Universal Theory of Temperature-Dependent Domain-Wall Widths in Uniaxial Heisenberg Magnets

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Magnetic textures, such as domain walls, play a central role in spintronic phenomena and are particularly appealing in ferrimagnets, where the combination of ferromagnetic controllability and antiferromagnetic speed [1] enables rapid and efficient manipulation. Nevertheless, a comprehensive understanding of how domain walls evolve with temperature in ferrimagnets is still lacking. In particular, no general analytical framework has yet been established to describe the temperature dependence of domain-wall width across different magnetic orders [2].

For ferromagnetic systems, the domain-wall width is conventionally determined by the competition between exchange interactions, described by the exchange stiffness parameter A, and the magnetic anisotropy K. This competition leads to the well-known expression $\delta = \sqrt{A/K}$, providing a tool to design magnets with domain walls from a few to hundreds of nanometers. However, these prediction have no yet been extended to more complex magnetic orders.

In this work, we present a universal analytical expression for the domain-wall width in Heisenberg magnets, including ferri-, ferro-, and antiferromagnetic systems. The derivation explores the link between the spin-wave spectrum and the effective parameters governing domain-wall profiles, providing a unified description across diverse magnetic orders. Temperature effects are included via a many-body Green-function formalism, capturing thermal renormalization of spin-model parameters and enabling an accurate description of the domain wall width up to the magnetic ordering transition [3]. The results are validated with atomistic spin dynamics simulations, showing solid agreement across a wide range of temperatures and material parameters.

References:

[1] J. Barker and U. Atxitia, J. Phys. Soc. Jpn. 90 (2021) 081001

[2] R. Moreno, P. G. Bercoff, et al. Phys. Rev. B 111 (2025) 184416

[3] L. Rózsa and U. Atxitia, Phys. Rev. Res. 5 (2023) 023139

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