Designing with spins: towards reconfigurable nano-magnonics based on patterned spin-textures.

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The control of spin-waves holds the promise to enable energy-efficient information transport and wave-based computing. Conventionally, the engineering of spin-waves is achieved via physically patterning magnetic structures such as magnonic crystals and micro-nanowires. However, controlling spin-waves at the nanoscale, which is crucial for the realization of magnonic nanodevices, proved itself extremely challenging due to the difficulty in controlling the nanoscopic magnetic properties via conventional nanofabrication techniques.

We demonstrate a new concept for creating reconfigurable magnonic structures, by crafting at the nanoscale the magnetic anisotropy landscape of a ferromagnet exchange-coupled to an antiferromagnet. By performing a highly localized field cooling with the hot tip of a scanning probe microscope, spin-textures, with arbitrarily oriented magnetization and tunable unidirectional anisotropy, are patterned without modifying the film chemistry and topography (Fig. 1). We show that, in such structures, the spin-wave excitation and propagation can be spatially controlled at remanence, and can be tuned by external magnetic fields. [1,2]

Furthermore, we provide direct evidence for the channeling and steering of propagating spin-waves in arbitrarily shaped nanomagnonic waveguides based on patterned domain walls (Fig. 2), with no need for external magnetic fields or currents, and demonstrate a prototypic nanomagnonic circuit based on two converging waveguides, allowing for the tunable spatial superposition and interaction of confined spin-waves modes. [3]

The ability to control magnons via nanoscale-designed spin-textures opens up a plethora of exciting possibilities for the realization of energy-efficient reconfigurable computing architectures.

[1] E. Albisetti et al., Nature Nanotechnology, 11 545–551 (2016).
[2] E. Albisetti et al., AIP Advances, 7(5), 55601 (2017).
[3] E. Albisetti et al., submitted. (arXiv preprint: 1712.08293). (2017).

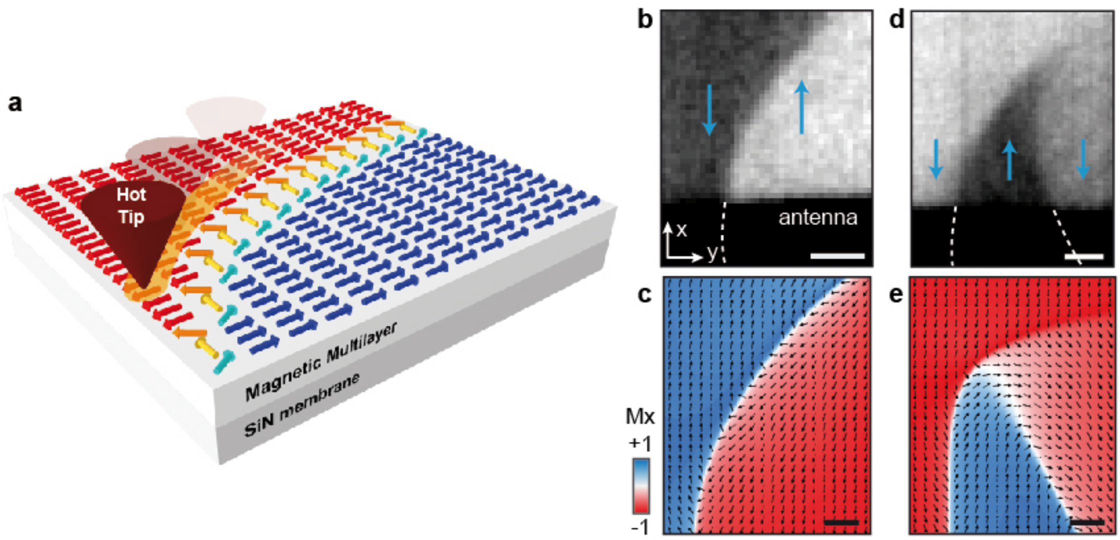

Figure 1. a. Nanoscale spin-textures, such as magnetic domain walls with tailored spin configuration, are patterned via thermally assisted magnetic Scanning Probe Lithography (tam-SPL) in a continuous exchange biased ferromagnetic layer. **b, d.** Static STXM images of a parabola-shaped 180° Néel wall, and a complex spin-texture comprising two converging 180° Néel walls. **c, e.** Micromagnetic simulations corresponding to the upper panels. The black arrows indicate the local spin-configuration. The blue (red) color indicates $M_x > 0$ (< 0). Scale bars 500 nm.

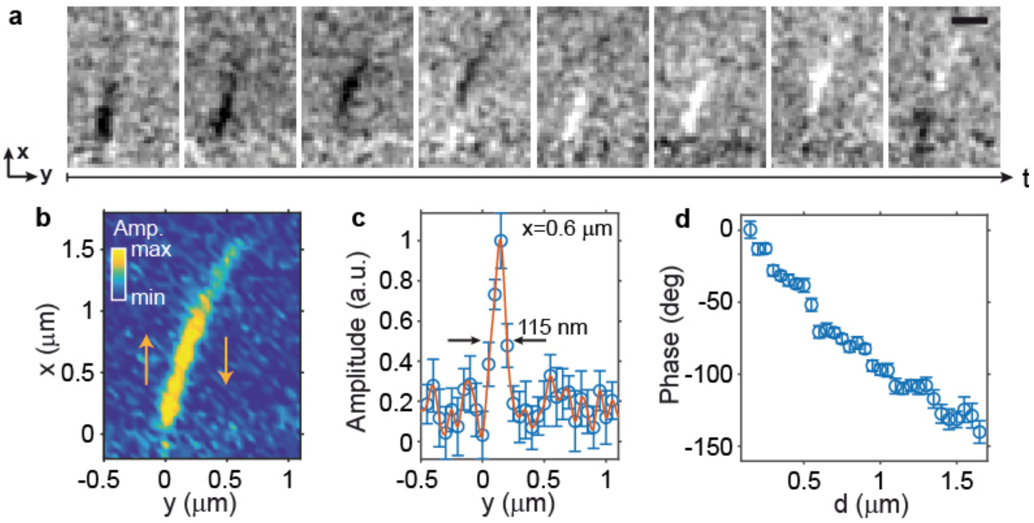

Figure 2. a. Time-resolved STXM images showing the propagation of localized spin-waves along a parabola-shaped 180° Néel wall. Scale bar: 500 nm. **b.** Spatial maps of the spin-wave excitation amplitude, showing localization at the domain wall. The arrows indicate the direction of the magnetization within the domains. **c.** Horizontal profiles extracted from panel b at x=0.6 μm from the antenna. **d.** Phase shift as a function of distance from the antenna along the curved domain wall confirming the propagating character of the spin-waves.