A hundred gigahertz spin-wave soliton in FePt nanoparticles

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Magnetic nanoparticles such as FePt in the $L1_0$ phase are considered as a possible basis of the future data storage technology. As the grains become smaller to keep up with technological demands, the superparamagnetic limit calls for materials with higher magnetocrystalline anisotropy. This, in turn, reduces the magnetic exchange length to just a few nanometers, enabling magnetic structures to be induced within the nanoparticles. In our work [1], we demonstrated the formation of sub-10 nm sized spin-wave solitons in FePt nanoparticles. The magnetic droplet solitons are dynamical magnetic textures that may form in materials with perpendicular magnetic anisotropy due to the condensation of spin-waves in highly non-equilibrium conditions [2,3]. Our time-resolved diffuse x-ray scattering experiment at the SCS Instrument of European XFEL (Fig. 1A) showed the presence of strong coherent lattice vibrations in FePt nanoparticles after the femtosecond laser excitation. These vibrations have a very distinct spectrum (Fig. 1B) that can be explained via the coupling of a magnetic precession at the perimeter of spin-wave soliton, forming from the non-equilibrium demagnetized state of FePt nanoparticles, to the lattice. This result was supported by the micromagnetic and magnetoelastic simulations. In our recent follow-up experiment we verified and improved our previous result [1], which was obtained on the FePt particles with the average grain size of 16 nm. Furthermore, we also observed the formation of spin-wave soliton in the smaller FePt particles with the average size of 7 nm. Such a spin-wave soliton would have the smallest size of 5 nm, and the fastest precession frequency of 0.12 THz, observed so far. This new information allows us to address the scaling of spin-wave soliton in the FePt nanoparticles, as well as the aspects of spin-lattice coupling and other related non-equilibrium magnetic phenomena in material with exchange length approaching the atomic scale.

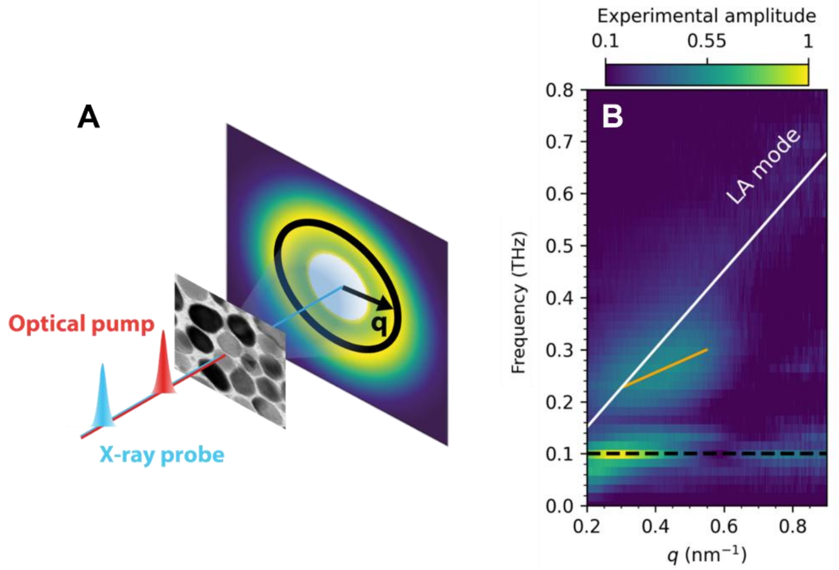

Figure 1. (A) Optical pump x-ray probe experiment on FePt nanoparticles at the SCS Instrument of European XFEL. (B) The representation of the experimental data measured on the 16 nm FePt particles vs. the frequency and the wave vector [1]. The white line shows the calculated dispersion of the bulk FePt longitudinal acoustic phonon mode. The intense feature at 0.1 THz (the dashed black line) is the signature of spin-wave soliton magnetisation precession, quadratically coupled to the lattice. The frequency band between 0.2-0.3 THz (the orange line) is likely of a strain wave-related origin.

References

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