Excitation of spinwaves in square nanoelements by rotating field

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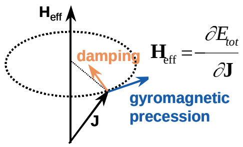
MOTIVATION

Previous micromagnetic simulations revealed precessional oscillation effects of the magnetization in NiFe- and Co nanoelements during fast switching processes [1,2]. Detailed distribution of the magnetization inside the nanoelements is obtained through numerical integration of the Landau-Lifshitz Gilbert equation of motion. We have used a 3D numerical micromagnetic model with tetrahedral finite elements with a constant edge length of 5 nm to study a NiFe square with 100x100x20 nm^3 and K_1=0. Our simulation model combines a hybrid finite element/boundary element method for the magnetostatic field calculation with a BDF/GMRES method for the time integration. Micromagnetic simulations were performed for a magnetic field rotation of half a cycle ($\mu_0 H_{ext}$= 0.2 T) from +J_y to -J_y in the (x,y) plane for various rotation frequencies from 1 to 16 GHz. Thermal fluctuations, defects and other forms of disorder as well as eddy currents occurring during the fast switching process are not included in the simulations.

MICROMAGNETIC FRAMEWORK

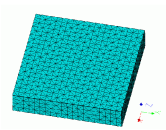
Landau-Lifshitz-Gilbert equation:

$$\frac{\partial \mathbf{J}}{\partial t} = -|\gamma|\left(\mathbf{J} \times \mathbf{H}_{eff}\right) + \frac{\alpha}{J_s}\left(\mathbf{J} \times \frac{\partial \mathbf{J}}{\partial t}\right)$$



$$\mathbf{H}_{eff} = -\frac{\partial E_{tot}}{\partial \mathbf{J}}$$

Finite element model:



square
100x100x20 nm^3
8960/64000 elements

Intrinsic magnetic properties:

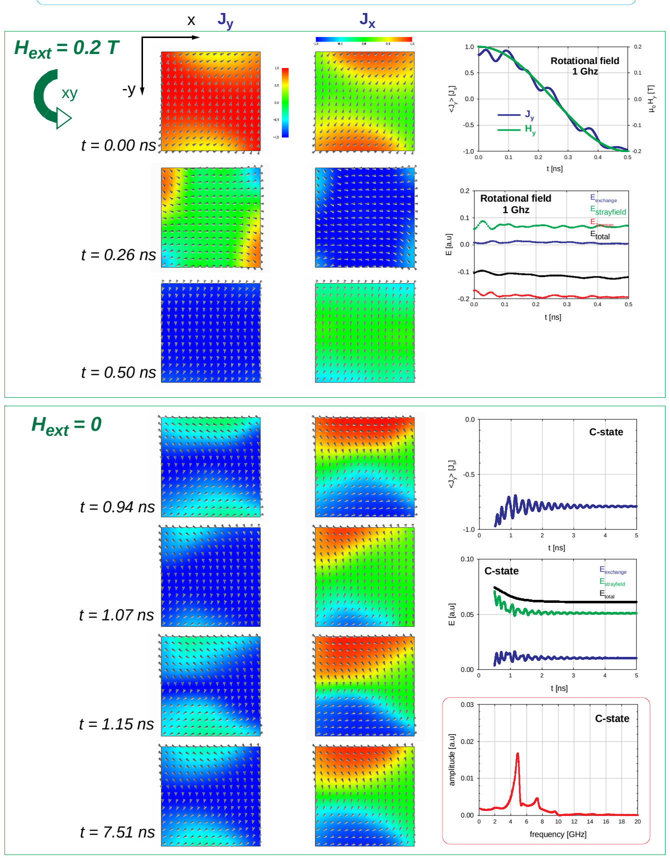
$Ni_{80}Fe_{20}$
J_s = 1.0 T, K_1 = 0, A = 13 pJ/m
α = 0.02
Finite element size = 5 nm

RESULTS

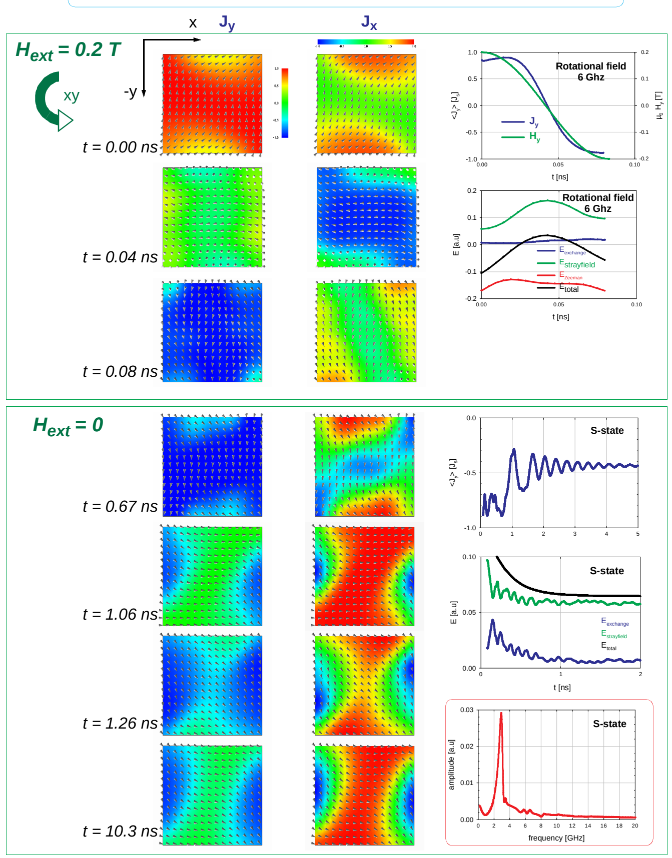
Compared to low switching frequencies an overshot of the overall magnetization direction occurred for frequencies of 6 GHz and higher. The simulations for the Gilbert damping constant of α=0.02 showed that the C (1, 10 GHz) or S (6, 8, 12, 16 GHz) domain configuration was formed after approximately 1 ns, in what follows the magnetization oscillates in the region with the highest demagnetization field for more than 10 ns. The damped oscillation of the magnetization after switching is related to changes of the exchange and internal field energies of the system. The different inhomogeneous field strength values inside the square for the C- and S-state with higher maximum values for the C-state lead to different frequencies of spinwaves modes, such as about 3 GHz for the C-state and 4.5 GHz for the S-state, respectively. The figures show the typical time evolution and the spinwave frequencies for the various domain configurations.

[1] J. Fidler, T. Schrefl, V.D. Tsiantos, W. Scholz, D. Suess and H. Forster,
"Ultrafast switching of magnetic nanoelements using a rotating field", JAP 91 (2002) 7974-7976.
[2] J. Fidler, T. Schrefl, V.D. Tsiantos,
"FE-Simulation of fast switching behaviour of granular nanoelements", Intermag 2002, IEEE Trans Magn. (2002) in press.

1 GHZ ROTATIONAL FIELD - *C-STATE*



6 GHZ ROTATIONAL FIELD - *S-STATE*



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