Q 39: Ultrashort Laser Pulses

Time: Wednesday 14:00–16:30 Location: S SR 211 Maschb.

Group Report Q 39.1 Wed 14:00 S SR 211 Maschb.

The Accelerator on a Chip International Program (ACHIP): Status and Outlook — •Norbert Schönenberger, Johannes Illmer, Ang Li, Stefanie Kraus, Anna Mittelbach, Roy Shiloh, Alexander Tafel, Peyman Yousefi, Peter Hommelhoff, and The ACHIP Team — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Dielectric laser acceleration (DLA) is based on the interaction of pulsed electron beams and laser-excited near-fields at photonic structures. Resulting acceleration gradients have approached 1 GeV/m and thus make this technology a promising candidate for a small-footprint accelerator. ACHIP aims to demonstrate an electron accelerator with a shoebox-sized footprint and 1 MeV final beam energy. Here the status and outlook of this endeavour are summarized. The emphasis is on recent results showing velocity micro bunching of sub relativistic electrons and subsequent probing of the phase space via a second laser-electron interaction. Furthermore, challenges and developments related to the necessary high brightness cathodes, transverse and longitudinal sub-relativistic electron dynamics, on-chip photonics-based laser coupling and the integration of all components of the envisioned MeV accelerator are detailed.

Q 39.2 Wed 14:30 S SR 211 Maschb.

Kagome-fiber prism compressor combination for Yb:KGW laser pulse compression to sub-40fs — •Dennis Mayer[1], Christian T. Matthaei[1,2], Axel Heuer[1], and Markus Gühr[1] — [1]Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam-Golm — [2]Institut für physikalische und theoretische Chemie, Julius-Maximilians-Universität Würzburg, 97074 Würzburg

Spectral broadening in hollow core fibers is an important tool for pulse compression of low-peak power laser pulses, especially for Yb-based lasers. Here, we present a pulse compression scheme to reduce the pulse duration of a commercial Yb:KGW laser operating at 100 kHz repetition rate and 40 μJ pulse energy from 390 fs to 38 fs. The spectral braodening is accomplished using a krypton-filled Kagome-type fiber. We report broadened spectra for variable Kr-pressures and input powers. At optimal settings of 8 bar Kr-pressure and 3.3 W input power, the bandwidth of the pulse at the -10 dB level increased from 9.5 nm to 85 nm corresponding to a Fourier limit of 26 fs. A simple SF10 prism compressor is used to reduce the accumulated chirp and shortens the fiber output from about 500 fs to 38 fs. In addition to the spectral broadening, a pressure dependent change of the polarization is observed.

Q 39.3 Wed 14:45 S SR 211 Maschb.

Sub-two cycle laser sources around 800 nm and 1560 nm for strong-field photoemission from metallic needle tips — •Philip Dienstbier[1], Timo Paschen[1], Lennart Seiffert[2], Thomas Fennel[2], and Peter Hommelhoff[1] — [1]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany — [2]Institute of Physics, University of Rostock, Rostock, Germany

In order to study photoemission dynamics in the strong-field regime few-cycle laser pulses are required. Such pulses have been used to investigate field-driven electron dynamics in photoemission from needle tips by changing the carrier-envelope phase (CEP) [1]. To enhance temporal resolution, we shorten pulses around 800 nm from 6 fs to sub 4 fs duration in a CEP-stable manner. We achieve this by spectrally broadening the output of a Ti:Sapphire oscillator in an all-normal dispersive photonic crystal fiber and compression with a 4f pulse shaper. Another approach for studying the coherent dynamics is a two-color scheme with strong driving pulses around 1560 nm, where the optical phase between this driving pulse and its second harmonic is predicted to modulate the photocurrent due to trajectory manipulation [2]. To obtain sub-two cycle pulses around 1560 nm, the output of an Erbium-doped fiber is spectrally broadened and compressed in a highly nonlinear fiber before its phase-locked second harmonic is generated. We will report on this two-color scheme and present initial data.

[1] M. Krüger et al., Nature **475**, 78-81 (2011).
[2] L. Seiffert et al., J. Phys. B **51**, 13 (2018).

Q 39.4 Wed 15:00 S SR 211 Maschb.

All-Optical Switching and Spectroscopy of Soliton Molecules — •Felix Kurtz[1], Claus Ropers[1], and Georg Herink[2] — [1]IV. Physical Insitute, University of Göttingen, Germany — [2]Experimental Physics VIII, University of Bayreuth, Germany

Bound-states of femtosecond solitons are experimentally generated and controlled in a kerr-lens mode-locked oscillator. Based on single-shot time-stretch interferometry [1], we resolve the resonance of vibrating soliton molecules [2] and demonstrate highly deterministic all-optical switching between stable doublet states of different temporal binding separation [3]. We discuss distinct interaction regimes and present a theoretical model for the underlying nonlinear dynamics.

[1] G. Herink, F. Kurtz, B. Jalali, D.R. Solli, C. Ropers, "Real-time spectral interferometry probes the internal dynamics of femtosecond soliton molecules.", Science 356, 50-54 (2017).
[2] F.M. Mitschke, L.F. Mollenauer, "Experimental observation of interaction forces between solitons in optical fibers", Opt. Lett. 12, 355 (1987).
[3] F. Kurtz, C. Ropers, G. Herink, "Nonlinear Spectroscopy and All-Optical Switching of Femtosecond Soliton Molecules", under revision (2018).

Q 39.5 Wed 15:15 S SR 211 Maschb.

Single-shot temporal characterization of extreme ultraviolet pulses with duration from sub 15 fs to 350 fs at the Free Electron Laser in Hamburg. — •Ivette Jazmin Bermudez Macias[1], Stefan Düsterer[1], Rosen Ivanov[1], Günter Brenner[1], Jia Liu[2], Andrey Kazansky[3], Nikolay Kabachnik[1], and Juliane Rönsch-Schulenburg[1] — [1]Deutsches Elektronen-Synchrotron — [2]European XFEL — [3]University of the Basque Country UPV/EHU

We present the results of a single-shot temporal charachterization of extreme ultraviolet (XUV) Free-electron Laser (FEL) pulses generated by the Free electron Laser in Hamburg (FLASH) at DESY, measured with a THz-field-driven streaking setup.

In order to investigate the limits of this technique, measurements were taken at different pulse durations, from sub 10fs to ~300fs, and different XUV wavelengths. Limits and possible error sources of the diagnostic method are discussed. Furthermore, the single-shot XUV pulse duration measurement allows the detailed investigation of the interplay between different properties of the strongly fluctuating self-amplified spontaneous emission (SASE) radiation. Correlations between pulse duration, pulse energy, spectral distribution, arrival time, electron bunch shapes,... are explored in the experimental data as well as in simulations. In addition, the results of different pulse reconstruction methods to retrieve the actual XUV pulse shape have been compared.

Q 39.6 Wed 15:30 S SR 211 Maschb.

Strong-field control of photoemission from tungsten needle tips with a two-color laser field — •Timo Paschen[1], Philip Dienstbier[1], Lennart Seiffert[2], Thomas Fennel[2], and Peter Hommelhoff[1] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]Institut für Physik, Universität Rostock, 18051 Rostock

Ionization by two-color laser fields with well-defined relative phase allows one to tune and control electronic dynamics on the (sub-) femtosecond time scale. Recently, we demonstrated that in the perturbative photoemission regime electron emission induced by a fundamental pulse can be modulated with a contrast of up to 97.5% when superimposing a weak second harmonic. This modulation is based on the interference between two different quantum channels involved in the photoelectron emission process [1,2]. In the strong-field photoemission regime, a model based on the time-dependent Schrödinger Equation and also the three-step model predict a two-color phase-dependent modulation of the plateau and high-energy cutoff in electron energy spectra [3]. In this talk we show similar field-driven dynamics in two-color photoemission from needle tips by employing a highly nonlinear fiber that generates IR laser pulses with sub-two cycle duration.

[1] M. Förster et al., Phys. Rev. Lett. 117, 217601 (2016).
[2] T. Paschen et al., J. Mod. Opt. 64, 10-11, 1054-1060 (2017).
[3] L. Seiffert et al., J. Phys. B. 51, 134001 (2018).

Q 39.7 Wed 15:45 S SR 211 Maschb.

Attosecond charge transfer over a graphene Schottky junction — •Christian Heide, Martin Hauck, Takuya Higuchi, Jürgen Ristein, Lothar Ley, Heiko B. Weber, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Epitaxially grown monolayer graphene on bulk n-doped silicon carbide (SiC) forms a Schottky junction with remarkable electronic and optical properties. After illumination with ultrashort laser pulses photoexcited electrons in graphene can overcome the Schottky barrier towards SiC. In our study we demonstrate that this charge transfer occurs on a timescale of about 300 as, which is the fastest charge transfer observed between two materials relevant to electronics. To reveal this attosecond dynamics, we interpret the photocurrent as a function of laser fluence and pulse duration in terms of a detailed rate equation model that takes saturable absorption and various electron thermalization pathways into account.

Q 39.8 Wed 16:00 S SR 211 Maschb.

Steering electrons in graphene with few-cycle laser pulses — •Tobias Boolakee, Christian Heide, Takuya Higuchi, Heiko B. Weber, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

We present recent advances on light-field driven electron dynamics in epitaxially grown monolayer graphene. Illuminating the monolayer with few-cycle laser pulses results in a carrier-envelope-phase (CEP) and polarization state dependent photocurrent that is sensitive to the waveform of the laser pulses on a sub-optical-cycle time scale [1]. We observe a transition of the laser-induced photocurrent from the perturbative regime towards the strong-field regime at a field strength of 2 V/nm. A tight-binding-model simulation supports this observation as a manifestation of Landau-Zener-Stückelberg interference. This finding allows us to investigate quantum-path interference and transport phenomena in graphene. Particularly, we can use the polarization state of the laser pulses to control electron trajectories coherently and thus the ensuing currents [2].

[1] Higuchi, T. et al., Nature 550, 224-228 (2017).
[2] Heide, C. et al., Phys. Rev. Lett. 121, 207401 (2018).

Q 39.9 Wed 16:15 S SR 211 Maschb.

Manifesting Berry phase in graphene without magnetic field — •Hamed Koochaki Kelardeh[1], Alexandra Landsman[1,2], Vadym Apalkov[3], and Mark Stockman[3] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck Postech, Pohang, Republic of Korea — [3]Georgia State University, Atlanta, USA

We explore the coherent electron dynamics of graphene superlattices imposed on periodic nanowires, irradiated by a strong few-cycle circularly-polarized pulse. The conduction-band population distribution in the reciprocal space forms an interferogram with discontinuities related to the topological (Berry) fluxes at the Dirac points. One of the fundamental problems of topological physics of graphene is a direct observation of the Berry phase, which essentially requires self-referenced interferometry of electronic waves in the reciprocal space (PRB 93 (15), 155434). However, the Berry phase is $\pm\pi$, and the self-referenced interferometry doubles it to $\pm 2\pi$; thereby avoiding any discontinuities in the interference fringes. Here we propose an approach to overtake this subtlety by coupling graphene to a nanowire superlattice. The Bragg scattering from the superlattices creates diffraction and "which way" interference in the reciprocal space reducing the Berry phase and making it directly observable in the electron interferograms without the involvement of the magnetic field.