O 104: Ultrafast Electron Dynamics III (joint session O/MA)

Time: Thursday 10:30–12:45 Location: WIL B321

O 104.1 Thu 10:30 WIL B321

THz-induced oscillations of the band structures in the topological insulator Bi_2Te_3 — •Suguru Ito[1], Johannes Reimann[1], Stefan Schlauderer[2], Christoph Schmid[2], Fabian Langer[2], Sebastian Baierl[2], Josef Freudenstein[2], Manuel Meierhofer[2], Konstantin Kokh[3], Oleg Tereshchenko[3], Akio Kimura[4], Christoph Lange[2], Jens Güdde[1], Rupert Huber[2], and Ulrich Höfer[1] — [1]Fachbereich Physik, Philipps-Universität Marburg, Germany — [2]Fakultät für Physik, Universität Regensburg, Germany — [3]Novosibirsk State University, Russia — [4]Graduate School of Science, Hiroshima University, Japan

Time- and angle-resolved photoemission spectroscopy (time-resolved ARPES) is a powerful tool to map ultrafast dynamics occurring in electronic band structures. New opportunities arise in combination with THz excitation. As demonstrated recently for the topological surface bands of Bi_2Te_3, THz-ARPES is capable of mapping the dynamics of electrical currents in k-space with sub-cycle time resolution [1]. Here, we show that the THz light field also induces oscillations of the electronic bands on a time scale longer than the duration of the field transient. Frequency analysis implies the origin in atomic displacements but reveals the existence of oscillation modes that cannot be attributed to phonons in bulk Bi_2Te_3. Our results suggest another perspective of THz-ARPES, the capability to track band-structure engineering by light. We will discuss the experiment and compare with electronic structure calculations.

[1] J. Reimann *et al.* Nature **562**, 396 (2018).

O 104.2 Thu 10:45 WIL B321

Spin-, time- and angle-resolved photoemission spectroscopy on WTe2 — •Mauro Fanciulli[1,2], Jakub Schusser[1,3], Christine Richter[1,2], Cephise Cacho[4], David Bresteau[2], Thierry Ruchon[2], Jan Minár[3], and Karol Hricovini[1,2] — [1]LPMS, CY Cergy Paris Université, Cergy, FR — [2]LIDYL, CEA Saclay, Gif-sur-Yvette, FR — [3]NTC, University of West Bohemia, Pilsen, CZ — [4]Diamond Light Source, Didcot, UK

We combined a spin-resolved photoemission spectrometer with a high-harmonic generation (HHG) laser source in order to perform spin-, time- and angle-resolved photoemission spectroscopy (STARPES) experiments on the transition metal dichalcogenide bulk WTe2, a possible Weyl type-II semimetal. Measurements at different femtosecond pump-probe delays and comparison with spin-resolved one-step photoemission calculations provide insight into the spin polarization of electrons above the Fermi level in the region where Weyl points of WTe2 are expected. We observe a spin accumulation above the Weyl points region, that is consistent with a spin-selective bottleneck effect due to the presence of spin polarized cone-like electronic structure. Our results support the feasibility of STARPES with HHG, which despite being experimentally challenging provides a unique way to study spin dynamics in photoemission.

O 104.3 Thu 11:00 WIL B321

Mode-resolved reciprocal space mapping of electron-phonon interaction in the Weyl semimetal candidate *Td*-WTe_2 — •Petra Hein[1], Stephan Jauernik[1], Hermann Erk[1], Lexian Yang[2], Yanpeng Qi[3], Yan Sun[4], Claudia Felser[4], and Michael Bauer[1] — [1]Institute of Experimental and Applied Physics, CAU Kiel, Germany — [2]State Key Laboratory of Low Dimensional Quantum Physics, Tsinghua University, China — [3]School of Physical Science and Technology, ShanghaiTech University, China — [4]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

The selective excitation of coherent phonons provides unique capabilities to control fundamental properties of quantum materials on ultrafast time scales. For instance, in the presence of strong electron-phonon coupling, the electronic band structure can become substantially modulated. Recently, it was predicted that by this means even topologically protected states of matter can be manipulated: Pairs of Weyl points in *Td*-WTe_2 are expected to annihilate as an interlayer shear mode drives the material towards a centrosymmetric phase [1].

Here, time- and angle-resolved photoelectron spectroscopy is used to monitor the changes in the electronic structure of *Td*-WTe_2 upon absorption of 1.5 eV femtosecond laser pulses. We provide direct experimental evidence that the coherent excitation of the shear mode acts on the electronic states near the Weyl points. By comparison with higher-frequency coherent phonon modes, we finally prove the shear mode-selectivity of the observed changes in the electronic structure.

[1] E. J. Sie *et al.*, Nature **565**, 61-66 (2019).

O 104.4 Thu 11:15 WIL B321

Ultrafast Light-Induced Lifshitz Transition — •Samuel Beaulieu[1], Shuo Dong[1], Nicolas Tancogne-Dejean[2], Maciej Dendzik[1], Julian Maklar[1], Tomasso Pincelli[1], R. Patrick Xian[1], Martin Wolf[1], Angel Rubio[2,3], Michael A. Sentef[2], Laurenz Rettig[1], and Ralph Ernstorfer[1] — [1]Fritz-Haber- Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Max Planck Institute for the Structure and Dynamics, of Matter and Center for Free-Electron Laser Science, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Center for Computational Quantum Physics (CCQ), The Flatiron Institute, 162 Fifth Avenue, New York NY 10010

Fermi surface is at the heart of our understanding of the properties of metals and strongly correlated many-body systems. An abrupt change in the Fermi surface topology, also called Lifshitz transition, can lead to the emergence of fascinating phenomena like colossal magnetoresistance and superconductivity. While Lifshitz transitions have been demonstrated for a broad range of materials and using different types of static external perturbations like strain, doping, pressure and temperature, a nonequilibrium route toward ultrafast and transient switching of the Fermi surface topology has not been demonstrated yet. Using time-resolved multidimensional photoemission spectroscopy combined with TDDFT+U simulations, we demonstrate a scheme based on ultrafast laser-driven band renormalization that drives a Lifshitz transition in the topological type-II Weyl semimetal $T_d - MoTe_2$, due to transient modification of effective electron-electron interactions.

O 104.5 Thu 11:30 WIL B321

Time-resolved Momentum Microscopy of an Ultrafast Charge-Density-Wave-to-Metal Transition — •Julian Maklar[1], Shuo Dong[1], Samuel Beaulieu[1], Tommaso Pincelli[1], Maciej Dendzik[1], Philip Walmsley[2], Ian Fisher[2], Ralph Ernstorfer[1], Martin Wolf[1], and Laurenz Rettig[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Deutschland — [2]GLAM, Department of Applied Physics, Stanford, California, USA

Complex solids exhibit a multitude of competing and intertwined orders. A promising approach to disentangle relevant interactions and energy scales is by perturbation via ultrafast photoexcitation. However, this requires tracking of the electronic structure upon photoexcitation across a large energy and momentum range with femtosecond (fs) time-resolution in order to capture all relevant electronic processes.

Here, we investigate the evolution of the electronic band structure of the prototypical 2D charge-density-wave (CDW) compound $TbTe_3$ after photo-excitation. We utilize a new method, i.e. XUV time-resolved momentum microscopy, to simultaneously map a large energy- and momentum region with 40 fs temporal resolution. This allows us to identify collective excitations of the CDW as well as a strong coupling to a distinct phonon mode across multiple Brillouin zones.

O 104.6 Thu 11:45 WIL B321

Heavy fermion dynamics in semimetallic and insulating phases — •chul-hee min[1], michael heber[2], simon müller[3], lukas wenthaus[2], steffen palutke[2], dmytro kutnyakhov[2], federico pressacco[4], lenart dudy[5], mathieu silly[5], celso fornari[3], kiana baumgärtner[3], hendrik bentmann[3], woojae choi[6], yong seung kwon[6], markus scholz[7], friedrich reinert[3], wilfried wurth[2,4], and kai rossnagel[1,2] — [1]IEAP, CAU Kiel, Germany — [2]DESY, Hamburg, Germany — [3]EP7 and ct.qmat, University of Würzburg, Germany — [4]Department of Physics, University of Hamburg, Germany — [5]Synchrotron-SOLEIL, Saint-Aubin, France — [6]Department of Emerging Materials Science, DGIST, Republic of Korea — [7]European XFEL GmbH, Schenefeld, Germany

Due to time–energy correlation, heavy fermion systems with hard-to-detect meV energy scales are expected to show relatively slow dynamics on ps time scales, which are relatively easy to measure. Using the free-electron laser FLASH, we have performed time-resolved pump-probe photoemission spectroscopy of mixed valent $TmSe_{1-x}Te_x$. The sys-

tem is composed of two magnetic $4f^{12}$ and $4f^{13}$ configurations in the ground state and can be tuned from semimetallic to insulating behavior via the Te concentration x without destroying the periodicity of the Tm ions. Here, we present and discuss the transient dynamics of the $4f$ states near E_F showing a remarkably strong dependence on x.

O 104.7 Thu 12:00 WIL B321

Polarisation effects in real space and real time in Xe-Cs solvatomers on Cu(111) — John Thomas[1], •Cord Bertram[1,2], Ping Zhou[1], Manuel Ligges[1], Karina Morgenstern[2], and Uwe Bovensiepen[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Lehrstuhl für Physikalische Chemie I, Ruhr-Universität Bochum, 44780 Bochum, Germany

For understanding solvation under spatial constraints, morphology and ultrafast electron dynamics of solvent-solute complexes on surfaces are essential. In this contribution, we present the influence of the rare-gas, non-polar solvent xenon on the electronic structure of Cs/Cu(111) investigated by Scanning Tunneling Microscopy (STM) and Two-Photon-Photoelectron Spectroscopy (2PPE). After adsorption of xenon onto Cs precovered Cu(111), Cs agglomerates in xenon islands to a distance within the islands that is limited by Coulomb repulsion. The cesium antibonding resonance attributed to the Cs 6s orbital shifts up in energy with increasing Xe coverage and the lifetime of the antibonding resonance is increased from 15 fs to 81 fs. We interpret these results as an enhanced localization of the antibonding resonance and a decoupling of Cs from Cu(111), mediated by the polarization response of Xe in the close vicinity of Cs. Such effects will be discussed in the context of solvation and de-solvation of Cs-Xe complexes on Cu(111). We acknowledge that this contribution is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2033 - Projektnummer 390677874.

O 104.8 Thu 12:15 WIL B321

Investigation of coherent phonons at the interface of GaP/Si(001) heterostructures — •Steven Youngkin[1], Gerson Mette[1], Kunie Ishioka[2], Wolfgang Stolz[1], and Ulrich Höfer[1] — [1]Fachbereich Physik, Philipps Universität Marburg, Germany — [2]National Institute for Material Science, Tsukuba, Japan

Breaking of the bulk lattice atomic ordering by a surface leads to a plethora of novel and interesting physical phenomena such as new vibronic states, commonly known as surface phonon modes. However, very little is known about the vibronic states that arise at an interface of two solids.

Here, we use coherent phonon spectroscopy to study the interface vibronic system of GaP/Si(001) heterostructures, which represent a structurally well characterized model system of a polar/non-polar inorganic semiconductor interface. By measuring the transient reflectivity change of the probe beam at various pump photon energies, we can monitor the energy dependence of the coherent excitation of phonon modes with a resolution limited by the ultrashort laser pulses. Our studies reveal the existence of a low-frequency phonon mode with a frequency of 2 THz. This vibrational mode is absent in both bulk systems and is therefore assigned to originate from the buried interface between GaP and Si.

O 104.9 Thu 12:30 WIL B321

Three time-resolved photoelectron spectroscopies in one setup - time-of-flight momentum microscope at free electron laser. — •D. Kutnyakhov[1], R.P. Xian[2], M. Dendzik[2], M. Heber[1], F. Pressacco[3], S.Y. Agustsson[4], L. Wenthaus[1], H. Meyer[3], S. Gieschen[3], K. Bühlman[5], S. Däster[5], R. Gort[5], D. Curcio[6], K. Volckaert[6], M. Bianchi[6], Ch. Sanders[6], J.A. Miwa[6], S. Ulstrup[6], A. Oelsner[7], C. Tusche[8,9], Y.-J. Chen[8,9], D. Vasilyev[4], K. Medjanik[4], G. Brenner[1], S. Dziarzhytski[1], S. Dong[2], J. Hauer[2], L. Rettig[2], J. Demsar[4], K. Rossnagel[1,10], H.-J. Elmers[4], Ph. Hofmann[6], R. Ernstorfer[2], G. Schönhense[4], Y. Acremann[5], and W. Wurth[1,3] — [1]DESY, Hamburg — [2]FHI Berlin — [3]CFEL, Univ. Hamburg — [4]Univ. Mainz — [5]ETH Zürich — [6]Univ. Aarhus — [7]Surface Concept GmbH, Mainz — [8]FZ Jülich GmbH — [9]Univ. Duisburg-Essen — [10]IEAP, CAU Kiel

Time-resolved photoemission with ultrafast pump and probe pulses is an emerging technique with wide application potential. Combining valence-band and core-level spectroscopy with photoelectron diffraction in a single efficient photoelectron-detection setup for electronic, chemical and structural analysis requires soft X-ray pulses (width few 10 fs) with some 10 meV spectral resolution. This is feasible at high repetition rate free-electron lasers using parallel imaging with segmented single-shot detectors with increased multi-hit capabilities. We have constructed and optimized a versatile setup commissioned at FLASH/PG2 that combines free-electron-laser capabilities with a multidimensional recording scheme for photoemission studies.