O 85: Ultrafast Electron Dynamics at Surfaces and Interfaces II: New Methods and Developments

Time: Thursday 15:00–17:30 Location: H16

O 85.1 Thu 15:00 H16

The role of the spin-orbit interaction and the exchange interaction in the ultrafast demagnetization of antiferromagnetic RE intermetallics — •S.E. Lee[1], Y.W. Windsor[1], D. Zahn[1], K. Kliemt[2], C. Krellner[2], K. Kummer[3], C. Schüssler-Langeheine[4], N. Pontius[4], D.V. Vyalikh[5,6], U. Staub[7], and L. Rettig[1] — [1]FHI, Faradayweg 4-6, 14195 Berlin, Germany — [2]Physik. Institut, Uni. Frankfurt, Max-von-Laue Straße 1, 60438 Frankfurt am Main, Germany — [3]ESRF, 71 Avenue des Martyrs, CS40220, F-38043 Grenoble Cedex 9, France — [4]BESSY II, Albert-Einstein-Strasse 15, 12489 Berlin, Germany — [5]DIPC, 20080 San Sebastian, Spain — [6]IKERBASQUE, 48011 Bilbao, Spain — [7]SLS, 5232 Villigen PSI, Switzerland

We have investigated the ultrafast dynamics of the antiferromagnetic rare-earth intermetallics, $GdTM_2Si_2$ (TM = Rh, Ir) employing time-resolved resonant magnetic soft X-ray scattering, which directly probes the transient $4f$ magnetic order. Following excitation by 40 fs pulses at 1.5 eV, $GdTM_2Si_2$ shows ultrafast demagnetization, which can be described by two exponential functions, one on a subpicosecond timescale and the other one on a tens of picoseconds timescale. While both compounds behave qualitatively very similar, $GdIr_2Si_2$ demagnetizes for a given fluence slightly more but with a slower time constant than $GdRh_2Si_2$. By comparing these two materials we will discuss the importance of the spin-orbit interaction and the exchange interaction for the ultrafast demagnetization for these antiferromagnetic materials.

O 85.2 Thu 15:15 H16

Comparison of RABBITT and streaking delays in attosecond time-resolved photoemission at solid surfaces — •Andreas Gebauer[1,2], Sergej Neb[1,3], Walter Enns[1], Benjamin Stadtmüller[2], Martin Aeschlimann[2], and Walter Pfeiffer[1] — [1]Bielefeld University, Germany — [2]University of Kaiserslautern, Germany — [3]ETH Zürich, Switzerland

The availability of single attosecond pulses and pulse trains paved the way to study electron dynamics at solid surfaces on their natural time scale [1] by applying either the attosecond streaking spectroscopy or RABBITT approach. Both techniques allow investigating time delays in the photoemission process from different initial states in the solid.

Here, we present a theoretical comparison between such delays that can be measured either by attosecond streaking or RABBITT, respectively. The time-resolved photoemission spectra are obtained by solving the 1D time-dependent Schrödinger equation using model potentials that were recently successfully applied to explain experimental data [2]. We show a continuous transition from the RABBITT regime to the streaking regime.

The absolute delays obtained by both methods are in agreement with each other within the available accuracy for kinetic energies >10eV. However, the evaluation of RABBITT spectra that are generated by a few-cycle infrared field is hindered by subtle systematic deviations between simulated results and commonly applied model functions.

[1] A.L. Cavalieri, et al. Nature 449, 1029 (2007)
[2] F. Siek, et al., Science 357, 1274 (2017)

O 85.3 Thu 15:30 H16

Measuring spin polarization and attosecond time delay in photoemission: current possibilities and perspectives — •Mauro Fanciulli[1,2], David Bresteau[2], Jakub Schusser[1], Zakariae El Youbi[1], Olivier Heckmann[1], Christine Richter[1], Thierry Ruchon[2], and Karol Hricovini[1] — [1]LPMS, Université de Cergy-Pontoise, France — [2]LIDYL, CEA Saclay, France

The phase term of the photoemission matrix elements is related to both the Wigner time delay of the process and to the spin polarization of photoelectrons from spin-degenerate states in the presence of spin-orbit coupling. Thus it is possible to make an estimate of the photoemission time scale by measuring the spin polarization [1].

In the first part of the talk, the model [2] that allows to indirectly access attosecond (as) time delays with spin-resolved experiments will be reviewed. In the second part, current attempts to combine spin resolution with direct femtosecond (fs) and as time resolution will be presented. We have installed an angle-resolved photoemission spectroscopy setup with a 3D VLEED spin detector at the recent Attolab beamline of CEA Saclay. The beamline provides a 10 kHz IR fs laser and a XUV laser based on high-harmonic generation. This give us the unique possibility to perform spin-resolved fs pump-probe and reconstruction of as-beating by interference of two-photon transitions (RABBIT) experiments on solid targets, with the aim of studying the spin polarization of the photoelectrons at their fundamental time scale.

[1] M. Fanciulli et al., PRL 118, 067402 (2017) [2] M. Fanciulli and H. Dil, arXiv:1806.05895 (2018)

O 85.4 Thu 15:45 H16

Visualization of Charge Carrier Motion in Nanosystems by Point-projection Microscopy — •Ivana Lapšanská, Faruk Krecinic, Melanie Müller, and Ralph Ernstorfer — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

The ultrafast motion of charge carriers at the nanoscale plays a crucial role in the understanding and development of new optoelectronic devices. To visualize nanoscale dynamics, we employ femtosecond point projection microscopy (fs-PPM) - a technique based on low-energy (<200 eV) electron imaging in a pump-probe configuration. Probe electrons are photo-emitted from a nanotip by a femtosecond laser pulse, and diverge towards a sample producing an enlarged image of the electrostatic environment of a nanoscale object. The sample is optically excited by a laser pulse and the induced charge motion can be visualized via the interaction of the low-energy electrons with the carrier motion-induced local electric fields. We obtain a temporal resolution of the dynamics of charge motion down to tens of femtoseconds, with a spatial resolution down to 10 nm. We demonstrate the concept of charge motion visualization for amorphous carbon nanostructures, graphene and III-V semiconductor nanowires.

O 85.5 Thu 16:00 H16

Experimental setup for time-resolved momentum microscopy — •Jasmin Fehl[1], Katerina Medjanik[2], David Janas[1], Felix Passlack[1], Stefano Ponzoni[1], Mahdi Hajlaoui[1], Giovanni Zamborlini[1], Gerd Schönhense[2], and Mirko Cinchetti[1] — [1]Experimentelle Physik VI, TU Dortmund, Otto-Hahn-Straße 4, 44227 Dortmund, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität, Staudinger Weg 7, 55128 Mainz, Germany

ARPES is the most common method to map electronic bands. Recently, momentum microscopy (MM), has been introduced as a novel highly efficient way to perform ARPES in large momentum space regions [1]. In this talk, we will discuss the realization and characterization of an experimental apparatus for laser-assisted MM. The setup is based on a sub-100 fs laser system for pump-probe experiments with pump and probe beams tunable in the whole visible spectrum (photon energy range: 1.0 eV - 6.0 eV) and repetition rate tunable from single shot up to 1 MHz. The laser is coupled to a momentum microscope equipped with a time of flight analyser. This system will allow us to probe the ultrafast dynamics in low-dimensional electron systems, with particular emphasis on hybrid interfaces - so called molecular spinterfaces [2] - and on materials with non-trivial spin-texture, such as topological insulators.

[1] Medjanik, K. et al. Nature Materials 16, 61 (2017)
[2] M. Cinchetti, V. A. Dediu, and L.E. Hueso, Nature Materials 16, 507 (2017).

O 85.6 Thu 16:15 H16

Time resolved momentum microscopy on FeRh thin films, revealing ultrafast time scales for antiferro- to ferromagnetic phase transition. — •Steinn Ymir Agustsson[1], Federico Pressacco[2], Michael Heber[3], Dmytro Kutnyakhov[3], Dmitry Vasilyev[1], Jon Ander Arregi[4], Vojtech Uhlir[4], Guenter Brenner[3], Davide Curcio[5], Yves Acremann[6], Fausto Sirotti[7], Gerd Schoenhense[1], Hans-Joachim Elmers[1], Jure Demsar[1], and Wilfried Wurth[2,3] — [1]Institute of Physics, Uni. Mainz, Germany — [2]CFEL, Hamburg, Germany — [3]DESY, Hamburg, Germany — [4]CEITEC BUT, Czech Republic — [5]Aarhus University, Denmark — [6]ETH Zurich, Switzerland — [7]École Polytechnique, CNRS, France

The development of a momentum microscope for parallel electron detection, coupled to ultrafast extreme ultraviolet laser sources allows

simultaneous observation of time, momentum and energy resolved photo-electrons excited by femtosecond laser pulses. In such experiments performed at the Free Electron Laser FLASH (DESY, Hamburg) we studied the electron redistribution upon laser induced phase transition between anti-ferromagnetic and ferromagnetic phases of FeRh. By optimizing the microscope and changing the settings of the electron optics, we could strongly reduce the effect of space charge with no loss of energy or time resolution. Such experimental conditions are the key to measuring the ultrafast response of excited carriers in complex quantum materials as well as in simple metals, where photo-excited electron-electron and electron-phonon thermalization dynamics are still not fully understood.

O 85.7 Thu 16:30 H16

Momentum dependent hot electron dynamics in Ag(110) — •Tobias Eul[1], Eva-Sophia Walther[1], Michael Hartelt[1], Eva Prinz[1,2], Benjamin Frisch[1], Mirko Cinchetti[3], Martin Aeschlimann[1], and Benjamin Stadtmüller[1,2] — [1]Department of Physics and Research Center Optimas, University of Kaiserslautern, Germany — [2]Graduate School MAINZ, Germany — [3]Experimentelle Physik IV, TU Dortmund University, Germany

Electron dynamics in solid state systems and at interfaces play a crucial role for the performance of nanoscale electronic and spintronic devices. Therefore, it is essential to investigate hot electrons and the corresponding energy and momentum dissipation mechanisms in such materials.

To go beyond the energy dissipation mechanisms, we combine the well-established time-resolved two-photon photoemission technique with ToF-momentum microscopy (PEEM operated in k-space mode). From our data set, we extract and analyze cross-correlation traces for different intermediate state energies at each point of the accessible momentum space, which can be directly translated into momentum dependent lifetime maps.

Here, we focused on single crystalline Ag(110), where we observe lifetime differences of several femtoseconds, which can be correlated to the character of the optical transition as well as to the excited state dynamics of the band structure. Our first results already point to a complex momentum dependent lifetime of electrons even for simple material systems.

O 85.8 Thu 16:45 H16

Excitation and decay mechanisms in the quantum-well state system Pb/Ag(111) — •Florian Haag[1,2], Tobias Eul[1], Mirko Cinchetti[3], Martin Aeschlimann[1], and Benjmain Stadtmüller[1,2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Erwin Schroedinger Straße 46, 67663 Kaiserslautern, Germany — [3]Experimentelle Physik VI, Technische Universität Dortmund, 44221 Dortmund, Germany

Hetero-metallic bilayer systems have developed into a highly tunable class of materials where the electronic properties can be controlled by the interaction across the interface. However, the implementation of low dimensional materials in new nanoscale devices is limited by the comprehension of the hot carrier dynamics of such materials.

Here, we focus on the quantum-well state system of one monolayer Pb on a Ag(111) single crystal. Using light with different polarizations, we are able to identify three different states at the Pb-Ag interface with characteristic momentum dependent lifetimes. Furthermore, we performed time-resolved 2-photon momentum microscopy (tr-2PMM) measurements with a phase stabilized interferometer to obtain information about the excitation pathways and decay mechanisms at the hetero-metallic bilayer system to extend todays understanding of the electron dynamics in low dimensional systems.

O 85.9 Thu 17:00 H16

Time- and angle-resolved photoelectron spectroscopy of the three-dimensional Dirac semimetal Cd_3As_2 — •Hermann Erk[1], Petra Hein[1], Stephan Jauernik[1], Lexian Yang[2], Yulin Chen[3], Zhongkai Liu[4], Dharmalingam Prabhakaran[3], and Michael Bauer[1] — [1]IEAP, CAU Kiel, Germany — [2]Physics Department, Tsinghua University, Beijing, China — [3]Physics Department, Oxford University, United Kingdom — [4]School of Physical Science and Technology, ShanghaiTech University, China

Dirac semimetals exhibit a characteristic linear band dispersion in the vicinity of discrete points in momentum space. The most prominent examples are 2D Dirac cones in graphene and at the surfaces of topological insulators. However, cone-shaped band dispersions were proposed to exist also in 3D [1]. A material that was experimentally verified to host a pair of 3D Dirac cones is Cd_3As_2 [2].

Here, we present first results of a time- and angle-resolved photoemission study of the (112) surface of Cd_3As_2. While the band dispersion of the Dirac cone has already been subject of several studies, only little is known about the ultrafast carrier dynamics in this material. Our technique enables us to get the first momentum-resolved insights into the dynamics in the vicinity of the 3D Dirac cone initiated by the absorption of 840 nm pump pulses. The results are discussed under consideration of recent studies of Cd_3As_2 and in comparison to ultrafast dynamics observed in related materials.

[1] S. M. Young, S. Zaheer et al., Phys. Rev. Lett. 108, 140405 (2012).

[2] M. Neupane, S.-Y. Xu et al., Nat. Commun. 5, 3786 (2014).

O 85.10 Thu 17:15 H16

Time-resolved scanning electron microscope — •Simon Däster, Yves Acremann und Andreas Vaterlaus — ETH Zurich, Switzerland

We develop a time-resolved SEM by energy-analyzing secondary electrons which provides a contrast mechanism for local potentials of a sample. This way, we intent to observe integrated microwave electronic circuits in operando.