MA 12: Focus Session: Terahertz Spintronics

Organizer: M. Münzenberg (Georg-August-University Göttingen)

Currently a new window has opened up in working with spin-polarized current bunches with a width of 100 fs from different directions. Generated by the non-equilibrium electrons, these can be treated by superdiffusive transport of magnetization. Experiments demonstrate a new way of manipulation of the spin bunches by non-magnetic materials, acting as a spin localizer, and their impact on the magnetization itself - paving the way for a THz spintronics.

Time: Tuesday 9:30–12:00 Location: H10

Topical Talk MA 12.1 Tue 9:30 H10

Ultrafast magnetization enhancement in metallic multilayers driven by superdiffusive spin current — •Roman Adam[1], Chan La-O-Vorakiat[2], Marco Battiato[3], Dennis Rudolf[1], Justin M. Shaw4[4], Emrah Turgut[2], Pablo Maldonado[3], Stefan Mathias[5], Patrik Grychtol[2], Hans T. Nembach[4], Thomas J. Silva[4], Martin Aeschlimann[5], Henry C. Kapteyn[2], Margaret M. Murnane[2], Claus M. Schneider[1], and Peter M. Oppeneer[3] — [1]Peter Grünberg Institut PGI-6, Research Centre Jülich, 52425, Germany — [2]Department of Physics and JILA, University of Colorado, Boulder, CO 80309-0440, USA — [3]Department of Physics and Astronomy, Uppsala University, Sweden — [4]Electromagnetics Division, NIST, Boulder, CO 80305-3328, USA — [5]University of Kaiserslautern and Research Center OPTIMAS, 67663, Kaiserslautern, Germany

Combining the femtosecond time resolution with element selectivity in pump-probe experiment we studied the magnetic response of Ni/Ru/Fe trilayers. By exciting the trilayer with infrared laser light we observed the ultrafast magnetization response in the Ni and Fe layers separately using synchronized extreme ultraviolet probe pulses tuned to the 3p absorption edges of Ni and Fe. Following the optical excitation, we detected both magnetization quenching as well as, an unexpected magnetization enhancement in the buried Fe layer. We ascribe the observed response to the optically generated superdiffusive spin currents between the layers [1,2].

[1] D. Rudolf, et al. Nature Commun. 3, 1037 (2012)
[2] M. Battiato, et al. Phys. Rev. Lett. 105, 027203 (2010)

Topical Talk MA 12.2 Tue 10:00 H10

New frontiers of ultrafast spin manipulation: femtosecond spin superdiffusion — •Marco Battiato — Uppsala University, Uppsala, Sweden

The origin of the ultrafast demagnetization has been a mystery for long time. Recently an approach based on spin dependent electron diffusion has been proposed. In the theoretical work the spin dependent electron transport in the femtosecond timescale had been accurately modeled and predicted as responsible for the ultrafast demagnetization.

It has been shown that 1) the femtosecond transport is within the more general regime of superdiffusion; 2) spin bunches with velocities higher than the Fermi velocity can be launched from a ferromagnetic material and 3) can be used to strongly manipulate the magnetization of distant layers. The newest experimental findings are proving the model by showing uncontrovertibly the sign of spin transport and validating the model*s unexpected predictions (see other talks within the symposium on THz spinelectronics).

The impact of these new discoveries goes beyond the field of ultrafast demagnetization. It shows how spin information can be, not only manipulated but most importantly transferred at unprecedented speeds. This new discovery lays the basis for femtosecond spintronics.

Topical Talk MA 12.3 Tue 10:30 H10

Engineering of terahertz spin currents in magnetic heterostructures — •T. Kampfrath[1], M. Battiato[2], P. Maldonado[2], G. Eilers[3], J. Nötzold[1], S. Mährlein[1], V. Zbarsky[3], I. Radu[4], F. Freimuth[5], Y. Mokrousov[5], S. Blügel[5], M. Wolf[1], P. M. Oppeneer[2], and M. Münzenberg[3] — [1]Fritz Haber Institute, Berlin, Germany — [2]University of Uppsala, Sweden — [3]University of Göttingen, Germany — [4]BESSY II, Helmholtz Center Berlin, Germany — [5]Forschungszentrum Jülich, Germany

One goal of spintronics research is the controlled transport of spin-polarized electron bunches through a solid, preferably at frequencies reaching the so far unexplored terahertz (THz) regime. Here, we show, by experiment and theory, that femtosecond spin currents can be manipulated by using suitable magnetic heterostructures. A femtosecond laser pulse is employed to trigger spin transport from a ferromagnetic Fe thin film into a nonmagnetic cap layer with either low (Ru) or high (Au) electron mobility. To detect the transient spin current $j_s(t)$, we make use of the inverse spin Hall effect that converts $j_s(t)$ into a charge current $j_c(t)$. By sampling the subsequently emitted electromagnetic THz transient in the time domain, the temporal structure of the femtosecond spin current can be determined. We find that the Fe-Ru bilayer yields a considerably longer $j_s(t)$ because electrons are injected in Ru d states that have a much lower mobility than Au sp states. Thus, THz spin current pulses can be shaped by tailoring magnetic heterostructures, which may open a route to engineering high-speed spintronic devices.

Topical Talk MA 12.4 Tue 11:00 H10

Ultrafast spin dynamics induced by laser-generated spin currents in metallic multilayers probed by non-linear magneto-optics — •Alexey Melnikov — Fritz-Haber-Institut der MPG, Abt. Phys. Chemie, Faradayweg 4-6, 14195 Berlin

The ultrafast spin dynamics (SD) induced by a transport of spin-polarized carriers is a hot topic motivated by the fundamental interest in magnetic excitations and applications like spintronics and data storage. To understand underlying elementary processes typically occurring on femtosecond time scales, we have developed a time-of-flight-like approach that probes the SD induced by hot carriers (HC) and demonstrated a spin polarized HC transport through an epitaxial Au/Fe/MgO(001) structure. Optical second harmonic generated at the Au surface monitors the transient surface HC density and spin polarization. Using a back pump-front probe configuration, we establish that HC induced in Fe by the pump laser pulse can form a nearly ballistic spin current (SC) in the Au layer which works as spin-selective HC retarder/attenuator. First experiments on the SD induced by femtosecond SC pulses in Fe/Au/Fe/MgO(001) structures demonstrate the spin transfer between the two Fe layers and the Au spacer serving as a spin sink. We discuss the key role of spin-dependent interface scattering of HC in the excited SD and consider the extension of our experimental approach to the investigation of spin transfer torque effects induced by femtosecond SC pulses. Financial support by the DFG through ME 3570/1-1 is acknowledged.

Topical Talk MA 12.5 Tue 11:30 H10

Ultra-fast spin currents in transparent magnetic tunnel junctions — •Andy Thomas — Universität Bielefeld, Universitätsstrasse 25, 33615 Bielefeld

Ultra-fast spin current can also be excited in magnetic tunnel junctions (MTJs). We prepared MTJs with tunnel magnetoresistance (TMR) ratios of up to 320% at room temperature with 2.4 nm magnesia tunnel barriers. Current induced magnetic switching (3×10^6 A/cm^2) was observed for MTJs with 1.1 nm MgO barrier while maintaining a TMR ratio of 100%. We further reduced the barrier thickness and we were able to achieve 60% TMR ratio for 3 ML ultra-transparent MgO tunnel barriers. In these junctions, low switching currents can be realized. Furthermore, currents can be generated using a femtosecond laser and temperature gradients of 10 K/nm are possible across the tunnel barrier. These ultra-fast pulses generate spin-polarized charge current bunches which can be modified via the TMR effect of the junctions.

[1] A. Mann et al., Phys. Rev. X 2 (2012) 041008
[2] M. Walter et al., Nature Mater. 10 (2011) 742
[3] G. M. Müller et al., Nature Mater. 8 (2009) 56