# Abstract

## Quantum Sensing with BOlometric Superconducting Optical Nanoscopy (BOSON)

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The development of superconducting qubits has propelled quantum computing to the forefront of modern science and technology. However, critical challenges remain in understanding and mitigating decoherence mechanisms that limit qubit performance. Many of these challenges stem from subtle material imperfections and microscopic inhomogeneities that are difficult to detect with conventional techniques. In this project, we propose to harness a novel scanning probe platform—**Bolometric Superconducting Optical Nanoscopy (BOSON)**—to probe and image the local superconducting properties of qubit devices with nanometer spatial resolution and unprecedented sensitivity.

BOSON uniquely combines superconducting transition-edge sensors (TES) with tip-enhanced optical nanoscopy, offering bolometric detection of local photothermal effects and quasiparticle dynamics near the superconducting transition. The technique exploits the steep resistive response of superconductors near their critical temperature, enabling the detection of weak excitations such as polaritons, phonons, and Cooper pair fluctuations—using optical powers in the nanowatt range. This capability makes BOSON ideally suited to explore microscopic mechanisms behind qubit decoherence, including local variations in superconducting transition temperature, dissipation hotspots, surface defects, and hybrid interface effects in Josephson junctions and superconducting resonators.

The primary objective of this proposal is to apply BOSON to the nanoscale characterization of superconducting qubit devices, including Nb- and Ta-based structures and hybrid van der Waals interfaces. We will demonstrate how BOSON can spatially resolve the transition-edge temperature inhomogeneities, visualize local suppression of superconductivity under weak optical stimulation, and detect quasiparticle-induced losses with sub-micron resolution—all of which are crucial for improving qubit coherence times and yield.

Beyond superconducting qubits, the BOSON platform will enable a broad range of quantum sensing applications, including single-polariton detection, ultrasensitive spectroscopy at cryogenic temperatures, and the study of novel quantum materials such as Nickelates, Fe(Te,Se) and $MgB_2$. By expanding the capabilities of optical nanoscopy into the quantum regime, this work opens new frontiers for material characterization, quantum device diagnostics, and the future of scalable quantum technologies.

The expected outcomes will directly impact quantum computing, superconducting circuit design, and low-temperature photonics, fostering external funding opportunities in quantum sensing and materials research. This project directly aligns with the goals of the OVPR seed grant by laying the groundwork for future external proposals focused on **quantum sensing, superconducting circuits, and materials-driven quantum information science**.