# A 40: Interaction with strong or short laser pulses III

Time: Thursday 14:00–16:00 Location: BEBEL E34

A 40.1 Thu 14:00 BEBEL E34

**Time-dependent renormalized natural orbital theory applied to correlated two-electron dynamics** — •Martins Brics, Julius Rapp, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

Time-dependent density functional theory (TDDFT) with practicable exchange-correlation functionals fails in capturing highly correlated electron dynamics. In particular, the description of doubly-excited states requires exchange-correlation functionals with memory, which are both unknown and numerically unfavorable. Time-dependent renormalized natural orbital theory (TDRNOT) [1] is a promising approach to circumvent this problem while still overcoming the so-called "exponential wall". In TDRNOT, the renormalized eigenfunctions of the one-body reduced density matrix, natural orbitals, are the basic variables (instead of the single-particle density, as in TDDFT).

The laser-driven two-electron spin-singlet system is known to be the "worst case" testing ground for TDDFT. Therefore we employ the widely used, numerically exactly solvable, one-dimensional helium model atom (in a laser field) to benchmark the TDRNOT approach. The method is almost as inexpensive numerically as adiabatic TDDFT, but is capable of describing correlated phenomena such as doubly excited states, autoionization, Fano profiles in the photoelectron spectra, and resonant processes such as Rabi oscillations.

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

A 40.2 Thu 14:15 BEBEL E34

**Challenges in the application of time-dependent renormalized natural orbital theory (TDRNOT)** — •Julius Rapp, Martins Brics, and Dieter Bauer — Institut für Physik, Universität Rostock

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 that it captures phenomena [1] utterly unaccessible by time-dependent density functional theory (TDDFT) using practicable and known exchange-correlation functionals.

After an introduction to TDRNOT, we address current challenges in the numerical solution of the TDRNOT equations of motion for the renormalized natural orbitals. In particular, we investigate the effect of (1) the truncation to a finite number of orbitals and (2) the splitting of the time propagator. Despite these two major issues, TDRNOT results for the widely-used one-dimensional helium model (in both singlet and triplet configuration) are clearly superior to those obtained by any practicable TDDFT approach [2].

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

A 40.3 Thu 14:30 BEBEL E34

**Strong-field Kapitza-Dirac Scattering of Neutral Atoms** — •Sebastian Eilzer, Henri Zimmermann, and Ulli Eichmann — Max-Born-Institut for Nonlinear Optics und Short Pulse Spectroscopy, Berlin, Germany

Laser induced strong-field phenomena in atoms and molecules on the femtosecond time scale have been almost exclusively investigated with traveling wave fields. Most observed phenomena are well explained in the dipole approximation which, however, reduces the field to a purely electric field oscillating in time. Spatially dependent electromagnetic fields, e.g., in a standing light wave, allow for strong energy and momentum transfer. We report a strong-field version of the Kapitza-Dirac effect for neutral atoms where we scatter neutral He atoms in an intense short pulse standing light wave with femtosecond duration and intensities well in the strong-field tunneling regime. We observe substantial longitudinal momentum transfer concomitant with an unprecedented atomic photon scattering rate greater than $10^{16} s^{-1}$.

A 40.4 Thu 14:45 BEBEL E34

**On the transient optical response of atomic gases** — •Michael Hofmann and Carsten Bree — Weierstrass Institute, Berlin, Germany

Femtosecond filaments are strings of intense laser light and dilute plasma in transparent dielectrics. They maintain high intensities and small beamwaists along several times the Rayleigh length, making them powerful tools for remote spectroscopy, supercontinuum generation, or femtosecond LIDAR. In 2009, an experiment [1] challenged our understanding of the physics underlying filamentation, leading to a still unresolved debate about the very nature of the optical nonlinearities that maintain filamentation.

It has recently been indicated that the main shortcomings of the standard model of filamentation are related to the perturbative, purely phenomenological treatment of the optical nonlinearities. Therefore, the controversy can only be settled by a fully quantum mechanical treatment of the atomic optical response. Here, we present a numerical method enabling us to compute the transient optical response of hydrogen-like atoms subject to strong laser fields, based on numerically solving the time dependent Schrödinger equation. This method allows us to calculate transient absorption spectra, and the impact of Autler-Townes and dynamical AC-Stark atomic level splitting therein. In particular, we discuss the contribution of laser-dressed atomic states [2] to the optical response.

[1] Loriot et al. 2009 Optics Express 17, pp. 13429-13434
[2] Richter et al. 2013 New J. Phys. 15 083012

A 40.5 Thu 15:00 BEBEL E34

**Compton scattering of X-ray photons assisted by a strong laser pulse** — •Daniel Seipt[1,2] and Burkhard Kämpfer[2,3] — [1]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden — [3]TU Dresden, Institut für Theoretische Physik, 01062 Dresden

The presence of a strong optical laser pulse modifies the spectral distribution and polarization properties of hard X-ray photons scattered off free electrons. We discuss this process of laser assisted Compton scattering, taking into account the finite pulse length of both the high-intensity laser and the X-rays. Side-bands emerge in the energy spectrum via non-linear frequency mixing and multi-photon effects are amplified by the large frequency ratio. Up to 1000 laser photons can be scattered together with an X-ray photon—the side-bands form a broad plateau of several keV width—for laser intensities of $10^{18}$ W/cm$^2$. The photons in the side-bands experience a polarization rotation due to the non-linear mixing of X-ray and laser photons.

A 40.6 Thu 15:15 BEBEL E34

**Strong-field gas excitation and EUV light generation in plasmonic nanostructures** — •Murat Sivis, Frederik Busse, and Claus Ropers — IV. Physical Institute, University of Göttingen, Göttingen, Germany

Spatial confinement of electromagnetic fields in tailored plasmonic nanostructures allows for the enhancement of a variety of high-order nonlinear optical phenomena using low-energy laser pulses at MHz repetition rates. Here, we present a detailed study of extreme-ultraviolet (EUV) light generation in noble gases employing bowtie-antennas and tapered hollow waveguides for field-enhancement. In contrast to former expectations [1], we do not observe any signature of coherent high harmonic generation. Instead, we identify atomic and ionic fluorescence induced by multiphoton or strong-fieldgas excitation and ionization as the predominant mechanisms of EUV light generation in such plasmon-assisted scenarios [2,3]. Furthermore, we discuss novel nonlinear effects such as the formation of a waveguide nanoplasma exhibiting a strong bistability, manifest as a pronounced intensity- and pressure-dependent hysteresis in the fluorescence signal. These observations lead to a deeper understanding of nanostructure-enhanced gas excitations and EUV light generation, representing an intriguing link between strong-field physics, plasma dynamics and ultrafast nanooptics.

[1] S. Kim *et al.*, Nature **453**, 757 (2008).
[2] M. Sivis *et al.*, Nature **485**, E1 (2012).
[3] M. Sivis and C. Ropers, Phys. Rev. Lett. **111**, 085001 (2013).

A 40.7 Thu 15:30 BEBEL E34

**Signatures of minicharged particles and paraphotons in a high-intensity laser field** — •Selym Villalba Chavez and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

Polarimetric experiments in the field of a high-intensity laser wave are illuminating scenarios from which the low energy frontiers of the standard model can be investigated. Particularly, the occurrence of extra

$U(1)$ symmetries implies the existence of both hidden-photons called paraphotons and light minicharged particles. We show how the absorption and dispersion of probe photons in the vacuum polarized by a high-intensity circularly polarized laser field are modified due to the coupling between the visible electromagnetic sector and these hypothetical degrees of freedom. The result of this analysis reveals that – in such a background – only the regime close to the two-photon reaction can be a sensitive probe of these hidden particles. Parameters of modern laser systems are used to impose stringent constraints on the respective coupling constants in regions where experiments driven by dipole magnets are less constricted.

[1] S. Villalba-Chavez and C. Müller, Ann. Phys. **339**, 460 (2013).

A 40.8 Thu 15:45 BEBEL E34

**Strongly enhanced pair production in combined high- and low-frequency laser fields** — •Martin J.A. Jansen and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Creation of electron-positron pairs resulting from the decay of high-energy probe photons traveling in high-intensity laser fields is investigated [1]. The rate of the strong-field Breit-Wheeler process is shown to be strongly enhanced by the application of an additional laser mode with high-frequency but low amplitude, which effectively lowers the energetic barrier of the process. Our calculations are carried out non-perturbatively in an experimentally accessible regime.

[1] M.J.A. Jansen and C. Müller, Phys. Rev. A 88, 052125 (2013)