Quasi-2D Time Crystals on NISQ Hardware: Challenges & Opportunities

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Recent advancements have showcased the capability of noisy intermediate-scale quantum (NISQ) hardware to create many-body localization using a one-dimensional chain of spins, subjected to periodic driving [1-5]. These implementations reveal several useful features, including period multiplicity under periodic driving, retention of initial state information amidst noise, and other characteristics indicative of a phase of matter known as a discrete time crystal (DTC). However, these demonstrations have primarily been confined to one-dimensional systems. It has been suggested that the distinctive traits of a DTC might extend to two-dimensional and quasi-two-dimensional lattice structures [6]. In this study, we leverage cutting-edge NISQ hardware (IBM Torino) to simulate the dynamics of a quasi-two-dimensional heavy-hexagonal spin ½ lattice. Our investigation unveils approximate period doubling phenomena and robustness of dynamics against noise interference. Additionally, we address the intricacies associated with implementation of these lattices on NISQ devices and outline avenues for further exploration into the characteristic signatures of many-body localization.

References

[1] M. Ippoliti *et al.*, PRX Quantum 2 (2021), 030346.
[2] X. Mi *et al.*, Nature 601 (2022), 531.
[3] A. Smith *et al.*, npj Quantum Inf 5 (2019), 1.
[4] P. Frey and S. Rachel, Science Advances 8 (2022), eabm7652.
[5] V. Zhang and P. D. Nation, arXiv: 2301.07625 (2023).
[6] C. Sims, Crystals 13 (2023), 1188.

Figures

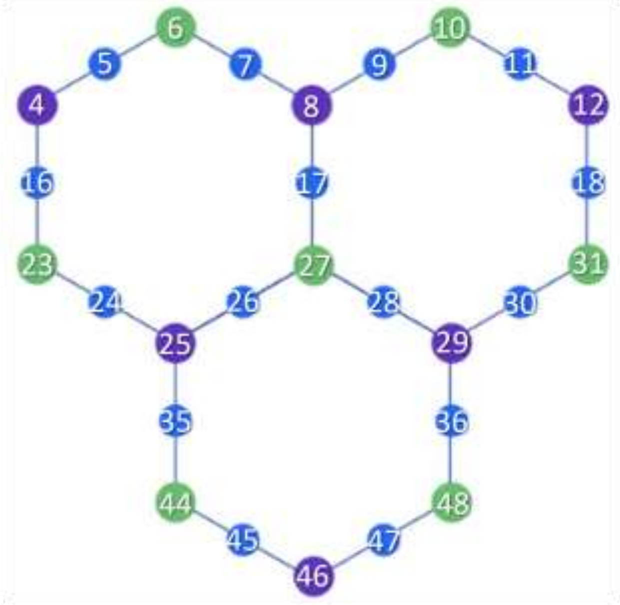

Figure 1: Subset of 28 qubits in a heavy-hex lattice (quasi-2D) geometry, with the corresponding physical qubit index label. A total of 125 qubits (18 hexagons) is used on IBM Torino.

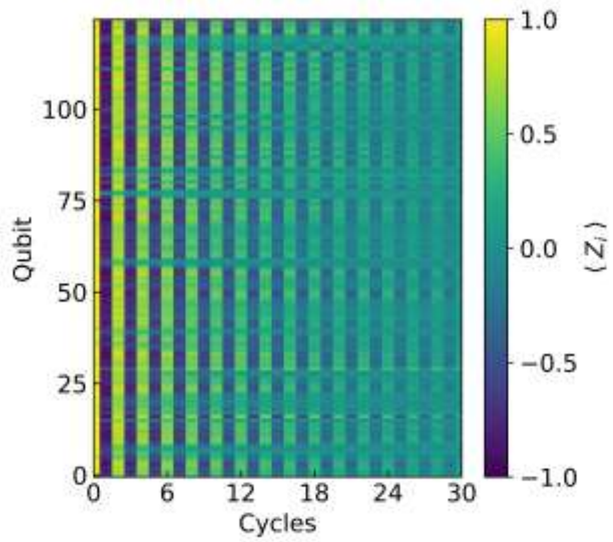

Figure 2: Polarization per qubit as a function of time (Floquet cycles) for the geometry described in Figure 1, for a single realization of disorder. The polarization exhibits approximate period doubling, a necessary component for a discrete time crystal.