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BD-06. Low frequency noise in vortex spin torque nano-oscillators.

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With their very rich static and dynamical properties, magnetic vortex dynamics excited by a spin polarized current represent not only a model system to study the physical mechanisms of spin transfer phenomena but could also give birth to a new generation of multi-functional microwave spintronic devices [1]. The key property of spin-torque nano-oscillators (STNOs) is their high nonlinearity [2] which gives rise to manifold phenomena such as injection locking to an external rf signal [3-4] or synchronization of multiple STNOs [5-7]. On the other hand, their large nonlinearity causes the oscillator's very poor spectral coherence and leads to a coupling between amplitude and phase noise [8]. While the noise distribution for offset frequencies far from the carrier frequency is reasonably well understood [8] and described by the general nonlinear autooscillator theory [2], low frequency noise remains under investigation as it limits the frequency stability of the oscillator. Extensively studied in GMR and TMR sensors [9-12], this work addresses the low frequency noise of a TMR-based spin-torque vortex oscillator in the regime of large amplitude steady oscillations. In detail, we present a precise experimental study of the TMR-based spin-torque vortex oscillator's low frequency noise, which remains poorly investigated for STNOs in the regime of large amplitude steady oscillations, as we propose here. The measured STNO's magnetic tunnel junction layer stack of PtMn/CoFe/Ru/ CoFeB/CoFe/MgO/FeB/MgO/Ta/Ru was realized by sputter deposition and nanopillar devices of 100-600nm were nanofabricated. The devices have a free running frequency from 100 MHz to 1 GHz depending on the diameter and the applied field value, with an integrated power of up to a few μW and a linewidth of typically ~100 kHz. In complement to the experimental measurements, we have also developed a phenomenological theory aiming to investigate the low frequency flicker noise in these vortex-STNOs. Starting from the corresponding nonlinear Langevin equations and a colored noise distribution, we find additional noise contributions to the white noise power spectral densities. This also gives an additional coupling term between amplitude and phase noise. Noteworthy, we find that this prediction agrees well to our experimental results of the gyrotropic mode's low frequency noise (fig. (a)). Furthermore, we analyze the noise dependence on the control parameter (the operating dc current) and the oscillator's active magnetic volume, reflected by the Hooge-formula for TMR sensors [12] and the oscillator's nonlinearity itself (fig. (b)).
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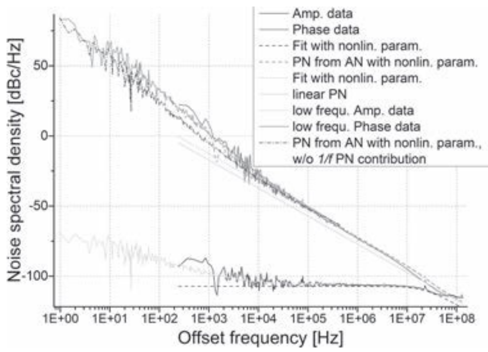

Fig. 1. Noise power spectral density of a spin torque vortex oscillator. The experimental data are shown together with the theoretical curves governed by the preliminarily determined nonlinear parameters [13] as well as the noise curve for a linear oscillator. Theoretical and experimental curves exhibit a good agreement. Here, the theoretical low frequency phase noise curve underestimates the experimental data because the low frequency pure phase noise contribution was neglected due to an experimentally hardly determinable parameter (the corresponding Hooge-factor). AN: Amplitude Noise, PN: Phase Noise.

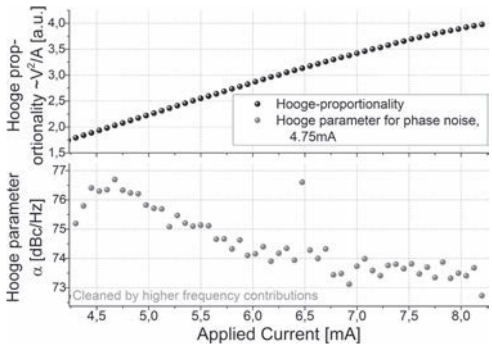

Fig. 2. Although the Hooge-proportionality, which mainly determines the 1/f noise in magnetic sensors, increases, the experimental Hooge-parameter decreases with higher applied current due to the dominant nonlinear effects. V: Voltage, A: Active magnetic surface.