Phonon-qubit hybrid quantum simulation with trapped ions

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Abstract:

Trapped-ion systems are a leading platform for quantum computing, but achieving scalability to large system sizes remains a challenge. In order to significantly increase the available Hilbert space, we incorporate the quantized vibrational (motional) modes originating from the ion confinement directly into the computational toolkit. This talk presents experiments demonstrating this capability in a chain of individually addressed Ytterbium ions. We present an analog-digital hybrid simulation of the Yukawa model, a simplified model of interacting nucleons and pions. High-energy physics models of this kind are notoriously challenging for both classical and quantum computers due to the complex interactions involved and the infinite-dimensional bosonic Hilbert space, which is costly to map to qubits. The motional modes of trapped ions provide a natural, direct representation for these bosons. We present results from the first analog-digital hybrid quantum simulation of the Yukawa model that combines digital gates on qubits with motional modes along multiple directions, demonstrating the substantial resource savings offered by this approach for simulating complex field theories.

We also present recent quantum applications on commercial quantum computers from our quantum computing user facility, QLab, at the University of Maryland.