Long-range mutual synchronization of spin torque and spin Hall nano-oscillators

Johan Åkerman[1,2]

[1]Department of Physics, University of Gothenburg, 412 96 Gothenburg, Sweden

[2]Materials and Nanophysics, School of Engineering Sciences, KTH Royal Institute of Technology, 164 40 Kista, Sweden

We present our most recent advances in synchronizing nano-contact spin torque nano-oscillators (STNOs) and spin Hall nano-oscillators (SHNOs). The synchronization of STNOs [1-3] is mediated by propagating spin waves (SWs), which, under the influence of the local Oersted field, can form SW beams. Not only have we recently demonstrated the robust synchronization between two oscillators separated by over 1 micron, but also the driven synchronization of up to five oscillators by purposefully taking advantage of such SW beams [1]. More recently, a new breed of nanoscale magnetic oscillator, which rely on the transverse spin currents generated by the spin Hall effect, have emerged. Our particular SHNO device geometry relies on a nano-constriction [2, 3] to focus the spin currents and stabilize auto-oscillations. By carefully considering the importance of the applied field angle [4] we have demonstrated robust synchronization of up to nine serially connected SHNOs [5]. The mutual synchronization is observed both as a strong increase in the power and coherence of the electrically measured microwave signal. The mutual synchronization is also optically probed using scanning micro-focused Brillouin light scattering microscopy (μ-BLS), providing the first direct imaging of synchronized nano-magnetic oscillators. Through tailoring of the region connecting two SHNOs, we can extend the synchronization range to 4 μm. Given the design flexibility of nano-constriction SHNOs, and their very long synchronization range, our results open up many research and application opportunities where coherent phase locking is believed to be advantageous, e.g. for energy efficient spin wave computing on the nanoscale.

[1] A. Houshang, E. Iacocca, P. Dürrenfeld, S. R. Sani, J. Åkerman, and R. K. Dumas, Nature Nanotechnology **11**, 280 (2016)

[2] V. E. Demidov, S. Urazhdin, A. Zholud, A. V. Sadovnikov, and S. O. Demokritov, Appl. Phys. Lett. **105**, 172410 (2014)

[3] P. Dürrenfeld, A. A. Awad, A. Houshang, R. K. Dumas, and J. Åkerman, Nanoscale **9**, 1285 (2017)

[4] M. Dvornik, A. A. Awad, and J. Åkerman, arXiv:1702.04155

[5] A. A. Awad, P. Dürrenfeld, A. Houshang, M. Dvornik, E. Iacocca, R. K. Dumas, and J. Åkerman, Nature Physics **13**, 292 (2017).