SIMULATIONS OF MAGNETIZATION SWITCHING IN IRON NANOPILLARS

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Introduction

Magnetic nanoparticles are promising materials for ultra-high density magnetic recording [1]. In this project we simulate magnetization switching in such particles using the finite-temperature Landau-Lifshitz-Gilbert (LLG) stochastic differential equation for the local magnetization \( \mathbf{M}(\mathbf{r}_i) \), subject to a local field \( \mathbf{H}(\mathbf{r}_i) \),

\[
\frac{d\mathbf{M}(\mathbf{r}_i)}{dt} = \frac{\gamma_0}{1 + \alpha^2} \mathbf{M}(\mathbf{r}_i) \times \left( \mathbf{H}(\mathbf{r}_i) - \frac{\alpha}{M_s} \mathbf{M}(\mathbf{r}_i) \times \mathbf{H}(\mathbf{r}_i) \right)
\]

The local field includes exchange and magnetostatic interactions, anisotropy, and random thermal fluctuations. The intensity of the fluctuation field is related to the temperature through a fluctuation-dissipation relation [2].

Results and Discussion

Visualization of the results is essential for extracting physical understanding from the simulations. Figure 1 shows such a visualization of the internal magnetic flux lines in a simulated 9 nm x 9 nm x 150 nm Fe nanopillar [3]. Simulations of switching in an obliquely oriented magnetic field shows two different switching modes, one very fast, and one much slower. The slow mode corresponds to exit from a metastable free-energy well, while the metastable state appears to be avoided by the fast mode [2].

![Figure 1. Magnetic flux lines in a Fe nanopillar in an applied magnetic field at an angle of 75° to the long axis. Initially, the pillar is in the metastable state, with most of its spins aligned antiparallel to the z-component of the applied field. Red: metastable direction. Blue: stable direction. Left: at absolute zero temperature, 0 K. Middle: at 20 K before switching. Right: at 20 K during switching.](image)

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References