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Digital simulation of a 1D spin chain in qudits

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Digital quantum simulation is an exciting near-term application of NISQ quantum devices. The re-programmable digital approach allows them to emulate a wide range of interesting materials, such as topological matter or large molecules, that have proven too complex to understand using classical physics and standard computation. Digital simulation combines the tool-set of quantum information with high performance gate-based evolution [1], enabling the use of quantum control and error mitigation protocols designed for gate-based algorithms [2, 3]. The high fidelities and long coherence times of trapped ion systems make them an excellent candidate to demonstrate digital quantum simulation.

Here we will demonstrate the quantum simulation of a topological spin chain on a trapped-ion quantum processor. In this work, we utilize qudits to directly simulate higher-dimensional spin systems in nature. We generate the spin chain sequentially using an ancilla qubit [4] and verify the expected properties of the state. In particular, we probe error-robust edge modes that arise due to topological symmetry in our material, and study the correlations and entanglement behaviour between qudits.

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[4] Schön, C. et al., "Sequential generation of matrix-product states in cavity QED", Phys. Rev. A 75, 032311 (2007).

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