Q 52: Ultrashort Laser Pulses II

Time: Thursday 14:30–16:30 Location: a310

Q 52.1 Thu 14:30 a310

Elements of a Dielectric Laser Accelerator Beamline: Staging, Focusing, and Tapering — •Joshua McNeur, Martin Kozak, Norbert Schönenberger, Alexander Tafel, Ang Li, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstrasse 1, 91058 Erlangen

Dielectric laser accelerators (DLAs) provide an attractive alternative to the high-cost radio frequency accelerators that currently define the high energy particle physics landscape. Their orders-of-magnitude smaller footprints and larger acceleration gradients potentially enable University-lab scale (and smaller) high energy electron sources with a wide range of applications. However, to progress from the proof of principle DLA experiments [1,2] to a DLA-based accelerator beamline, many challenges need to be addressed. Here, we report on first evidence of DLA-based staging, focusing, and compensation for electron dephasing. All of these results are crucial towards the realization of a multi-stage DLA that can generate a collimated high brightness relativistic electron beam.

1.Peralta, E. A. et al. Demonstration of electron acceleration in a laser-driven dielectric microstructure Nature 503, 91-94 (2013).

2.Breuer, J. & Hommelhoff, P. Laser-Based Acceleration of Nonrelativistic Electrons at a Dielectric Structure. Phys. Rev. Lett. 111, 134803 (2013).

Q 52.2 Thu 14:45 a310

Attosecond electron gating and streaking by optical fields — •Martin Kozák, Joshua McNeur, Norbert Schönenberger, Alexander Tafel, Ang Li, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstrasse 1, 91058 Erlangen

We report on recent experimental results of sub-optical cycle temporal gating and streaking of free electrons at sub-relativistic energies (25-30 keV). In our experiments, the energy and transverse momentum of a DC electron beam is modulated in time by the interaction with the optical near-fields of a dielectric nanostructure utilizing the inverse Smith-Purcell effect [1,2]. As this interaction is linear with the electric field, the sub-cycle temporal structure of the femtosecond laser pulse is imprinted to the electron beam with very high precision (200 attoseconds in our experiment). Combined with a high-pass energy filter for accelerated electrons, this technique will enable sub-cycle temporal resolution in ultrafast electron diffraction and microscopy experiments (1.3 fs demonstrated). Moreover, the simple variation of the setup will serve as an attosecond streak camera for charged particle beams, potentially offering 10 as temporal resolution.

[1] J. Breuer, and P. Hommelhoff, Phys. Rev. Lett. 111, 134803 (2013).

[2] E. A. Peralta, et al. Nature 503, 91-94 (2013).

Q 52.3 Thu 15:00 a310

Ultrafast streaking of photo-electric emission from tungsten nanotips — •Thomas Juffmann[1], Brannon Klopfer[1], Gunnar Skulason[1], Catherine Kealhofer[1], Fan Xiao[1], Seth Foreman[2], and Mark Kasevich[1] — [1]Stanford University, California 94305, USA — [2]University of San Francisco, California 94117, USA

We present a new technique to study the photo-electric effect with femtosecond resolution. Laser-triggered electrons emitted from a tungsten nanotip interact with a cavity enhanced radiofrequency field. The final kinetic energy of the electrons depends on the phase of the RF field at the time of emission. We reach femtosecond resolution and a dynamic range of tens of picoseconds. Our results have implications for ultrafast electron microscopy and diffraction.

Q 52.4 Thu 15:15 a310

Charge transfer between unbiased metallic nanocontacts illuminated by phase-controlled ultrashort light pulses — •Andrey S. Moskalenko, Daniele Brida, Tobias Rybka, Alfred Leitenstorfer, and Guido Burkard — Department of Physics and Center for Applied Photonics, University of Konstanz, Germany

We theoretically investigate tunneling through free space nanogaps, which are formed between metallic nanocontacts, driven by few-fs broadband light pulses. Since the seminal work of Keldysh [1], it is known that the tunneling process can be significantly influenced by the energy gain as the electron moves in the classically forbidden region. In the past, this was demonstrated theoretically for atomic ionization by ultrashort light pulses [2]. We argue that the analogous regime is realizable for experimentally available nanocontacts and light pulses. In a certain range of parameters, a decrease of the pulse duration leads to a drastic increase of the tunneling probability.

Taking realistic pulse profiles and nanostructure configurations and using a time-dependent quasiclassical approach, we demonstrate that the preferred direction of the electron transport through the nanogap can be controlled by changing the carrier-envelope phase of the pulse, in agreement with our recent experimental findings. We calculate the tunneling probability and estimate the amount of transferred electrons per pulse in dependence on the parameters of the pulse and nanogap.

[1] L.V. Keldysh, Sov. Phys. JETP 20, 1307 (1965).

[2] V.S. Popov, Phys. Usp. 47, 855 (2004).

Q 52.5 Thu 15:30 a310

Theoretical modeling of light-field control of photocurrent in graphene — •Takuya Higuchi, Christian Heide, Konrad Ullmann, Heiko B. Weber, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Under an intense electric field (> 1 V/Å) of a focused pulsed laser, electrons in solids undergo both inter- and intra-band motions driven by the field [1,2]. In this presentation, we discuss theoretically how the interplay of these two dynamics of electrons contributes to the generation of photocurrent in graphene. Numerical simulation suggests that the excitation from the valence band to the conduction band is well described as a result of interference of electron wave packets generated by tunneling within subcycles of the oscillating field. This interference is sensitive to the temporal evolution of the electric field, which explains the experimentally observed carrier-envelope-phase dependence of the photocurrent under few-cycle laser pulse illumination.

[1] M. Hohenleutner *et al.*, Nature **523**, 573 (2015).

[2] T. Higuchi *et al.*, Phys. Rev. Lett., **113**, 213901 (2014).

Q 52.6 Thu 15:45 a310

Experimental observation of light-field controlled current in graphene — •Christian Heide, Takuya Higuchi, Konrad Ullmann, Heiko B. Weber, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) 91058 Erlangen

Here, we show experimental data of photocurrent generation in an epitaxially grown monolayer graphene ribbon under the illumination of few-cycle laser pulses. Thereby, we control the carrier-envelope-phase (CEP) of the pulses to change the carrier waveform, maintaining the temporal intensity envelope and the spectrum. We observed a dependence of the induced photocurrent on the CEP and the polarization of the laser. Both strongly suggest that the electrons are directly steered by the electric field within subcycles of the laser pulse. To explain the experimental findings we numerically simulate the population transfer from the valence band to the conduction band, which persists after the pulse is gone.

Q 52.7 Thu 16:00 a310

Effect of multiphoton resonances on femtosecond filaments in gaseous media — •Carsten Bree[1,2] and Michael Hofmann[1,3] — [1]Weierstraß-Institut für Angewandte Analysis und Stochastik — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie — [3]Institut für Theoretische Physik, Technische Universität Berlin

A femtosecond filament is a longitudinally extended channel of intense laser radiation and plasma which appears to be diffraction-free. Theoretically, it is described by assuming a phenomenological model of the optical response which consists of the all-optical Kerr effect and the Drude model accounting for ionization effects due to the high field-strength. However, recent research indicates that one has to go beyond this phenomenological description and resort to full quantum calculations of the optical response [1]. By solving the time-dependent Schrödinger equation, we obtain the atomic dipole response and conclude that multiphoton resonances strongly influence the field-induced nonlinear refractive index Δn. Plugging the calculated Δn into a

propagation equation for the optical field enables us to observe the impact of multiphoton resonances on filamentary propagation [2].

[1] M. Kolesik *et* al., Optica **1**, 323(2014).
[2] M. Hofmann and C. Brée, Phys. Rev. A **92**, 013813(2015).

Q 52.8 Thu 16:15 a310

Two-color multi-photon photoemission from a tungsten nanotip: Time-resolved dynamics — •Timo Paschen[1], Michael Förster[1,2], Michael Krüger[1,2], Florian Libisch[3], Christoph Lemell[3], Georg Wachter[3], Thomas Madlener[3], Joachim Burgdörfer[3], and Peter Hommelhoff[1,2,4] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstrasse 1, 91058 Erlangen — [2]Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [3]Institute for Theoretical Physics, Vienna University of Technology, Wiedner Hauptstr. 8-10/E136, 1040 Wien — [4]Max-Planck Institut für die Physik des Lichts, Günther-Scharowsky-Str. 1/Geb. 24, 91058 Erlangen

By superimposing a fundamental laser pulse and a perturbative second harmonic admixture on a nanometric metal tip we coherently control multi-photon photoemission. We show that the photo-induced electron emission is dependent on the phase of the two light fields. By using a single solid state nanoemitter, contrast values of the phase-dependent electron signal of more than 90 per cent are reached, which is among the highest reported values for two-color coherent control measurements [1]. The experimentally observed phase-dependent electron emission is explained via quantum pathway interference and is compared to time-dependent density functional theory (TDDFT) and DFT simulations [2].

[1] P. Ackermann et al., Phys. Rev. A, 89, 063804 (2014).
[2] M. Förster et al., manuscript in preparation.