Master thesis in Forschungszentrum Jülich - Institute for Microstructure Research (PGI-5)

**Nanoscale superconducting quantum interference devices (nano-SQUIDs)**



Background:

Unique quantum effects in superconducting nano-devices give them a great advantage in achieving low noise, energy efficiency and ultra-high-speed processing. Scanning nanoscale superconducting quantum interference devices (nano-SQUIDs) are of particular interest for magnetic imaging in the fields of nanomagnetism and spintronics due to their sensitivity, negligible influence on the object and large frequency bandwidth. Nano-SQUIDs can also potentially be implemented for the non-destructive readout of the final states of superconducting flux qubits after their protection by sufficiently high potential barriers. Nano-SQUIDs have demonstrated an unprecedented spin sensitivity of 0.38 μB/Hz (Vasyukov et al., *Nature Nanotechnology* **8**, 639, 2013) and spatial resolution of 20 nm (Anahory et al., *Nano Lett*. **14**, 6481, 2014). The implementation of an electrically-tunable multi-terminal nano-SQUID configuration (Uri et al., *Nano Lett.* **16**, 6910, 2016) has provided optimal flux bias conditions by the direct injection of flux modulation and feedback current into the SQUID loop. It is planned to develop a nano-SQUID measurement system for studying magnetic effects in samples on the nanometer scale, as a complementary technique to electron holography measurements performed in the transmission electron microscope

Project description:

This project will be embedded in an international team working in the Institute for Microstructure Research (PGI-5) and the Ernst Ruska-Centre in Forschungszentrum Jülich. The candidate will perform nanofabrication of superconducting devices (nanobridges, Josephson junctions and nano-SQUIDs) and characterize their microstructural and electron transport properties. Deposition of thin films of Au, Pt, Ag, Ti, low-Tc superconductors (Nb and TiN), the epitaxial high-Tc superconductor YBa2Cu3O7-x and different epitaxial insulating metal oxide materials will be performed in PGI-5. Nanostructuring down to 10 nm will be performed using electron beam lithography and (reactive) ion (beam) etching in the clean room of the Helmholtz Nano Facility (HNF). Microstructural properties of superconducting devices will be studied using scanning and transmission electron microscopy in the Ernst Ruska-Centre. Electron transport and noise properties will be characterised at 4.2 K, 77 K and room temperature using different measurement systems and comparisons with theoretical models will be performed. The best nanoSQUIDs will be placed on cantilevers in a low temperature piezo scanning system with an ultra-large scan range for imaging the magnetic fields of different nanoscale objects that are of interest for the rapidly evolving research fields of topological materials, spintronics, quantum computation and artificial intelligence.

**Contact person**:

Prof. Dr. Michael Faley m.faley@fz-juelich.de