INTEGRATED QUANTUM SCIENCE AND TECHNOLOGY

University of Stuttgart Germany

Detecting single spins in biological molecules | 1YR

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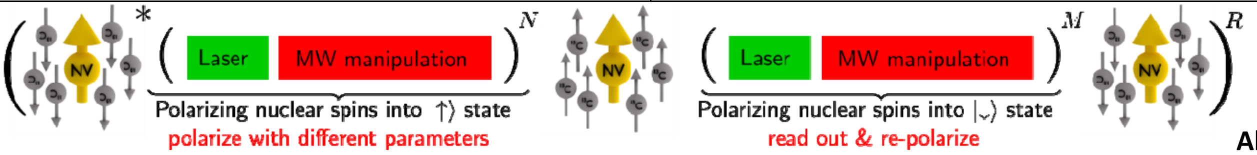

Abstract: Single colour centres in diamond and especially the nitrogen-vacancy centres (NV) have remarkable physical properties with a wide range of applications, e.g. qubits, single photon sources and nano-scale ultra- sensitive magnetic field sensors. The aim of this project is to utilize single NVs for the detection, control and spectroscopy of single nuclear spins. In our experiments the magnetic dipolar coupling of the NV to the nuclear spins is much stronger compared to the coupling among the spins. In this case we cannot consider the system as sensor and sample separately, but we have to describe it using a Hamiltonian including all the spins. We want to explore this “quantum” regime (also called strong coupling regime) by studying single nuclear spins using shallow NV centres. In our project we plan to implement the recently proposed methods for “quantum enhanced sensing”. The basic idea is to create a correlated quantum state, e.g. entanglement, between two or more spins and use this new state as a sensor. The advantage over the single spin approach is better sensitivity and bandwidth, compared to uncorrelated quantum states. One of the first goals here is to fabricate stable shallow NV centres in diamond. We follow two approaches – low energy nitrogen ion implantation and delta doping during the diamond growth. For the realization of the former approach we designed and constructed an ion implanter. For the latter we developed a novel method for creation and stabilization of shallow NVs by introducing nitrogen gas during the chemical vapour deposition process [1]. For detecting nuclear spins we first demonstrated a method for optical hyperpolarisation of ^{13}C spins in a macroscopic diamond [2]. We obtained an increase of the NMR signal by a factor of 45 and a speed-up of the measurement time of many orders of magnitude due to the long time required for building up thermal polarisation. Later a technique for quantitative measurement of small nuclear spin ensembles (few tens of spins) was developed - Polarization Read Out by Polarization Inversion (PROPI) [3], see figure. With this method we are able to not only to detect the nuclear spins, but also to determine the exact number of spin quanta transferred from the NV’s electron spin to the ensemble.

Recent results:

- Construction of a low energy ion implanter
- Fabrication of shallow NV using CVD growth with nitrogen delta doping
- Improved hyperpolarization and detection of nuclear spins in diamond
- Novel method for detection of small nuclear spin ensembles

Publications:

[1] C. Osterkamp et al., Appl. Phys. Lett. 106, 113109 (2015), **Stabilizing shallow color centers in diamond created by nitrogen delta-doping using SF6 plasma treatment**

[2] J. Scheuer et al., New J. Phys., 18, 013040 (2016), **Optically induced dynamic nuclear spin polarisation in diamond**

[3] J. Scheuer et al., arXiv:1706.01315v1 (2017), **Robust techniques for polarization and detection of nuclear spin ensembles**

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