Current-induced control of chiral magnetic textures in magnetic insulators

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The use of the spin of the electrons in devices is having a tremendous impact on our electronics and computing technologies. Tell-tale examples are found in the electric switching and reading of magnetic tunnel junctions as well as in the controlled displacement of domains and domain walls in magnetic thin films. Despite the enormous progress that has been made, 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 Gilbert damping and high-frequency dynamics. Although being electrically insulating, MIs can couple to spin currents, making thus possible to employ these materials as active elements in electronic devices.
In this talk, we show how we can stabilize chiral domain walls and skyrmions in $Tm_3Fe_5O_{12}$ (TmIG) coupled to Pt and manipulate them by proximity electric currents (Fig. 1) [1,2]. We demonstrate the chiral nature of the domain walls and skyrmions via nitrogen-vacancy magnetometry and investigate their dynamics driven by current pulses. We find that the domain walls in TmIG exhibit mobilities comparable to those achieved with metallic ferromagnets and reveal that the dynamics of the skyrmions are governed by the ferrimagnetic order of the4 crystal and pinning, resulting in a large skyrmion Hall effect characterized by a negative deflection angle and hopping motion. Further, we show that the mobility of the walls and skyrmions can be modified by exchange coupling TmIG to an in-plane magnetized $Y_3Fe_5O_{12}$ (YIG) layer, which distorts the spin texture of the magnetic nanostructures leading to a directional-dependent rectification of their dynamics. This effect, which is equivalent to a magnetic ratchet, is exploited to control the flow of domain walls and skyrmions in devices.

References

[1] S. Vélez et al., *Nat. Comm.* **10**, 4750 (2019).
[2] S. Vélez et al., *Nat. Nanotech.* (*in press*).

Figures

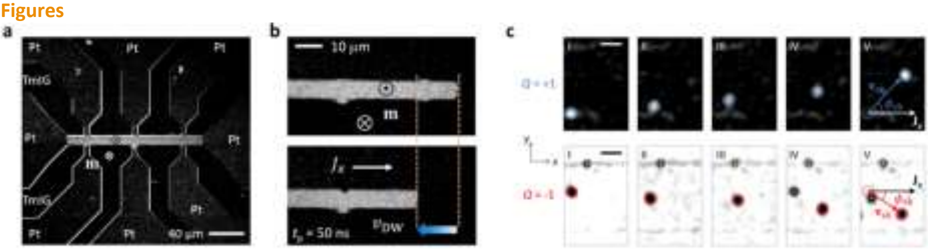

Figure 1: **a**, Magneto-optical Kerr effect (MOKE) image of a TmIG/Pt device showing current-induced switching of TmIG (bright region). **b**, Demonstration of current-driven wall motion. A current pulse $J_x \sim 10^{12}$ A m^{-2} in Pt drives the walls in TmIG at velocities v_{DW} of 300 m/s. **c**, MOKE images showing the displacement of skyrmions in YIG/TmIG/Pt following a sequence of current pulses. The topological charge of the skyrmions (*Q*), which can be controlled by the orientation of the skyrmion core (bright/dark), results in a transverse deflection of the skyrmions.