Relativistic Dynamics of Antiferromagnetic Domain Walls: Route to Chaos

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Abstract

This research examines the dynamic behavior of antiferromagnetic domain walls (AFM-DW) under the influence of a harmonically time-varying spin-orbit field, with a special focus on its applicability in reservoir computing systems. By employing the Landau-Lifshitz-Gilbert (LLG) equation to simulate the temporal evolution of spins within the Mn2Au structure, our findings reveal that when approaching the maximum spin-wave group velocity, not only do they undergo Lorentz contraction and emit spin waves at terahertz frequencies [1], but we also observe a breakdown of the domain walls and a proliferation of DWs [2], depicting behaviors that break Lorentz invariance.

In the context of reservoir computing, we observe that domain walls can serve as memory and processing elements, maintaining a record of the system's dynamic state. Analysis of dynamics across different regimes, from periodic to chaotic, unveils the potential for manipulating these structures to perform complex computational tasks. Complexity indicators and phase diagrams provide a clear characterization of system behavior, enabling the distinction between periodic and chaotic states and facilitating predictions of system behavior under various conditions.

We propose a reservoir computing scheme that leverages the inherent stability and complexity of AFM-DWs. The process starts with the induction of domain wall proliferation through an alternating field, followed by a relaxation period to stabilize the system. The remaining domain walls constitute a reservoir that preserves the memory of the system's previous states, thus offering a platform for neuromorphic computing [3]. Our approach points to a path towards ultra-fast and energy-efficient computing, harnessing the speed and dynamic richness of antiferromagnetic materials.

Keywords: antiferromagnetic domain walls, spin-orbit fields, reservoir computing, deterministic chaos, relativistic dynamics.

Reference

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