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Simulation of Quantum Chaotic Dynamics with Superconducting Qubits: A Blueprint for Quantum Supremacy

The long coherence times achieved in the scalable superconducting transmon qubit architecture allow realization of complex many-body dynamics of highly entangled quantum states. Each transmon qubit is a weakly non-linear quantum oscillator and allowing multi-photon excitation of each qubit results in a non-trivial many-body quantum system already in the one-dimensional chain geometry. In this work we develop a theoretical model of a chain of inductively coupled transmon qubits. The driven unitary evolution of this system generates quantum chaotic states. We analyze physical characteristics of the final wave function statistics, Lyapunov-type exponents and entanglement dynamics in this system in various parameter regimes. We argue that in the chaotic regime the task of sampling the output wave function distribution with random model parameters is likely to be exponentially hard to simulate on a classical computer. It is therefore a route to achieve the so-called quantum supremacy on superconducting hardware.
