Coherent suppression of magnetization dynamics in circular microdots of Ni$_{81}$Fe$_{19}$ has been observed by time-resolved scanning Kerr effect microscopy. The applied pulsed field rose sharply, stimulating precession, and then exhibited an oscillatory behavior. For certain values of the static magnetic field the precession was suppressed at the point at which the magnetization lay in the sample plane. Time resolved images confirmed that coherent suppression had occurred at the center of the element, but nonuniformity was observed at the edges of the element, which became greater with decreasing aspect ratio. The nonuniform magnetization dynamics result from the dephasing of confined spin wave modes, suggesting that a more involved pulse shaping scheme may be required to coherently suppress the full mode spectrum. © 2005 American Institute of Physics.
$\mathbf{M}$ must first become aligned with the total effective field so that the torque upon the magnetization vanishes, and thereafter the total effective field must only change slowly. Since $\mathbf{H}$ and $\mathbf{h}$ lie within the sample plane (we neglect the small in-plane uniaxial anisotropy) and the demagnetizing field is antiparallel to the out-of-plane magnetization component, the magnetization can only become parallel to the total effective field if the magnetization lies within the sample plane. Suppression may then only be achieved for certain values of $H$ such that $\mathbf{H} + \mathbf{h}$ is parallel to $\mathbf{M}$ at this instant in time. From Fig. 1(c) we see that suppression indeed occurs at the point at which the out-of-plane component of magnetization vanishes.

In order to study the spatial character of the suppression mechanism, time-resolved images of S1 were acquired for the values of $H$ used in Fig. 1(c), and are presented in Figs. 2(a)–2(c) for four different time delays. The physical area of the element is shown by the intensity image included at the left. The gray scale represents the out-of-plane component of the instantaneous magnetization. At $H = 145$ and 732 Oe, alternative white and black contrast is observed in images obtained at positive and negative antinodes of the precessional motion, respectively. The images at all time delays are spatially uniform apart from very small nonuniform edge regions perpendicular to the direction of $\mathbf{H}$. For $H = 400$ Oe, where coherent suppression is expected to occur, the time resolved images are white and black at the first positive and negative antinodes before becoming gray after precession has been suppressed.

Figure 1(d) shows the time dependent Kerr rotation observed at the center of S3 for $H = 145$ Oe, $H = 380$ Oe and $H = 656$ Oe. For $H = 145$ and 656 Oe, long-lived precession is seen, whereas for $H = 380$ Oe, coherent suppression is achieved. The spatial character of the coherent suppression was again studied through the acquisition of time-resolved images at $H = 145$ and 380 Oe. The images are shown in Figs. 2(d) and 2(e) with their width scaled to match those in (a)–(c). The variation in contrast from left to right in the S3 images is an artifact resulting from a slight misalignment of the sample, whereas the variation in contrast from top to bottom shows the homogeneity of the magnetic response. At $H = 145$ Oe the central region alternates between light and dark at positive and negative antinodes, but the nonuniform edge regions perpendicular to $\mathbf{H}$ are found to be proportionately larger than for S1. Consequently, for $H = 380$ Oe the first two antinodes show light and dark contrast, and after coherent suppression has occurred, the images become gray, but with greater nonuniformity at the upper and lower edges than observed for S1. The nonuniform magnetic response cannot result from spatial nonuniformity of the pulsed field, or else the response of S1 would be expected to be less rather than more uniform than that of S3.

In a finite nonellipsoidal magnetic element, free magnetic poles at the edges of the element generate a nonuniform demagnetizing field in the static configuration. Regions where the demagnetizing field is nonuniform provide dynamic pinning and confined spin waves have been observed after application of a pulsed field both within the central region of the element\(^3\) and at the edges.\(^7\) The confinement depends upon the shape and aspect ratio of the elements. In order to study the effect of aspect ratio on the generation of spin waves in circular microdots we acquired time-resolved images of S1–S4. The time dependent Kerr rotation measured at the center of each element is shown in Fig. 3, with the scan for S4 clearly showing beating. The fast Fourier transform (FFT) spectra of S1–S3 show a single resonance mode but S4 shows two resonant modes. The time-resolved images of S1–S4 are presented in Fig. 4 for four different
time delays. The variation in contrast from left to right within the images of S2 and S3 is an artifact as mentioned previously. Nonuniformity is confined to near the edges perpendicular to $\mathbf{H}$, becoming proportionately larger from S1 to S3. However, for S4, the nonuniformity also spreads into the central area of the element, with a stripe pattern developing due to dephasing of spin wave modes within the central region.

Micromagnetic simulations, performed with the OOMMF software,$^{13}$ of the magnetization before the application of the pulsed field are shown in Fig. 4(b). The samples were divided into $250 \times 250$ cells and the arrows in each simulated image represent the in-plane magnetization sampled over 20 cells. The simulated images clearly show that the edge regions become more nonuniform from S1 to S4, as the aspect ratio decreases. These regions pin the spin waves excited in the center of the element and may confine additional modes at the edges. Coherent suppression requires the phase of the precession to be matched to that of the pulsed field in the manner described previously. The phase of the precession depends upon the mode frequency, which can be controlled by adjusting $\mathbf{H}$, as was shown for S1. However, when multiple modes of different frequency are present, the condition for suppression cannot be achieved for all modes simultaneously. In the case of S3, precession may therefore continue at the edges after suppression has been achieved at the center.

In conclusion, we have observed coherent suppression of magnetization precession in circular microdots of Ni$_{81}$Fe$_{19}$. The pulsed field rose within about 40 ps before oscillating with a period of about 400 ps. Coherent suppression was achieved by adjusting the static field so that there was no net torque acting upon the magnetization after one cycle of precession. The coherent suppression became more spatially nonuniform as the aspect ratio of the element was decreased. Time-resolved Kerr images and simulations of the demagnetizing field within samples with aspect ratio in the range of 454–67 suggest that increased nonuniformity results from confinement and dephasing of multiple spin wave modes. For samples of smaller aspect ratio and/or lower symmetry, where the splitting of the mode frequencies increases, a simple pulse-tailoring scheme will be less effective in suppressing precession and may lead to increased high frequency magnetic noise. A more involved pulse-shaping scheme,$^{14}$ may be required to suppress all resonant modes so that spatially uniform precessional switching may be achieved in confined magnetic structures of arbitrary shape and aspect ratio.

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