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Hysteresis Design of Magnetic Materials for Efficient Energy Conversion

Tuesday, 01 Jun. 2021, 9:00 s.t., UDE, Zoom



Prof. Igor Barsukov

**Physics and Astronomy,
University of California, Riverside**

Controlling magnetic dissipation at nanoscale via magnon scattering

Abstract:

Dissipation rate of magnetic energy, is a key characteristic and performance metric for many spin-based technologies. It is determined by the material, but also by the geometry of a magnet. In the nanoscale confinement, the spectrum of magnons – quanta of collective spin excitations – is discrete, which leads to dissipation phenomena which we find to present with rather counter-intuitive behavior [1,2].

Interaction between magnons opens up dissipation channels that show resonant enhancement at characteristic magnetic fields corresponding to a degenerate three-magnon process [1,3]. This nonlinear process appears to dominate magnetization dynamics in nanomagnets even at low excitation levels. Surprisingly, it also redefines the nanomagnet's response to spin-torque.

Generally, spin-torques are generated by injecting a spin current into the magnet. They allow for manipulating magnetic dissipation via external stimuli and provide an essential tool for many spintronic applications. We find, however, that the three-magnon process inverts the effect of the spin-torque on magnetic dissipation. It turns an anti-damping spin-torque into a torque that enhances magnetic dissipation. The discovery of this phenomenon has far-reaching implications for spin-torque oscillators [4], memory, magnetic neural networks, and other spintronic technologies [5].

Our results further hold promise for the emergent field of quantum-magnonics, where magnon scattering processes could play a major role in manipulating magnetic states on the quantum level. Controlling magnon processes, while being imperative for both classical and quantum paradigms, has remained difficult to achieve.

We develop an approach for toggling magnon processes by a nanoscale dipole switch. We demonstrate an experimental proof-of-concept in magnetic tunnel junction nanodevices, consisting of a free layer and a synthetic antiferromagnet. By triggering the spin-flop transition in the synthetic antiferromagnet and utilizing its dipole field, we controllably modify magnon interaction in the free layer. We achieve its tunability by at least one order of magnitude and realize two distinct dissipative states. The results open up an avenue for controlling magnon processes by external stimuli at nanoscale and show prospects for spin-torque applications and hybrid quantum information technologies. This work was supported by the National Science Foundation through Grant No. ECCS-1810541.

REFERENCES: [1] I. Barsukov et al., *Sci. Adv.* 5, eaav6943 (2019); [2] A. Navabi et al., *Phys. Rev. Appl.* 11, 034046 (2019); [3] A.M. Gonçalves et al., *Appl. Phys. Lett.* 103, 172406 (2013); [4] C. Safranski et al., *Nat. Commun.* 8, 117 (2017); [5] Y.-J. Chen et al., *Nano Lett.* 17, 572 (2017)

About the speaker:

Igor Barsukov is an Assistant Professor and JET Distinguished Faculty at the University of California, Riverside. He studied physics at Ruhr-University Bochum where he developed magnetodynamic microscopy techniques. As a recipient of a Marie-Curie Fellowship, he then worked on magnetic core-shell nanoparticles at the Academy of Sciences in Prague. He holds PhD in Physics (2012) from the University Duisburg-Essen, where he investigated magnetism-structure correlations using molecular beam epitaxy and magnetic resonance spectroscopy. As a postdoc, he moved to University of California Irvine, where he worked on nonlinear magnetodynamics and interfacial spin torques and collaborated with spintronics industry. Since 2016, his research group at UCR's Department of Physics and Astronomy designs spintronic applications and investigates spin dynamics in nanoscale magnetic systems using microwave/terahertz spectroscopy, computational methods, and low-temperature magnetotransport. He is executive committee member of MIND in the American Vacuum Society, Outstanding Referee for Communications Physics, and co-chair/organizer of the upcoming 7th Magnonics conference.

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Spokesperson: Prof. Dr. Oliver Gutfleisch • Co-Spokesperson: Prof. Dr. Michael Farle
Management: Dr. Sonja Laubach • L2 | 07 110 • sonja.laubach@tu-darmstadt.de • +49 (0)6151 16-22153
Address: CRC/TRR 270 • TU Darmstadt • Alarich-Weiss-Str. 16 • 64287 Darmstadt