Quantum information spreading measured by out-of-time-order correlations with magnetic resonance

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Abstract The development of quantum technologies requires reliable processing of quantum information on large quantum systems. This is highly challenging as quantum systems are more sensitive to perturbations with increasing system size. In the last years, out-of-time-order correlations (OTOC) have gained special interest for measuring sensitivity to perturbations of many-body systems [1]. These OTOCs can be experimentally measured with time reversion of quantum evolutions, on which the reversion is considered perfect [1]. However, in practice the time reversion always contains imperfections. We study the spreading of information from a local state by monitoring OTOC dynamics [2,3]. We perform quantum simulations with solid-state Nuclear Magnetic Resonance.

Keywords Quantum Information, NMR, information scrambling

We engineered a ½-spin system Hamiltonian and we add a variable perturbation [2,3]. When the perturbation interaction Hamiltonian is not reverted in time, we observe a localized spreading of information by the OTOC dynamic (orange dots, Fig. 1). The OTOC measures the effective cluster size of spins that were correlated by the ideal -control- Hamiltonian. If the perturbation is included in the time reversion, the localization effects are not manifested, and the information spreads over the system indefinitely (blue dots, Fig. 1). We also measured the decoherence rate of the spin system and we observe qualitatively different results in the cases with total reversion and with imperfect reversion (Fig. 2). The decoherence rate saturates when localization effects are manifested, while in the other case grows indefinitely as the cluster-size increases with time. These results provide a new tool to determine the maximum system size that can be controlled in realistic experimental setups with unavoidable imperfect control operations [4].

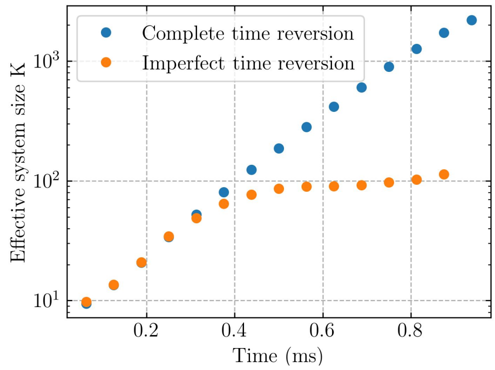

Figure 1 Effective system size $K(t)$ of correlated spins as a function of time. K quantifies the information scrambling.

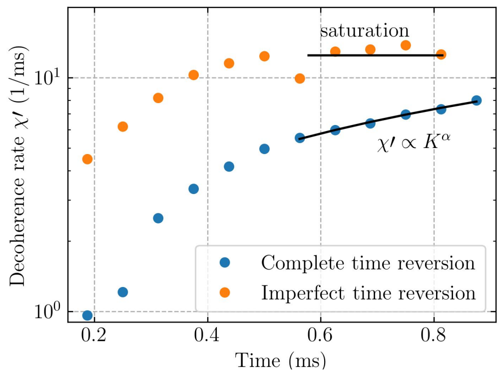

Figure 2 Decoherence rate of the time reversal echo (Loschmidt Echo) as a function of time.

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