A 15: Attosecond Physics I

Time: Wednesday 16:30–18:30 Location: F 107

A 15.1 We 16:30 F 107

Phasenanpassung Hoher Harmonischer Strahlung in einer Semi-infiniten Gaszelle — •Tobias Vockerodt[1,2], Daniel S. Steingrube[1,2], Emilia Schulz[1,2], Uwe Morgner[1,2,3] und Milutin Kovacev[1,2] — [1]QUEST Centre for Quantum Engineering and Space-Time Research, Hannover — [2]Institut für Quantenoptik, Leibniz Universität Hannover — [3]Laser Zentrum Hannover

Die systematische experimentelle Untersuchung von Phasenanpassungsbedingungen in einer Semi-Infiniten Gaszelle (SIGC) wird vorgestellt. Mit Hilfe zweier Edelgase (Helium und Xenon) werden verschiedene Parameter variiert und für die Harmonischenerzeugung optimiert. Die SIGC bietet neben einfacher Handhabung eine hoher Konversionseffizienz durch eine lange Wechselwirkungszone und die Möglichkeit zur Attosekunden-Pulserzeugung. Der konstante Druck ermöglicht, im Gegensatz zu gepulsten Gasdüsen, den Einsatz bei kHz-Repetitionsraten. Ferner ist die Teilchendichte in dieser Geometrie exakt bekannt, so dass ein direkter Vergleich mit Simulationsergebnissen möglich ist. In den Experimenten wird spektrale Aufspaltung und Blauverschiebung der Harmonischen Ordnungen in Abhängigkeit der Parameter beobachtet.

A 15.2 We 16:45 F 107

Emission times in high-order harmonic generation — Ciprian Constantin Chirila[1], Ingo Dreissigacker[1], •Elmar Vincent van der Zwan[1,2], and Manfred Lein[1] — [1]Centre for Quantum Engineering and Space-Time Research (QUEST) and Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 31432 Kassel, Germany

We calculate the emission times of the radiation in high-order harmonic generation using the Gabor transform of numerical data obtained from solving the time-dependent Schrödinger equation in one, two, and three dimensions. Both atomic and molecular systems, including nuclear motion, are investigated. Lewenstein model calculations are used to gauge the performance of the Gabor method. The resulting emission times are compared against the classical simple-man's model as well as against the more accurate quantum-orbit model based on complex trajectories. The influence of the range of the binding potential (long or short) on the level of agreement is assessed. Our analysis reveals that the short-trajectory harmonics are emitted slightly earlier than predicted by the quantum-orbit model. This explains partially recent experimental observations for atoms and molecules [1]. Furthermore, we observe a distinct signature of two-center interference in the emission times for H_2 and D_2. Model calculations show the effect of the laser-induced bound-state dynamics on this interference.

[1] S. Hässler *et al.*, J. Phys. B **42**, 134002 (2009)

A 15.3 We 17:00 F 107

High-Order Harmonic Generation at 100 kHz Repetition Rate for Time-Resolved Two-Photon Photoemission — •Christoph Heyl[1,2], Jens Güdde[1], Anne L'Huillier[2], and Ulrich Höfer[1] — [1]Fachbereich Physik und Zentrum für Materialwissenschaften, Philipps-Universität, Marburg, Germany — [2]Department of Physics, Lund University, Lund, Sweden

Two-photon photoemission (2PPE) has been successfully used to study the electron dynamics of surfaces and interfaces with femtosecond time resolution. With most of the current experimental setups the detectable energies and parallel momenta of electrons are limited by the availability of ultra-short pulsed UV laser systems. Recent progress in generating femtosecond and attosecond VUV pulses by means of high-order harmonic generation (HHG) opens the potential to access the whole Brillouin zone with high time resolution. Time-resolved 2PPE, however, benefits greatly from high repetition rates, whereas harmonics are usually generated at low repetition rates and high intensities.

We present a high-order harmonic source operating with remarkable stability at 100 kHz using a fundamental pulse energy of only 7 μJ. In contrast to earlier perceptions it turns out that high-order harmonics can be efficiently generated even at low pulse energies and thus at high repetition rates [1]. We compare the experimental onditions with theoretical simulations focusing on the characteristics of a tight focus geometry and its consequences for the process of HHG in gases.

[1] F. Lindner *et al.*, Phys. Rev. A. **68**, 013814 (2003)

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Control of attosecond pulse generation using kinetic heterodyne mixing — •Philipp Raith, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Tailored attosecond pulses generated by high-order harmonic generation provide coherent access to large-bandwidth electronic spectra and hence the possibility to directly control attosecond quantum dynamics in atoms, molecules and solids. Kinetic heterodyne mixing of a strong laser field with a weak field at a different frequency is an easily realizable method to shape the laser field of the driving femtosecond pulse on a subcycle basis and thus control the generation of attosecond pulses. An experimental design of such a pulse shaper is presented. Performing simulations of the shaped driver pulses and the resulting high-harmonic spectra it is shown how kinetic-heterodyne mixing can be used to generate isolated attosecond pulses. Furthermore, it is analyzed to which extent the spectrum and shape of attosecond pulses can be controlled e.g. to yield higher cutoff photon energies, to control attosecond pulse trains, or to generate very short isolated or double pulses for interferometry applications.

A 15.5 We 17:30 F 107

Towards pump-probe spectroscopy at the yoctosecond time scale — •Jörg Evers[1], Andreas Ipp[1,2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institut für Theoretische Physik, Technische Universität Wien, Österreich

For high-precision spectroscopy and structural studies, short light flashes with high photon energy are required. Shorter pulses with higher photon energy would improve the temporal and spatial resolution, or would allow for the investigation of smaller structures, such as for example atomic nuclei. This motivates the search for alternative light sources.

Here, we show that high-energetic photon pulses down to the yoctosecond timescale can be produced in heavy ion collisions [1]. In particular, we focus on light emission from the initial phase of an expanding quark-gluon plasma (QGP). Based on a recent model for the expansion dynamics of the QGP [2], we find that under certain conditions, a double peak structure in the emission envelope can be observed, which could be the first source for pump-probe experiments at the yoctosecond timescale. Finally, we discuss possible detection schemes for short pulses with high photon energy.

[1] A. Ipp, C. H. Keitel, and J. Evers, Phys. Rev. Lett. **103**, 152301 (2009)
[2] M. Martinez and M. Strickland, Phys. Rev. Lett. **100**, 102301 (2008).

A 15.6 We 17:45 F 107

High-order harmonic generation by ultra-short pulses from filamentation — •Daniel S. Steingrube[1,2], Emilia Schulz[1,2], Thomas Binhammer[3], Tobias Vockerodt[1,2], Uwe Morgner[1,2], and Milutin Kovacev[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]QUEST, Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, Hannover, Germany — [3]VENTEON Laser Technologies GmbH, 30167 Hannover, Germany

High-order harmonics with application to attosecond pulse generation are commonly generated by pulses which are previously compressed in hollow core fibers. An alternative promising scheme for pulse compression is based on filamentation. Therefore, 30-fs-pulses from a commercial amplifier system are focused into a filamentation cell filled with argon. An octave spanning spectrum from 400 to 900 nm is obtained which yields pulses with duration below 7 fs measured with SPIDER. The white light core of the filamented output beam contains an energy of 0.3 mJ.

The compressed pulse is applied for high-order harmonic generation (HHG) which is performed in a semi-infinite gas cell setup after dispersion compensation using double chirped mirrors (DCM). The resulting spectra are presented for different generating gas media as xenon, argon, and neon. The spectra are spectrally broadened compared to those generated by the 30-fs-pulse. Moreover, the cut-off energy of the generated spectra is investigated for different pulse durations which

are applied by varying the number of bounces on the DCMs.

A 15.7 We 18:00 F 107

Inducing and Probing Attosecond-Time-Scale Electronic Wavefunction Beating — •Christian Ott, Philipp Raith, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Much of the current interest in the field of ultrafast science focuses on the observation of attosecond dynamics of electronic wavepackets. These experiments typically require attosecond pulses either for pumping or probing such dynamics and/or are limited to observing electronic states embedded in the ionization continuum of atoms. Here, we present numerical evidence – based on solutions of the time-dependent Schrödinger equation for a 1-dimensional model atom – that a pump-probe scheme with two few-cycle femtosecond laser pulses provides interferometric access to sub-femtosecond electron wavepacket dynamics. Both continuum- and bound-state electronic wavepacket interference can be simultaneously observed by recording and analyzing time-delay dependent interferences in the ATI spectrum of an atom. Both dipole-allowed and forbidden electronic transition information can be extracted from the data, making this approach a versatile and comprehensive spectroscopic method for probing the bound electronic level structure of an atom.

A 15.8 We 18:15 F 107

High Harmonic Transient Grating Spectroscopy — •Markus Gühr[1,2], Joseph P. Farrell[1,2], Limor S. Spector[1,2], Brian K. McFarland[1,2], Mette Gaarde[1,3], Kenneth Schafer[1,3], and Philip H. Bucksbaum[1,2] — [1]Stanford PULSE Institute, SLAC National Accelerator Laboratory, Menlo Park, USA — [2]Physics and Applied Physics, Stanford University, USA — [3]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803, USA

High harmonic generation (HHG) spectra contain valuable information about the electronic structure of the generation medium, information that has proven to be powerful for monitoring molecular and atomic ground states. All HHG experiments on excited atomic or molecular states suffer from a ground state harmonic background, thereby reducing excited state sensitivity. We use a transient grating (TG) scheme to overcome this problem and also obtain spectrally resolved high harmonics without the need for a spectrometer. We imprint a 400 nm excited state grating structure on the HHG medium by two counter-propagating 800 nm pulses. A strongly focused 800 nm probe pulse hits the grating under a shallow angle. The harmonics of order n are scattered into the Bragg angle $\theta_{Bragg} = asin(1/n)$. We test the scheme with plasma gratings in argon gas and molecular alignment gratings in N_2. The generated harmonics are scattered into their respective Bragg angle and we observe up to 6 spectrally resolved harmonics that show enhanced sensitivity to the atomic or molecular excitation.