A 41: Interaction with Strong or Short Laser Pulses II

Time: Friday 11:00–12:45 Location: N 2

Invited Talk A 41.1 Fri 11:00 N 2

State-resolved femtosecond phase control in dense-gas laser-atom interaction enabled by XUV interferometry — •Lina Hedewig[1,2], Carlo Kleine[1], Yu He[1], Felix Wieder[1,2], Christian Ott[1,2], and Thomas Pfeifer[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Ruprecht-Karls-Universität Heidelberg, Germany

We perform an interferometric measurement of an extreme ultraviolet (XUV) pulse passing through an optically dense gas-phase target. Utilizing the interaction with strong and narrow atomic resonances, we demonstrate the femtosecond phase control of the resonant XUV pulse propagation by means of a time-delayed intense near-infrared (NIR) laser pulse. To this end, the concept of spectral interferometry is transferred to the extreme ultraviolet in combination with a computational phase stabilization during post–processing [1]. By doing so, we obtain direct access to the amplitude and phase of the transmitted pulse and hence to the ultrafast dynamics in the target gas.

We benchmark our measurement approach with the singly excited 1s4p Rydberg state of helium to directly reconstruct the temporal structure of the transmitted XUV pulse beyond the single-atom response. An NIR-intensity-controlled variable phase step between 0 and 2 rad is measured on the XUV pulse after passage through the medium, originating from laser-induced transient Stark shifts. [2]

[1] L. Hedewig et al., Opt. Express 33, 48151-48159 (2025)
[2] L. Hedewig et al., Opt. Lett. 50, 3006-3009 (2025)

A 41.2 Fri 11:30 N 2

Phenomenological rate formulas for over-barrier ionization in strong constant electric fields — •Svea Remme[1], Alexander B. Voitkiv[1], Georg Pretzler[2], and Carsten Müller[1] — [1]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf — [2]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Over-barrier ionization (OBI) of atoms in strong constant electric fields is studied [1]. To develop an intuitive physical picture behind established empirical formulas in the near OBI regime, we extend corresponding tunneling rates by the combined action of the Stark effect and a widened electron emission angle. Furthermore, we present analytical rate formulas in a far OBI regime which closely agree with numerical data. In result, compact rate expressions describing OBI in a broad range of applied field strengths are obtained. They can be useful in numerical laser-plasma simulation codes to describe elementary ionization events.

[1] S. Remme, A. B. Voitkiv, G. Pretzler, and C. Müller, J. Phys. B: At. Mol. Opt. Phys. 58, 195602 (2025)

A 41.3 Fri 11:45 N 2

Deep learning for the retrieval of internuclear motion from photoelectron momentum distributions based on full quantum dynamics — •Nikolay Shvetsov-Shilovski and Manfred Lein — Leibniz Universität Hannover

We retrieve the time-dependent internuclear distance of a dissociating one-dimensional molecule using a neural network that takes photoelectron momentum distributions (PMDs) generated by strong-field ionization as input. The PMDs are calculated by solving the time-dependent Schrödinger equation, with nuclear motion treated fully quantum mechanically. We find that a neural network trained on distributions with fixed bond lengths can recover the time-varying internuclear distance with an absolute error of 0.3 a.u. This opens new perspectives for applying machine learning to real-time visualization of molecular dynamics.

A 41.4 Fri 12:00 N 2

Strong-field ionization and electron diffraction in standing waves — •Tobias Heldt, Jan-Hendrik Oelmann, Lennart Guth, Lukas Matt, Anant Agarwal, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Achieving the intensities required for strong-field effects, such as multiphoton ionization (MPI), usually relies on kilohertz-rate amplified laser systems. We employ a femtosecond enhancement cavity seeded by a near-infrared frequency comb to reach intensities exceeding $10^{13}\,\mathrm{W\,cm^{-2}}$ at a repetition rate of 100 MHz. The bow-tie cavity supports counter-propagating pulses that form a transient standing wave at the focus. Combined with a gas jet and velocity-map imaging (VMI) [1], this setup allows angle-resolved photoelectron spectroscopy to compare traveling- and standing-wave ionization.

The standing wave doubles the peak intensity and compresses the interaction volume from the Rayleigh length to the < 200 fs pulse-overlap region, enabling momentum imaging without electrostatic refocusing [2]. Furthermore, the spatially periodic ponderomotive potential of a standing wave diffracts electrons (Kapitza-Dirac effect), reshaping the momentum distribution. We aim to time-resolve the diffraction dynamics using an additional interferometer that generates two successive standing waves.

[1] J.-H. Oelmann et al., Rev. Sci. Instrum., 93(12), 123303 (2022).
[2] T. Heldt et al., Opt. Lett. 49, 6825-6828 (2024).

A 41.5 Fri 12:15 N 2

Optimizing the incident electron momentum for resonant three-photon Kapitza-Dirac scattering in bichromatic laser fields — •Ingo Elsner and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Spin dynamics in Kapitza-Dirac scattering of electrons from counter-propagating bichromatic X-ray laser waves is studied theoretically in the resonant Bragg regime [1]. We show that the intrinsic field-induced detuning, which arises in the Rabi oscillation dynamics between initial and scattering electron state, can be compensated by a suitable adjustment of its incident momentum. Analytical formulas of the optimized electron momentum for spin-dependent three-photon Kapitza-Dirac scattering are obtained from simplified model systems in reduced dimensionality.

[1] Ingo Elsner and Carsten Müller, Phys. Rev. A 112, 032215 (2025).

A 41.6 Fri 12:30 N 2

Can the Quantum Supeluminalilty of Tunnel-Ionization be experimentally confirmed? — •Ossama Kullie[1] and Igor Ivanov[2] — [1]Institute for Physics, Department of Mathematics and Natural Science, University of Kassel, Germany. — [2]Department of Fundamental and Theoretical Physics, Australian National University, Australia.

The quantum tunneling time remains the subject of heated debate, and one of its most curious features is the faster-than-light tunneling or quantum superluminality (QS). In our tunnel-ionization model presented in previous work [1,2,3], we showed that tunnel-ionization time-delay exhibits a universal behavior, which amounts to determine the barrier time-delay with good agreement with the experimental result and it corresponds to the interaction time. In the present work, we show that the the tunnel-ionization time-delay for H-like atoms with large nuclear charge can be superluminal, which could be validated experimentally using the attoclock scheme. We discuss the QS in detail for the two experimental calibrations of the field strength (adiabatic and nonadiabatic) of the attoclock and support our result with numerical integration of the time-dependent Schrödinger equation [2]. Our result shows that QS is indeed possible, albeit under somewhat extreme conditions [4]. This raises the question of experimental confirmation of QS. [1] O. Kullie, J. Phyis. Commun. 9, 015003, (2025). [2] O. Kullie and I. A. Ivanov, Annals of Physics 464, 169648 (2024). [3] O. Kullie, Phy. Rev. A **92**, 052118 (2015). [4] O. Kullie and I. A. Ivanov, the quantum suprluminlality of tunnel-ionization. In preparation.