

Optical Two-Dimensional Coherent Spectroscopy of Color-Center Arrays in Diamond

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Defect-induced color centers in solids are promising candidates for applications in quantum information science. Quantum sensing applications and quantum-logic operations can utilize quantum entanglements mediated by coherent coupling between color centers. Therefore, a critical step is to enable deterministic coherent coupling of individual optically addressable color centers, which still remains challenging. The challenge is two-folded. First, it is difficult to deterministically grow two color centers at a controlled distance. Second, it is difficult to probe and characterize the coupling especially when the coupling is weak.

In this presentation, I will present our effort of probing coupling between SiV color centers by using optical two-dimensional coherent spectroscopy (2DCS), a technique that provides an extremely sensitive and background-free detection of coupling. In this experiment, arrays of SiV color centers were fabricated by implanting Si ions into a diamond substrate with focused ion beam (FIB). The technique allows us to fabricate SiV color center samples with pre-designed and well-controlled parameters including pattern geometry, spacing, and the number of color centers at a site. To measure the potential couplings, we use a novel ultrafast spectroscopic technique, optical 2DCS, to probe the coupling between the color centers. Optical 2DCS has been proven to be extremely sensitive to dipole-dipole interactions and can probe the dipole-dipole interaction between atoms at an interatomic separation of up to 10 microns. Combining these two unique capabilities, we can study how the coupling is dependent on the sample and fabrication parameters, which will be essential for the reliable and deterministic fabrication of coupled color centers in diamonds for quantum information applications.

We have performed both one- and two-quantum 2DCS on the fabricated color-center arrays with various dosages and separations. Two-quantum 2D spectra were obtained from different regions on the sample, including arrays of single SiV color centers with different separation. The results revealed coherent coupling between single SiV color centers when the separations are much larger than 10 nm. We have demonstrated that two-quantum 2DCS has sufficient sensitivity to detect coupling between single SiV color centers, addressing the challenge of probing weak coupling between color centers.