Entangled states of dipolar magnetic atoms in multimode traps

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Abstract

The controlled generation and certification of entangled many-body states is a fundamental task in quantum simulation with ultracold atoms. Here we studied theoretically the generation of highly entangled states among the large spins of magnetic atoms (such as Chromium, Erbium or Dysprosium) trapped in multi-mode traps, and interacting at long distance via dipolar XXZ interactions- such systems offer a paradigmatic exemple of ensembles of interacting qudits.

We considered two situations of experimental relevance: 1) initializing a 1d lattice of large spins (one particle per site) in a coherent spin state with alternating orientations, we show that the ensuing non-equilibrium dynamics leads to the formation of a Schrödinger's cat state. The appearance of such a state in the dynamics can be proven analytically for two spins; for a larger number of spins, we show that the cat state formation is closely related to weak ergodicity breaking of the dynamics and quantum scars in the many-body spectrum; 2) two large spin ensembles are trapped in two separated modes, and undergo an entangling dynamics due to dipolar interactions – which is nonetheless hindered by atom losses due to dipolar relaxation. We model the dissipative dynamics of the system, and probe the robustness to losses of bipartite entanglement, as certified through a recent criterion based on collective-spin correlations.

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