NANOMAGNETISM - A PERSPECTIVE FROM THE DYNAMIC SIDE

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The fundamental dynamic excitations of a magnetically ordered solid state material are spin waves. In small magnetic structures these spin waves have unusual dispersion and propagation properties given by finite size effects, the spatially varying direction of magnetization and interactions. While propagation of spin waves has been intensively studied in the model system Yttrium-Iron-Garnet (YIG), which exhibits very low magnetic damping but allows only for millimeter-scale object sizes, experimental investigations on the sub-micron scale are still rare.

I will give an introduction into the diverse field of spin-wave propagation phenomena in nanomagnets. The experimental technique is time- and phase resolved Brillouin light scattering microscopy, a powerful and versatile tool to investigate the properties of spin waves on the sub-micrometer length scale.

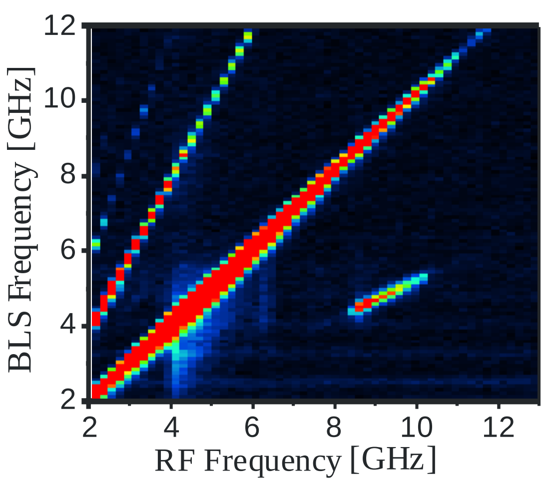

Fig. 1. Investigation of the spin-wave dynamics in a nano-contact subject to a microwave current. Shown is the BLS spectral intensity as a function of the microwave excitation frequency for an externally applied in-plane field of 245 Oe. The diagonal indicates the directly excited magnetic resonances whereas the signals above and below the diagonal show the intensities of spin waves created by nonlinear processes.

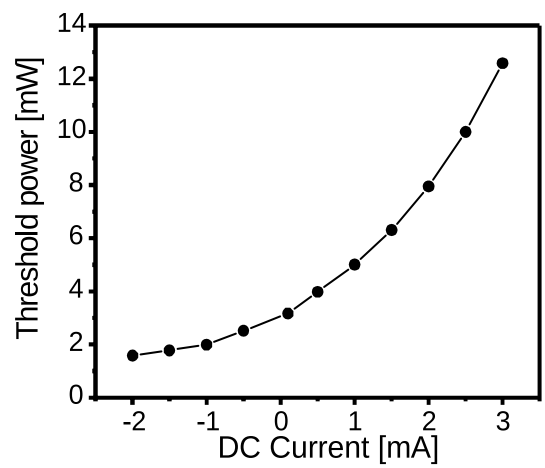

Fig. 2. Threshold power of the spin waves with half the excitation frequency as a function of the applied dc current. The applied field is 245 Oe.

I will present two scenarios of spin-wave dynamics in magnetic nanostructures. First, I will briefly discuss spin-wave propagation in small magnetic ring structures. Modes can be identified which exist due to quantization along the ring perimeter, due do quantization because of the ring width, and due to localization effects in regions of large inhomogeneity of the internal field. These modes can be driven into the nonlinear regime, and nonlinear mode coupling is observed.

A ferromagnetic nano-structure may emit spin waves if subject to an electric current flowing through the structure. We have investigated the dynamics of the magnetization in the Py free layer of one spin-valve structure with a point contact with 80 nm in diameter subject to a combined microwave and dc current. The magnetic resonance frequencies are determined for different externally applied magnetic fields. The spin-waves radiation from the contact are studied for several applied microwave frequencies and under the influence of the applied dc current, as well as a function of the applied power from the microwave source. The results reveal strong nonlinear effects namely the generation of eigenmodes with higher frequency (2*f*, 3*f*) but also modes with a non-integer factor (0.5*f*, 1.5 *f*) with respect to the excitation microwave frequency *f*, see Fig. 1. These non-integer factor modes are assumed to be associated with three-magnon-scattering processes. In order to localize the eigenmodes around the nanocontact we have performed 2D scans with high spatial resolution of 250 nm. The obtained patterns show that half and second harmonic modes are localized within the point contact area.

For obtaining more information about the effect of the dc current on these nonlinear processes we studied the power dependence of the emitted spin waves as a function of the applied microwave power and the dc current. An interesting result is that the appearance of spin waves with half the excitation frequency shows clearly a threshold behaviour as a function of the applied microwave power. The threshold shows an exponentially increasing dependence on the dc current, see Fig. 2, independent on the scan position. This can be understood as an effect of the spin torque and not due to the Oersted field created by the current.

Support by the DFG within the SPP 1133 and by the EC-MRTN SPINSWITCH (MRTN-CT-2006-035327) is gratefully acknowledged.