Diamond and 4H-Silicon Carbide Quantum Photonics

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Color centers -- atomic defects in wide-band semiconductors with long spin coherence times and optical readout -- combine solid-state integrability of superconducting qubits with optical interfaces of cold atom quantum computing systems. However, color-center quantum computing comes with challenges of its own, one of which is device nanofabrication. The two most promising material hosts for color centers are diamond and Silicon Carbide (SiC), and due to strict requirements on the crystalline quality for favorable qubit properties, many traditional nanofabrication processing techniques are not accessible for device production. In this talk I will discuss how we use novel approaches to device fabrication: Bulk-carving fabrication techniques in high-quality diamond based on angled and quasi-isotropic etching, and a thin-film fabrication method in SiC that enables industry-compatible SiC photonics. Furthermore, we utilize inverse-design optimization techniques, which can search the full parameter space of fabricable devices to overcome remaining fabrication constraints and to design efficient, compact and robust photonic components with new device functionalities. By combining traditional- and inverse-designed devices we are able to efficiently interface color centers with photonic components to increase light-matter interactions with record Q-factor devices. Our approaches represent promising paths towards integrated quantum photonic circuits, which will ultimately enable applications in color center quantum information processing.

Relevant publications:

[1] Optimized Diamond Quantum Photonics, Constantin Dory, et al., arXiv:1812.02287 (2018).

[2] Characterization of Optical and Spin Properties of Single Tin-Vacancy Centers in Diamond Nanopillars, Alison E. Rugar, et al. arXiv:1811.09941 (2018).

[3] Cavity-enhanced Raman emission from a single color center in a solid, Shuo Sun, et al., Phys. Rev. Lett. 121, 083601 (2018).

[4] Strongly Cavity-Enhanced Spontaneous Emission from Silicon-Vacancy Centers in Diamond, Jingyuan Linda Zhang, et. al., Nano Lett., 18 (2), pp 1360–1365 (2018).

[5] Daniil Lukin, et al., “4H-SiC-on-Insulator platform for quantum photonics with color centers,” Bulletin of the American Physical Society (2019).