HARVARD UNIVERSITY
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Mathematical Picture Language Seminar

Tuesday, March 3

4:00 p.m. Boston time

Jefferson 256 and Zoom

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A fault-tolerant neutral-atom architecture for universal quantum computation

Abstract: Quantum error correction enables coherent computation on encoded logical qubits while simultaneously removing errors from the underlying physical qubits. Here we utilize reconfigurable arrays of up to 448 neutral atoms to experimentally explore the key elements of a fault-tolerant quantum processing architecture, including below-threshold correction, fault-tolerant gate operations, universality, and physical error removal during deep-circuit computation. We first demonstrate performance of 2.14(13)x below-threshold in a four-round characterization circuit on individual surface codes, leveraging loss detection and machine learning decoding. We further explore the physics of repeated error correction in logical entanglement based on transversal gates and lattice surgery and extend to universal logic using transversal teleportation with 3D color codes for analog-angle synthesis. Finally, we demonstrate a method for mid-circuit qubit re-use, increasing the experimental cycle rate by two orders of magnitude and implementing deep-circuit protocols involving hundreds of logical teleportations while maintaining constant internal entropy. These results establish foundations for scalable, universal error-corrected processing and its practical implementation with neutral atom systems.

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