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Current-induced spin wave Doppler shift

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In metal ferromagnets -namely Fe, Co and Ni and their alloys- magnetism and electrical transport are strongly entangled (itinerant magnetism). This results in a number of properties such as the tunnel and giant magnetoresistance (i.e. the dependence of the electrical resistance on the magnetic state) and the more recently addressed spin transfer (i.e. the ability to manipulate the magnetic state with the help of an electrical current). The spin waves, being the low-energy elementary excitations of any ferromagnet, also exist in itinerant magnets, but they are expected to exhibit some peculiar properties due the itinerant character of the carriers. Accessing these specific properties experimentally could shed a new light on the microscopic mechanism governing itinerant magnetism, which -in turn- could help in optimizing material properties for spintronics applications. As a simple example of these specific properties, it was predicted theoretically that forcing a DC current through a ferromagnetic metal should induce a shift of the frequency of the spin waves [1,2]. This shift can be identified to a Doppler shift undergone by the electron system when it is put in motion by the electrical current. We will show how detailed spin wave measurements allow one to access this current-induced Doppler shift [3]. From an experimental point of view, we will discuss the peculiarities of propagating spin wave spectroscopy experiments carried out at a sub-micrometer length-scale and with MHz frequency resolution. Then, we will discuss the measured value of the Doppler shift in the context of both the old two-current model of spin-polarized transport and the more recent model of adiabatic spin transfer torque.

[1] P.Lederer and D.L. Mills, Phys.Rev. 148, 542 (1966).
[2] J. Fernandez-Rossier et al., Phys. Rev. B 69, 174412 (2004)
[3] V. Vlaminck and M. Bailleul, Science 322, 410 (2008).