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Cryogenic Linear Ion Trap for Large-Scale Quantum Simulations[1]

GUIDO PAGANO, PAUL HESS, HARVEY KAPLAN, ERIC BIRCKELBAW, MICAH HERNANEZ, AARON LEE, JAKE SMITH, JIEHANG ZHANG, CHRISTOPHER MONROE, Joint Quantum Institute, University of Maryland Department of Physics and National Institute of Standards and Technology, College Park, Maryland 2074 — Ions confined in RF Paul traps are a useful tool for quantum simulation of long-range spin-spin interaction models. As the system size increases, classical simulation methods become incapable of modeling the exponentially growing Hilbert space, necessitating quantum simulation for precise predictions. Current experiments are limited to less than 30 qubits due to collisions with background gas that regularly destroys the ion crystal. We present progress toward the construction of a cryogenic ion trap apparatus, which uses differential cryopumping to reduce vacuum pressure to a level where collisions do not occur. This should allow robust trapping of about 100 ions/qubits in a single chain with long lifetimes. Such a long chain will provide a platform to investigate simultaneously cooling of various vibrational modes and will enable quantum simulations that outperform their classical counterpart. Our apparatus will provide a powerful test-bed to investigate a large variety of Hamiltonians, including spin 1 and spin 1/2 systems with Ising or XY interactions.

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