Magnetic force microscopy with nanowire transducers

Principle investigators: Prof. Martino Poggio (Department of Physics, University of Basel), Prof. Ernst Meyer (Department of Physics, University of Basel),

Recent years have seen rapid progress in nanometer-scale magnetic imaging technology, with scanning probe microscopy driving remarkable improvements in both sensitivity and resolution. Among the most successful tools are magnetic force microscopy (MFM), spin-polarized scanning tunneling microscopy, as well as scanning magnetometers based on nitrogen-vacancy centers in diamond, Hall-bars, and superconducting quantum interference devices. Here, we propose the development and application of recently developed nanowire (NW) force sensors as MFM probes. Using NWs functionalized with magnetic tips, we will realize MFM capable of mapping magnetic fields and dissipation with enhanced sensitivity and resolution compared to the state of the art. With these new capabilities, we will image mesoscopic current flow, magnetism, and dissipation in 2D van der Waals (vdW) heterostructures with well-defined twist angles, which allow for control over strong electronic correlations. These structures include ‘magic-angle’ twisted bilayer graphene, which – in a major breakthrough – recently showed gate-controllable superconductivity.

Until now only one proof-of-principle NW MFM experiment has been carried out on the well-known magnetic field profile of a current-carrying wire. We now intend to move past this demonstration stage by:

1. optimizing the magnet-tipped NW transducers to achieve the highest possible sensitivity and resolution;
2. using the new scanning probes to image current flow and magnetism in 2D vdW systems.

Although MFM is already applied to a wide array of samples for its ability to work at various temperatures, some materials remain out of reach because of limitations in resolution and due to the perturbative effect of conventional tips. High force sensitivity coupled with small tip size should allow magnetic NW sensors to work both close to a sample, maximizing spatial resolution, and in a regime of weak interaction, remaining noninvasive. These characteristics will allow NW MFM to provide magnetic contrast, which has not been available through existing techniques. These include spatial maps of Biot-Savart fields, magnetic stray fields, and dissipation tied to the various strongly correlated states, which have recently been discovered within of 2D vdW materials.