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Towards high-resolution scanning SQUID microscopy in a conduction-cooled cryostat

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Scanning superconducting quantum interference device (SQUID) microscopy (SSM) is a powerful scanning probe technique that enables spatially resolved mapping of local magnetic flux at a surface. It has been used to image diverse phenomena such as ferromagnetism in magnetic materials, Abrikosov vortices in superconductors, and edge currents in topological devices. However, conventional SQUID probes, fabricated on planar silicon substrates using standard wafer processes, are limited to spatial resolutions of several micrometers due to the finite spacing between the pickup loop and the sample surface. Achieving higher spatial resolution and improved magnetic sensitivity requires bringing the SQUID pickup area much closer to the surface.
Another challenge in SSM is the reliance on liquid helium to reach the low operating temperatures required for SQUID operation. While liquid helium cooling provides mechanical stability with minimal vibrations, its risen cost in recent years motivates the transition to cryogen-free cooling technologies.
To address these limitations, we have developed novel SQUID-on-cantilever probes. By combining conventional silicon processing with corner lithography and focused-ion beam milling, we fabricate SQUID-on-tip devices with dimensions ranging from below 100 nm to several micrometers. In parallel, we have constructed a cryostat based on a commercial cryogen-free cryocooler, designed to host a future high-resolution SSM system. Together, these advances pave the way for cryogen-free, high-resolution SQUID microscopy with nanoscale sensitivity.

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Author Affiliations & Email Addresses

Co-Author Affirmation

Author: ROSKAMP, Thijs

Presenter: ROSKAMP, Thijs

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