Same-species sympathetic cooling of trapped ions

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Trapped ions are a promising hardware platform for quantum computing as they unite properties like long coherence times, high gate fidelities, low state preparation and measurement errors, and networking capabilities. While running algorithms composed of long gate sequences on trapped-ion quantum computers, it is essential to cool the ions' motional modes in order to minimize errors caused by motional heating. This can be achieved by sympathetically cooling the logic ion with an ion of a different species, such that the laser beams required for cooling one ion do not affect the information stored in the other. However, this approach significantly increases the hardware complexity, and the difference in mass between the ion species leads to a suboptimal cooling efficiency.

Using microwave-driven sideband cooling in combination with a narrow-linewidth quadrupole laser at 729 nm, we demonstrate sympathetic cooling with two ions of the same species to the motional ground state. Due to the large hyperfine splitting of the $^{43}Ca^{+}$ ground-state manifold at 28.8 T, the information stored in the logic ion is well-isolated from the cooling process and the introduced error ($\lesssim 5 \cdot 10^{-3}$ per second) does not limit algorithm performance.
In addition to reducing hardware complexity and increasing cooling efficiency, same-species sympathetic cooling offers the benefit that, between cooling cycles, the coolant ions could be repurposed as ancilla qubits for error correction schemes.

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