Laser induced magnetization precession in cobalt ferrite nano-cubes

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Abstract

Designing complex nanostructures with controlled magnetic anisotropy is of great importance for innovative information processing technologies as well as for medical applications such as cancer therapy. Simultaneously, a faster manipulation of the magnetization is receiving lots of attention[1]. In that context, emerging technologies aim at combining high temporal and spatial resolutions for the study of structures with reduced dimensionality[2]. Here, we have studied the impact of the time dependent anisotropy of $Co_xFe_{3-x}O_4$ crystalline nano-cubes on the laser induced magnetization precession. We show that the phase of the precession, which depends on the orientation of an external static magnetic field, can be π-shifted due to the competition between the time dependent magneto-crystalline and shape anisotropies.

The crystalline 35 nm $Co_xFe_{3-x}O_4$ cubes (x = 0, 0.15, 0.30, 0.60, 1.00) are deposited on quartz substrates. They are organized in quasi single layer islands which are influenced by the presence and orientation of an external magnetic field applied during the organization process. The time resolved magneto-optical experiments are performed in Faraday geometry (120 fs, 5 kHz, pump 400 nm, probe 800 nm). In a Cartesian referential (Figure 1a) the sample is placed in the xOy plane and a static magnetic field **H** can be rotated in the *xOz* plane.

The variation of the phase and period of the magnetization precession as a function of θ_H obtained for a Co concentration of 10% is displayed in figure 1b. Two important features can be observed. First, the abrupt change of the precession phase ϕ_{Prec} occurring for $\theta_H^{ph} \approx 25°$ is attributed to the competition between the temperature dependent cubic magneto-crystalline anisotropy of the individual nanoparticles and the time dependent demagnetizing field modified by the change of the magnetization modulus. Second, the continuous increase of the precession period Ω_{Prec} with decreasing θ_H indicates the existence of dipolar interactions between nanoparticles.

The magnetization precession is modelled using the Landau-Lifshitz-Gilbert equation taking into account the time dependent electron, spin and lattice temperatures, as well as the temperature dependent anisotropy. The results corresponding to the sample of Co 10% are presented in Fig. 1c. The good agreement between the simulation and the experimental results is obtained using a simple approximation of the nano-cubes organization on the plane of the substrate i.e. as acting like an average demagnetizing field similar to a thin continuous layer. The competition between the magneto-crystalline and shape anisotropies arises from their different variation with the temperature.

In addition, we have performed a detailed analysis on the influence of the magneto-crystalline anisotropy, the degree of organization of the nano-cubes as well as the density of the laser excitation on the phase of the magnetization precession, which brings valuable insights in the control of magnetization in confined nanostructures.

References

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Figures