All-optical stochastic switching of magnetization textures in Fe_3Sn_2

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The interaction of magnetic materials with ultrashort light pulses provides both intriguing glimpses into the inner workings of the magnetic interactions in a material but also an important experimental handle to locally manipulate magnetic textures and phases. Whereas many studies in the field of ultrafast magnetism utilized various optical pump-probe methodologies, these approaches often lack the required spatial resolution for mapping the nanoscale details of magnetic textures. Here, we present our work on *in-situ* Lorentz microscopy with femtosecond optical excitation which combines access to nonlinearities in light-driven magnetic systems with the high spatial resolution of electron microscopy [1]. In a recent experiment [2], we applied this approach to investigate light-induced switching in the magnetic texture of Fe_3Sn_2 thin films (Fig. 1a), which host dipolar skyrmions [3], composed of chiral Bloch-like domain walls in the interior of the film and chiral Néel-like caps at each film surface. The chirality of each Bloch wall is directly mapped by Lorentz microscopy (Fig. 1b) as a bright or dark contrast in the rim of the skyrmions. The image intensities in the skyrmion centers are a combined effect of the chirality of both Néel caps. After femtosecond optical excitation, we find the chirality of the Bloch domain walls to be unchanged whereas the central image intensity changes between three states corresponding to the three possible chirality combinations of the Néel caps (Fig. 1c,d). By recording a large number of electron micrographs before and after excitation (Fig. 1f), we gain experimental access to the chirality switching statistics in each skyrmion, demonstrating a strong influence of the local magnetic environment on the detailed micromagnetic energy landscape. We reproduce the experimentally observed static image contrast by micromagnetic simulations (Fig. 1e). The light-induced image changes are recovered in the simulations by applying picosecond temperature spikes resulting in a partial melting of the spin textures. Overall, the optical induced switching in Néel cap chirality observed here is a rare case where internal magnetic degrees-of-freedom can be controlled by light, without generation or annihilation of magnetic particles, representing an intriguing platform, for example, for spin-based stochastic computing.

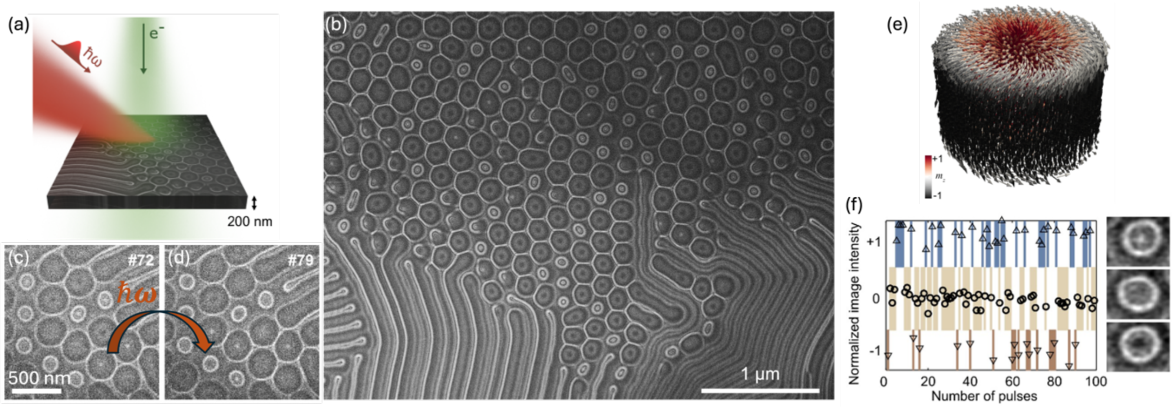

Figure 1. (a) Principle of in-situ Lorentz microscopy with femtosecond optical excitation. (b) Lorentz micrograph of a Fe_3Sn_2 thin film showing a dense network of dipolar skyrmions. (c,d) Example of Lorentz micrographs before and after optical excitation (index: number of applied optical pulses). (e) Spin texture of a dipolar skyrmion as obtained from a micromagnetic simulation. (f) Change of central image intensity in one skyrmion after a different number of applied optical pulses, demonstrating the stochastic switching of the chirality of both Néel caps at the film surface.

References

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