Universität Basel
Swiss Nanoscience Institute

SNI SWISS NANOSCIENCE INSTITUTE
EINE INITIATIVE DER UNIVERSITÄT BASEL UND DES KANTONS AARGAU

Nanoscale quantum sensing of complex spin systems in extreme environments
Prof. Dr. P. Maletinsky and Prof. Dr. M. Poggio (Physics Department, Uni Basel)

Quantum sensing is an emerging field in the nanosciences, where individual quantum systems are exploited as highly precise sensors for nanoscale sensing and imaging of magnetic fields, temperatures and more. Prime examples are atomic-scale “Nitrogen Vacancy" spins in diamond [3], or scanning superconducting quantum interference devices (SQUIDs) used as nanoscale magnetometers [4]. These and other approaches have seen increased attention and success in recent years [5], in particular for fundamental studies and materials engineering in the nanosciences.

In this project, we will further advance the field by pushing the functionality and performance of nanoscale quantum sensing and by pursuing a specific application in nano-magnetism. Namely, we will conduct nanoscale studies of individual magnetic Skyrmions in single-crystal magnets at low temperatures, ultimately in the sub-Kelvin temperature range, where quantum phenomena are expected [6]. Skyrmions are topologically non-trivial spin textures that have attracted significant recent attention in the field of nano-magnetism due to their nanoscale dimensions and enhanced functionalities they promise in spintronics [7]. To achieve our goals, we will invest in technological improvements for low-temperature quantum sensing, for which we will also explore novel color-centers (such as the “Silicon-Vacancy” centre) for sensing.

Our project builds on established technologies in the Maletinsky and Poggio groups and exploits synergies in their complementary expertise in fields relevant to this project. With this, we propose to bring together two research groups of the SNI network for a new research project of relevance to quantum-sensing, nanotechnology and nano-magnetism - as such, the project lies at the heart of the SNI's core activities. The successful project will bring nanoscale quantum sensing to a new level of performance, and with our targeted studies of Skyrmion-physics address a key topic in nano-magetism and spintronics. The synthesis of this project might ultimately enable the observation of quantum- mechanical behavior of individual Skyrmions at millikelvin-range temperatures [6] - a result of far-reaching nature, which would demonstrate quantum-mechanical phenomenon in a solid-state macroscopic spin texture consisting of thousands of spins.

[1] L. Rondin, et al., Magnetometry with nitrogen-vacancy defects in diamond, Reports on Progress in Physics 77, 56503 (2014)

[2] D. Vasyukov, et al., Imaging Stray Magnetic Field of Individual Ferromagnetic Nanotubes, Nano Letters 18, 964 (2018)

[3] L. Thiel, et al., Probing magnetism in 2D materials at the nanoscale with single-spin microscopy, Science 364, 973 (2019), URL.

[4] A. Marguerite, et al., Imaging work and dissipation in the quantum Hall state in graphene, Nature 575, 628 (2019)

[5] A. Fert, et al., Magnetic skyrmions: advances in physics and potential applications, Nature Reviews Materials 2, 17031 (2017)

[6] C. Psaroudaki et al., Quantum Depinning of a Magnetic Skyrmion, Phys. Rev. Lett. 124, 097202

[7] D. D. Sukachev, et al., Silicon-Vacancy Spin Qubit in Diamond: A Quantum Memory Exceeding 10 ms with Single-Shot State Readout, Phys. Rev. Lett. 119, 223602 (2017)

[8] P. Maletinsky, et al., A robust scanning diamond sensor for nanoscale imaging with single nitrogen-vacancy centres, Nature Nanotechnology 7, 320 (2012).