Q 18: Strong-Field and Ultrafast Phenomena (joint session Q/MO)

Time: Tuesday 11:00–12:45 Location: HS V

Invited Talk Q 18.1 Tue 11:00 HS V

Strong-field physics and nonlinear optical phenomena in two-dimensional honeycomb materials — •Anna Galler — Institute of Theoretical and Computational Physics, TU Graz, Austria

Strong-field physics and extreme nonlinear optical processes in solids have emerged as powerful tools for ultrafast spectroscopy of electron dynamics. Ultrashort intense laser pulses have also been used to control and probe the valley pseudospin in two-dimensional honeycomb materials like transition-metal dichalcogenides. These phenomena are governed by the material-specific electronic structure and the nature of light-matter interaction. In this talk, I will present how ab-initio calculations can provide insights into these processes. Specifically, I will explore the role of the Floquet light-driven electronic structure in nonlinear optical phenomena and demonstrate how valley polarization and photocurrents in monolayer hexagonal boron nitride can be controlled using elliptically polarized, ultrashort laser pulses. Additionally, I will address high-harmonic generation (HHG) in two-dimensional materials, focusing on how interference effects from HHG emissions at distinct k-points in the Brillouin zone explain spectral features like peak splitting in monolayer WS_2. Finally, I will compare these simulation results with experimental observations to highlight the predictive power of our theoretical approach.

Q 18.2 Tue 11:30 HS V

What does extreme nonlinear optics tell about black holes? — •Lorenzo M. Procopio[1,2], Raul Aguero-Santacruz[3], David Bermudez[3], and Lorenzo Procopio[2] — [1]Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany — [2]Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 761001, Israel — [3]Department of Physics, Cinvestav, A.P. 14-740, 07000 Ciudad de Mexico, Mexico

In 1974, Hawking predicted that black holes should emit radiation. Seven years later, Unruh showed a mathematical analogy of the Hawking effect with sound waves in a fluid flow. Since then, several systems have emerged to demonstrate experimentally Hawking's predictions. Extreme nonlinear optics is a promising platform to study analog event horizons in photonic crystal fibers, where the event horizon is created with near-single-cycle light pulses. We experimentally studied the backreaction of Hawking radiation and present a more complete description of the Hawking process in fiber-optical analogues. For astrophysical black holes, this process would correspond to the mechanism of how Hawking radiation is made at the event horizon, how quanta of gravity produce quanta of radiation. In astrophysics, such a process is elusive and unknown, in extreme nonlinear fiber optics we believe to have observed it.

Q 18.3 Tue 11:45 HS V

Photocurrent control in a light-dressed Floquet topological insulator — •Weizhe Li[1], Daniel Lesko[1], Tobias Weitz[1], Simon Wittigschlager[1], Christian Heide[1,2], Ofer Neufeld[3], and Peter Hommelhoff[1,4] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany — [2]Stanford PULSE Institute, SLAC National Accelerator Laboratory, Menlo Park, CA, USA — [3]Schulich Faculty of Chemistry, Technion - Israel Institute of Technology, Haifa, Israel — [4]Department Physik, Ludwig-Maximilians-Universität München (LMU), 80799 München

Light-dressed materials, based on Floquet engineering, offers unique opportunities to design transient band structures. Most commonly, circularly-polarized dressing light can generate topologically nontrivial nonequilibrium states known as Floquet topological insulators (FTIs) which host a variety of topological phenomena. Floquet engineering with strong optical fields opens routes to optically tunable band structures and devices for petahertz electronics.

Here we demonstrate coherent control of photocurrents in light-dressed graphene. Circularly-polarized laser pulses dress the graphene into an FTI, and phase-locked second harmonic pulses drive electrons in the FTI. We map the resulting dynamics onto two-color phase dependent photocurrents. This approach allows us to measure all-optical anomalous Hall currents and photocurrent circular dichroism. Furthermore, we map out the attosecond Floquet phase by varying the two-color phase. The coherent control of photocurrents in graphene-based FTI connects optics tools to condensed matter physics.

Q 18.4 Tue 12:00 HS V

Strong-field electron dynamics in non-classical light after photoemission from nanometric needle tips — •Jonathan Pölloth[1], Jonas Heimerl[1], Andrei Rasputnyi[2], Stefan Meier[1], Maria Chekhova[1,2], and Peter Hommelhoff[1,2,3] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]Max-Planck-Institut für die Physik des Lichts (MPL), 91058 Erlangen — [3]Department Physik, Ludwig-Maximilians-Universität München (LMU), 80799 München

In the past, strong-field physics and quantum optics were two seemingly unrelated fields of research. However, in recent years, the development of intense non-classical light sources such as bright squeezed vacuum (BSV) has made it possible to connect these topics and to explore nonlinear interaction processes between intense quantum light and matter. Recent theoretical [1] and experimental [2] studies investigate the influence of the quantum state of light on strong-field processes such as high harmonic generation. For the case of nonlinear electron photoemission from needle tips, it was shown that the electrons inherit the number statistics of the driving light state [3]. Here, we will present the first measurements of strong-field electron energy spectra for photoemission from nanometric needle tips driven by BSV and explain them based on the theoretical frameworks.

[1] A. Gorlach *et al.*, Nat. Phys. **19**, 1689-1696 (2023)
[2] A. Rasputnyi *et al.*, Nat. Phys. (2024)
[3] J. Heimerl *et al.*, Nat. Phys. **20**, 945-950 (2024)

Q 18.5 Tue 12:15 HS V

Ultrafast photoemission from gold tips in the intermediate regime — •Leon Brückner[1], Jonas Heimerl[1], Stefan Meier[1], Philip Dienstbier[1], Constantin Nauk[1,2], and Peter Hommelhoff[1,3] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [3]Department Physik, Ludwig-Maximilians-Universität München (LMU), 80799 München

The intermediate regime in photoemission, corresponding to a Keldysh parameter γ around 1-3, lies in between the extreme cases of multiphoton and the quasi-static tunneling emission. This regime shows characteristic features, namely a smooth decrease in the nonlinearity of the emission process as well as the appearance of channel closings. In strong-field experiments at sharp metal needle tips, this picture becomes more complex due to the possible influence of space-charge effects arising from the large number of emitted electrons. We investigate the emitted current from an array of sharp gold tips illuminated with 25 fs laser pulses. Through comparison with time-dependent Schrödinger equation (TDSE) calculations, we identify characteristic intensity-dependent changes in the rate scaling and discuss the influence of space-charge effects.

Q 18.6 Tue 12:30 HS V

Recent advances in splitting and coherent beam recombining of femtosecond beams/pulses using optical vortex lattices — •Lyubomir Stoyanov[1], Yinyu Zhang[2,3], Alexander Dreischuh[1], and Gerhard Paulus[2,3] — [1]Department of Quantum electronics, Faculty of Physics, Sofia University — [2]Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena — [3]Helmholtz Institute Jena

In this work, we will present our recent advances in addressing spectral broadening and temporal compression of high-energy femtosecond pulses by the controllable splitting and coherent beam recombining of such beams/pulses using optical vortex lattices. This controllable and reversible beam reshaping technique known from singular optics is the key feature in this approach. Using fused silica vortex phase plates, etched with square-shaped optical vortex lattices we achieved an experimental realization of controllable beam splitting of intense femtosecond beams/pulses, followed by nonlinear spectral broadening (both in ambient air and fused silica substrate) and a final coherent beam recombination. Moreover, the compression in time of the spectrally broadened pulses down to the Fourier transform limit is demonstrated as well. In our view, the results confirm the feasibility of the proposed idea and provide strong motivation for further optimization and investigation serving as potential alternative to the established methods for coherent beam recombining.