O 94: Ultrafast Surface Dynamics II

Time: Friday 10:30–12:15 Location: S054

Invited Talk O 94.1 Fri 10:30 S054

Time-resolved electron microscopy: probing ultrafast processes at the nanoscale — •Sascha Schäfer — 4th Physical Institute-Solids and Nanostructures, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Ultrafast transmission electron microscopy (UTEM) is a promising technique for the investigation of ultrafast dynamics with nanoscale spatial resolution [1]. In UTEM, a pulsed electron beam with subpicosecond bunch duration is utilized to stroboscopically probe laser-induced processes, using the versatile imaging and diffraction capabilities of electron microscopy. However, up to now, its applicability was limited by the coherence properties of available pulsed electron sources. In the Göttingen UTEM project, we developed nanoscale laser-driven photocathodes, which allow for the generation of highly coherent electron pulses. At the sample position, we achieve electron focal spot sizes down to a few nanometers with a pulse duration of about 300 fs. Such a tightly focused ultrafast probe enables the investigation of fast processes in heterogeneous systems and at interfaces, and I will present some first applications, including the inelastic electron scattering in optical near-fields [2], and the mapping of optically induced structural dynamics at the edge of a single-crystalline graphite membrane.

[1] A. H. Zewail, Science 328, 187-93 (2010). [2] A. Feist, K. E. Echternkamp, J. Schauss, S. V. Yalunin, S. Schäfer, C. Ropers. Nature 521, 200-203 (2015).

O 94.2 Fri 11:00 S054

A remotely driven ultrafast electron source — •Jan Vogelsang[1], Jörg Robin[1], Benedek J. Nagy[2], Péter Dombi[2], Daniel Rosenkranz[1], Manuela Schiek[1], Petra Gross[1], and Christoph Lienau[1] — [1]Institut für Physik, Carl von Ossietzky Universität, 26129 Oldenburg, Germany — [2]Wigner Research Centre for Physics, 1121 Budapest, Hungary

The combination of high spatial resolution electron microscopes and high temporal resolution laser spectroscopy promises experiments in today unexplored spatio-temporal regimes. However, in such microscopes the time resolution is so far limited to ~100fs: The distance between electron emission site and the sample must be larger than the laser focus radius. This gives rise to electron pulse broadening due to dispersion. Yet, many fundamental photoinduced processes such as coherent charge and energy transport phenomena, e.g. in solar cells, occur on few femtosecond time scales and remain hidden.

Here, we present photoelectron emission from the apex of a gold nanotaper illuminated via grating coupling at a distance of 50μm from the emission site with few-cycle laser pulses (Nano Lett. 15, 4685). Compared to direct apex illumination, we find a fifty-fold increase in electron yield. Point-projection microscopic imaging of Ag-nanowires is performed and spatial localization of the electron emission to a nanometer-sized region is demonstrated. This novel emission scheme allows for arbitrarily small distances between emission site and sample. Hence, it is of immediate interest for miniaturized electron microscopy and diffraction schemes with ultrahigh time resolution.

O 94.3 Fri 11:15 S054

Femtosecond electron dynamics: Accessing the momentum space — •Norman Haag, Johannes Seidel, Lisa Grad, Benjamin Stadtmüller, Mirko Cinchetti, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany

Time resolved two-photon photoemission spectroscopy has proven to be a powerful tool to investigate electron dynamics at surfaces on a femtosecond timescale [1]. Combining this method with momentum microscopy [2], a novel tool for angle resolved photoemission, offers the possibility to follow electron dynamics throughout the entire accessible momentum space.

As a prototype system, we have studied the pristine Ag(111) surface as well as a monolayer of Pb grown on Ag(111) with time resolved momentum microscopy. We have chosen these systems as they exhibit either surface states or quantum well states. The significantly different wave function overlap of these states with bulk states of the silver substrate will yield different relaxation dynamics of excited electrons. Analyzing different regions in momentum-space for constant intermediate state energy provides a detailed view of the momentum space dynamics of optically excited electrons.

References
[1] M. Bauer et al., Prog. in Surf. Sc. 90, 319 (2015)
[2] C. Tusche et al., Ultramicroscopy (2015)

O 94.4 Fri 11:30 S054

Novel light source for time- and angle-resolved photoelectron spectroscopy — •Michele Puppin[1], Yunpei Deng[2], Johannes Feldl[1], Chris Nicholson[1], Claude Monney[3], Hendrik Vita[1], Martin Wolf[1], and Ralph Ernstorfer[1] — [1]Fritz-Haber Institut, Berlin, Germany — [2]Paul-Scherrer Institut, Switzerland — [3]University of Zurich, Switzerland

Time- and Angle- Resolved Photoemission Spectroscopy (tr-ARPES) accesses the out-of-equilibrium electronic band structure in the time domain and provides information on coupling and correlation effects between electronic and lattice degrees of freedom as well as on excited state dynamics. These studies benefit from the high counting statistics of light sources with 100s of kHz repetition rate. However, due to their low photon energy (< 6.3 eV), high repetition rate sources were limited so far to investigations at the Brillouin zone center. We have developed an efficient femtosecond source with 500 kHz repetition rate capable of tr-ARPES with XUV pulses, granting access the full Brillouin zone. The key component of this approach is an optical parametric chirped-pulse amplifier (OPCPA) providing intense 30 fs pulses. A simple monochromatization scheme allows selecting a single harmonic at 22.3 eV with 100 meV bandwidth with a photon flux exceeding 10^{11} photons/s. First proof-of-concept tr-ARPES data on transition metal dichalcogenides are presented.

O 94.5 Fri 11:45 S054

Attosecond Delays in the Photoemission from the Layered Crystals Bi_2Te_3 and Non-Centrosymmetric BiTeCl — •Sergej Neb[1], Christian Oberer[1], Walter Enns[1], Norbert Müller[1], J. Hugo Dil[2,3], Evgueni V. Chulkov[4,5], Pedro M. Echenique[4], Walter Pfeiffer[1], and Ulrich Heinzmann[1] — [1]Universität Bielefeld, Germany — [2]Paul-Scherrer-Institut, Villigen, Switzerland — [3]Institute of Condensed Matter Physics, École Polytechnique Fédérale de Lausanne, Switzerland — [4]Donostia International Physics Center (DIPC) and Unidad de Fisica de Materiales CSIC-UPV/EHU, Basque Country, Spain — [5]Tomsk State University, Russian Federation

The availability of single attosecond (as) XUV pulses allows investigating ultrafast electron dynamics on the as time scale by recording slight temporal shifts of the photoelectron streaking in a simultaneously present strong IR field. The physical origin of the observed delays is not yet understood and controversial theoretical models coexist demonstrating our still limited understanding of the fundamentals of the photoemission process. Here we report on as-time-resolved photoemission from the layered crystals Bi_2Te_3 and non-centrosymmetric BiTeCl. The lack of inversion symmetry allows studying relative photoemission delays on differently terminated but well-defined surfaces. Due to reversed layer stacking, photoelectron propagation effects such as the mean free path and the internal effective potential can be determined. However, the measured relative delays cannot be explained by electron propagation alone. Hence effects beyond pure propagation through the layers influence the photoemission dynamics.

O 94.6 Fri 12:00 S054

Pump laser-induced space-charge effects in HHG-driven time- and angle-resolved photoelectron spectroscopy — •Lars-Philip Oloff, Kerstin Hanff, Ankatrin Stange, Gerald Rohde, Florian Diekmann, Michael Bauer, and Kai Rossnagel — Insitut für Experimentelle und Angewandte Physik, Universität Kiel, 24098 Kiel, Germany

The development of fs-pulsed XUV sources such as free-electron lasers or high-harmonic-generation (HHG) sources has opened up a new scientific field for photoelectron spectroscopy in terms of time-resolved pump-probe experiments. While the impact of the high peak brilliance of these novel sources on photoemission spectra has been studied extensively, the effect of high pump fluences has not been investigated systematically yet. In the strong excitation regime, the low photon

energy pump pulses may lead to the emission of electrons from the sample via multiple photon absorption, thus directly influencing the electrons ejected by the probe pulse through Coulomb interaction. We have systematically investigated these so called space-charge effects at a HHG source (22.3 eV) for the case of a graphite (HOPG) sample. Specifically, we have studied the influence on the photoelectron energy and momentum distributions as a function of power density, spot size, pump-probe delay, and pump wavelength. The results are interpreted in terms of a simple mean-field model.