Vortex and magnetization reversal dynamics in patterned structures imaged using time-resolved PEEM

D.J. Keavney, X.F. Han,* K. Guslienko, R. Divan, S.D. Bader

Argonne National Laboratory, Argonne, IL U.S.A.

Introduction

The dynamics of nanoscale magnetic structures are of both fundamental interest and primary importance for devices that incorporate nanomagnets into high-speed electronics. One of the principal questions is the behavior of magnetic vortices, as vortex phenomena offer insight into magnetization dynamics on a fundamental level and also govern the magnetic reversal of device structures. In magnetic devices, the shape of the structures can also have a strong effect on the fields needed and the time required for switching, with a corresponding impact on their real-world applicability. Therefore, techniques to characterize magnetic nanostructures with both high spatial and time resolution are crucial to understand how these structures respond to fast, time-dependent external magnetic field pulses, and to the more fundamental influence of finite size effects on magnetism.

Methods and Materials

Photoemission electron microscopy (PEEM) with soft x-ray excitation offers chemical and magnetic imaging at 100 nm resolution and can be used in a stroboscopic mode for a time resolution limited by the source x-ray pulse width. We have recently implemented this technique in sector 4 of the Advanced Photon Source and used it to examine dynamics in circular and elongated NiFe dots. In Fig. 1, we show a schematic of the pump-probe arrangement for acquiring time-resolved images. In circular structures, we followed the evolution of the vortex state after removal of an in-plane bias field.

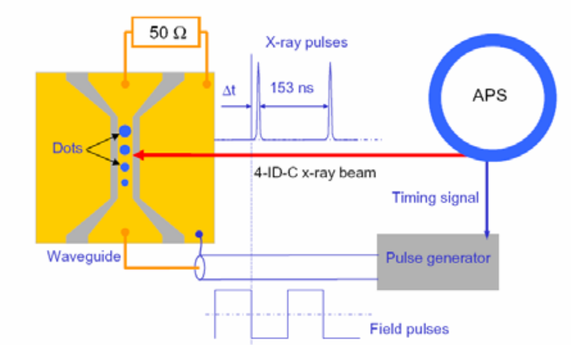

Fig. 1. Timing arrangement for stroboscopic time-resolved magnetic imaging. The field pulses generated by the coplanar waveguide are synchronized with the x-ray pulses with a variable delay, Δt. Domain images are taken of the nanostructures using the PEEM at varying delay times.

Results and Discussion

In previous work, a controversy has existed over the trajectory of the vortex core, and the frequencies of motion have not been measured. In Fig. 2, we show selected domain images of a 5.3μm NiFe disk after the removal of a 30Oe horizontal bias field, along with a plot of the vortex core position. We find that the vortex core position oscillates essentially perpendicular to the applied field with frequencies that are in agreement with theoretical predictions for a given aspect ratio.[1] Surprisingly, we detect no significant vortex motion *parallel* to the field as would be expected. In the elongated structures, we looked at the effect of end shape on the reversal of 2x7μm needles. We find that if the ends are rectangular, the dots reverse in a disordered way, with multiple domain nucleation points throughout the structure. As the ends become tapered, the reversal begins only at the center and moves out towards the ends. This reveals that undesirable magnetic instabilities in the rectangular dots can affect their switching and shows how they may be controlled by adjusting the shape.

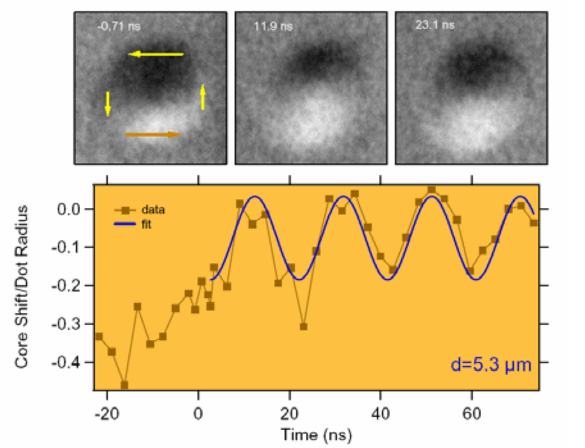

Fig. 2. Selected difference images of a 5.3μm diameter NiFe disk taken after the removal of a 30Oe bias field in the horizontal direction (top), with a plot of the vertical core displacement (bottom). A 30Oe bias field was applied for 75ns and removed at t=0. Magnetization directions given by the light/dark contrast are indicated by the arrows in the first image.

This work was supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

*Present Address: Seagate Technology, Minneapolis, MN U.S.A

References

[1] K. Yu. Guslienko, X.F. Han, D.J. Keavney, R. Divan, and S. D. Bader, Phys. Rev. Lett. **96**, 067205 (2006).