Stochastic Dynamics of Skyrmions on a Racetrack: Impact of Equilibrium and Nonequilibrium Noise

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Current-driven motion of domain walls and skyrmions is central to the operation of non-volatile magnetic memory devices [1,2]. Racetrack memory requires current densities high enough to generate velocities above 50 m/s, but such conditions also enhance spin-current noise [3]. We develop a theoretical framework based on the stochastic Thiele equation to analyze the effects of equilibrium (thermal) and nonequilibrium (spin-current) fluctuations on skyrmion dynamics. From this approach, we derive diffusion coefficients and mean-squared displacements that quantify stochastic motion under both noise sources. Micromagnetic simulations and analytical results demonstrate that spin-current noise dominates skyrmion dynamics in typical racetrack structures up to room temperature. We further address the first-passage-time problem, obtaining the mean first-passage time and its standard deviation along and across the racetrack. These results quantify how random displacements affect skyrmion propagation and detection, providing insights into error sources in high-speed racetrack memory devices.

References:

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[3] A. Fert et al., Nat. Nanotechnol. 8 (2013) 152.