Micromagnetic investigation of temperature dependence of microwave nanoscillator linewidths driven by spin-polarized currents

Mario Carpentieri, Luis Torres, Giovanni Finocchio, Bruno Azzerboni

I. INTRODUCTION

Spin-transfer torque from a dc spin-polarized current can provide magnetic switching or excite periodic oscillations of the magnetization in spin-valve nanostructures [1]-[2]. Thermal fluctuations can modify the magnetization dynamics behavior of spin-torque nano-oscillator (STNO) and the thermal noise implies the generation of a linewidth, which is a fundamental parameter to characterize the spectrum of a non-linear STNO. In this digest, the temperature dependence of the full width at half maximum (FWHM) for the experimental sample by Sankey et al. [3] has been fully investigated from a micromagnetic point of view. In agreement with the theory, the linewidth depends strongly on the temperature *T* [3]-[4].

The studied nanopillar consists on a 20 nm thick pinned layer of Permalloy (Py), a 6 nm Cu spacer, and a free layer of d=2 nm thick of Py with elliptical cross sectional area of 100nm x 50nm. Our simulations have been performed by a micromagnetic 3D dynamical code developed by our group [5]-[6]. The magnetic parameters set used in the computations is obtained by fitting static magnetoresistance measurements [3] (saturation magnetization M_S=645×10^3 A/m, exchange constant A=1.3×10^{-11} J/m). The magnetostatic coupling and the initial states of the ferromagnetic layers have also been computed by means of a 3D simulation of the whole structure.

II. RESULTS

In the precessional regime, the thermal activation is manifested by the "inhomogeneous" broadening of the linewidth of the magnetization spectrum that provides a decreasing of the coherence degree of the phase noise.

Figure 1(a) shows the temperature dependence of the linewidth when a magnetic field $\mu_0 H_{app}$=100 mT and a dc bias of 1.6 mA are applied (see region labelled "LD" in Fig. 1b of Ref. 3). The strong temperature dependence indicates that thermal effects determine the coherence time for the phase fluctuation of spin-transfer driven precession, and this time is "correlated" to the lineshape.

Mario Carpentieri is with the Department of Elettronica, Informatica e Sistemistica – University of Calabria, I-87036 Cosenza, Italy. E-mail: mcarpentieri@deis.unical.it.
Luis Torres is with the Department of Fisica Aplicada – University of Salamanca, E-37008 Salamanca, Spain.
Giovanni Finocchio and Bruno Azzerboni are with the Department of Fisica della Materia e Ingegneria Elettronica – University of Messina, I-98166 Messina, Italy.

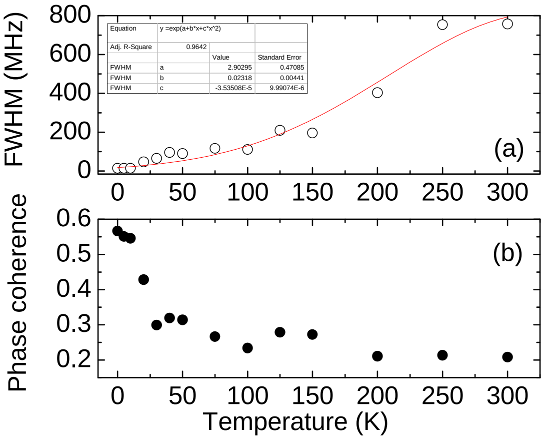

Fig. 1. (a) Temperature dependence of the FWHM when a magnetic field $\mu_0 H_{app}$=100 mT and a dc bias of 1.6 mA are applied together to an exponential fit. (b) Temperature dependence of the phase coherence for the same applied field and current.

Indeed, the lineshape fitting is Lorentzian up to about 100 K and the dependence of the temperature is linear. On the other hand, at high temperature regime, the lineshape is better described by a Gaussian function. The temperature dependence of the coherence degree for the phase fluctuations is shown in Fig. 1(b). The coherence can vary from 0 to 1. At low temperature, the precession of the magnetization shows a similar behavior to the sinusoidal one, so the coherence degree is high. However, for temperatures above than 50 K, thermal activation provides noisy phase fluctuations with low coherence degree (less than 0.3).

In agreement with experimental data, the linewidth increases linearly by a factor 5 varying the temperature from 30 to 180 K [3]. Furthermore, the analytical theory of Tiberkevich [4] indicates the same temperature dependence (linear at low temperature and $T^{1/2}$ behavior at high temperature) of the FWHM with respect to our micromagnetic simulations for *T* up to 300 K.

III. REFERENCES

[1] J.C. Slonczewski, *J. Magn. Magn. Mater*., vol. 159, pp. L1-L7, (1996). L. Berger, *Phys. Rev. B*, vol. 54, pp. 9353-9358, (1996).
[2] S. I. Kiselev, J. C. Sankey, I. N. Krivorotov, N. C. Emley, R. J. Schoelkopf, R. A. Buhrman, and D. C. Ralph, *Nature* (London), vol. 425, pp. 380-383, (2003).
[3] J. C. Sankey, I. N. Krivorotov, S. I. Kiselev, P. M. Braganca, N. C. Emley, R. A. Buhrman, and D. C. Ralph, *Phys. Rev. B*, vol. 72, 224427, (2005).
[4] V. Tiberkevich, A.N. Slavin, J.V. Kim, *Phys. Rev. B*, vol. 78, 092401, (2008).
[5] M. Carpentieri, L. Torres, B. Azzerboni, et al. *J. Mag. Magn. Mat*., vol. 316, pp. 488-491, (2007).
[6] M. Carpentieri, L. Torres, G. Finocchio, B. Azzerboni, *J. Appl. Phys.*, vol. 103, 07B107, 2008.