Inhomogeneous entanglement structure in monoaxial chiral ferromagnetic quantum spin chain

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We study the entanglement properties of a one-dimensional monoaxial chiral ferromagnetic quantum spin chain under an external magnetic field. The model consists of spin-1/2 moments with exchange interaction, Dzyaloshinskii–Moriya interaction, and a Zeeman term, which classically supports helical and chiral soliton lattice states commonly observed in chiral magnetic materials [1].

Using large-scale density matrix renormalization group (DMRG) calculations, we demonstrate that the ground-state entanglement entropy exhibits a pronounced spatial modulation reflecting the inhomogeneous spin texture. The oscillatory pattern of the entanglement entropy is strongly correlated with the positions of solitons, as identified by local magnetization and spin chirality profiles. This establishes a direct correspondence between quantum entanglement and solitonic spin structures in chiral magnets.

We further show that the number and amplitude of these oscillations can be controlled by the magnetic field. With increasing field strength, solitons are gradually expelled from the system, and the entanglement entropy evolves toward a uniform, vanishing profile in the fully polarized ferromagnetic phase. Notably, the entanglement entropy is more sensitive to transitions between different soliton-number sectors than conventional magnetic observables such as total magnetization.

Our results highlight entanglement entropy as a novel diagnostic of inhomogeneous and topological spin states in quantum chiral magnets, providing a new perspective on quantum effects in soliton-bearing magnetic systems and offering potential relevance for quantum simulators and low-dimensional magnetic materials.

References:

[1] K. Nishimura and R. Yoshii, arXiv:2504.08273 (2025).