Experimental Quantum Control of Spin Defects in Solids

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Optically active spin defects in diamond have proven to be a promising resource for the implementation of quantum communication and have recently enabled the first demonstration of a 3-node network. In this presentation I bridge ongoing and anticipated work in the control, analysis and engineering of single spin defects for applications in quantum communication. I introduce a recent proposal in which we demonstrate theoretically that the realization of quantum communication over 1000 km becomes achievable with relatively few solid-state spin qubits that are efficiently coupled to an optical nanostructure. These coupled spin defects and their coherent control, however, have complex requirements that go beyond current state-of-the-art.

In our work, we focus on understanding the spin qubits‘ nano- and microscopic noise environment, on coupling to nanostructures, and on system control schemes. To illustrate these efforts, I outline how to coherently control diamond spin qubits, how to enhance qubit-to-photon coupling with nanostructures, and how to mitigate noise in such nanostructures. In particular, I discuss how to achieve single ‘central’ spin qubits with long coherence times through decoupling from spin bath noise, and how several of such quantum memories can be controlled simultaneously in a sub- diffraction volume. For enhanced qubit-to-photon coupling I introduce photonic nanostructures and methods for their fabrication, and demonstrate how such qubit-nanostructure devices facilitate flux control of electromagnetic radiation. One important (yet undesired) ‘side-effect’ of nanostructures is spectral diffusion of the spin system’s optical transition frequency induced by time-varying electrostatic field noise. I introduce ways to investigate and mitigate the impact of this noise, and show that certain spin defects are immune to electric field noise to first order. Finally, I look into the near future and lay out how we plan to generate multi-qubit entangled states—an important step towards applying solid-state spin defects for the implementation of long-distance quantum communication and quantum networks.