Dr. Tobias Nöbauer

Sensing, coherent coupling and optimal control with nitrogen-vacancy colour centres in diamond

Supervisor: Jörg Schmiedmayer

ABSTRACT

The negatively charged nitrogen-vacancy (NV) defect centre in diamond shows great promise as a quantum bit in scalable quantum information architectures as well as for quantum-limited sensing. This thesis explores robust quantum control techniques for NV centres, and approaches to creating and characterizing dense NV ensembles. It presents contributions to demonstrations of single-NV based electric sensing, and of coherent coupling of NVs to a superconducting microwave resonator.

An experimental setup for confocal microscopy and optically detected spin-resonance experiments was constructed, capable of imaging and manipulating single NV centres. Time-resolved photon counting was used to identify single emitters via photon anti-bunching. Pulsed as well as quadrature-amplitude modulated microwave signals were used to characterize and coherently manipulate the spin properties of NVs. Smooth, robust optimal control pulses were implemented using this setup, and were shown to perform quantum operations on ensembles of NVs at greatly improved fidelity. This result will enable the improvement of the sensitivity of NV-based magnetometers and is a step towards the storage and retrieval of single excitations in the collective spin state of NV ensembles.

Neutron and electron irradiation were used to create high densities of NVs in diamond samples in an optimal way. The samples were analysed using a combination of UV/Vis and infrared spectroscopy, fluorescence microscopy and optically detected spin resonance techniques. Using the resulting samples, strong coupling of NVs to a superconducting microwave resonator was demonstrated, implementing a major milestone towards a quantum memory in a hybrid, all solid-state architecture.

Finally, contributions as a co-author to the first demonstration of single-NV-based electric sensing are presented and discussed in the context of intracellular sensing using fluorescent nanodiamonds.