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Presentation Title

Perspectives of quantum information processing in diamond

Abstract

The main aim of this project will be to design, fabricate and test a multi-qubit quantum computer based on electron and nuclear spins in diamond. The initialization, readout and multi-qubit coupling will be accomplished via interactions with the electron spin of nearby nitrogen-vacancy (NV) color centers. For this project a two-dimensional array are NV centers will be the main focus, though making use of the third dimension and/or microstructures for longer range coupling or more robust logical qubits is considered within scope. Improvements in the material properties of diamond over the past year have substantially improved the performance of the NV defects allowing breakthrough results in creating of small quantum registers including entanglement generation.

Future directions

Novel robust qubit gates

We will extend our two-qubit gate demonstration, which was done using NV electron spin qubits, to the case where the qubits are nuclear spins. Detailed theory work was performed to investigate the fidelity of tis gate in realistic conditions.

Selective optical addressing techniques

This task will require sub-wavelength addressing of the individual qubits. Initially STED-like schemes will be explored, because they have recently shown 10’s of nanometer resolution for the selective magnetic probing of neighboring NVs. This technique will be optimized to achieve higher resolution, for example by employing long-living spin states. Later magnetic field gradients may be needed to augment the resolution with MRI techniques.

Fluorescence collection efficiency enhancement

To improve fluorescent collection efficiency, two approaches have showed promise. The first is to use plasmon enhancement of the Purcell factor. So far enhancement factors up to five have been seen for NVs in nanocrystals attached to silver nanowires. Techniques for detecting these guided photons are now being explored and include plasmon-to-fiber coupling as well as direct detection of the plasmon light with nanoscale photodetectors such as semiconductor nanowires. The second technique to enhance collection efficiency is to etch diamond nano-pillars around the NV to make a single mode waveguide. Both these techniques have encouraging preliminary results and will be pursued further.

Applications of small quantum registers: sensing at nanoscale

Advances quantum control techniques open the way towards applications of small scale (3-5 qubits) quantum registers for sensing at nanoscale. Such sensors can reach spatial resolution able to image individual electron and nuclear spins. Remarkably, sensitivity of sensors will profit from our ability to generate and entanglement and perform quantum measurements.