Propagating Spin-Wave Spectroscopy at ultra-short wavelengths

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The spin waves (or magnons) are the low energy excitations of magnetically ordered materials. In typical ferromagnets, they exist over a range of frequencies (1 GHz – 1THz) and wavelengths (1µm-1nm) which correspond precisely to the time- and length- scales relevant for modern electronics. This suggests the possibility to use spin waves for developing new architectures for data processing and storage, which motivates the emergence of a new sub-field of nanomagnetism and spintronics called “magnonics” [1]. In this context, we have been developing in the past five years at IPCMS an original microwave technique allowing one to measure precisely the propagation of spin waves with sub-micrometer wavelength [2]. In this technique, spin waves propagating along a narrow ferromagnetic strip are excited and detected inductively using nanofabricated metal circuits, the so-called spin wave antennas (see figure). This technique was used to observe a new effect called current-induced spin-wave Doppler shift.

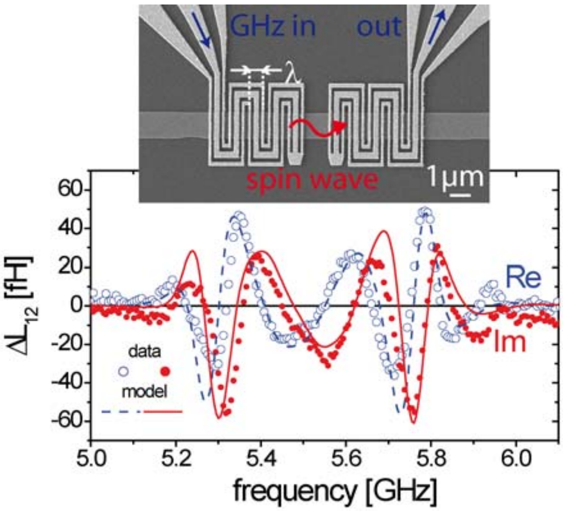

Figure: (top) Scanning electron microscope picture of a sample fabricated for propagating spin wave spectroscopy: two meander shape “antennas” are fabricated on top of a 2µm wide ferromagnetic strip. (bottom) Measured propagating spin wave signal

We propose to investigate a new method called “spin-wave refraction” for measuring spin waves of even shorter wavelength (100 nm or smaller). For this purpose, a magnetic inhomogeneity will be introduced into the propagation path of the spin waves. This inhomogeneity (a constriction of the ferromagnetic strip or a non-uniform external magnetic field) will be able to accelerate locally the spin waves.

If successful, this work will open the way for truly nanoscale measurements of spin-wave propagation, which is an essential step for demonstrating the potential of magnonics for integration into conventional micro-electronics. From a fundamental point of view, ultra-short wavelength spin waves will also be used to test recent theoretical predictions about the role of conduction electrons in the magnetization damping of metal ferromagnets [3].

[1] B. Lenk et al., cond-mat: http://xxx.lanl.gov/abs/1101.0479 (2011)
[2] V. Vlaminck and M. Bailleul, Science **322**, 410 (2008).
[3] S. Zhang and S.L. Zhang, Phys. Rev. Lett. **102**, 086601 (2009).