Decoherence of Chiral Magnon Edge Modes in a Topological Bosonic Chern Insulator

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Topological magnonic systems host chiral edge modes that propagate unidirectionally along system boundaries without elastic backscattering. Understanding how these modes lose coherence in realistic environments is essential both for fundamental studies and for magnon-based information transport. In this work, we present a comprehensive theoretical analysis of decoherence in chiral magnon edge modes of a honeycomb ferromagnet with Dzyaloshinskii–Moriya interactions. Starting from a microscopic spin Hamiltonian, we perform a Holstein–Primakoff expansion to derive the bosonic Haldane model and compute the full edge dispersion in a zigzag ribbon geometry. Using these numerically resolved edge wavefunctions, we construct a momentum-resolved open-quantum-system description and derive a Lindblad master equation within the Born–Markov and secular approximations. Analytical expressions for relaxation, thermal excitation, and pure-dephasing rates are obtained, revealing which decoherence pathways are topology-constrained and which remain unaffected by the Chern number. Our numerical simulations show strong momentum and temperature dependence of coherence times, identify regimes where edge localization enhances robustness, and provide experimentally accessible predictions for linewidths, coherence decay, and entanglement loss in squeezed magnon states. The framework developed here establishes a unified route combining spin-wave theory, ribbon-geometry band calculations, and dissipative quantum dynamics, offering a pedagogical reference for decoherence in topological magnonic systems.

References:

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