Real-space Imaging of Non-collinear Antiferromagnetic Order with a Single Spin Magnetometer

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While ferromagnets are at the heart of daily life applications, the large magnetization and energy costs for switching bring into question their suitability for reliable low-power spintronic devices. Non-collinear antiferromagnetic systems do not suffer from this problem and often possess remarkable extra functionalities: non-collinear spin order[1] may break space-inversion symmetry[2, 3] and thus allow electric-field control of magnetism[4, 5], or produce emergent spin-orbit effects[6, 7] which enable efficient spin-charge interconversion[8]. To harness these unique traits for next-generation spintronics, the equivalent nanoscale control and imaging capabilities, now routine for ferromagnets, must be developed for antiferromagnetic systems. Here, using a non-invasive scanning magnetometer based on a single nitrogen-vacancy (NV) defect in diamond[9-11], we demonstrate the first real-space visualization of non-collinear antiferromagnetic order in a magnetic thin film, at room temperature. We image the spin cycloid of a multiferroic $BiFeO_3$ thin film and extract a period of ~70 nm, consistent with values determined by macroscopic diffraction[12, 13]. In addition, we take advantage of the magnetoelectric coupling present in $BiFeO_3$ to manipulate the cycloid propagation direction with an electric field. Besides highlighting the unique potential of NV magnetometry for imaging complex antiferromagnetic order at the nanoscale, these results demonstrate how $BiFeO_3$ can be used as a versatile platform for the design of reconfigurable nanoscale spin textures.

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