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Measurement-Induced Phase Transition in Free Fermionic Systems

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This project investigates the dynamics of Measurement-Induced Phase Transitions (MIPT) within non-interacting free-fermionic systems, exploring the competition between unitary evolution, which drives information scrambling, and stochastic projective measurements, which induce disentanglement. By employing the Fermionic Gaussian State (FGS) formalism and Peschel's trick, the simulation tracks the time-evolution of the system's correlation matrix with polynomial complexity $\mathcal{O}(L^3)$, avoiding the exponential cost associated with generic quantum states.
The study focuses on a tight-binding Hamiltonian applied to two distinct topologies: a one-dimensional periodic chain and a two-dimensional torus. To characterize the phase transition, three primary observables were calculated: von Neumann Entanglement Entropy, Inverse Participation Ratio (IPR), and Summed Point-to-Point Mutual Information.
The results demonstrate a fundamental dependence on system dimensionality. Finite-size scaling analysis reveals that the 1D system is fragile to measurements, exhibiting no stable volume-law phase in the thermodynamic limit, effectively yielding a critical probability of $p_c = 0$. In contrast, the 2D system sustains a robust entangled phase against weak monitoring, with a phase transition occurring at a finite critical measurement probability in the interval $0.2 < p_c < 0.3$. These findings validate the developed computational framework for simulating measurement-induced dynamics in free fermions.

Field of Research/Work

Condensed Matter and Materials

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