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Towards Quantum Sensing for Directional Dark Matter Detection Using Nitrogen Vacancy Centers in Diamond

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Current detection methods for Weakly Interacting Massive Particle (WIMP) dark matter are approaching the so-called "neutrino fog," where irreducible background from solar neutrinos will obscure dark matter signals. To overcome this challenge, directional discrimination of events is critical. We propose developing a diamond-based particle detector that utilizes embedded quantum sensors to enable directional detection, supplementing conventional event registration techniques. When a WIMP or solar neutrino interacts with the diamond, it induces a nuclear recoil that leaves a permanent damage track measuring 10–100 nm. This track can be located and imaged using nitrogen-vacancy (NV) centers in diamond, leveraging advanced quantum sensing techniques. In this presentation, we will report recent progress in our group towards realizing a diamond-based directional dark matter detector, such as artificial track detection experiments via ion implantation, three-dimensional micron-scale strain imaging with a light-sheet quantum diamond microscope, and nanoscale strain imaging using super-resolution microscopy.

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