MO 16: Poster – Attosecond Physics (joint session A/MO)

Time: Wednesday 17:00–19:00 Location: Philo 1. OG

MO 16.1 Wed 17:00 Philo 1. OG

New 1D atomic model potential for more accurate high-order-harmonic-generation spectra — •Krisztina Sallai[1,2], Szabolcs Hack[1,2], Szilárd Majorosi[1], and Attila Czirják[1,2] — [1]The Extreme Light Infrastructure ERIC | ALPS Facility, Szeged, H-6728, Hungary — [2]University of Szeged, Szeged, H-6720, Hungary

Building on the favourable properties of previously used one-dimensional (1D) atomic model potentials, we introduced a new 1D Gaussian-windowed atomic model potential in [1] for simulating the quantum dynamics of a single active electron atom driven by a strong, linearly polarized near-infrared laser pulse. This new model potential upgraded the accuracy of 1D numerical simulations for single-atom high-order-harmonic-generation (HHG) spectra under commonly used driving laser pulse parameters. By combining two model potentials, we define the Gaussian windowed soft-core Coulomb (GSC) potential (with a =2.551 and b = 2) as

$V_{\mathrm{GSC}}^{\mathrm{1D}}(z) = V_{\mathrm{SC}}^{\mathrm{1D}}(z)\exp(-(z/a)^2) + V_{\mathrm{MSC}}^{\mathrm{1D}}(z)\left(1-\exp(-(z/b)^2)\right).$

The GSC potential offers an outstanding balance of accuracy and computational efficiency, enabling TDSE simulations that generate reliable HHG spectra within minutes in the $1.26 \times 10^{14} - 6.88 \times 10^{14}\, W/cm^2$ peak intensity range. Our research suggests that the GSC potential performs best when the Keldysh parameter is within $0.45 \leq \gamma \leq 1$ and the 1D ground state population loss simulated with the GSC potential, is not greater than 0.6 at the end of the laser pulse, which is well in line with most GHHG methods.

References: [1] K Sallai et al., Phys. Rev. A 110, 063117 (2024)

MO 16.2 Wed 17:00 Philo 1. OG

A rigorous and universal approach for highly-oscillatory integrals in attosecond science — •Anne Weber[1], Job Feldbrugge[2], and Emilio Pisanty[1] — [1]Attosecond Quantum Physics Laboratory, King's College London, WC2R2LS London, UK — [2]Higgs Centre for Theoretical Physics, University of Edinburgh, UK

Light-matter interactions within the strong-field regime, such as high-harmonic generation, typically give rise to highly-oscillatory integrals, which are often solved using saddle-point methods. Not only do these methods promise a much faster computation, but they also inform a more intuitive understanding of the process in terms of quantum orbits, as the saddle points correspond to interfering quantum trajectories (think Feynman's path integral formalism). Despite these advantages, a sound understanding of how to apply saddle-point methods to highly-oscillatory integrals in a rigorous way, and with algorithms which work uniformly for arbitrary configurations and laser drivers, remains lacking. This hinders our ability to keep up with state-of-the-art experimental setups which increasingly rely on tightly-controlled laser waveforms. Here, I will introduce the key ideas of Picard-Lefschetz theory – the foundation of all saddle-point methods – and their implementation. Using high-harmonic generation and above-threshold ionisation as examples, I will show how those ideas provide a robust framework for the fast computation of integrals, as well as a widely-applicable algorithm to derive the relevant semiclassical quantum orbits that underlie the physical processes.

MO 16.3 Wed 17:00 Philo 1. OG

Coulomb-corrected reconstruction of ionization and recombination times in high-order harmonic generation — •Mohammad Monfared and Manfred Lein — Institute for Theoretical Physics, Leibniz Universität Hannover, Hannover, Germany

Accurate attosecond-scale measurement of electron dynamics is fundamental to ultrafast science. The orthogonally polarized two-color (OTC) field technique enables the reconstruction of electron ionization and recombination times from high-order harmonic generation (HHG) spectra. However, established retrieval methods often neglect or utilize an oversimplified treatment of the Coulomb interaction, limiting their precision. In this work, we introduce a refined time-retrieval method that significantly improves the accuracy of reconstructing ionization and recombination times in OTC fields. We identify that one of the main time-retrieval equations, namely the condition used in earlier works to maximize the harmonic intensity as a function of the two-color delay, is only approximate and replace it with a more accurate stationarity equation. In addition, we incorporate Coulomb effects beyond the simple approximation of an instantaneous momentum kick by numerically integrating the Coulomb force and potential along the classical electron trajectories, providing a more physically consistent correction. We benchmark our method against exact time-dependent Schrödinger equation simulations and the analytical R-matrix theory. Our results demonstrate a substantial improvement in the accuracy of the retrieved ionization times, achieving near-perfect agreement with benchmark models especially for high-frequency probe fields.

MO 16.4 Wed 17:00 Philo 1. OG

Technical performance of the upgraded XUV and soft X-ray split-and-delay unit at FLASH1 — •Matthias Dreimann, Michael Wöstmann, and Helmut Zacharias — Center for Soft Nanoscience, Universität Münster

The split-and-delay unit at FLASH1, in operation since 2007, has been upgraded to meet the advances of increasing photon energies of FLASH1 since then. With the original design first experiments were performed in 2007 and the SDU was permanently incorporated in the BL2 at FLASH1 in 2010. The upgrade increases the spectral range of the SDU from former hv = 250 eV to now hv = 750 eV. Two different mirror coatings achieve a high transmission in the whole spectral range. The design is based on a three dimensional beam path and allows choosing the propagation via two sets of mirrors with different coatings. A carbon coating allows a total transmission on the order of T > 0.74 for photon energies between hv = 30 eV and hv = 200 eV at a grazing angle of 3.0° in the variable beam path. In the fixed beam path a shallower grazing angle of 2.5° is used, which yields a total transmission of T > 0.79. An Ni coating can be used to additionally cover a range up to hv = 750 eV. This results in a total transmission of typically T = 0.4 in the variable and T = 0.3 in the fixed beam path. The delay range of the new set-up is -1 ps < t < +9 ps with a subfemtosecond temporal delay.

MO 16.5 Wed 17:00 Philo 1. OG

Attosecond Streaking Spectroscopy: From Gas-Phase Dynamics to Adsorbed Molecules — •Ron Ducke, Sven-Joachim Paul, Maximilian Pollanka, Christian Schröder, Pascal Freisinger, Andreas Duensing, Reinhard Kienberger, and Maximilian Forster — Technische Universität München, Garching, Germany

We present the attosecond streaking setup established in our laboratory, designed to investigate time-resolved photoemission dynamics with high temporal precision. By using attosecond pulses, generated by HHG, we successfully determined absolute photoemission delays across a broad range of systems. In the gas phase, we review key results including absolute delays in the valence range of water and comparative studies of isosteric molecules, which elucidate the link between electronic structure and emission timing. Furthermore, a systematic analysis of iodoalkanes reveals the significant influence of the molecular environment on the emission from the iodine atom. Moving beyond the gas state, we discuss the photoemission delays of molecules adsorbed on crystal surfaces. Investigations of iodomethane and iodoethane on Pt(111) demonstrate how molecular orientation and surface interactions affect the measured delays compared to the gas phase. Finally, we present an outlook on our current measurements regarding e.g. Xenon and Neon.

MO 16.6 Wed 17:00 Philo 1. OG

Phase control in XUV-assisted high-order harmonic generation — •Zeinab Hardani and Manfred Lein — Leibniz University Hannover, Institute of Theoretical Physics,30167 Hannover, Germany

We investigate high-order harmonic generation (HHG) driven by a combined extreme-ultraviolet (XUV) pulse combined with a strong infrared (IR) laser field. Single-photon absorption of the XUV pulse releases the electron with well-defined initial conditions, while the IR field governs its motion in the continuum and its recombination with the parent ion. We evaluate the harmonic phase in XUV-assisted HHG and identify four main contributions: the strong-field phase, the Coulomb phase from the long-range potential, the recombination phase from the transition dipole, and an additional ionization phase associated with XUV-assisted emission. To quantify these contributions, we solve the one-dimensional time-dependent Schrödinger equation (TDSE) for an atomic model driven by combined IR+XUV fields and

compare the extracted phase with the theoretical methods: strong-field approximation, analytical R-matrix, and scattering-theory predictions. In addition, we employ a classical model including the Coulomb potential and the XUV-imposed initial velocity to obtain ionization and recollision times, these recollision times agree with those inferred from the TDSE. Overall, we show that the XUV field shifts ionization and recombination to later times, thereby delaying harmonic emission and reshaping the phase of attosecond electron trajectories in agreement with both quantum simulations and classical modeling, and offering a flexible route to control XUV-triggered HHG in time.

MO 16.7 Wed 17:00 Philo 1. OG

Building a high-resolution XUV attosecond transient absorption spectrometer to observe time-dependent effects in atoms and molecules — •Noah L. Wach[1], Gergana D. Borisova[1,2], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Department of Physics, Lund University, P.O. Box 118, 22100 Lund, Sweden

Attosecond transient absorption spectroscopy (ATAS) has been extensively used to observe ultrafast electronic as well as vibrational dynamics in atoms and molecules[1,2]. Here, a combination of intense NIR femtosecond pulses, together with a high-harmonic-generated XUV pulse derived from them, is used to probe and control the systems quantum dynamics. We develop a new experimental setup, SHARP-XUV, which combines a conventional ATAS setup with a high-resolution XUV spectrometer in a Rowland configuration featuring a 3-meter arm length. This design is aimed to obtain an energy resolution of more than 10 000. Together with a time resolution of about a hundred attoseconds, we will be able to observe the complex dynamics where electronic or vibrational resonances lie extremely close and are hard to resolve with conventional XUV spectrometers. This setup will enable us to study the laser control of the overlapping series of highly doubly excited helium states as well as the laser-driven dynamics of increasingly closely spaced transitions near an ionization threshold.

[1] C. Ott et al., Nature 516, 374-378 (2014)
[2] G. Borisova et al., Phys. Rev. Research 6, 033326 (2024)