Prof. Dr. Jairo Sinova
Institut für Physik, SPICE
sinova@uni-mainz.de

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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Theory of Condensed Matter: Hard Condensed Matter

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Galilei room, 01-128 (Staudinger Weg 9)

Jonathan Leliaert
Dept. of Solid State Sciences, Universität Gent, Belgien

Thermally driven micromagnetic systems

Thermal fluctuations have always been a topic of interest in micromagnetism. Theoretical descriptions already date back to the fifties as W. F. Brown derived and presented the statistical properties of the randomly fluctuating thermal field required to physically describe the switching behaviour of single-domain nanoparticles. In this talk, I present the results of 2 studies on the measurement and simulation of thermally driven magnetization dynamics.

In the first part, the switching of magnetic nanoparticles is investigated via an experimental study, introducing a new method for magnetic nanoparticle characterization: Thermal magnetic noise spectroscopy. Typically, particle characterization is performed by measuring the particles' response to an external excitation like an applied field. However, such excitations are known to alter the nanoparticle's aggregation state and thus affect the characterization results. Recently, we demonstrated the feasibility of measuring the thermal magnetic noise emitted by magnetic nanoparticles in the absence of any excitation. The magnetic particles' noise spectrum was recorded using a SQUID in a magnetically shielded environment and the recorded spectra could then be interpreted in order to characterize the magnetic nanoparticles.

The second part of the talk deals with the thermally activated motion of domain walls in a magnetic nanowire. Because each finite-difference cell in micromagnetic simulations can be considered as a single-domain "particle", the thermal field described by Brown can be added as an effective field term in the Landau-Lifshitz-Gilbert equation. Using large- scale micromagnetic simulations, we explore the current-driven creep regime of a transverse domain wall in disordered Permalloy nanostrips. Our results show that the domain wall creep velocity exhibits a simple linear dependence on the

current density instead of the highly non-linear creep scaling law usually encountered in rough elastic systems. To explain this, we derived an equation describing the motion of a current-driven domain wall in a disordered nanowire at finite temperatures. In contrast to the creep scaling law found in elastic systems, this equation is only valid for domain walls sufficiently small to be described as rigid objects. We validated this equation against experimental data and our micromagnetic simulations and could conclude that the domain walls under study can indeed be described as a rigid object instead of an elastic line.
The ongoing miniaturization of spintronic devices dictates that thermal effects will become increasingly important in micromagnetic research, and the two presented systems show that they can accurately be taken into account in numerical studies and can even be exploited in technological applications.

Contact:
Hjördis Pusch
hjopusch@uni-mainz.de