Magnetic antidot arrays for frequency-based detection of magnetic beads

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Recently, it was shown that magnetic patterned films based on antidot arrays can be employed as high-sensitivity magnetic field detectors, exploiting their dynamic behavior in the Gigahertz range. The sensing mechanism was demonstrated for the case of magnetic nanoparticles or beads adsorbed on the surface of $Ni_{80}Fe_{20}$ nanostructured films[1-3]. In particular, the magnetic stray field generated by the particles interact with the magnetization state of the antidot array, producing a measurable shift in its ferromagnetic resonance (FMR) frequencies.

This work investigates from a modeling point of view the dynamic response of $Ni_{80}Fe_{20}$ antidot arrays with hexagonal lattice, in presence of different types of magnetic beads with variable size and saturation magnetic moment. The beads are immobilized on the film surface in correspondence of the holes, where magnetic interaction is stronger. The simulations are performed by means of an advanced micromagnetic solver, which was engineered to run on Graphics Processing Units to efficiently solve Landau-Lifshitz-Gilbert equation [4].

The final objective is a parametric analysis, aimed at finding the optimal antidot geometry (size and density of holes) leading to the higher sensitivity to the bead stray field. As an example, Fig. 1 reports the FMR response of an antidot array with circular holes (diameter of 330 nm and centre-to-centre distance of 500 nm), comparing the cases with different percentages of beads on the film surface. The bead presence produces a clear shift in the FMR resonance frequencies of edge, extended and localized modes (~0.4 GHz for complete hole-bead filling).

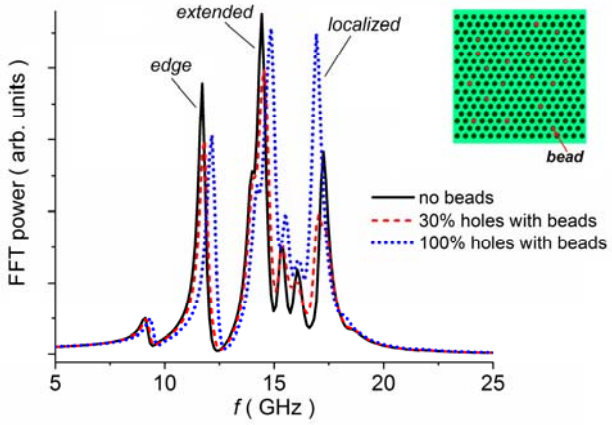

Figure 1. Calculated FFT power spectra of the magnetization component along the excitation field direction (*x*-axis), for a dc bias field of 150 kA/m (*y*-axis). The curves compare the FMR response of a $Ni_{80}Fe_{20}$ antidot array with MagSIGNAL beads with 300 nm size and saturation magnetic moment of 2×10^{-15} Am^2, immobilized on the film surface in different percentage (see scheme in the inset).

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