Nucleation of dissipative solitons in constriction-based spin Hall nano-oscillators

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Direct-current-driven magnetization auto-oscillations in spin torque and spin Hall nano-oscillators typically have a highly nonlinear character. For thin unpatterned magnetic films with positive magnonic dispersion, the dynamics could be either of a linear-like or a self-localized solitonic character, for positive and negative nonlinearities, respectively [1].

We have recently demonstrated that in constriction-based spin Hall oscillators (SHNOs), the magnetization auto-oscillations emerge from the linear localized mode of the constriction [2]. Compared to unpatterned oscillators, such linear-like auto-oscillations have low threshold currents and does not require negative nonlinearity to emerge. It is however important for applications to understand the properties of such auto-oscillations in large applied supercritical currents.

Here we use micromagnetic simulations to reveal complex solitonic regimes of the constriction-based SHNOs depending on the applied current supercriticality, as well as on the strength and out-of-plane angle of the applied magnetic field. First of all, we demonstrate that in weak fields the dynamics remain linear-like in a wide range of supercritical currents (see Fig.1a), consistent with small non-linearity. Secondly, we report on the very first observation of the droplet-like solitons in strong mostly in-plane applied fields (see Fig. 2a), as these have so far been observed in materials with perpendicular anisotropy. Thirdly, we observe nucleation of spin-wave bullet-like solitons in oblique fields of moderate strengths (see Fig. 3b), consistent with our experimental results on Py/W constriction-based SHNOs [3]. Our results not only allow one to optimize the performance of the constriction-based SHNOs for applications in rf signal generation and neuromorphic computing, but allow for further fundamental studies of magnetic solitons.

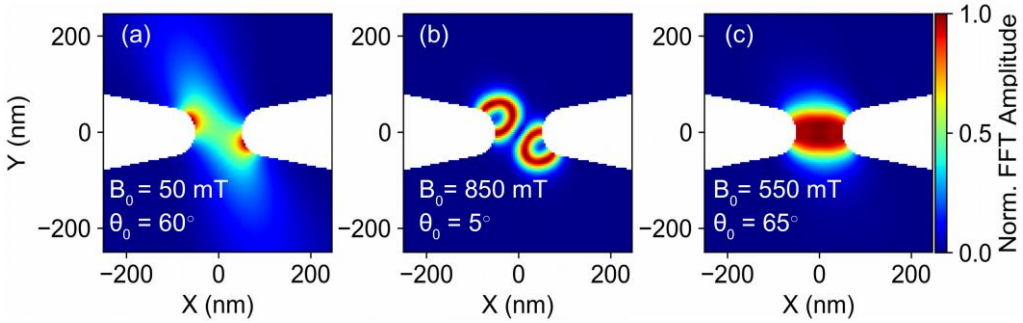

Figure 1. Simulated profiles of (a) linear-like, (b) droplet-like and (c) spin-wave bullet-like auto-oscillations of 100 nm width constriction spin Hall nano-oscillator.

[1] G. Gerhart et al., Phys. Rev. B **76**, 024437 (2007).
[2] M. Dvornik et al., "Origin of magnetization auto-oscillations in constriction-based spin Hall oscillators", arXiv:1702.04155 (2017).
[3] H. Mazraati, M. Dvornik et al., "Nucleation of dissipative solitons in constriction-based spin Hall nano-oscillators", in preparation (2017).