

# Scaling Up Quantum Simulation Using Ion Chains

**M. Cetina**<sup>\*1,2</sup>, **T. Wang**<sup>1,2</sup>, **J. Tost**<sup>1,2</sup>, **E. Wette**<sup>1,2</sup>, **N. Taylor**<sup>1,3</sup>

*1. Duke Quantum Center, 701 W Main St, Durham, NC, 27701, USA*

*2. Duke University Department of Physics*

*3. Duke University Department of Electrical and Computer Engineering*

Trapped ions have demonstrated the highest gate fidelities of any quantum platform. However, scaling to thousands of qubits while preserving qubit connectivity remains a challenge.

Here, I present two routes to scaling ion-based quantum simulation based on linear ion chains. In one approach, mixed-species chains of  $^{171}\text{Yb}^+$  and  $^{172}\text{Yb}^+$  ions are trapped in a room-temperature microfabricated trap. Sympathetic laser cooling on a narrow transition using  $^{172}\text{Yb}^+$  ions counters the effects of motional heating and allows long gate operations on chains of up to 27 ions. Simultaneous cooling [1] and combined digital/analog operations open the door to the simulation of spin-boson systems with engineered dissipation.

In another approach, an optical cavity is integrated coaxially with a silicon microfabricated surface electrode trap for chains of individually addressable  $\text{Ba}^+$  ions. We align the cavity to the ion trap with sub-10  $\mu\text{m}$  precision and achieve finesse of about 5,000, corresponding to predicted peak single ion-photon cooperativity  $\eta = 0.2$ . I will report on the mechanical resonances, initial bakeout, cavity performance, and ion trapping in this system. This ion-cavity system may be used to realize a coherent, single-photon interface between spatially separated ion chains with multi-kHz entanglement rates [2]. The cavity mode can also form a blue-detuned optical lattice to suppress the motion of ions along the axial direction of the ion chain. This may allow individual addressing and controlled spin-spin interactions in chains up to 50  $\text{Ba}^+$  ions with multiple internal states, with applications to quantum simulation.

## References

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\*marko.cetina@duke.edu