Towards Fast Neutral Atom Imaging Enabled by SNSPDs

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Superconducting nanowire single photon detectors (SNSPDs) are a cornerstone technology for low-noise, high-efficiency photon counting, enabling advances across quantum science. Improvements in efficiency, timing resolution, and scalability make SNSPDs well-suited for demanding tasks requiring precise, rapid photon imaging. In neutral atom quantum computing, rapid scaling to thousands of qubits drives the need for fast imaging capable of supporting mid-circuit measurements for quantum error correction. Experiments have demonstrated fluorescence imaging of up to 6,100 atoms over 10s of microseconds using commercial cameras[1], but these systems lack the photon detection efficiency and readout speeds necessary to perform real-time feedback across thousands of atoms, creating a bottleneck for scaling error-corrected operations.

This work explores SNSPD-based alternatives to conventional camera readout for neutral-atom platforms. We investigate the thermally coupled imager (TCI) architecture[2] as a multiplexing strategy for large SNSPD arrays, in which localized detector events thermally excite a shared superconducting transmission line. Monte Carlo simulations of TCI buses with over 100 pixels identify regimes supporting high count rates with low misidentification error, enabling chip-scale imaging of >4,000 atoms within 50 microseconds.

To probe TCI operation and SNSPD scaling, we build an imaging platform in which spatial light modulator-generated optical tweezer arrays emulate atomic ensembles. By applying controlled optical stimulation to the TCI-coupled SNSPDs, we investigate the underlying bus dynamics and error mechanisms, providing experimental insights for future scaling. Building on these insights, we aim to demonstrate a low-latency imaging platform compatible with the scaling and mid-circuit measurement requirements of neutral atom quantum computing.

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References

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