SYCP 1: Charged particles in ultra-fast fields

Zeit: Donnerstag 14:00–18:00 Raum: HS D

Hauptvortrag SYCP 1.1 Do 14:00 HS D

Relativistic plasma mirrors: from attoseconds to zeptoseconds — •Alexander Pukhov — University of Duesseldorf, Germany

Generation of high harmonics from overdense plasmas is considered in relativistic regime. It is shown that the plasma surface oscillates as a relativistic mirror and leads to quasiperiodic ultrashort flashes of xuv radiation. Already at the presently available laser intensity levels the generated xuv pulses may be of sub-attosecond duration. The frequency spectrum of the high harmonics can be described as a power law. The most common exponent of the power law is -8/3. However, there are important exceptions leading to much flatter spectra. These spectra are produced due to the electron nanobunching phenomenon. In this case, the generated attosecond pulses may have significantly higher intensity than the incident laser pulse. Due to the temporal laser pulse profile, the high harmonics are chirped. This chirp is observed in experiments as spectral modulations and displacement of the individual harmonic lines.

Hauptvortrag SYCP 1.2 Do 14:30 HS D

High Energy Density Experiments at the Free-Electron Laser Facility FLASH at DESY — •Sven Toleikis — Deutsches Elektronen-Synchrotron DESY, Hamburg

FLASH is a unique source of extremely bright, coherent, and ultrashort pulses of extreme-ultraviolet radiation and soft X-rays enabling researchers to explore the temporal evolution of physical, chemical, and biochemical processes happening in femtoseconds or picoseconds. FLASH produces laser light of short wavelengths from the extreme ultraviolet down to soft X-rays (wavelength range of the fundamental: 4.5 - 60 nm). The light comes in pulses, as in an electronic flashlight, but the pulses are a 100 billion times shorter (pulse duration 20-200 fs) [1]. Since 2005 FLASH operates as a user facility. Since then, the unprecedented shortness and intensity of the soft X-ray pulses as well as their coherence has opened entirely new fields of research and led to new discoveries. The unique radiation properties of FLASH allows when focussed to *1 *m sizes to reach record intensities over 1016 W/cm* in the soft X-ray wavelength regime. Employing these intensities in an experiment, it became possible to saturate the absorption of an L-shell transition in aluminium, hereby the Al sample becomes transparent for soft X-rays (at 92 eV photon energy) [2]. This has never been observed in core-electron transitions owing to the short lifetime of the exited states involved and the high intensities of soft X-rays needed. Considering the relevant lifetimes, one can infer that after the soft X-rays have passed, the sample is an exotic state, where all irradiated aluminium atoms have an L-shell hole, and the valence band has been heated to ~9 eV temperature, whereas the atoms are still on their crystallographic positions. Subsequently, Auger decay heats the material to the warm dense matter regime, at ~25 eV temperatures. This method is ideal to create homogenous warm dense matter (WDM), which is highly relevant to planetary science, astrophysics and inertial confinement fusion. The short pulse duration and high intensity of FLASH soft x-ray radiation also allows to heat and probe highly homogeneous warm dense non-equilibrium hydrogen within a single light pulse. By analyzing the spectrum of the Thomson scattered photons around 13.5 nm (92 eV photon energy), one can determine the plasma temperature and electron density. These results have been compared via simulations with different models for impact ionization, which is the main interaction on this early femtosecond time scale. From the comparison one finds that classical models of this interaction describe our dense plasma conditions better than state of the art theories [3].

References [1] W. Ackermann et al., "Operation of a free-electron laser from the extreme ultraviolet to the water window", Nature Photon. 1, 336 (2007). [2] B. Nagler et al., "Turning solid aluminium transparent by intense soft X-ray photoionization", Nature Phys. 5, 693 (2009). [3] R.R. Fäustlin et al., "Observation of Ultrafast Nonequilibrium Collective Dynamics in Warm Dense Hydrogen", Phys. Rev. Lett. 104, 125002 (2010).

Hauptvortrag SYCP 1.3 Do 15:00 HS D

How to probe Warm Dense Matter — •Jan Vorberger — The University of Warwick, Centre for Fusion, Space and Astrophysics Department of Physics, Coventry, UK

Warme dichte Materie existiert im Labor nur auf extrem kurzen Zeitskalen. Der Energieinhalt solcher Materie mit Dichten vergleichbar mit Festkoerpern und Temperaturen von einigen bis einigen zehn Elektronenvolt ist so hoch, dass im Nano- bis Mikrosekundenbereich hydrodynamische Expansion diesen Materiezustand zerstoert. Aufgrund der hohen Dichten sind Nichtgleichgewichtsvorgaenge wie Ionisation, Rekombination und Temperaturrelaxation allerdings im Pikosekundenbereich abgeschlossen, so dass fuer kurze Zeit trotzdem ein Gleichgewichtszustand warmer dichter Materie im Labor vorliegt. Neuere Entwicklungen in der Laser- und Beschleunigerphysik sowie in der Diagnostik erlauben es seit einigen Jahren, im Nanosekundenbereich Messungen an warmer dichter Materie durchzufuehren. In Kombination mit numerischen Simulationen und anderen theoretischen Methoden hat dies zu unzaehligen neuen Einsichten in die Physik der warmen dichten Materie gefuehrt. Es werden Experimente zu statischer und dynamischer Struktur und zu kollektiven Eigenschaften warmer dichter Materie vorgestellt und in Relation zu theoretischen Beschreibungen derselben Systeme gestellt. Ebenso werden neuere Experimente und Rechnungen zur Zustandsgleichung von z.B. Wasserstoff vorgestellt. Desweiteren sollen die Moeglichkeiten diskutiert werden, die sich mit den neuen Freie-Elektron-Lasern FLASH (Desy) und LCLS (SLAC) bieten, Vorgaenge im Pikosekundenbereich aufzuloesen. Das schliesst Ionisationskinetik, Temperaturrelaxation, Dynamik der Festkoerperstrukur (Schmelzen) sowie die Aufloesung des Ionenpeaks des dynamischen Strukturfaktors ein.

30 Min. Pause

Hauptvortrag SYCP 1.4 Do 16:00 HS D

Correlated and ultrafast electron dynamics (in atoms and molecules) excited by UV radiation — •Karsten Balzer, Sebastian Bauch, David Hochstuhl, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität Kiel, 24098 Kiel, Germany

New sub-femtosecond light sources such as free electron lasers (FELs) and elaborate table-top setups based on higher harmonic generation give access to the interesting wavelength regime from ultraviolet (UV) light towards x-rays at high coherence. This radiation can trigger intra-atomic transitions and processes on attosecond time-scales [1], and, hence, provides a tool to observe, explore and control electron dynamics in atoms, molecules or surfaces in real-time with increasing precision [2]. Moreover, even intra-atomic electron collisions are expected to be resolvable [3].

As the system's response to such fields is ultrafast and involves electron-electron correlation effects, highly accurate modeling is required from the theoretical perspective, and, to understand current and future experiments, the multi-electron dynamics need to be simulated at attosecond time-resolution.

In this talk, we discuss complementary methods and their limitations for describing ultrafast atomic-scale motion of electrons: The direct solution of the time-dependent Schrödinger equation (TDSE), the multiconfguration time-dependent Hartree-Fock (MCTDHF) method and the application of nonequilibrium Green function (NEGF) techniques. Thereby, we focus on the governing role of correlations in systems ranging from correlated model atoms and molecules to realistic atomic systems. In particular, we report on the ionization dynamics in attosecond XUV-infrared pump-probe experiments [4], on the two-photon ionization of Helium in the direct regime [5] and the correlated UV excitation dynamics in models for Helium, Hydrogen and Lithiumhydride [6].

[1] F. Krausz and M. Ivanov, Rev. Mod. Phys. 81, 163 (2009). [2] M. Drescher, M. Hentschel, R. Kienberger, M. Uiberacker, V. Yakovlev, A. Scrinzi, Th. Westerwalbesloh, U. Kleineberg, U. Heinzmann, and F. Krausz, Nature 419, 803 (2002). [3] A. Emmanouilidou, A. Staudte, P. B. Corkum, New J. Phys. 12, 103024 (2010). [4] S. Bauch, K. Balzer and M. Bonitz, Europhys. Lett. 91, 53001 (2010). [5] D. Hochstuhl and M. Bonitz, submitted to J. Chem. Phys. (2010), [arXiv:1010.5422] [6] K. Balzer, S. Bauch and M. Bonitz, Phys. Rev. A 81, 022510 (2010); ibid. 82, 033427 (2010).

Hauptvortrag SYCP 1.5 Do 16:30 HS D

Multiple ionization of atoms by FEL radiation: a time-dependent density functional perspective — •Dieter Bauer — Universität Rostock, Institut für Physik, 18051 Rostock, Germany

One of the most fundamental quantum processes in intense laser-matter interaction is the nonlinear photoeffect where several photons are absorbed by the emitted electron. Multiphoton and tunneling ionization for laser wavelengths around 800nm have been studied since many years. Now, with more and more short-wavelengths free electron lasers (FEL) coming into operation a new parameter regime is increasingly accessible. On one hand the situation at short wavelengths seems to simplify because the ponderomotive energy (typically considered to be a measure for "nonperturbativeness") is negligible. On the other hand FEL experiments showed [1,2] that surprisingly high charge states are also generated in this regime. A purely sequential ionization scenario was shown to underestimate the maximum charge state [3]. Hence, electron correlation or even collective effects must play a role. Moreover, while at long wavelengths the outcome of ionization experiments is largely species-independent and rather scales with the laser parameters only, at short wavelengths the electronic structure of the target system is important [2].

Because the time-dependent Schrödinger equation for atoms in intense laser fields can be solved only for at most two active electrons in full dimensionality alternative methods for strongly-driven many-electron systems are needed. One of the most successful may-particle method in electronic structure theory is density functional theory (DFT). It has been extended for the treatment of time-dependent problems (TDDFT) but is mostly applied in the linear-response regime there [4]. In principle, TDDFT is also applicable to matter in strong fields (nonlinear TDDFT) but benchmark calculations showed that for strongly correlated processes standard exchange correlation potentials are insufficiently accurate and often the density functionals for the observables are unknown in terms of the density or the Kohn-Sham orbitals alone [5-7]. In the talk I will discuss recent progress in the understanding of TDDFT, show comparisons of TDDFT predictions with exact results for highly correlated model systems, and present the outcome of TDDFT simulations of rare gas atoms in strong EUV pulses.

[1] A.A. Sorokin et al., Phys. Rev. Lett. 99, 213002 (2007). [2] M. Richter et al., Phys. Rev. Lett. 102, 163002 (2009). [3] S.V. Popruzhenko, V.D. Mur, V.S. Popov, and D. Bauer, Phys. Rev. Lett. 101, 193003 (2008). [4] M.A.L. Marques et al., Time-Dependent Density Functional Theory (Springer, Heidelberg, 2006). [5] M. Lein and S. Kümmel, Phys. Rev. Lett. 94, 143003 (2005). [6] F. Wilken and D. Bauer, Phys. Rev. Lett. 97, 203001 (2006). [7] M. Ruggenthaler and D. Bauer, Phys. Rev. Lett. 102, 233001 (2009).

Hauptvortrag SYCP 1.6 Do 17:00 HS D

QED, radiative reaction and particle physics with strong laser-charged particle interaction — •Christoph Keitel, Antonino Di Piazza, Karen Z. Hatsagortsyan, and Carsten Müller — Max Planck Institute for Nuclear Physics, Theory Division, Heidelberg, Germany

Laser-driven relativistic quantum dynamics is discussed for bound and free electrons [1,2]. Applications such as the generation of harmonics and short pulses is discussed and compared to other means [3]. Then emphasis is placed on situations where the influence of vacuum fluctuations is shown to become observable with present facilities or those under construction, especially on the concept of a matterless double slit [4]. In the following, pair production is investigated in strong laser fields, especially with the aid of other injected particles [5]. Finally, the role of radiative reaction is presented for realistic situations, both in the classical and quantum regime [6].

References

[1] H. G. Hetzheim, C. H. Keitel, Phys. Rev. Lett. 102, 083003 (2009). [2] F. Mackenrodt, A. Di Piazza, C. H. Keitel, Phys. Rev. Lett. 105, 063903 (2010). [3] A. Ipp, C. H. Keitel, J. Evers, Phys. Rev. Lett. 103, 152301 (2009). [4] B. King, A. Di Piazza, C. H. Keitel, Nature Photonics 4, 92 (2010). [5] H. Hu, C. Müller, C. H. Keitel, Phys. Rev. Lett. 105, 080401 (2010). [6] A. Di Piazza, K. Z. Hatsagortsyan, C. H. Keitel, Phys. Rev. Lett. 102, 254802 (2009) and Phys. Rev. Lett. 105, 220403 (2010).

Hauptvortrag SYCP 1.7 Do 17:30 HS D

Experiments on ultrafast electron dynamics in solids at FLASH — •Wilfried Wurth — Physics Department and Center for Free Electron Laser Science, University of Hamburg, Germany

FLASH, the Free-Electron Laser at DESY in Hamburg is a worldwide unique facility delivering intense ultra-short coherent radiation pulses in the wavelength range between 47 and 4.5 nm. Since 2005 FLASH has been operating as a user facility serving a large variety of experiments. The unprecedented brilliance of the femtosecond coherent pulses in the extreme ultraviolet (XUV) and soft x-ray regime has been used to study nonlinear process in laser-matter interaction for atoms and molecules, to gain new insights in the properties of matter under extreme conditions and to perform single shot lens-less imaging of nano-sized objects. Furthermore, the pulse duration of less than 30 femtoseconds has allowed to gain new insights in ultrafast dynamics of matter. In the talk I will review opportunities to study ultrafast electron dynamics in solids using time-resolved x-ray spectroscopy and give examples of highlight experiments.

This work is supported by BMBF through the priority program FSP-301 "FLASH: Matter in the Light of Ultrashort and Extremely Intense X-ray Pulses"