Antiferromagnetic spin-orbit torque oscillator

P. K. Rout[1], J. A. Vélez[2,3], J. Godinho[1], F. Vilsmeier[4], R. Salikhov[5], Z. Šobáň[6], D. Lazore[7], C. H. Back[4], O. Hellwig[5,8], R. M. Otxoa[9,2], and J. Wunderlich[1,6]

[1]Institute of Experimental and Applied Physics, University of Regensburg, Germany
[2]Donostia International Physics Center, San Sebastián, Spain
[3]Polymers and Advanced Materials Department: Physics, Chemistry, and Technology, University of the Basque Country, San Sebastián, Spain
[4]Fakultät für Physik, Technische Universität München, Germany
[5]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany
[6]Institute of Physics, Czech Academy of Sciences, Czech Republic
[7]Instituto de Alta Investigación, CEDENNA, Universidad de Tarapacá, Chile
[8]Institute of Physics, Chemnitz University of Technology, Germany
[9]Hitachi Cambridge Labyoratory, Cambridge CB3 0HE, United Kingdom

Pradeep-Kumar.Rout@physik.uni-regensburg.de

Antiferromagnetic materials have unique properties due to their alternating exchange-coupled magnetic moment arrangements, leading to exchange-field enhanced fast and complex spin dynamics [1, 2]. A nonvolatile antiferromagnetic memory mimicking an artificial synapse with extremely reproducible synaptic weights has been realized in a synthetic antiferromagnet (SAF), in which the reconfigurable synaptic weight is encoded in the ratio between reversed antiferromagnetic domains [3]. The non-volatile memory is “written” by spin-orbit torque-driven antiferromagnetic domain wall motion and “read” by nonlinear magneto-transport. We also realize a spin-orbit torque driven antiferromagnetic oscillator inside a nano-constriction patterned from a SAF multilayer. By exploiting the spin rectification effect (SRE), we identify spin-orbit torque-driven excitations of optical and acoustic antiferromagnetic modes. Near the spin-flop transition, additional resonant modes appear in the SRE signal when applying a dc current above a critical current density. We associate these additional modes with spin-orbit torque driven antiferromagnetic self-oscillations that are injection locked to SRE the detection frequencies. Macro-spin and micromagnetic simulations of our nano-constriction spin orbit-torque oscillator confirm antiferromagnetic self-oscillations in the studied applied magnetic field regime. The simulations show, also in agreement with our experimental findings, a chaotic behavior of the self-oscillations around the antiferromagnetic spin-flop transition.

References

[1] Jungwirth, T., Marti, X., Wadley, P. & Wunderlich, J. Nat. Nanotechnol. Antiferromagnetic spintronics. 11, 231–241 (2016)

[2] Wolba, B., Gomonay, O. & Kravchuk, V. P. Chaotic antiferromagnetic nano-oscillator driven by spin torque. Phys. Rev. B 104, 024407 (2021).

[3] Godinho, J., Rout, P.K., Salikhov, R. et al. Antiferromagnetic domain wall memory with neuromorphic functionality. npj Spintronics 2, 39 (2024).