A 15: Attosecond physics

Time: Wednesday 10:30–12:30 Location: S HS 3 Physik

Invited Talk A 15.1 Wed 10:30 S HS 3 Physik

Decomposition of the Temporal and Spectral Response in Attosecond Transient Absorption Spectroscopy — •Lorenz Drescher, Vishal Shokeen, Tobias Witting, Serguei Patchkovskii, Marc Vrakking, and Jochen Mikosch — Max-Born-Institut, Berlin, Deutschland

Attosecond Transient Absorption Spectroscopy (ATAS) of core-excited states provides the opportunity to study ultrafast phenomena in organic molecules from the local perspective of a reporter atom. In molecules, high densities of states and broad natural linewidths may complicate the analysis of overlapping features, while the low flux of current-generation attosecond sources requires high detector sensitivity and long acquisition times. Here we discuss the use of Singular Value Decomposition for ATAS to extract spectral and temporal dynamics associated with the state-dependent light-induced phase, while efficiently separating contributions from energy-and-time correlated features and detector noise. We apply the technique to our recent results of ATAS in iodomethane (CH_3I) [1] to extract the state-resolved polarizability of the molecule. We also discuss the possibility to *in-situ* characterize the electric-field of the laser from the molecular ATAS measurement.

[1] L. Drescher et al., submitted to J. Phys. Chem. Lett. (2018)

A 15.2 Wed 11:00 S HS 3 Physik

Tunneling time in attosecond experiments and time operator in Quantum Mechanics — •Ossama Kullie — Institute of Physics, Department of Mathematics and Natural Science, University of Kassel, Germany

Attosecond science is of a fundamental interest in physics. The measurement of the tunneling time in attosecond experiments, offers a fruitful opportunity to understand the role of time in quantum mechanics. We discuss in this paper, our tunneling time model in relation to two time operator definitions introduced by Bauer (Phys. Rev. A 2017, **96**, 022139) and Aharonov-Bohm (Phys. Rev. 1961, **122**, 1649). We found that both definitions can be generalized to the same type of time operator. Moreover, we found that the introduction of a phenomenological parameter by Bauer to fit the experimental data is unnecessary. The issue is resolved with our tunneling model by considering the correct barrier width, which avoids a misleading interpretation of the experimental data. Our analysis shows that the use of the so-called classical barrier width, to be precise, is incorrect [1,2].

[1] O. Kullie. open access Mathematics 2018, 6, 192; doi:10.3390/math6100192

[2] O. Kullie. Phys. Rev. A, 2015 **92**, 052118

A 15.3 Wed 11:15 S HS 3 Physik

Analysis of sub-cycle XUV-NIR-induced excitation dynamics in helium by UV photoelectron spectroscopy — Jesse Klei[1], Renate Pazourek[2,3], Christian Neidel[1], Arnaud Rouzee[1], Martin Galbraith[1], Mette Gaarde[2], Ken Schafer[2], Marc J. J. Vrakking[1], and •Jochen Mikosch[1] — [1]Max-Born-Institut, Berlin, Germany — [2]Louisiana State University, Louisiana, USA — [3]University of Technology, Vienna, Austria

We use UV photoelectron spectroscopy to study the excitation dynamics of 1snp neutral states in helium from XUV-NIR excitation with an attosecond pulse train and a co-propagating NIR field. The excited state population is found to oscillate with the XUV-NIR delay at twice the NIR field frequency. We measure the phase of the 1s3p population oscillation with respect to the oscillating NIR-dressed ionization yield related to the 17th harmonic order, as a function of energy shift of the XUV frequency comb. Numerical TDSE calculations are performed and found to be in good agreement with the experimental results. The observed oscillation of the 1s3p population is the result of interference between two independent two-color excitation channels, which are out-of-phase: Apart from the previously identified NIR-assisted interference of excitation pathways involving the 15th and the below-ionization-threshold 13th harmonic, we find the phase-shifted interference of excitation pathways involving the 15th harmonic and the above-ionization-threshold 17th harmonic to contribute to the 1s3p excitation yield. Importantly, the relative yield of the two channels is found to depend on the frequency comb spectral position.

A 15.4 Wed 11:30 S HS 3 Physik

Probing of electronic wavefunctions and chiral structure by all-optical attosecond interferometry — Doron Azoury[1], Omer Kneller[1], Shaked Rozen[1], Barry D. Bruner[1], Alex Clergerie[2], Bernard Pons[2], Baptiste Fabre[2], Yann Mairesse[2], Oren Cohen[3], •Michael Krüger[1], and Nirit Dudovich[1] — [1]Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel — [2]Universite de Bordeaux - CNRS - CEA, CELIA, Talence, France — [3]Department of Physics and Solid State Institute, Technion, Haifa, Israel

Phase retrieval of electronic wavefunctions generated by photoionization has been a long-standing challenge. Here we measure the time-reversed process of photo-ionization – photo-recombination – in attosecond pulse generation. We demonstrate all-optical interferometry of two independent phase-locked attosecond light sources [1]. Our measurement enables us to directly determine the phase shift associated with electron scattering and with structural minima in simple atomic systems.

In a second study, we superimpose two attosecond light sources with perpendicular polarization, achieving direct time-domain polarization control [2]. We establish an extreme-ultraviolet lock-in detection scheme, allowing the isolation and amplification of weak chiral signals. We demonstrate our scheme by a phase-resolved measurement of magnetic circular dichroism.

[1] D. Azoury et al., arXiv:1810.05021, Nature Photonics in press.

[2] D. Azoury et al., accepted for publication in Nature Photonics.

A 15.5 Wed 11:45 S HS 3 Physik

Spatio-temporal characterisation of laser pulses in the single-cycle regime — •Tobias Witting[1,2], Federico Furch[1], and Marc J.J. Vrakking[1] — [1]Max-Born-Institut, Max-Born-Strasse 2A, 12489 Berlin — [2]Max-Born-Straße 2A

We review spatio-temporal laser pulse characterisation technology for single cycle laser pulses. We show results obtained using spatially-encoded arrangement filter-based spectral phase interferometry for direct electric field reconstruction (SEA-F-SPIDER). We discuss spatio-temporal pulse measurements of hollow fibre-based pulse compressors [1,2] and non-collinear optical parametric chirped pulse amplifier (NOPCPA) laser systems [3]. Recently, we demonstrated pulse characterisation based on time-domain ptychography [4]. We show how time-domain ptychography can be multiplexed for spatio-temporal measurements and compare the results to SEA-F-SPIDER. [1] T. Witting, D.R. Austin, T. Barillot, D. Greening, P. Matia-Hernando, D. Walke, J. P. Marangos, and J. W. G. Tisch. Optics Letters 41, 2382 (2016) [2] D.R. Austin, T. Witting, S.J. Weber, P. Ye, T. Siegel, P. Matía-Hernando, A.S. Johnson, J.W.G. Tisch, and J.P. Marangos. Optics Express 24, 24786 (2016) [3] F. Furch, T. Witting, A. Giree, C. Luan, F. Schell, G. Arisholm, C.P. Schulz, and M.J.J. Vrakking. Optics Letters 42, 2495 (2017) [4] T. Witting, D. Greening, D. Walke, P. Matia-Hernando, T. Barillot, J. P. Marangos, and J. W. G. Tisch. Optics Letters 41, 4218 (2016)

A 15.6 Wed 12:00 S HS 3 Physik

Isolated attosecond pulse generation at 100 kHz repetition rate — •Tobias Witting[1], Federico Furch[1], Mikhail Osolodkov[1], Felix Schell[1], Peter Susnjar[1], Carmen Menoni[2], Claus-Peter Schulz[1], and Marc JJ. Vrakking[1] — [1]Max-Born-Institut, Max-Born-Strasse 2A, 12489 Berlin — [2]Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, CO 80523, USA

We aim to perform attosecond pump-probe experiments with coincidence detection of photoelectrons and -ions in a reaction microscope. To increase the data-rates we have developed a non-collinear optical parametric chirped pulse amplification (NOPCPA) laser system providing 7 fs, 190 μJ laser pulses at 100 kHz repetition rate [1]. We achieved further compression to 3.2 fs near single-cycle pulses and demonstrate their use for attosecond pulse generation by high harmonic generation up to 55 eV at 100 kHz. Our source provides an XUV flux of 10^{13} photons/sec. We present our progress towards a complete attosecond pump-probe beamline coupled to a reaction microscope. By means of velocity map imaging we characterised the attoseocond pulse trains produced by the 7 fs pulses from the NOPCPA

system with the RABBITT technique. The isolated attosecond pulses produced by the post compressed near single-cycle pulses have been characterised with attosecond streaking.

[1] F.J. Furch, T. Witting, A. Giree, C. Luan, F. Schell, G. Arisholm, C.P. Schulz, and M.J.J. Vrakking. Optics Letters 42, no. 13 (2017)

A 15.7 Wed 12:15 S HS 3 Physik

Attosecond-resolved petahertz carrier motion in semimetallic TiS2 — Barbara Buades[1], Antonio Picon[1,2], Iker Leon[1], •Nicola Di Palo[1], Seth Cousin[1], Caterina Cocchi[3], Eric Pellegrin[4], Javier Herrero Martin[4], Samuel Mañas Valero[5], Eugenio Coronado[5], Thomas Danz[6], Claudia Draxl[3], Mitsuharo Uemoto[7], Katsuhiro Yabana[7], Martin Schultze[8], Simon Wall[1], and Jens Biegert[1,9] — [1]ICFO-Institut de Ciencies Fotoniques, 08860 Castelldefels, Spain — [2]Grupo de Investigación en Óptica Extrema, Universidad de Salamanca, Salamanca 37008, Spain — [3]Institut für Physik Adlershof, Humboldt-Universität Berlin, Berlin, Germany — [4]ALBA Synchrotron Light Source, 08290 Barcelona, Spain — [5]Instituto de Ciencia Molecular, Universitat de València, Paterna, Spain — [6]4th Physical Institute, University of Göttingen, Göttingen, Germany — [7]Center for Computational Sciences, University of Tsukuba, Tsukuba 305-8577, Japan — [8]Fakultät für Physik, Ludwig-Maximilians-Universität, 85748 Garching, Germany — [9]ICREA, 08010 Barcelona, Spain

We examine the opto-electronic response of TiS2 by means of attosecond soft x-ray spectroscopy at the L-edges of Ti at 460 eV. Using weak-field infrared single-photon excitation, we demonstrate the efficient carrier injection into the conduction band and observe petahertz opto-electronic response of its carriers. Our results are an important step towards understanding the dynamics of carriers and their control under field conditions.