# MA 22: Terahertz Spintronics

Time: Tuesday 15:00–16:15 Location: POT 6

MA 22.1 Tue 15:00 POT 6

**Optimizing spin-based terahertz emission from magnetic heterostructures** — •Francesco Foggetti, Francesco Cosco, and Peter M. Oppeneer — Uppsala University, Uppsala, Sweden

Terahertz radiation pulses can be generated efficiently through femtosecond laser excitation of a magnetic heterostructure, where an ultrafast laser-induced spin current results in an electromagnetic THz pulse due to the inverse spin Hall effect. It is however still poorly known how the THz emission amplitude and its bandwidth in the frequency regime can be optimized. Here, we perform a systematic analysis of the THz emission from various magnetic heterostructures. The dynamics of the spin current is described by the semiclassical, superdiffusive spin-transport model and, in order to identify the optimal setup for the THz emission, the properties of the wave profile are studied by changing the materials of the heterostructures, their thicknesses, and the laser pulses, allowing us to give optimization guidelines. The energy dependence of spin Hall effect of hot electrons is furthermore taken into account, leading to emission profiles comparable to experiment.

MA 22.2 Tue 15:15 POT 6

**Terahertz probing of interfacial Curie temperatures in spintronic thin-film stacks** — •Oliver Gueckstock[1], Reza Rouzegar[1], Vincent Baltz[2], Gerhard Jakob[3], Mathias Kläui[3], Tom S. Seifert[1], and Tobias Kampfrath[1] — [1]FU Berlin, Germany — [2]SPINTEC, France — [3]JGU Mainz, Germany

Transport of spin angular momentum and spin-charge-current interconversion are fundamental operations for future spin-electronic devices. Femtosecond laser pulses are well suited to trigger ultrafast spin transport from a ferromagnetic metal F into an adjacent paramagnetic layer P [1,2]. The inverse spin Hall effect converts the spin current into an in-plane charge current that gives rise to the emission of an electromagnetic pulse with frequencies extending into the terahertz (THz) range. As the ultrafast currents are confined to only ~1 nm around the F/P interface, the emitted THz pulse is expected to be a highly sensitive probe of interface properties. Here, we investigate the impact of the F/P interface morphology and sample temperature on the THz-emission signal. We find that the temperature-dependence of the THz emission signal depends critically on the roughness of the F/P interface. We conclude that the Curie temperature of F at the F/P interface is strongly reduced relative to the bulk by the higher degree of disorder at the F/P interface.

References [1] T. Seifert et al., Nature Photonics 10, 483 (2016). [2] R. Rouzegar et al., Physical Review B 106, 144427 (2022).

MA 22.3 Tue 15:30 POT 6

**Switching and excitation of THz spin waves in $Mn_2Au$ due to femtosecond spin-transfer torques** — •Markus Weissenhofer[1,2], Francesco Foggetti[1], and Peter Oppeneer[1] — [1]Department of Physics and Astronomy, Uppsala University — [2]Department of Physics, Free University Berlin

In trilayer spin valves consisting of Fe|Cu|Fe, ultrafast laser pulses can generate hot-electron spin currents that exert spin-transfer torques, which excite THz spin waves [1]. Here, we replace the second Fe layer by antiferromagnetic $Mn_2Au$ and demonstrate that spin waves with even higher frequencies can be excited. We compute the temporal evolution of the hot-electron spin currents by means of the superdiffusive transport model and simulate the response of the $Mn_2Au$ layer to the resulting femtosecond spin-transfer torque pulse using atomistic spin dynamics simulations. Our results reveal that - due to the small thickness of the $Mn_2Au$ layer and exchange enhancement - standing spin waves of up to several THz can be excited. Upon increasing the laser fluence, we even find that the excited spin-current pulses are sufficient to induce switching of $Mn_2Au$ layer, faster than the experimentally demonstrated electrically induced switching of $Mn_2Au$ [2].

[1] U. Ritzmann, P. Baláž, P. Maldonado, K. Carva, and P. M. Oppeneer, Phys. Rev. B 101, 174427 (2020).

[2] S. Y. Bodnar, L. Šmejkal, I. Turek, T. Jungwirth, O. Gomonay, J. Sinova, A. A. Sapozhnik, H.-J. Elmers, M. Kläui, and M. Jourdan, Nature Communications 9, 348 (2018).

MA 22.4 Tue 15:45 POT 6

**Element-selective and THz study of spin dynamics in Fe/Ru/Ni tri-layer systems** — •Christian Greb[1,2], Roman Adam[1], Daniel Bürgler[1], Sarah Heidtfeld[1,2], Markus Büscher[1,3], and Claus M. Schneider[1,2] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich,52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany — [3]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

Ultrafast spin dynamics induced by femtosecond optical laser pulses in ferromagnetic thin films are of great interest due to their high potential for future information technology. Relevant materials are often multi-element compounds or multilayer stacks. We present an element-selective study of Ni/Ru/Fe/MgO(capping) multilayers in which Ni and Fe layers are coupled either ferromagnetically or antiferromagnetically, depending on the Ru thickness. The spin dynamics in the multilayers can be explained by super-diffusive spin transport [1,2]. In addition to element-selective T-MOKE measurements using a high harmonic generation source, we measured and analyzed THz transients [3] to gain further insight into the non-equilibrium interlayer spin transport. We show that spin currents can be triggered at lower laser fluences (<1uJ/cm2) than previously reported [1]. The THz amplitude as a function of the external magnetic field gives insights into the interlayer exchange coupling. [1] D. Rudolf et al., Nature Commun. 3, 1037 (2012). [2] M. Battiato et al., Phys. Rev. Lett. 105, 027203 (2010). [3] R. Adam et al., Appl. Phys. Lett. 114, 212405 (2019).

MA 22.5 Tue 16:00 POT 6

**Impact of the magnetic layer crystal growth optimization on the THz emission from spintronic Fe/Pt emitters** — •Laura Scheuer[1], Agne Ciuciulkaite[2], Anna L. Ravensburg[2], Merlin Pohlit[2], Tobias Warnatz[2], Garik Torosyan[3], René Beigang[1], Georg Schmidt[4], Evangelos Th. Papaioannou[4], and Vassilios Kapaklis[2] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663, Kaiserslautern, Germany — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [3]Photonic Center Kaiserslautern, 67663, Kaiserslautern, Germany — [4]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 2, 06120 Halle, Germany

We investigate the THz emission characteristics of ferromagnetic/nonmagnetic metallic heterostructures, focusing on thin Fe/Pt bilayers. In particular, we report on the impact of optimized crystal growth of the epitaxial Fe layers on the THz emission amplitude and spectral bandwidth. We demonstrate a 5% enhancement of the emitted intensity related to structural quality of the Fe layer. Our work provides a pathway for optimal spintronic THz emitters devices based on epitaxial Fe. It also highlights how THz emission measurements can be utilized to characterize the changes in out-of-equilibrium spin current dynamics in metallic heterostructures, driven by subtle structural refinement.