	Experiment title: Magnetization Dynamics in Exchange-Coupled Microstructures	**Experiment number:** HE-1437
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Report:

The time-resolved XPEEM experiments were performed during the 16-bunch operation mode. Contrary to expectations, the image intensities were high enough to allow for the use of the CCD camera detector. This significantly improved the image quality and enabled us to take image series at a fast pace. The time-resolution is mainly determined by the width of the light pulse (FWHM ~105 ps) and the electronic jitter in the set-up, and was estimated to about 130 ps. However, consecutive images taken with 125 ps time distance (Fig. 1) still exhibit clear differences and sharp structures. This suggests that the effective time-resolution is considerably better. The high repetition rate of ~5 MHz still provided enough time (176 ns) for the Permalloy patterns to relax back into the Landau-Lifshitz ground state in the field-free situation. It should be pointed out that each image represents the accumulation over 10^7–10^8 consecutive remagnetization events. The high image quality proves the reproducibility of these events in the Permalloy case. In the exchange-coupled trilayers, however, we encountered several problems, which may associated with both a frequency-dependent coercivity and nonreproducibility of the individual switching events.

In this report we concentrate on the results from the Permalloy microstructures. As the magnetic field pulse was about 8 ns (Fig. 2), we focused mainly on the response of the magnetic system at the leading and trailing edges of the pulse, where the largest changes occur. At the leading edge, the most important finding is the strong dependence of the response on the relative orientation between domain magnetization $\underline{M}$ and the pulse field $\underline{H}$ (Fig. 1). In the initial part of the leading edge, the domains with $\underline{M} \parallel \underline{H}$ and $\underline{M}$ □ $\underline{H}$ remain almost unchanged, whereas the areas with $\underline{M}$ *antiparallel* to $\underline{H}$ develop a rich stationary finestructure, which can best be described as a stripe-like or “ripple” contrast pattern. From a quantitative analysis of the contrast levels we are led to conclude that the initial domain magnetization breaks up into a sequence of stripe-like domains with $\underline{M}$ □ $\underline{H}$. This process is associated with an incoherent rotation of the local magnetization vector [1]. Further experiments with a bipolar field pulse show that the stripe-like patterns switch from the left to the right hand Landau-Lifshitz triangles and vice versa upon change of field polarity. This confirms that the observed phenomenon is not due to the geometrical configuration, but depends indeed only on the condition M □ H. If the field pulse reaches its maximum values, the other domains start to respond to the field by domain wall motion in a peculiar way (Fig. 2). The domain with M || H grows on the expense of the areas with M □ H. However, in contrast to a slow remagnetization process, in which the central vortex will be moved to the left (Figs. 2a' □ 2a''), also this vortex breaks up into at least two vortices during the fast remagnetization event. These vortices move along the boundary of the stripe-like boundary. In other words, the initially formed stripe-like structure basically blocks the entry of the domain walls into this region, thereby stabilizing it against complete magnetization reversal. This stabilization effect could be one of the microscopic mechanisms responsible for the enhanced coercivity at high frequencies. In addition, this situation is associated with a considerable stray field at the particle edge, as can be inferred from the associated image distortion due to Lorentz forces (Fig. 2d'). The reason for this peculiar behavior is not yet understood and requires both further experiments with higher spatial resolution and detailed time-dependent micromagnetic simulations. It will be particularly useful to investigate the formation and motion of the various types of vortex structures in these systems, and study their dependence on magnetic coupling parameters.

Some of the material has already been accepted for publication [1]. Another manuscript on the details of the incoherent magnetization rotation processes has been submitted to Appl. Phys. Lett.

References:

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[2] A. Kuksov, C.M. Schneider, A. Oelsner, A. Krasyuk, D. Neeb, G. Schönhense, C. de Nadaï, N. Brookes, J. Appl. Phys. (in print).

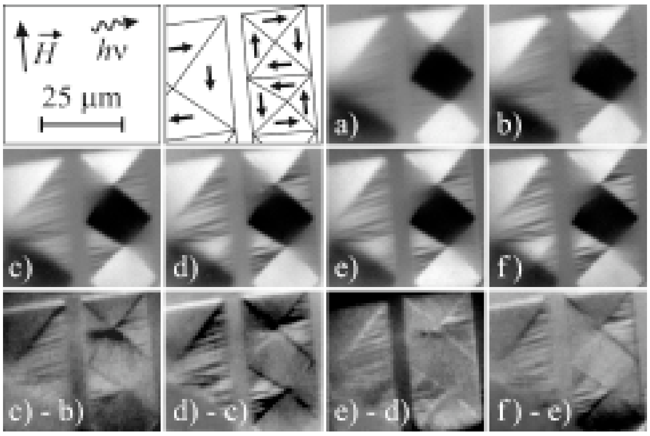

FIG. 1: Sequence of time-resolved XPEEM images of a Permalloy microstructure taken along the rising edge of a unipolar magnetic field pulse at t = 0 (a), 0.125 (b), 0.250 (c), 0.375 (d), 0.500 (e) and 0.625 ns (f). Directions of light incidence (projection on the sample surface) and remagnetization field H are indicated. A sketch of the particle domain structure in the field free state is also given.

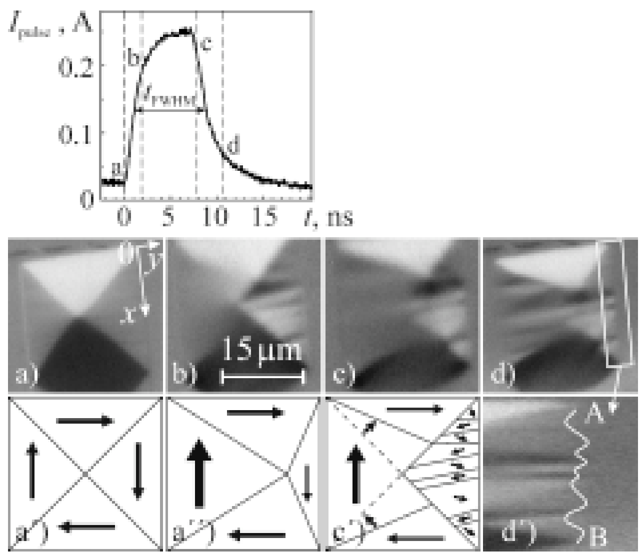

FIG. 2: Magnetic domain images of the top part of the narrow rectangle in Figure 1 mapping the unipolar field pulse (top panel) at t = 0 (a), 1.750 (b), 7.875 (c) and 10.875 ns (d). Area marked by a square in (d) is stretched by factor of 5 in horizontal direction (d'). Schematic images of expected behavior of the Landau structure (a') in a slowly varying field (a'') and formation of a stripe-like structure at t = 7.875 ns after the leading edge of the pulse. The white line traces the deformation profile of the right edge AB of the particle.