Q 34: Ultrashort laser pulses: Applications

Time: Tuesday 14:00–15:45 Location: F 142

Q 34.1 Tue 14:00 F 142

Strong-field photoemission from metal nanotips in experiment and theory — •Michael Krüger[1], Georg Wachter[2], Michael Förster[1], Christoph Lemell[2], Joachim Burgdörfer[2], and Peter Hommelhoff[1,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching bei München — [2]Institut für Theoretische Physik, Technische Universität Wien, A-1080 Wien, Austria — [3]Universität Erlangen-Nürnberg, 91058 Erlangen

Few-cycle laser-induced strong-field photoemission from metal nanotips has recently attracted a lot of interest because of new findings, for example the strong sensitivity of the photoemission on the carrier-envelope phase [1]. Here we show spectrally resolved measurements of strong-field photoemission from tungsten tips for different experimental parameters such as laser intensity and applied static field strength [1–3]. We present theory models, among them the semiclassical three-step model and a more sophisticated time-dependent density functional theory (TDDFT) simulation. Despite the complexity of the system due to its solid-state nature, the interpretation of the involved physics is conceptionally even simpler than in the atomic analogue. Unlike in the atomic case, the tip breaks the symmetry, hence the number of electron trajectories is reduced and whole trajectory classes are forbidden.

[1] M. Krüger, M. Schenk, P. Hommelhoff, *Nature* **475**, 78 (2011).
[2] G. Wachter et al., *Phys. Rev. B* **86**, 035402 (2012).
[3] M. Krüger et al., *New J. Phys.* **14**, 085019 (2012).

Q 34.2 Tue 14:15 F 142

Sub-diffraction-limited spatial resolution in CARS microscopy — Carsten Cleff[1], Petra Gross[1], Chris Lee[2], Kai Kruse[2], Willem Beeker[2], Herman Offerhaus[2], Jennifer Herek[2], Klaus Boller[2], and •Carsten Fallnich[1] — [1]WWU Münster, Münster, Germany — [2]University of Twente, Enschede, The Netherlands

Based on the density matrix formalism we investigate CARS signal suppression enabling spatial resolution below the diffraction limit. Pulsed control light fields are used to manipulate the population distribution of the CARS sample in order to achieve a saturable suppression of the CARS process. If the control light fields are applied with a donut-shaped beam profile the saturable suppression of CARS signal generation can be used to enhance the spatial resolution beyond the diffraction limit similar to STED microscopy. Using computer-generated test images we numerically demonstrate sub-diffraction-limited spatial resolution in CARS microscopy down to 18 nm.

[1] Cleff et al., PRA 86, 023825 (2012)

Q 34.3 Tue 14:30 F 142

Small-polaron based hologram recording with sub-ps laser pulses in thermally reduced $LiNbO_3$ — •Holger Badorreck, Stefan Nolte, Pia Baeune, Hauke Bruening, Andreas Buescher, Volker Dieckmann, and Mirco Imlau — School of Physics, Osnabrueck University, Germany

The recording of mixed amplitude and index gratings with fs-laser pulses is studied by means of spatially modulated small polaron densities in single crystals of lithium niobate. Small bound polarons, that appear in the majority of polar oxides, exhibit a tremendous potential for the research field of ultrafast photonics due to their unique optical features. Only recently, the possibility to apply small polarons for highly efficient recording of holograms was successfully demonstrated with single ns-laser pulses in thermally reduced $LiNbO_3$ (M. Imlau et al., Opt. Express 19, 15322 (2011)). However, the turnover of the widely established results on polaron formation, transport and recombination obtained with cw-light and ns-pulses to dynamic fs-holography has only rarely been addressed in literature. We present our first systematic studies on the recording of mixed holograms with single 100 fs laser pulses in samples with thermal pre-treatment. The results have been corrected for nonlinearities, such as the two photon absorption coefficient and the nonlinear refractive index, that superimpose the diffraction signal. An experimental approach to determine the dispersive features of the recorded holograms in a single measurement, called *ultrafast holographic spectroscopy* is deduced. Financial support by the DFG (IM 37/5, INST 190/137-1) is gratefully acknowledged.

Q 34.4 Tue 14:45 F 142

Controlling electron localization in H_2^+ with optical cycles — •T. Rathje[1], A.M. Sayler[1], S. Zeng[2], P. Wustelt[1], B. Esry[2], and G.G. Paulus[1] — [1]Institute of Optics and Quantum Electronics and Helmholtz-Institute Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]J.R. Macdonald Laboratory, Kansas State University, Manhattan Kansas, 66506 US

We report on measurements and calculations of the absolute phase effects in the photodissociation of the simplest molecule, H_2^+, with a 5-fs few-cycle laser pulse. Control of the localization of the electron between the two nuclei during the dissociation process is facilitated by ultra-short laser pulses. The H_2^+ molecule is generated with a duoplasmatron ion source. Compared to previous experiments using neutral molecules, our dissociation process is not preceded by an photoionization process through a laser pulse. This well collimated ion beam is perpendicular to and overlapped with the laser beam, focused to peak intensities up to $4x10^{14}\,W/cm^2$. At the same time an accurate measurement of the absolute phase for every single laser shot is obtained with a phase-meter. The two dissociation fragments are recorded in coincidence with a position- and time-sensitive detector. In this way, a phase-resolved and kinematically complete measurement is realized from which the phase-dependence of the KER-spectra and electron localization can be determined. The experimental results agree well with 3D-TDSE calculations, that take nuclear vibration and rotation into account.

Q 34.5 Tue 15:00 F 142

Coherent Phonons in Graphite studied by Femtosecond Transmission Electron Diffraction — •Christian Gerbig, Silvio Morgenstern, Vanessa Sporleder, Cristian Sarpe, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), D-34132 Kassel, Germany

In carbon layered materials (graphite, graphene, carbon nanotubes) the electron subsystem, stimulated by high currents or optical excitations, is strongly coupled to a small set of optical phonons which limits the ballistic conductance. A detailed understanding of phonon decay mechanism is thus essential in improving the performance of carbon-based future electronic devices [1,2]. Time-resolved diffraction, using x-ray or electron probes, has become a promising technique to directly provide insights into dynamics at the molecular level with ultrafast precision [3,4]. We use a femtosecond transmission electron diffractometer to study the evolution of phonon decays in single crystalline graphite after ultrashort laser excitation. Our highly compact setup is well characterized [4] with excellent spatial-temporal resolution (coherence length > 8 nm, electron pulse duration < 200 fs). In this contribution the generation and decay of coherent acoustic phonons are discussed in dependence of film thickness down to few-layer graphene.

[1] T. Kampfrath et al., Phys. Rev. Lett. **95**, 187403 (2005)
[2] S. Schäfer *et al.*, New J. Phys. **13**, 063030 (2011)
[3] M. Chergui & A. H. Zewail, Chem. Phys. Chem. **10**, 28 (2009)
[4] G. Sciaini & R. J. D. Miller, Rep. Prog. Phys **74**, 096101 (2011)

Q 34.6 Tue 15:15 F 142

Nanoscale probing of optical field enhancement by electron rescattering — •Sebastian Thomas[1], Michael Krüger[1], Michael Förster[1], Markus Schenk[1], and Peter Hommelhoff[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Gemany — [2]Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany

The enhancement of optical electric fields in the vicinity of nanostructures enables the localization of electromagnetic energy on the nanoscale. We present a new method of measuring the local field with a resolution of 1 nm. Experimentally, we study the photoemission of electrons from a metal nanotip under laser illumination. In this setup, some of the emitted electrons return to and scatter from the tip surface within one optical cycle of the driving field [1]. By measuring the kinetic energy of these electrons, we obtain the enhanced field strength within 1 nm from the tip surface [2]. A comparison with the field strength we calculate from focal and laser parameters yields the field enhancement factor. Our results are in good agreement with Maxwell simulations.

The resolution of 1 nm is about an order of magnitude better than previous work [3] and close to the length scale of quantum plasmonics, where quantum mechanical effects near the tip surface are expected to reduce the local field strength [4]. We discuss the implications.

[1] M. Krüger, M. Schenk, P. Hommelhoff, Nature 475, 78 (2011)
[2] S. Thomas et al., arxiv:1209.5195 (2012)
[3] M. Raschke et al., ChemPhysChem 6, 2197 (2005)
[4] J. Zuloaga, E. Prodan, P. Nordlander, ACS Nano 4, 5269 (2010)

Q 34.7 Tue 15:30 F 142

Direct laser acceleration of non-relativistic electrons at a dielectric grating structure — •John Breuer[1] and Peter Hommelhoff[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching bei München, Deutschland — [2]Department für Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Deutschland

Direct laser acceleration using dielectric structures has been envisioned to revolutionize particle accelerators [1]. Grating structures can support very high acceleration gradients [2] and may therefore lead to much smaller accelerators that can operate at high repetition rates, with application in free electron lasers. We report a proof-of-concept experiment demonstrating the first observation of direct laser acceleration of non-relativistic electrons using an evanescent mode excited by Titanium:sapphire laser pulses at 800nm at a dielectric grating. This work also represents the first demonstration of realistically scalable laser acceleration. We observe a maximum acceleration gradient of 25 MeV/m that is already comparable to state-of-the-art acceleration structures of today's accelerators operated with radio frequency fields. For relativistic electrons about two orders of magnitude larger acceleration gradients are expected.

[1] J. Rosenzweig, A. Murokh, C. Pellegrini, PRL 74, 2467 (1995).
[2] T. Plettner, R. L. Byer et al., PRSTAB, 9, 111301 (2006).