic and computational schemes.

Methodology:
The student will carry out harmonic transport and wide-field magneto-optical Kerr effect microscopy measurements in prefabricated TmIG/Pt and Bi-doped $Y_3Fe_5O_{12}$/Pt devices (Fig. 1a) with different growth conditions and thicknesses. From these measurements, the student will determine the magnetic anisotropy of the films, characterize the spin-to-charge conversion in Pt and the spin transmission across the MI/Pt interface, as well as to investigate the displacement of domain walls and skyrmions driven by current pulses (see Fig. 1b). The aim of this TFM is to investigate the conditions for bubble skyrmion stabilization in MIs (Fig. 1c) and the characteristics of their dynamics driven by current pulses.

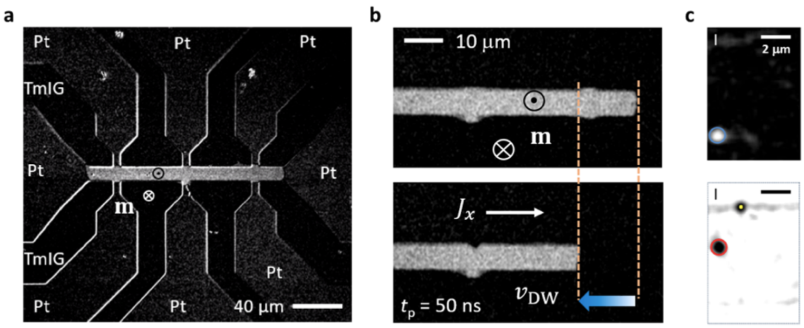

Fig. 1. a, Magneto-optical Kerr effect (MOKE) image of a TmIG/Pt device showing current-induced switching of TmIG (bright region). **b**, Demonstration of current-driven wall motion. A current pulse in Pt drives the walls in TmIG at velocities of a few 100 m/s. **c**, Skyrmion bubbles imaged by MOKE.

About the group and director: The Nanodevices and Spintronics is a newly founded group at the UAM in the framework of the Maria de Maeztu center of excellence IFIMAC, the Condensed Matter Physics Center located at the Faculty of Science at the UAM (https://www.ifimac.uam.es/). The Nanodevices and Spintronics Laboratory is led by Prof. Saül Vélez, expert in experimental condensed matter physics with focus on spin transport, magnetotransport, and optoelectronic phenomena in low dimensional materials and nanodevices. His recent research has focused on investigating the interfacial stabilization and electric control of magnetic textures and spin transport in oxide materials. His aim is to investigate new phenomena at the nanoscale with the purpose to use it in novel technologies. See https://scholar.google.es/citations?user=ErOxhXcAAAAJ&hl=en for the full list of publications.

Reference: S. Vélez et al., Nature Communications **10**, 4750 (2019).