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Digital Quantum Simulation of Heisenberg Spin-Spin Interactions with Superconducting Qubits Y. SALATHE, M. MONDAL, P. KURPIERS, M. OPPLIGER, L. STEFFEN, S. FILIPP, A. WALLRAFF, ETH Zurich, A. MEZZACAPO, U. LAS HERAS, L. LAMATA, E. SOLANO, University of the Basque Country, Bilbao — A major application of a scalable quantum computer is the simulation of intricate quantum systems, including spin models, which cannot be carried out efficiently on classical computers for more than a few tens of qubits. The Heisenberg model describes a spin system that cannot be obtained directly from available interactions in circuit QED. Nevertheless, it can be achieved by a stroboscopic decomposition in terms of elementary gates in a digital quantum simulation approach. In our experiments, we digitally simulate a system of two spin-1/2 particles interacting via an isotropic Heisenberg XYZ interaction in the circuit QED architecture. The XYZ interaction is decomposed into a set of discrete two-qubit gates based on the exchange interaction mediated by the dispersive coupling of both qubits to a common cavity mode. The state evolution during the simulation is analyzed tomographically after each step for varying interaction strengths. This technique can be extended to general spin models, such that our experiments represent a first step towards the digital quantum simulation of larger spin systems with controllable lattice topology.

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