O 15: Mini-Symposium: Ultrafast surface dynamics at the space-time limit II

Time: Monday 13:30–15:30 Location: R1

Invited Talk O 15.1 Mon 13:30 R1

The ultrafast Einstein-de Haas effect triggered by ultrafast demagnetization — •Steven L. Johnson[1,4], Christian Dornes[1], Yves Acremann[2], Matteo Savoini[1], Martin Kubli[1], Martin J. Neugebauer[1], Elsa Abreu[1], Lucas Huber[1], Gabriel Lantz[1], Carlos A. F. Vaz[3], Henrik Lemke[4], Elizabeth M. Bothschafter[3], Michael Porer[3], Vincent Esposito[3], Laurenz Rettig[3,5], Michael Buzzi[3,6], Aurora Alberca[3], Yoav W. Windsor[3,5], Paul Beaud[4], Urs Staub[3], Diling Zhu[7], Sanghoon Song[7], and James M. Glownia[7] — [1]Institute for Quantum Electronics, Physics Department, ETH Zurich, Zurich, Switzerland — [2]Laboratory for Solid State Physics, Physics Department, ETH Zurich, Zurich, Switzerland — [3]Swiss Light Source, Paul Scherrer Institute, Villigen, Switzerland — [4]SwissFEL, Paul Scherrer Institute, Villigen, Switzerland — [5]Fritz Haber Institute of the Max Planck Society, Berlin, Germany — [6]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [7]Linac Coherent Light Source (LCLS), SLAC National Accelerator Laboratory, Menlo Park, CA, USA

The Einstein-de Haas effect is a historically important experiment that demonstrated clearly the equivalence between spin angular momentum and mechanical angular momentum. Here I discuss an experiment where ultrafast demagnetization driven by laser excitation of a thin film of iron drives transverse atomic displacement waves from the interfaces of the film, a direct consequence of sub-picosecond angular momentum transfer from electronic spins to the lattice.

Round Table Discussion and introduction of panel members: All following contributed talks will be presented in form of a round table discussion with expert panel members Prof. Martin Aeschlimann (TU Kaiserslautern), Prof. Michael Horn-von-Hoegen (U Duisburg) and Prof. Julia Stähler (HU Berlin)

O 15.2 Mon 14:05 R1

Structural Dynamics at Surfaces: Current State and Prospects of tr-RHEED — •Christian Brand, Jonas Fortmann, Thorben Groven, Tobias Witte, Fabian Thiemann, Bernd Hafke, Mohammad Tajik, and Michael Horn-von Hoegen — Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg

Ultrafast time-resolved reflection high energy electron diffraction (tr-RHEED) is employed to follow structural dynamics at surfaces upon fs-laser excitation. We measure the transient changes of intensity, profile and position of diffraction spots in a pump-probe setup with a temporal resolution of 350 fs. We demonstrate the broad capabilities of this technique through three examples: Electron phonon coupling and nanoscale heat transport is studied for ultrathin epitaxial Pb and Bi films through the Debye-Waller effect [1,2]. Ultrafast dynamics in the In atomic wire system on Si(111) serves as an example for a strongly driven first order phase transition (PT) [3]. The dynamics of a second order PT are observed through the order-disorder transition in the Si spin chain system on the Si(553)-Au surface [4]. We discuss future developments of this technique for improving the temporal resolution below 200 fs at increased brightness of the electron pulses, the perspectives of mode specific excitation with reduced photon energy or with THz radiation, and the combination of electron and optical probes to access transient changes of electronic properties. [1] T. Witte *et al.*, Appl. Phys. Lett. **110**, 243103 (2017); [2] V. Tinnemann *et al.*, Structural Dynamics **6**, 035101 & 065101 (2019); [3] T. Frigge *et al.*, Nature **544**, 207 (2017); [4] B. Hafke *et al.*, PRL **124**, 016102 (2020).

O 15.3 Mon 14:25 R1

Towards understanding the time evolution of metastable charge-ordered states — •Yaroslav A. Gerasimenko[1,2], Jan Ravnik[1,3], Jaka Vodeb[1], Michele Diego[1], Yevhenii Vaskivskyi[1], Viktor V. Kabanov[1], Igor Vaskivskyi[4], Tomaz Mertelj[1,4], and Dragan Mihailovic[1,4,5] — [1]Jozef Stefan Institute, Ljubljana, Slovenia — [2]University of Regensburg, Regensburg, Germany — [3]Paul Scherrer Institute, Villigen, Switzerland — [4]CENN Nanocenter, Ljubljana, Slovenia — [5]University of Ljubljana, Ljubljana, Slovenia

Metastable self-organized electronic states in quantum materials are emergent states of matter[1] typically formed through phase transitions under non-equilibrium conditions. It is of fundamental importance to understand the process of their formation that can involve multiple mechanisms[1,2] spanning a large range of timescales.

Here we combine multiple techniques to map the evolution of metastable states in 1T-TaS_2, a prototypical charge-ordered quantum material, using the photon density and temperature as control parameters on timescales ranging from 10^{-12} to 10^{3}s. The combination of STM and in situ ultrafast excitation allows us to observe explicitly both parametric stability and nanoscale relaxation of the light-induced metastable states on the scale of seconds, while time-resolved optical techniques and electrical measurements allow us to study the ordering and relaxation processes down to a few picoseconds. [3]

[1] Ya. A. Gerasimenko et al., Nature Materials 18, 1078-1083 (2019)
[2] Ya. A. Gerasimenko et al., npj Quantum Materials 4, 1-9 (2019)
[3] J. Ravnik et al., arXiv:2011.00930

O 15.4 Mon 14:45 R1

Ultrafast atomic and electronic dynamics at the molecule-$TiSe_2$ interface — •Markus Scholz[1], Kiana Baumgärtner[2], Nils Wind[3], Christian Metzger[2], Dmytro Kutnyakhov[4], Michael Heber[4], Lukas Wenthaus[4], Friedrich Roth[5], Kai Rossnagel[6], Friedrich Reinert[2], and Serguei Molodtsov[1] — [1]European X-Ray Free-Electron Laser Facility, Schenefeld — [2]Experimentelle Physik 7, Julius-Maximilians-Universität, Würzburg — [3]Universität Hamburg — [4]Deutsches Elektronen-Synchrotron DESY, Hamburg — [5]TU Bergakademie Freiberg — [6]Christian-Albrechts-Universität zu Kiel

In recent years layered transition-metal dichalcogenides (TMDCs) have been extensively investigated due to their intriguing electronic phenomena ranging from Mott localization to charge-density-wave (CDW) formation [1] as well as their potential for novel electronic and optical devices. First studies of adsorbed molecules on the TMDC surface have revealed a rich potential to tailor optical, electronic, and magnetic properties of organic-TMDC devices. However, very few studies have been carried out on understanding fundamental interactions at the molecule-TMDC interface. Time-resolved imaging of orbitals with time-resolved photoelectron spectroscopy (trPES) will not only allow us to separate the molecular contribution to the trPES signal but also to determine the ultrafast charge-transfer dynamics at the interface. In order to probe structural changes at the interface, we also perform time-resolved XPD at FLASH FEL.

[1] Rossnagel K, et. al., J Phys Cond Matter 23:213001 (2011)

O 15.5 Mon 15:05 R1

Tracing orbital images on ultrafast time scales — •Robert Wallauer[1], Miriam Raths[2,3], Klaus Stallberg[1], Lasse Münster[1], Dominik Brandstetter[4], Xiaosheng Yang[2,3], Jens Güdde[1], Peter Puschnig[4], Sergey Soubatch[2], Christian Kumpf[2,3], Francois C. Bocquet[2], Frank Stefan Tautz[2,3], and Ulrich Höfer[1] — [1]Fachbereich Physik, Philipps-Universität Marburg, Germany — [2]Peter Grünberg Institut, PGI-3, Forschungszentrum Jülich, Germany — [3]Jülich Aachen Research Alliance (JARA), Jülich, Germany — [4]Insititute of Physics, Universität Graz, Austria

Photoemission tomography is a powerful tool to image the electron distribution in molecular orbitals in momentum space. Unoccupied molecular orbitals, however, have not been accessed until now. In our experiment, we combine time-resolved photoemission using high laser harmonics and a momentum microscope to establish a tomographic, femtosecond pump-probe experiment of unoccupied molecular orbitals. We measure the full momentum-space distribution of transiently excited electrons within a single molecular layer of PTCDA on an oxygen-passivated Cu(001) surface.

Beside the identification of the lowest unoccupied molecular orbital and its lifetime, we were able to link the excited state dynamics to real-space excitation pathways. Electron transfer from the substrate to the molecule and intramolecular excitation lead to distinct signatures in the time evolution of the respective momentum map. Our results show the potential of this technique to identify electron excitation and transfer processes at molecular surfaces and interfaces.

Concluding remarks