O 83: Poster Focus Session: Structural Dynamics in Nanoscale Materials, Probed by Ultrafast Electron Pulses

Time: Wednesday 18:15–20:30 Location: Poster A

O 83.1 Wed 18:15 Poster A

Energy relaxation and dissipation in laser-excited thin film heterostructures — •K. Sokolowski-Tinten[1], R. Li[2], A. H. Reid[2], X. Shen[2], Q. Zheng[2], T. Chase[2], M. Milnikel[1], R. Coffee[2], J. Corbett[2], H. Dürr[2], N. Hartmann[2], C. Hast[2], R. Hettel[2], M. Horn-von Hoegen[1], D. Janoschka[1], M. Jermann[1], M. Ligges[1], I. Makasyuk[2], M. Mo[2], F. Quirin[1], B. Rethfeld[3], S. Salamon[1], A. Terwey[1], T. Veccione[2], U. von Hörsten[1], S. P. Weathersby[2], H. Wende[1], C. Witt[1], and X. Wang[2] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany. — [2]SLAC Nat. Acc. Lab., Menlo Park, USA. — [3]Dep. of Physics and OPTIMAS Research Center, TU Kaiserslautern, Germany

We use time-resolved MeV transmission electron diffraction experiments to study the incoherent structural response of nanoscale materials after fs laser excitation. Experiments were carried out using the MeV Ultrafast Electron Diffraction (UED) facility recently established at SLAC [1]. UED@SLAC provides ultrashort <300fs electron pulses at relativistic energies (3-5 MeV), which we have used for precise measurements of the transient Debye-Waller-effect in different metal-insulator and metal-metal-heterostructures, highlighting the importance of interface [2] and transport effects.

[1] S. P. Weathersby et al., Rev. Sci. Instrum. 86, 073702 (2015).
[2] K. Sokolowski-Tinten et al., New J. Phys. 17, 113047 (2015); Struct. Dyn. 4, 054501 (2017).

O 83.2 Wed 18:15 Poster A

Ultrafast electron diffraction with RF-compressed electron pulses — •Marius Milnikel[1], Patrick Lapsien[1], Martin Otto[2], Laurent P. René de Cotret[2], Nico Rothenbach[1], Soma Salamon[1], Alexandra Terwey[1], Ping Zhou[1], Bradley J. Siwick[2], Heiko Wende[1], and Klaus Sokolowski-Tinten[1] — [1]University of Duisburg-Essen and Centre for Nanointegration Duisburg-Essen, Faculty of Physics, Lotharstraße 1, 47057 Duisburg, Germany — [2]Department of Chemistry, McGill University, 801 Sherbrooke St., Montreal, Quebec, Canada

One of the major challenges in ultrafast electron diffraction (UED) is the electron pulse broadening induced by space-charge effects at high bunch charge. It has been demonstrated that the linear chirp introduced by this effect allows re-compression of the electron pulses to a pulse duration of about 100 fs by a time-dependent electrical field using a radio-frequency cavity at bunch charges of up to 10^6 electrons [1,2]. Here we report about our current efforts to set up such a RF-compressed electron source based on the concept introduced in [1], which has been recently commercialized [3]. Additionally we will present results of time-resolved diffraction experiments on metal-insulator heterostructures performed at the RF-compressed short pulse electron source at McGill University [2].

[1] van Oudheusden et al, Phys. Rev. Lett. 105, 264801 (2010).
[2] Chatelain et al., Appl. Phys. Lett. 101, 081901 (2012).
[3] AccTec BV: "A poor man's X-FEL" (www.acctec.nl/acctec.nl/index.php/products)

O 83.3 Wed 18:15 Poster A

Picosecond acoustic waves in laser-excited metal-semiconductor heterostructures studied by ultrafast X-ray diffraction — •Fabian Brinks[1], Mohammadmahdi Afshari[1], Philipp Krumey[1], Andrey Akimov[2], Dmitri Yakovlev[3], Manfred Bayer[3], and Klaus Sokolowski-Tinten[1] — [1]Faculty of Physics and Centre for Nanointegration Duisburg-Essen, Lotharstrasse 1, 47057 Duisburg — [2]School of Physics and Astronomy, University of Nottingham, NG7 2RD, UK — [3]Faculty of Physics, Technical University Dortmund, 44221 Dortmund, Germany

Absorption of ultrashort optical pulses in solids leads to a quasi-instantaneous increase of stress/pressure which is subsequently released by acoustic strain waves traveling through the sample. We investigate the excitation and transient evolution of such coherent acoustic phonons in metal-semiconductor heterostructures composed of thin metal films (Ti, Cr, Al, Al, Pt, Au, Pd) deposited on 100-oriented GaAs substrates by time-resolved X-ray diffraction using ultrashort X-ray pulses at 4.5 keV from a fs laser-plasma X-ray source. By probing the GaAs (400) Bragg reflection in an optical pump - X-ray probe scheme and comparing our experimental data to dynamical diffraction calculations, we aim to develop a quantitative material-dependent understanding of the transient stress/strain evolution upon ultrafast laser excitation.

O 83.4 Wed 18:15 Poster A

Towards observing dynamics in molecular overlayers using Ultrafast Low Energy Electron Diffraction (ULEED) — •Bareld Wit, Erica Warth Pérez Arias, Theo Diekmann, Gerrit Horstmann, Simon Vogelgesang, Gero Storeck, and Claus Ropers — 4th Physical Institute, University of Göttingen, 37077 Göttingen, Germany

Very recently, we reported the successful implementation of ULEED in backscattering mode. This yielded new insights into the model system of charge density wave dynamics in 1T-TaS2 [1,2]. One of the next challenges is to expand the scope of ULEED to dedicated surface systems for which the structural dynamics cannot be accessed by other time resolved techniques. In this contribution, the progress towards resolving ultrafast dynamics in (sub-)monolayer molecular overlayers on solid substrates will be presented.

As a model system, we have chosen 1,2-bis(4-pyridyl)ethylene (bpe) on graphite. It has been shown that bpe forms ordered islands at sub-monolayer coverages that can reversibly melt at 414K [3]. We can observe this 'order-disorder' transition with LEED. Moreover, since the transition is reversible, it is in principle suited for pump-probe experiments yielding ultrafast structural dynamics.

[1] S. Vogelgesang et al., Nature Phys. doi:10.1038/nphys4309 (2017)
[2] G. Storeck et al., Struct. Dyn. 4, 044024 (2017)
[3] A. Y. Brewer et al., Mol. Phys. 111, 73 (2013)

O 83.5 Wed 18:15 Poster A

Nonequilibrium dynamics of laser excited SiC: Description of Laser excited SiC with the help of classical physics — •Malwin Xibraku, Bernd Bauerhenne, Sergej Krylow, and Martin E. Garcia — University of Kassel, Theoretical Physics, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

Silicon carbide (SiC) nanocrystals are of great interest in medicine, because of their pleasant properties, such as biocompability, high chemical and thermal stability. These nanocrystals can be very well generated using ultrashort laser pulses. Density Functional theory (DFT) has proven to be a appropriate tool to describe the influence of ultrashort laser pulses on solids due to the accurate quantum mechanical treatment of electrons. Due to the fact that 48 million particles are already contained in a cube SiC of side length 100 nm, such a system cannot be computed with DFT. Therefore, the aim of this work is to describe the forces between the atoms in the SiC cube by an effective potential in the context of classical physics. The classical potential should include the effect of the quantum properties of electrons as accurately as possible. Recently, we found such a potential for silicon (Si) and carbon (C). Therefore, the main goal of this work is to generalize the shape of those potentials to solids consisting of two types of atoms. We propose a general shape of a potential for laser excited binary solids and obtain the coefficients by fitting to data obtained from ab initio simulations on small supercells of SiC. We discuss the quality of the obtained potential by comparing MD simulations performed both with the potential and ab-initio.

O 83.6 Wed 18:15 Poster A

Ultrafast electron dynamics in free space controlled by femtosecond laser pulses — •Norbert Schönenberger, Martin Kozák, Joshua McNeur, Peyman Yousefi, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Pulsed electron beams are a unique probe for ultrafast studies of condensed matter systems, since they allow for both high spatial and temporal resolution. Light in the visible or near-infrared is an ideal candidate for controlling these electrons on single-femtosecond or even attosecond timescales. This can be achieved using electromagnetic near-fields created at dielectric structures, so called dielectric laser ac-

celerators (DLAs) [1]. In recent years, these devices have gained attention with the goal to build fully photonic particle accelerators. We report on new structures allowing better transverse control of the electron beam, leading to a more homogeneous interaction and providing a higher acceleration gradient. Furthermore, we present a technique for inelastic scattering of electron at a light wave in free space [2]. Two laser pulses are used to form an optical travelling wave that interacts with the electrons via ponderomotive scattering, provided that the parameters are chosen for the proper phase-matching. Both methods show promise for creating high-energy attosecond probes for the future ultrafast diffraction and microscopy research.

[1] Kozak M., McNeur J., et.al: Nat. Comms 8 (2017), DOI: 10.1038/ncomms14342 [2] Kozák, M., Eckstein, T., Schönenberger, N. & Hommelhoff, P., Nat. Phys. (2017), DOI: 10.1038/NPHYS4282.

O 83.7 Wed 18:15 Poster A

Ultrashort electron pulses in the space charge regime — •Nora Bach[1], Till Domröse[1], Armin Feist[1], Claus Ropers[1], and Sascha Schäfer[1,2] — [1]4th Physical Institute, Georg-August-University, Göttingen, Germany — [2]Institute of Physics, University of Oldenburg, Germany

Ultrafast transmission electron microscopy (UTEM) has become a powerful tool to investigate processes on the nanoscale with femtosecond temporal resolution [1]. The Göttingen UTEM is based on the modification of a commercial Schottky field emission TEM for which single-photon photoemission from a tip-shaped ZrO/W(100) emitter is employed. Spatial resolution down to the sub-nanometer regime and a spectral bandwidth of 0.6 eV is provided [2].

Here, we investigate the influence of the photoemitted electron density on the resulting transverse and longitudinal beam properties. For constant laser pulse duration, both emittance and energy width scale linearly with pulse charge. For increasing duration, however, both quantities decrease. Simulated results are in good agreement with the experimental data. The demonstrated high beam quality of the source and its tunability will enable new applications in the study of nanoscale ultrafast dynamics, including ultrafast electron holography and phase-contrast imaging.

[1] A. H. Zewail, Science 328, 187 (2010)
[2] A. Feist et al., Ultramicroscopy 176 (2016)

O 83.8 Wed 18:15 Poster A

Ultrafast transmission electron microscopy using laser-triggered field emitters — •Thomas Danz[1], Armin Feist[1], Nara Rubiano da Silva[1], Marcel Möller[1], Nora Bach[1], Sascha Schäfer[1,2], and Claus Ropers[1] — [1]IV. Physical Institute – Solids and Nanostructures, University of Göttingen, Germany — [2]Institute of Physics, University of Oldenburg, Germany

Ultrafast transmission electron microscopy (UTEM) is a promising approach to investigate structural, electronic, and magnetic dynamics with nanometer spatial and femtosecond temporal resolution in a laser pump/electron probe scheme using the versatile imaging, diffraction, and spectroscopy capabilities of such an instrument [1–3].

The pulsed electron source of the Göttingen UTEM project employs linear photoemission from a nanoscopic Schottky emitter, delivering highly coherent electron pulses with down to 200 fs pulse duration, 0.6 eV energy width, and sub-1 nm focused beam diameter [4]. Here, we discuss the present status of the Göttingen UTEM along with selected applications in ultrafast electron imaging and diffraction.

[1] A. H. Zewail, Science **328**, 187 (2010).
[2] A. Feist *et al.*, arXiv:1709.02805, accepted for publication in *Structural Dynamics*.
[3] N. Rubiano da Silva *et al.*, arXiv:1710.03307.
[4] A. Feist *et al.*, Ultramicroscopy **176**, 63 (2017).

O 83.9 Wed 18:15 Poster A

Ultrafast Microscopy of Charge Carrier Motion in Nanoscale Systems — •Faruk Krecinic[1], Melanie Müller[1], Jannik Malter[1], Alexander Paarmann[1], Vasily Kravtsov[2], Markus Raschke[2], and Ralph Ernstorfer[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [2]University of Colorado, Boulder, USA

The ultrafast motion of charge carriers at the nanoscale plays a crucial role in our understanding of optoelectronic systems. We recently developed femtosecond point projection microscopy (fs-PPM) as a new technique for visualizing ultrafast charge carrier motion with nanometer resolution [1]. Due to the use of low-energy electrons, the fs-PPM image is highly sensitive to local electric fields. Here we present our recent experiments visualizing the photoionization of silver nanowires excited with intense laser fields. The dynamics of the photoelectrons and the concomitant positive charging of the nanowires is shown to happen on a time scale as short as 40 fs. The field sensitivity of this technique can be further enhanced, down to the level of a single elementary charge, by taking advantage of the phase information of the imaging electron wavepacket, i.e. by performing electron holography. Our recent progress toward the development of femtosecond low-energy electron holography will also be reported. [1] M. Müller et al., Nature Comm. 5, 5292 (2014).

O 83.10 Wed 18:15 Poster A

Harmonicity and anharmonicity of phonon and surface phonon-polariton in high symmetry directions in wurtzite AlN — •Hrag Karakachian[1,2] and Michel Kazan[1] — [1]Department of Physics, American University of Beirut, P.O. Box 11-0236, Riad El-Solh, Beirut 1107-2020, Lebanon — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart, Germany

We report on the potential of self-nucleated AlN single crystal as a tunable near-field infrared source. The grown crystal exhibits natural AlN growth characteristics with several well-developed facets of different orientations. The characteristics of surface-phonon-polariton (SPhP) modes on the developed crystal facets have been investigated. Reflectivity spectra were recorded from five facets of different orientations. The measured spectra were analyzed by a model taking into account the dependence of harmonicity and anharmonicity of the excited zone center optical phonons on the surface orientation. Consequently, the dielectric properties that determine the condition of existence, dispersion relations, and lifetimes of the SPhP modes were accurately retrieved. The dielectric functions were determined as a function of the angle of incidence and used to compute the characteristics of the SPhP modes on each of the measured facets. We found that facets of different orientations exhibit SPhP modes of different frequencies and lifetimes, which makes the investigated self-nucleated crystal potential candidates for tunable near-field infrared sources.