Nanosecond Dynamics of Antiferromagnetic Quasiparticles Revealed by Sublattice-Resolved X-Ray Microscopy

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Antiferromagnetic (AFM) materials provide a platform for topological spin textures due to their compensated magnetization, absence of stray fields, and ultrafast spin dynamics [1]. However, in single-crystalline antiferromagnets, stabilizing pure homochiral spin textures is challenging due to the absence of significant Lifshitz invariants, leading to spin structures with random chirality [2,3]. Synthetic antiferromagnets (SyAFMs), composed of ferromagnetic thin films separated by nonmagnetic spacers and antiferromagnetically coupled via interlayer exchange interaction, offer a potentially compelling alternative.

In this talk, we will discuss our recent results for stabilizing, imaging, and probing the nanosecond dynamics of chiral spin textures in SyAFMs. A combination of advanced imaging techniques—including X-ray magnetic circular dichroism photoemission electron microscopy (XMCD-PEEM), scanning transmission x-ray microscopy (STXM), magnetic force microscopy (MFM), and scanning electron microscopy with polarization analysis (SEMPA)—has been employed to achieve sublattice-resolved visualization of the complex spin textures. Using these methods, we have resolved the intricate magnetization configurations of AFM topological textures, such as merons, antimerons, bimerons, and skyrmions (see Fig. 1(a) and (b)) which are stabilized through the precise optimization of materials parameters [3]. Employing pump-probe imaging by STXM, we demonstrate the nanosecond-scale current-driven dynamics of AFM skyrmion lattices, highlighting the absence of the skyrmion Hall effect in fully compensated SyAFMs due to gyrotropic force cancellation as shown in Fig 1(c). Finally, we explore the emergence of three-dimensional topological textures, such as hybrid chiral skyrmion tubes, which exhibit a current-polarity-dependent, non-reciprocal skyrmion Hall effect arising from their three-dimensional domain structure [4].

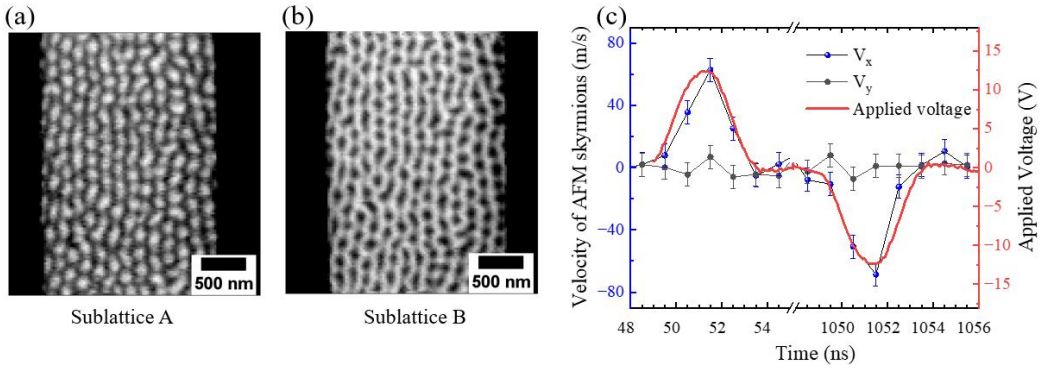

Figure 1. Sublattice-resolved imaging of AFM skyrmion lattices in (a) sublattice A and (b) sublattice B. (c) Dynamic velocity of AFM skyrmion lattices, showing the absence of the skyrmion Hall effect.

References

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