O 80: Surface Dynamics I

Time: Thursday 16:00–19:00 Location: GER 38

O 80.1 Thu 16:00 GER 38

High Remanent Spin Injection into GaAs(110): Strong Electron Energy Dependence with Steep Fall-Off — •Svenja Mühlenberend, Markus Gruyters, and Richard Berndt — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany

The spin polarization of electrons injected into GaAs from a magnetic tip of a scanning tunneling microscope is determined from the polarization of the induced electroluminescence. At low temperatures, unexpectedly high polarization values are observed. Moreover, the polarization exhibits a drastic electron energy dependence. Electron transport occurs at remanence, i.e. no external magnetic field is necessary to obtain a high spin injection efficiency.

O 80.2 Thu 16:15 GER 38

Spin-resolved electron transmission through chiral molecules and proteins on metal surfaces — •Matthias Kettner[1], Benjamin Göhler[1], Debabrata Mishra[2], Tal Z. Markus[2], Georg F. Hanne[1], Ron Naaman[2], and Helmut Zacharias[1] — [1]Physikalisches Institut, Universität Münster, Germany — [2]Department of Chemical Physics, Weizmann Institute, Rehovot, Israel

Electron spin polarization has been measured for photoelectrons emitted from aluminum and gold substrates and transmitted through adsorbed layers of the chiral membrane protein bacteriorhodopsin and the amino acid alanine. The samples are irradiated by 213nm laser radiation exciting photoelectrons within the metal substrate. These photoelectrons are then transmitted through the chiral layer and analyzed by a Mott polarimeter. The case of bacteriorhodopsin which is physisorbed on an aluminum substrate, electron spin polarization values of up to +15% are obtained independent of the polarization of the incident light. Taking earlier studies of bacteriorhodopsin on a gold substrate into account, spin-orbit-coupling of the substrate seems to have a minor influence [1]. Moreover the electron spin polarization shows a dependence on the coverage of the substrate. These studies are extended to the chiral amino acid polyalanine which is self-assembled on a gold surface. The results indicate that also in this case the interaction of chiral layers with the electrons depends on the spin orientation. This effect may enable the design of efficient spin filters for spintronic applications.

[1] D. Mishra, et al., PNAS 110, 14872 (2013)

O 80.3 Thu 16:30 GER 38

A photoinduced change of k_F in Bi2212 revealed by femtosecond time- and angle-resolved photoemission spectroscopy — •S. Freutel[1], J.D. Rameau[2], L. Rettig[1], I. Avigo[1], S. Thirupathaiah[1], M. Ligges[1], G.D. Gu[2], H. Eisaki[3], P.D. Johnson[2], and U. Bovensiepen[1] — [1]Faculty of Physics, University of Duisburg-Essen, Duisburg, Germany — [2]Brookhaven National Laboratory, New York, USA — [3]National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan

Optical excitation and subsequent ultrafast electronic relaxation leads to quasiparticle redistribution, which potentially changes the chemical potential, or the Fermi momentum k_F, in systems with non-constant density of states. Here, we report on time- and angle resolved photoemission spectroscopy on optimally doped Bi2212 in the pseudogap phase. We observed a change in k_F that appears as a photoinduced change of the effective doping level caused by an electron-hole asymmetry. Along the nodal line this effect scales linearly with the optical excitation density of 35 to 300 μJ/cm^2 and peaks at a delay of 100 fs. Since the change in k_F relaxes within 1 ps, we consider the excitation of secondary electrons and subsequent electron phonon coupling as the underlying processes. Additional results on chemically underdoped Bi2212 show that the shift in k_F increases for larger momenta which suggests a quantitative comparison and discussion of static chemical and transient photoinduced doping.

We acknowledge support by the DFG through SFB616 and the Mercur Research Center Ruhr through PR-2011-0003.

O 80.4 Thu 16:45 GER 38

Ultrafast electron dynamics in Pb nanowire arrays on Si(557) — Abdul Samad Syed[1], Vesna Mikšić Trontl[1], •Manuel Ligges[1], Mathias Sandhofer[1], Ishita Agarwal[1], Isabella Avigo[1], Daniel Lükermann[2], Christoph Tegenkamp[2], Herbert Pfnür[2], and Uwe Bovensiepen[1] — [1]Fakultät für Physik, Univ. Duisburg-Essen — [2]Institut für Festkörperphysik, Leibnitz Univ. Hannover

Quasi-1D materials are expected to exhibit exotic properties that are considerably different from those of their corresponding bulk material counterparts. As a consequence of the strong real-space anisotropy of these systems, significant differences in, e.g., electron scattering rates along and perpendicular to the wire structure can be expected. We investigate this particular aspect using time- and angle-resolved two photon photoemission from the Pb/Si(557) nanowire system. We present results regarding the unoccupied electronic structure and ultrafast relaxation of optically excited carriers probed as a function of two mutually independent in-plane momentum directions along and perpendicular to the nanowire orientation. We gratefully acknowledge funding by the DFG through FOR1700.

O 80.5 Thu 17:00 GER 38

Time-resolved photoemission spectroscopy on $1T$–$TaSe_2$: Mott physics at the surface? — •Christian Sohrt, Ankatrin Stange, Lutz Kipp, Michael Bauer, and Kai Rossnagel — Institute for Experimental and Applied Physics, University of Kiel, Germany

According to angle-resolved photoelectron spectroscopy and scanning tunneling microscopy studies, the surface of $1T$–$TaSe_2$ displays Mott insulating behavior in connection with a commensurate $\sqrt{13} \times \sqrt{13}$ charge-density wave, in a similar way as observed in $1T$–TaS_2 [1,2]. But the question is whether the observed spectral gap at the Fermi level is really a Mott gap.

A possible smoking-gun experiment to answer this question is time- and angle-resolved photoelectron spectroscopy (trARPES), which in principle enables us to distinguish between Peierls and Mott gaps by direct determination of the gap quenching times [3].

Here, we present the results of a comparative momentum-dependent trARPES study on $1T$–$TaSe_2$ and $1T$–TaS_2. In contrast to the prevailing view, no indications for Mott dynamics are found at the surface of $1T$–$TaSe_2$.

[1] L. Perfetti *et al.*, Phys. Rev. Lett., **90**, 166401 (2003)
[2] S. Colonna *et al.*, Phys. Rev. Lett., **94**, 036405 (2005)
[3] S. Hellmann *et al.*, Nat. Commun., **3**, 1069 (2012)

O 80.6 Thu 17:15 GER 38

Time- and angle-resolved 2PPE of unoccupied electronic states of topological insulators Sb_2Te_3 and Sb_2Te_2S — •Johannes Reimann, Jens Güdde, and Ulrich Höfer — Fachbereich Physik und Zentrum für Materialwissenschaften, Philipps-Universität, D-35032 Marburg

Topological insulators with their unique protected surface state offer promising potentials for a wide field of applications. In order to make use of the conducting properties of the surface state it is important to know the properties of both the occupied and the unoccupied electronic states close to the Fermi-energy.

In this work the unoccupied electronic states of the topological insulators Sb_2Te_3 and Sb_2Te_2S have been investigated by time- and angle-resolved two-photon photoemission (2PPE) along $\overline{\Gamma}$-$\overline{K}$- and $\overline{\Gamma}$-$\overline{M}$-direction. Both materials show a linear dispersive electronic state near Fermi-energy, resembling the typical Dirac-Cone structure. Additional bulk and surface states at higher energies can be identified. The experimental spectroscopic results will be compared with theoretical calculations of the surface and bulk band structure. First results on the electron-dynamics using time- and angle-resolved 2PPE are presented. While both materials show similar dynamics at room temperature, the dynamics at low temperatures differs.

O 80.7 Thu 17:30 GER 38

Bulk- and surface electron dynamics in a p-type topological insulator $SnSb_2Te_4$ — •Sebastian Otto, Daniel Niesner, Volker Hermann, and Thomas Fauster — Lehrstuhl für Festkörperphysik, Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

Time-resolved two-photon photoemission is used to study the electronic structure and dynamics at the surface of $SnSb_2Te_4$, a p-type topological insulator. The topological surface state is centered at 0.32 ± 0.03 eV above the Fermi level with a group velocity of 3.4 eVÅ.

Electrons from the conduction band minimum are scattered on a time scale of 43 ± 4 fs to the Dirac cone. From there they decay to the partly depleted valence band with a time constant of 78 ± 5 fs. The short time scales are attributed to the large overlap with the bulk bands. Higher doped samples show even shorter time constants indicating that the unoccupied bulk valence band provides the final states for decay. The infrared-pumped scattering processes above the Dirac cone in the conduction band are described by a rate equation model. States are populated by the pump pulse and electrons decaying from higher-lying states and decay into lower-lying states. The good agreement between filling and depleting decay rates of neighboring energy levels shows that the decay occurs mostly within the conduction band.

O 80.8 Thu 17:45 GER 38

2PPE measurement on Sb_2Te_2S with an angle-resolving time-of-flight spectrometer — •Thomas Kunze[1,2], Sophia Ketterl[1], Thorsten U. Kampen[2], Evgeny Chulkov[3], and Martin Weinelt[1] — [1]FU Berlin, Germany — [2]SPECS GmbH, Germany — [3]UPV/EHU San Sebastián, Spain

We present two-photon photoemission measurements on the p-doped topological insulator Sb_2Te_2S. The Dirac cone of this system lies above the Fermi energy and is therefore only accessible using two-photon photoemission.

We detect the photoemitted electrons with an angle-resolving time-of-flight spectrometer. This instrument allows us to measure the kinetic energy E as a function of $k_{x\|}$ and $k_{y\|}$ without rotating the sample. Our laser system with two OPAs gives us the opportunity to tune the photon energy of the infrared and ultraviolet pulse independently. This allows us to create a resonant population and efficient probing of the Dirac cone.

Sb_2Te_2S shows a Dirac cone with direction-dependent linear dispersion close above the Fermi level and hexagonal warping at higher energies. Polarization-dependent measurements manifest the spin texture of the Dirac cone. The population dynamics of Sb_2Te_2S have been analyzed. The femtosecond lifetimes of the first and second image-potential states show an n^3 dependence. The Dirac cone is populated by indirect filling via the conduction band. The relaxation of the Dirac cone happens on a picosecond timescale.

O 80.9 Thu 18:00 GER 38

How far-from-equilibrium dynamics drive the ultrafast melting of a charge-density wave in $TiSe_2$ — •S. Eich[1], J. Urbancic[1], A. V. Carr[2], A. Stange[3], T. Popmintchev[2], T. Rohwer[3], M. Wiesenmayer[1], A. Ruffing[1], S. Jakobs[1], S. Hellmann[3], P. Matyba[2], C. Chen[2], L. Kipp[3], M. Bauer[3], M. M. Murnane[2], K. Rossnagel[3], H. C. Kapteyn[2], S. Mathias[1,2], and M. Aeschlimann[1] — [1]TU Kaiserslautern and Research Center OPTIMAS, Germany — [2]JILA, Boulder, Co, USA — [3]IEAP, Kiel, Germany

We present fs XUV ARPES with sub 150 meV energy- and sub 30 fs time-resolution of the prototypical semiconductor-to-metal photo-induced phase transition in the charge-density wave compound 1T-$TiSe_2$ [1]. We elucidate the role of far-from-equilibrium dynamics in the ultrafast melting of the charge-density wave in $TiSe_2$, and show that photo-induced transient non-equilibrium states are indispensible for the ultrafast response of the system. We find that hot carrier multiplication, which is only present during the first 200 fs, is the main driver of the ultrafast phase transition.

[1] Rohwer et al., Nature 471,490 (2011)

O 80.10 Thu 18:15 GER 38

Ultrafast hot electron dynamics at the $SrTiO_3$-vacuum interface — •Marc Herzog, Daniel Wegkamp, Julia Stähler, and Martin Wolf — Abteilung Physikalische Chemie, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin

In the last decade many surprising properties have been observed at $SrTiO_3$-related oxide interfaces (e.g. metal-insulator transitions, superconductivity, large magnetoresistance) which originate from metallic states at the STO interface also referred to as quasi two-dimensional electron gas (2DEG). Due to the various exotic properties $SrTiO_3$ (STO) promises many applications in future oxide electronics. Recently, a 2DEG has been discovered even at the vacuum-cleaved surface of STO.

In order to gain insight into the role of electron interaction/correlation in the 2DEG we have studied the surface-confined electrons in STO by means of time- and angle-resolved photoemission spectroscopy (trARPES) and two-photon photoemission (2PPE) mapping the photoinduced dynamics of occupied and unoccupied electronic states, respectively. The ultrafast response of the 2DEG to below- and above-bandgap laser-pulse excitation reveals energy-dependent electron lifetimes below 60 fs which is much shorter than in 3D metals (e.g. Cu, Ag). These results suggest that electron screening may be strongly suppressed in the 2DEG. Moreover, we discuss the effect of transient surface photovoltage.

O 80.11 Thu 18:30 GER 38

Ultrafast electron dynamics around the antinode in optimally doped $Bi_2Sr_2CaCu_2O_{8+\delta}$ — •Kerstin Hanff, Lexian Yang, Gerald Rohde, Ankatrin Stange, Petra Hein, Lutz Kipp, Michael Bauer, and Kai Rossnagel — Institute of Experimental and Applied Physics, University of Kiel, Germany

Angle-resolved photoemission spectroscopy (ARPES) has added tremendously to our understanding of the electronic and superconducting properties of the cuprates, through direct measurement of the momentum-dependent electronic structure, spectral function, and order parameter. The technique is now also frequently used in pump-probe schemes and has thus added important insights on the momentum-dependent dynamics of quasiparticles and Cooper pairs. However, due to the use of ultraviolet (UV) probe pulses only, time-resolved ARPES studies on the cuprates have so far been limited in momentum space to the nodal region of the Fermi surface. Here, we report the results of time-resolved ARPES on optimally doped $Bi_2Sr_2CaCu_2O_{8+\delta}$ using extreme ultraviolet radiation delivered by a high-harmonic-generation source. The higher probe photon energy of 22 eV has allowed us to study the quasiparticle relaxation dynamics in momentum-space cuts that cover the complete region from the node to the antinode. Our results reveal bi-exponential decay dynamics with distinct temperature- and momentum-dependent time constants.

O 80.12 Thu 18:45 GER 38

Pump-laser-induced space-charge effects in time-resolved photoelectron spectroscopy — •Lars-Philip Oloff, Ankatrin Stange, Kerstin Hanff, Lutz Kipp, Michael Bauer, and Kai Rossnagel — Institute of Experimental and Applied Physics, University of Kiel, Germany

The development of ultrashort-pulsed extreme ultraviolet sources, such as high-harmonic generation sources (HHG) and free-electron lasers, has opened up a new field of physics by means of time-resolved pump-probe photoelectron spectroscopy experiments. The effects of these sources' high brilliance on photoemission spectra, i.e., intensity-dependent broadenings and shifts towards higher kinetic energies ("space-charge effects"), have been extensively studied by experiments and simulations [1,2] and are now rather well understood. However, in time-resolved photoelectron spectroscopy a further effect can be recognized in the high-pump-intensity regime: pump-induced space-charge effects due to nonlinear multiphoton photoemission. We have systematically studied these effects as a function of various experimental parameters (pump-probe delay, pump energy, pump intensity, work function of the sample) at our HHG-based photoemission setup (22 eV probing, 390 nm/780 nm pumping). The obtained experimental results are compared with the results of self-consistent N-body numerical simulations.

[1] S. Hellmann *et al.*, Phys. Rev. B **79**, 035402 (2009)
[2] S. Hellmann *et al.*, Phys. Rev. B **85**, 075109 (2012)