# Quantum and Quantum-Inspired Microscopy of Molecules and Materials

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Quantum resources like superposition and entanglement can be leveraged to realize sensing capabilities beyond what is possible with wholly classical sensors [1, 2]. One promising application space for quantum sensing is the imaging and spectroscopy of molecules and materials at the nanoscale. In this talk I will present my group's recent work on the development of methods to this end.

First, I will discuss our recent progress on magnetic resonance microscopy using nitrogen-vacancy (NV) centers in diamond. Shallow-implanted NVs are in principle capable of sensing magnetic signals emanating from single nuclear spins embedded in target molecules brought to the surface of the diamond. Direct single-molecule NMR would require NVs placed within a few nanometers of the target. However, when the NV is too shallow it's coherence properties and charge stability break down. To bridge the gap others have suggested the use of reporter electronic spins located external to the diamond that can couple directly to nuclei of interest and in turn relay information to NVs embedded somewhat deeper in the diamond [3]. In our work we repurpose a commonly used class of fluorescent dyes which form stable radical ions under the right buffer conditions. These photoswitchable reporter spins will enable new approaches to correlative fluorescence and magnetic resonance imaging.

Next I will describe our work aimed at placing optical nanoscopy of molecules in the context of quantum metrology. This facilitates comparison of experimental performance to the fundamental, measurement-independent precision bounds set by quantum mechanics. When these bounds are saturated, no amount of microscope engineering can improve the performance. When these bounds are not saturated, the development of new microscopy methods is warranted. Specifically I will discuss the age-old problem of optical resolution in this context, and show that our recently constructed vortex-polarized image inversion interferometer can greatly surpass direct imaging for the task of resolving a pair of fluorescent point emitters [4].

References

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