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Spin transfer Oscillations in MgO based Magnetic Tunnel Junctions

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1. Introduction

Microwave emission associated with sustained magnetization precession induced by the spin transfer torque is one of the most intense research topics in spin transfer phenomena as important potential applications are at stake in the field of telecommunications. While many crucial advances have been made in the fabrication and understanding of such Spin Transfer Nano-Oscillators (STNO) in magnetic nanostructures, there remain several critical problems yet to be resolved, in particular, the low microwave power and quality factor of single STNOs [1].

2. MTJ-based Spin Transfer Oscillators

In order to improve the emitted power, a solution that has been recently proposed is to use Magnetic Tunnel Junctions (MTJs) that should deliver large power because of the larger magneto-resistive ratios [2]. However, this increase of the microwave power with MTJs goes with a subtantial line broadening compared to nanostructures made of spin valves. Here, we first present a comprehensive experimental study of the microwave emission associated with spin transfer induced magnetization oscillations in PtMn/ CoFeB(3 nm)/Ru/CoFeB(3 nm)/MgO(1 nm)/CoFeB(2 nm) magnetic tunnel junctions. Our purpose is to identify the mechanisms at the origin of the peak linewidth. In agreement with recent theory of non linear oscillators, we demonstrate the strong impact of the oscillator agility on the line broadening by studying the emission as a function of the injected current. The linewidth evolution with the current as well as its amplitude is unexpectedly almost not affected by decreasing the temperature down to 20 K, except for very low currents (see Fig. 1). In this below-threshold regime for sustained oscillations, the strong linewidth enhancement at low temperature is attributed to an increase of the non linearity, probably due to the field-like torque. We also evidence that the dissipation process is not dominated by thermal fluctuations but rather by the chaotization of the magnetization system induced by the spin transfer torque.

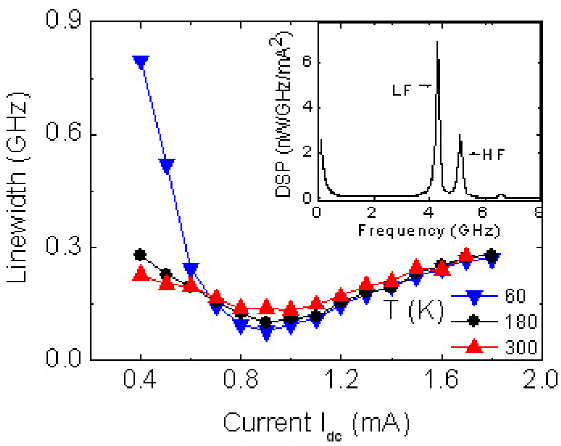

Fig. 1 : Variation of the linewidth with Idc for T = 60, 180 and 300 K and H = 205 Oe. Inset : Power spectral density (PSD) normalized by I^2_{dc}, obtained for I_{dc} = 1 mA and H = 110 Oe at T = 300 K. Two large peaks are observed labeled low frequency (LF) and high frequency (HF) modes.

3. Spin Transfer Induced Vortex Oscillations in MTJs

In the second part, we tackle the issue of the broad linewidth by following an alternative approach in which current driven vortex oscillations in the sub-gigahertz range are used as the source of microwave power. We demonstrate for the first time that such vortex oscillations can be generated under a large dc current and are detectable in MgO MTJs. They result in narrow spectral lines (about 1 MHz) and large emitted power (0.1 µW) as can be seen in Fig. 2. New analytical models have been developed to understand the excitation of the gyrotropic motion of the vortex core by spin transfer. Finally, we show that for low dc current,

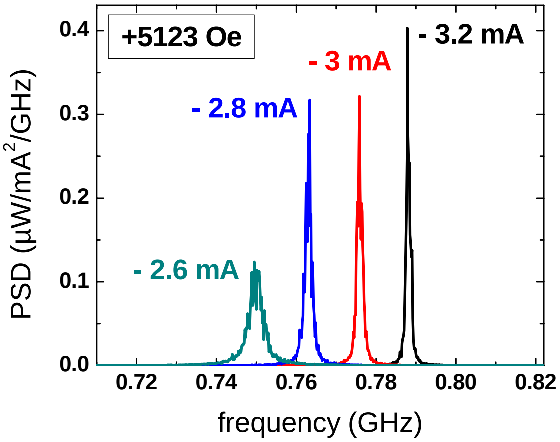

Fig. 2 : Power spectral density (PSD) normalized by I^2_{dc}, obtained for I_{dc} = -2.6, -2.8, -3 and -3.2 mA with H_{perp} = 5123 Oe.

the precession frequency oscillates with the magnetic field (in plane or out of plane), most probably because the vortex core is affected by intrinsic mechanism of pinning associated to the materials grains

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