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Progress on trap-integrated qubit control and readout for scalable trapped ion quantum computing

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The integration of qubit control and readout elements into microfabricated surface-electrode ion traps offers potential advantages for scaling to larger trapped-ion systems. We report progress on two efforts in this direction. First, we present measurements of improved trap-integrated superconducting photon detectors for qubit fluorescence readout. The detectors are shielded from the trap rf, enabling operation in a fully functional trap at temperatures up to 6 K, and should be suitable for high-fidelity readout of trapped Ca^+ ions. Second, we describe progress towards a mixed-species architecture based on laser-free quantum logic operations driven using trap-integrated current-carrying electrodes. We combine an entirely laser-free "data" species ($^{25}Mg^+$), which encodes quantum information in hyperfine states, with a co-trapped auxiliary "helper" species ($^{40}Ca^+$) that provides sympathetic cooling and quantum-logic-based state preparation/readout of the data ions. Only low-power resonant lasers are required for the helper species, making the architecture compatible with trap-integrated waveguides for laser light delivery across many trap zones. All operations on the data ions, and some on the helper ions, are driven using magnetic fields and magnetic field gradients generated by currents in the trap electrodes. This architecture eliminates memory errors/readout crosstalk from stray data qubit laser light, offers the potential for extremely low data qubit SPAM errors, and should enable high-fidelity, individually-addressable laser-free single-qubit and two-qubit operations carried out in parallel across many trap zones in the quantum CCD architecture.

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