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Active and Passive Control of Individual Atoms with Optical Cavities for Scalable Networked Quantum Processors

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Abstract
Arrays of individually trapped atoms are a promising platform for quantum information processing. Recent progress in this field includes increasing array sizes to thousands of atoms, demonstrating logical quantum operations, and achieving two-qubit gate fidelity exceeding 99.5%. Despite these advances, utility-level atomic quantum processors are expected to require millions of qubits operating under rapid quantum error correction. Optical cavities provide a route to scaling atomic quantum processors while improving system performance.

In this talk, I describe the integration of an optical bow-tie cavity with an array of cesium atoms, enabling a variety of active and passive control techniques. Dispersive light-matter coupling allows fast, nondestructive measurements for observing individual atomic collisions, as well as feedback control of atom number and temperature. Tailored light-matter coupling further supports passive cavity cooling to the atomic ground state and directional control of photon emission through the geometric structure of an atom array or through chiral cavity coupling of a single atom. These works highlight the power of optical cavities for advancing neutral-atom quantum computing as efficient photonic interfaces that enhance connectivity and enable scaling to utility-level system sizes.

Bio
David Spierings completed his B.Sc. at Harvey Mudd College in 2014, followed by an M.Sc. in 2015 and a Ph.D. in 2022 at the University of Toronto, under the mentorship of Professor Aephraim Steinberg. His doctoral work led to the first-ever measurement of the time atoms spend inside a barrier while tunneling—a longstanding question in quantum mechanics. He then received a Mitacs industrial postdoctoral fellowship to develop optical technologies for connecting distant quantum computers, addressing a key challenge in the development of scalable quantum computing systems. In 2023, he joined the Vuletić lab at MIT as a postdoctoral associate, where he has developed an array of individually trapped cesium atoms coupled to an optical cavity to enable strong light-matter interactions at the single-atom and single-photon level. His research spans neutral-atom quantum computing technologies and collective, many-body atomic physics.

Host
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