Imaging of magnetization dynamics in artificial ferromagnetic nanoscale structures

D.J. Keavney

Advanced Photon Source, Argonne National Laboratory, Argonne, IL USA

Artificial nanoscale magnets have recently experienced an enormous amount of interest. Nanomagnets form the building blocks for a new class of magneto-electronic devices, such as memory elements, sensors, and non-volatile logic devices. In these devices, the finite size of the structure plays a crucial role in both the static and dynamic spin properties. Of particular importance are the behaviors of magnetic vortices, domain walls, and spin currents.

We have used soft x-ray photoemission electron microscopy in a pump-probe arrangement to image the response of magnetic vortices and domain walls in artificially patterned $Ni_{80}Fe_{20}$ (Permalloy) structures to fast magnetic field pulses. In Permalloy disks, we find a strong dependence of the magnetic vortex core relaxation behavior on the excitation amplitude, indicative of non-linear magnetization dynamics. Below a critical field amplitude of ~2.5 mT, the core follows a damped circular oscillatory motion toward the center of the disk. However, above the critical field the trajectory of the core is dependent on the excitation amplitude, with elliptical trajectories appearing as the field is increased. The observed elliptical trajectories turn out to be associated with transient magnetic domain states that appear in the first 300ps of the core motion. These states result from non-linear magnetization dynamic processes that become significant when the core is displaced more than 20% of the disk radius. The non-linear phenomena are associated with distortions of the core and a cross-tie domain wall that promotes multiple core polarity reversals, profoundly influencing the core motion.

These time-resolved capabilities have contributed much to knowledge of magnetization dynamics in metals. However, even in these cases, where the dichroic effects at the L resonances are very strong, these experiments are flux-limited. New, higher brightness sources may enable a new class of experiments on dilute magnetic system, induced moments in semiconductors, and spin currents. In addition, shorter pulse lengths will allow the probing of ultrafast optically driven magnetization processes.

Work at Argonne National Laboratory is supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.