# A 21: Interaction with strong or short laser pulses

Time: Tuesday 16:30–19:00 Location: Empore Lichthof

A 21.1 Tue 16:30 Empore Lichthof

**Dynamic interference in the photoionization of helium by coherent intense high-frequency pulses** — •Anne D. Müller[1], Anton N. Artemyev[1], David Hochstuhl[2], Lorenz S. Cederbaum[3], and Philipp V. Demekhin[1] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [2]Institut für Theoretische Physik und Astrophysik, Leibnizstrasse 15, 24098 Kiel — [3]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, INF 229, 69120 Heidelberg

The direct ionization of the helium atom by intense coherent high-frequency laser pulses is investigated theoretically from first principles. To this end, we solve numerically the time-dependent Schrödinger equation for the two-electron wave-packets by the efficient time-dependent restricted-active-space configuration-interaction method (TD-RASCI, [1]). Thereby we investigate how the dynamic interference of the photoelectrons of the same kinetic energy emitted at different times along the pulse [2] is modified for systems with several electrons. In particular, we consider photon energies which are nearly resonant for the subsequent 1s–2p excitation in the $He^+$. In order to enable observations of the dynamic interference patterns in the computed photoionization spectrum, the two-electron wave-packets were propagated on large spatial grids over long times.

References.

[1] D. Hochstuhl, M. Bonitz, Phys. Rev. A, 053424 (2012).

[2] Ph.V. Demekhin, L.S. Cederbaum, Phys. Rev. Lett., 253001 (2012).

A 21.2 Tue 16:30 Empore Lichthof

**Beyond the dipole approximation for Coulomb focusing of tunnelled electrons in intense laser fields** — •Jiří Daněk, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

In recent experiments, the breakdown of the dipole approximation in strong-field ionization was demonstrated and the important role of magnetic field on the photoelectron spectra (PES) was investigated. Although many simulations are in agreement with the experiments, a comprehensible theoretical picture is still missing even for rather simple atoms. Meanwhile, the full understanding of the nondipole effects on the PES is essential for further development of the holography for atoms.

In our poster, we present quasi-classical Monte Carlo simulation for xenon atom in a strong mid-infrared laser field with linear polarization beyond the dipole approximation. We demonstrate how the magnetic component of the laser field influences the Coulomb focusing and modifies the final PES with respect to the dipole case. The modified PES shows a "bend" in the opposite direction towards the magnetic pressure caused by the laser field. This seemingly counterintuitive feature is explained as a modification of the Coulomb focusing under the magnetic force in the well known recollision picture.

A 21.3 Tue 16:30 Empore Lichthof

**CEP Dependence of Alkali ATI Spectra** — •Danilo Zille and Daniel Adolph — Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Exposing atoms to short, intense laser pulses reveals a number of interesting effects in their photoelectron spectra. In the last 25 years much time and effort has been devoted to investigate and understand the origin of these effects, primarily for rare gases.

So far the literature offers only very few results regarding alkali metal atoms, despite having multiple properties that make the investigation of their ATI spectra highly interesting.

To start, they fulfill the commonly used single active electron approximation better than other atoms. In addition, they have much lower ionization potentials than what is usually considered. This places the problem in the multiphoton regime. Another point of interest are strong atomic resonances.

We present results of our investigation of the carrier-envelope phase dependence of the photoionization spectra of alkali metal vapors at near-infrared wavelengths. These results are important for a potential application of alkali metals in a CE-phase meter. The experimental findings are compared with calculations obtained from solving the time-dependent Schrödinger Equation. As a first result, we confirm the previously made theoretical prediction that asymmetries occur predominantly between the ATI peaks.

A 21.4 Tue 16:30 Empore Lichthof

***In* and *ex situ* characterization of few-cycle NIR laser pulses for strong-field quantum dynamics measurements— Three complementary methods compared** — •Maximilian Hartmann[1], Alexander Blättermann[1], Huipeng Kang[1,2], Paul Birk[1], Veit Stooss[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan 430071

Strong few-cycle laser pulses are nowadays routinely generated by amplified Ti:sapphire lasers combined with spectral broadening in gas-filled hollow-core fibers and temporal compression by chirped–mirror compressors. They can be used to drive high–harmonic generation in gases in order to produce attosecond bursts of XUV radiation. Both XUV and NIR pulses can then be used to capture electron dynamics in atomic and molecular systems on their natural time scale.

To fully understand and optimize the experimental setup, and in order to compare experimental results and theoretical calculations quantitatively, characterization of the laser pulses is mandatory. Here, we compare three methods for the characterization of femtosecond NIR laser pulses. These methods comprise two *ex situ* techniques, namely the dispersion scan [Miranda et al., Opt. Express 20, 688-697 (2012)] and the interferometric autocorrelation. They are compared to an *in situ* optical scheme where the pulse properties are extracted from transient absorption spectra of XUV-excited atoms [Blättermann et al., Opt. Lett. 40, 3464-3467 (2015)].

A 21.5 Tue 16:30 Empore Lichthof

**Multi-photon vs. quasi-static regime of strong field dynamics for atomic bound states** — •Veit Stooss[1], Andreas Kaldun[2], Christian Ott[3], Alexander Blättermann[1], Paul Birk[1], Thomas Ding[1], Kristina Meyer[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]Stanford University, Stanford, CA — [3]University of California, Berkeley, CA

In his work introducing the framework for atomic ionization in strong-field physics Keldysh characterized two regimes for the dynamic process of ionization [1]: (i) the multi-photon regime that treats the ionization as the result of the interaction with many photons, and (ii) the regime of tunnel ionization where the electric field is considered as quasi-static and electrons can leave through a barrier created by the influence of the strong laser field on the coulomb potential of the atoms. We investigate the dynamics of bound states with respect to these regimes that apply for ionization in strong fields. We examine signatures that depend on both intensity and wavelength [2] to separate the regimes of the few-photon-perturbative and the quasi-static picture. We performed time-resolved measurements of perturbed polarization decay in helium and compare them to numerical simulations in order to study the transition between photon- and quasi-static regime as a function of intensity and wavelength. [1] Keldysh L. V., Sov. Phys. JETP 20, 1945-1950 (1964) [2] Gaarde, Schafer, Physical Review A 86, 063408 (2012)

A 21.6 Tue 16:30 Empore Lichthof

**Molecular wave-packet dynamics on laser induced transition states** — •Andreas Fischer[1], Martin Gärttner[1], Philipp Cörlin[1], Alexander Sperl[1], Michael Schönwald[1], Tomoya Mizuno[1], Giuseppe Sansone[2], Arne Senftleben[3], Joachim Ullrich[4], Bernold Feuerstein[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Dipartimento di Fisica, Politecnico Milano, Milano — [3]Institut für Physik, Universität Kassel, Kassel — [4]Physikalisch-Technische Bundesanstalt, Braunschweig

Using a XUV-pump IR-probe experiment in combination with a Reaction Microscope, we studied the dissociation dynamics of hydrogen molecules by varying the time delay between an ultra-short extreme-ultraviolet (XUV) and a near-infrared (IR) control pulse. The measured fragment momenta are time-delay dependent, showing that the reaction kinematics can be controlled by varying the retardation of the

control pulse. A semi-classical model, supported by a quantum dynamics simulation, provides an intuitive understanding of the underlying mechanism in terms of particle motion on laser-induced potential energy curves.

A 21.7 Tue 16:30 Empore Lichthof

**Spin dynamics in tunneling as well as multiphoton ionization** — •Enderalp Yakaboylu, Michael Klaiber, and Karen Z. Hatsagortsyan — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Spin effects in the tunneling regime of strong field ionization of hydrogenlike highly charged ions in linearly as well as circularly polarized laser fields are investigated. The impact of the polarization of a laser field on the spin effects are analyzed. Analytical expressions for spin asymmetries and spin flip probability, depending on the laser's polarization, are obtained for the photoelectron momentum corresponding to the maximum of tunneling probability [1]. Then, the results are extended to an arbitrary Keldysh parameter in order to reveal the nonadiabatic effects. It is shown that the spin flip is independent from the Keldysh parameter, whereas the spin asymmetries highly depend on it. All the results are comprehensively explained by an intuitive model which incorporates the spin dynamics in tunneling as well as multiphoton ionization.

[1] E. Yakaboylu, M. Klaiber, and K. Z. Hatsagortsyan Phys. Rev. A 91, 063407 (2015).

A 21.8 Tue 16:30 Empore Lichthof

**Spatial electron correlation and ionization of helium in strong, ultrashort laser pulses** — •Gergana Borisova, Andreas Fischer, Veit Stooss, Alexander Blättermann, Thomas Ding, Andreas Kaldun, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Motivated by a transient-absorption spectroscopy experiment, where a difference in the ionization of singly and doubly excited states with similar ionization energy was observed, the electron-electron correlation dynamics was investigated.

Here, we show results from the investigation of the electron dynamics in the helium atom interacting with strong laser fields on an attosecond time scale. We analyzed the electron-electron correlation dynamics responsible for the enhancement of the ionization in doubly excited helium by means of the time-dependent population of these states during and right after the laser pulse.

For this we employ a numerical quantum-mechanical model based on solving the one-dimensional time-dependent Schrödinger equation for two electrons.

A 21.9 Tue 16:30 Empore Lichthof

**Electron-positron-photon jets generated by circularly polarized lasers** — •suo tang, naveen kumar, and christoph h. keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69126, Heidelberg, Germany

With the next generation of ultra-intense laser pulse with intensities ($I \sim 10^{24}\mathrm{W/cm}^2$), pair production and QED cascades can be induced by slow electrons or positrons. The generated pairs are accelerated by the laser fields to ultrarelativistic energy. High quality electron-positron-photon jets can be emitted from the field formed by the two counterpropagating circular polarized laser pulses. By adjusting the relative frequency and intensity of the laser pulses, the direction and energy of the jets can be controlled.

A 21.10 Tue 16:30 Empore Lichthof

**Two-color strong-field ionization of methane** — •Martin Laux, Yonghao Mi, Nicolas Camus, Lutz Fechner, Robert Moshammer, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Laser pulses with an asymmetric electric field like those created by the superposition of two-color laser fields or single-cycle pulses with fixed carrier-envelope phase may serve as an excellent tool for the study of site- and channel-selective strong-field ionization of molecules. Here, we present experimental results for ionization of methane exposed to 25 fs two-color pulses in a reaction microscope. We investigate and compare the effects of the tunable phase between the fundamental 800 nm near-infrared pulse and its second harmonic on the 3-dimensional momenta of ions and electrons created in the various reaction channels, for example single ionization with and without dissociation, double ionization and Coulomb explosion.

A 21.11 Tue 16:30 Empore Lichthof

**Comparison of time-dependent strong-field effects in atoms and molecules observed by attosecond XUV absorption spectroscopy** — •Paul Birk, Veit Stooss, Maximilian Hartmann, Alexander Blättermann, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Extreme ultraviolet (XUV) light pulses in the attosecond regime produced by high-harmonic generation of near-infrared (NIR) light are powerful tools to achieve ultra-high time resolution of intra-atomic and -molecular processes. With the help of an all optical approach we get access to bound state dynamics and correlations between electronic states in atoms and molecules. In previous work [1], it was possible to reconstruct and control a time-dependent two-electron wave packet in a measurement of perturbed polarization decay in helium. Based on this work on atoms, we investigate and compare time-dependent strong-field effects in argon and molecular nitrogen by exciting electronic and vibrational states of the target gas by a weak XUV pulse and perturbing the system via a strong NIR pulse. We present first results and interpretations of absorption spectra in the XUV-range and their changes depending on both the time delay and intensity of the strong NIR pulse.

[1] C. Ott, et al., Nature 516, 374-378

A 21.12 Tue 16:30 Empore Lichthof

**Finding the global minimum using Gaussian processes** — •Mehrdad Baghery, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Minimising functions is crucial to many problems in ranging from astrophysics to quantum optimal design. Among these lies the problem of finding the minimum of expensive-to-evaluate functions, rendering the fact that the minimum has to be found by making as few observations as possible.

In order to tackle this problem, we introduce an auxiliary function (expressed as a Gaussian process) which mimics the original function as more and more observations are made. This function is relatively cheap-to-evaluate, and more importantly, its derivatives are analytically expressible. By finding the minimum of this auxiliary function using textbook gradient-based minimisation algorithms, it is possible to find the minimum of the original function.

As a physical application, we will use the algorithm to find a laser pulse shape which, when shone on a hydrogen atom, maximises the charge yield.

A 21.13 Tue 16:30 Empore Lichthof

**The orbital-truncation error in TDRNOT** — •Felix Steinmeyer, Julius Rapp, and Dieter Bauer — Universität Rostock

In time-dependent renormalized-natural-orbital theory (TDRNOT), the complete and generally infinite basis of natural orbitals (NOs) is used to derive equations of motion (EOM) for few-body systems [1,2]. In the case of two particles, the *exact* EOM of the NOs are known explicitly. However, numerical calculations require a truncation of the number of NOs to a finite value $N_\mathrm{o}$. This truncation introduces an error to the method which may spoil the (nonlinear) NO time evolution [3,4].

We analyze the impact of the truncation error by comparing the exact NOs with the NO subset of TDRNOT calculations considering exactly solvable model systems. Furthermore, we discuss our efforts in constructing an effective potential which mimics the effect of the omitted NOs on a mean-field level.

[1] M. Brics and D. Bauer, Phys. Rev. A 88, 052514 (2013)
[2] J. Rapp, M. Brics, and D. Bauer, Phys. Rev. A 90, 012518 (2014)
[3] M. Brics, J. Rapp, and D. Bauer, Phys. Rev. A 90, 053418 (2014)
[4] M. Brics, J. Rapp, and D. Bauer, arXiv:1510.01682 (2015)

A 21.14 Tue 16:30 Empore Lichthof

**OPCPA meets Reaction Microscope** — •Claus Peter Schulz, Federico Furch, Felix Schell, Achut Giree, Sascha Birkner, Jochen Mikosch, and Marc Vrakking — Max Born Institute, Berlin, Germany

Spectroscopy derived from intense laser fields and with energetic XUV photons from High Harmonic Generation promises to bring unprecedented temporal and spatial resolution to studies of molecular dynamics. In particular for polyatomic molecules a complete detection scheme of the full manifold of 3D momentum vectors of all outgoing

charged particles is invaluable for the interpretation of results. So-called reaction microscopes, which have already been developed more than a decade ago, enable this type of complete experiments by detecting the energy and angular distribution of photo electrons and ions in coincidence. Coincidence experiments benefit highly from increased repetition rates to boost the signal rates. Recently, we have set-up a laboratory where we combine a 400 kHz repetition rate laser system based on Optical Parametric Chirped-pulse Amplification (OPCPA) providing pulses with sub-7 fs duration and energies up to 10 $\mu$J with a reaction microscope. First results on atoms and small hydrocarbon chains will be presented as well as our plans for XUV-IR spectroscopy.

A 21.15 Tue 16:30 Empore Lichthof

**Photoelectrons and light from laser-driven 1D helium using TDRNOT** — •Martins Brics, Julius Rapp, Adrian Hanusch, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Time-dependent renormalized-natural-orbital theory (TDRNOT) is a promising approach to describe correlated electron quantum dynamics, even beyond linear response. It has been shown in [1] that TDRNOT with only two renormalized natural orbitals (RNOs) per spin is capable of describing correlated phenomena such as doubly excited states, autoionization, and Fano profiles in photoelectron spectra for He. Here we go one step further and investigate the performance of TDRNOT for processes which involve more than two RNOs. As test cases we consider nonsequential double ionization and single photon double ionization. Both are strongly correlated processes and therefore many RNOs are needed to describe them. Our main observable for this purpose is correlated photoelectron spectra. The other aspect we look at is what advantages offers TDRNOT over time-dependent density function theory (TDDFT) for cases where TDDFT already gives quite good results. For that purpose we test TDRNOT on high-order harmonic spectra.

[1] M. Brics, D. Bauer, *Phys. Rev. A* **88**, 052514 (2013).