A 39: Poster: Atomic systems in external fields

Time: Thursday 16:00–18:30 Location: Empore Lichthof

A 39.1 Thu 16:00 Empore Lichthof

Energy levels, oscillator strengths and transition probabilities for Si-like Zn XVII, Ga XVIII, Ge XIX and As XX — •Ahmed Abou El-Maaref[1], Mohamed A Uosif[1], Sami H Allam[2], and Tharwat M El-Sherbini[2] — [1]Physics Department, Al-Azhar University, Assuit, Egypt — [2]Laboratory of Lasers and New Materials, Physics Department, Faculty of Science, Cairo University, Giza, Egypt

Fine-structure calculations of energy levels, oscillator strengths, and transition probabilities for transitions among the terms belonging to 3s23p2, 3s3p3, 3s23p3d, 3s23p4s, 3s23p4p, 3s23p4d, 3s23p5s and 3s23p5p configurations of silicon-like ions Zn XVII, Ga XVIII, Ge XIX and As XX have been calculated using configuration-interaction version 3 (CIV3). We have also carried out calculations in the intermediate coupling scheme using the Breit-Pauli Hamiltonian. We compared our data with the available experimental data and other theoretical calculations. Most of our calculations of energy levels and oscillator strengths (in length form) show good agreement with both experimental and theoretical data. Lifetimes of the excited levels are also given

A 39.2 Thu 16:00 Empore Lichthof

Laser-induced tunneling in the relativistic regime — •Enderalp Yakaboylu, Michael Klaiber, Heiko Bauke, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

A novel physical picture of laser driven tunneling at ions in the relativistic regime is presented. In the quasi-static approximation of the process, it can be shown that the tunneling barrier is identical to the one in the non-relativistic case via the dipole-approximation and that only the energy level on which the electron tunnels through the barrier is altered by the magnetic field component. This leads to a shift of the momentum distribution of the ionized electron with a maximum at a value that compensates the action of the laser magnetic field during tunneling. Further, the total tunneling rate is increased compared to the non-relativistic case by the relativistic mass correction, that changes the energy-momentum dispersion relation. Other relativistic correction terms are playing no role. Finally, it is shown that the electron experiences no drift in laser propagation direction under the barrier in the quasi-classical approximation, i.e., solely moves along the laser polarization direction [1].

[1] Michael Klaiber, Enderalp Yakaboylu, Heiko Bauke, Karen Z. Hatsagortsyan, and Christoph H. Keitel, preprint arXiv:1205.2004

A 39.3 Thu 16:00 Empore Lichthof

Testing the Jarzynski equality with single trapped neutral atoms — •Noomen Belmechri[1], Andrea Alberti[1], Andreas Steffen[1], Wolfgang Alt[1], Artur Widera[2], and Dieter Meschede[1] — [1]Institut für Angewandte Physik, Universität Bonn, Germany — [2]Fachbereich Physik und Forschungszentrum OPTIMAS, Universität Kaiserslautern, Germany

The Jarzynski equation complements the thermodynamics inequality $\Delta F \leqslant \overline{W}$ by the more general equality $\Delta F = -\beta^{-1} \ln \overline{\exp(-\beta W)}$. Both equations relate the free energy difference between two equilibrium states of a system to the average work performed when switching it from one state to another. The Jarzynski equality is valid regardless of the way the switching process is performed. This allows one to infer exact equilibrium state information from measurements where the system may be driven far away from equilibrium. This surprising result has already been verified with mesoscopic systems, i.e. large molecules or colloidal particles in optical tweezers, as well as with microscopic systems such as effective two-level systems formed by defect centres in diamond. Here, we present recent results in which we use a spin-dependent optical lattice to perform and measure work exerted on individual trapped atoms which promises a direct verification of the Jarzynski equality with a multi-level quantum system consisting of single neutral atoms.

A 39.4 Thu 16:00 Empore Lichthof

Quantum breathing mode of trapped dipolar bosons — •Jan Willem Abraham, Alexei Filinov, Tim Schoof, David Hochstuhl, and Michael Bonitz — Christian-Albrechts-Universität zu Kiel, ITAP

We study the quantum breathing mode (monopole mode) of finite systems at low temperature from weak to strong coupling. Using an improved version of the quantum mechanical sum rule formula of Stringari et al. [1], we perform ab-initio Quantum Monte Carlo simulations to obtain the mode frequencies for dipole-interacting bosons in a harmonic trap. [1] We compare our results to those from other methods and present additional results for fermions. [3]

[1] C. Menotti, and S. Stringari, Phys. Rev. A **66**, 043610 (2002)
[2] A. Filinov et al., Phys. Rev. Lett. **105**, 070401 (2010)
[3] T. Schoof et al., Contrib. Plasma Phys. **51**, No. 8, 687-697 (2011)

A 39.5 Thu 16:00 Empore Lichthof

Quantum breathing mode of charged fermions in a 2D harmonic trap — Chris McDonald[2], G. Orlando[2], •Jan Willem Abraham[1], David Hochstuhl[1], Michael Bonitz[1], and Thomas Brabec[2] — [1]Christian-Albrechts-Universität zu Kiel, ITAP — [2]Department of Physics, University of Ottawa, Ottawa, Canada

The N-particle time-dependent Schrödinger equation is solved to investigate the quantum breathing mode of Coulomb-interacting fermions confined in two-dimensional quantum dots. [1] The Multi-Configurational Time-Dependent Hartree-Fock method allows us to obtain the mode frequencies for up to 6 particles in the whole range of coupling parameters, from the ideal quantum gas to Wigner crystallization. Furthermore, a new approximate analytical approach to the quantum breathing mode is presented.

[1] C. McDonald et al., submitted to Phys. Rev. Lett. (2012)

A 39.6 Thu 16:00 Empore Lichthof

Radiation-assisted relativistic electron vortex beams — •Armen Hayrapetyan[1], Oliver Matula[1,2], Andrey Surzhykov[1,2], and Stephan Fritzsche[2,3] — [1]Physikalisches Institut, Universität Heidelberg, D-69120 Heidelberg, Germany — [2]Gesellschaft für Schwerionenforschung (GSI), D-64291, Darmstadt, Germany — [3]Department of Physics, P.O., Box 3000, Fin-90014 University of Oulu, Finland

We study relativistic electron vortex beams under the impact of the field of a plane electromagnetic wave. We construct exact Bessel-beam solutions by making use of Volkov solutions for the Dirac equation. When switching off the field we show that these solutions contain the new type of free electron-Bessel beams, reported by Bliokh et al. [Phys. Rev. Lett. 107, 174802 (2011)]. We study total-angular-momentum-dependent distribution of probability density and current for nonparaxial Bessel beams as a dependence on electromagnetic field parameters, such as frequency and amplitude of vector potential. Moreover, we show that the kinetic momentum density in the Bessel-state implies that the effective mass of the twisted electron coupled to the field acquires a shift. Such beams may be of interest for experiments relating to the Compton and electron-electron scattering under impact of external fields, as well as radiative electron capture in relativistic ion-atom collisions and photoelectric effects in atomic systems.

A 39.7 Thu 16:00 Empore Lichthof

On the response of electromagnetically-induced transparency to laser phase changes — Carl Basler, •Katrin Reininger, Stephan Welte, and Jannis Seyfried — Universität Freiburg

We study the transient response of the refractive index to changes of the phase of the laser field under conditions of electromagnetically induced transparency. This is an extension of recent work in our group, FM et al. PR A 85, 013820 (2012) where the dynamic response to frequency changes was explored. Under EIT conditions the quantum superposition state $\Psi = |1\rangle - e^{i\eta}|2\rangle$, called dark state, develops by spontaneous emission in the presence of two phase-stable laser fields $E_j(\omega_j, \varphi_j)$. The dark state phase fulfills the requirement $\eta = \varphi_1 - \varphi_2$ and is thus sensitive to the laser phase. If under EIT conditions the relative phase of the laser fields is changed by π the dark state superposition instantly becomes bright. More intricate is the behavior under conditions near EIT resonance. Here the dynamic response shows instant as well as slow components which mirror the interplay between rapid and slow coherences in the density matrix. With phase jumps of short duration we can determine the relative phase between the dark state and the laser field in a minimally destructive way, we can measure the absolute depth of the dark resonance and the absolute detuning from EIT resonance without detuning the lasers.

A 39.8 Thu 16:00 Empore Lichthof

Vibrational Mechanics in an Optical Lattice: Controlling Transport via Potential Renormalization — •Arne Wickenbrock[1], Philip C. Holz[1], Nihal A. Abdul Wahab[1], David Cubero[2], and Ferruccio Renzoni[1] — [1]University College London, London, UK — [2]Universidad de Sevilla, Sevilla, Spain

We demonstrate theoretically and experimentally the phenomenon of vibrational resonance in a periodic potential, using cold atoms in an optical lattice as a model system. A high-frequency (HF) drive, with a frequency much larger than any characteristic frequency of the system, is applied by phase modulating one of the lattice beams. We show that the HF drive leads to the renormalization of the potential. We used transport measurements as a probe of the potential renormalization. The very same experiments also demonstrate that transport can be controlled by the HF drive via potential renormalization.

A 39.9 Thu 16:00 Empore Lichthof

Time-dependent reduced density matrix functional theory applied to laser-driven, correlated two-electron dynamics — •Martins Brics, Varun Kapoor, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

Time-dependent density functional theory (TDDFT) with known and practicable exchange-correlation potentials does not capture highly correlated electron dynamics such as single-photon double ionization, autoionization, or nonsequential ionization. Time-dependent reduced density matrix functional theory (TDRDMFT) may remedy these problems. The key ingredients in TDRDMFT are the natural orbitals (NOs), i.e., the eigenfunctions of the one-body reduced density matrix (1-RDM), and the occupation numbers (OCs), i.e., the respective eigenvalues. The two-body reduced density matrix (2-RDM) is then expanded in NOs, and equations of motion for the NOs can be derived. If the expansion coefficients of the 2-RDM were known exactly, the problem at hand would be solved. In practice, approximations have to be made. We study the prospects of TDRDMFT following a top-down approach. We solve the exact two-electron time-dependent Schrödinger equation for a model Helium atom in intense laser fields in order to study highly correlated phenomena such as the population of autoionizing states or single-photon double ionization. From the exact wave function we calculate the exact NOs, OCs, the exact expansion coefficients of the 2-RDM, and the exact potentials in the equations of motion. In that way we can identify how many NOs and which level of approximations are necessary to capture such phenomena.

A 39.10 Thu 16:00 Empore Lichthof

Dynamic phase studies at EIT conditions in thermal rubidium — •Stephan Welte — Physikalisches Institut Uni Freiburg

We investigate the response of an EIT medium to changes of the magnetic field vector. Employing two phase locked external cavity diode lasers, we prepare the atoms in a dark superposition of two Rb ground states, (F=1, mF=-1) and (F=2, mF=1). During preparation of the dark state a constant magnetic field is employed as quantization axis. Its magnitude is chosen as the magic 3.2 Gauss where ground state transition is magnetic-field insensitive in the first-order Zeeman effect. Applying a second magnetic field in the same direction as the quantization field results in a small Zeeman shift of the two mF states. When returning to the original field, the two states of the superposition have picked up unequal dynamical phases due to the quadratic Zeeman effect. As a result, there is a relative phase change in the superposition state which manifests itself in a rise of the absorption signal. We compare our findings with numerical simulations using a realistic eight-level density matrix. A further experiment in progress concerns the detection of a Berry phase imposed in a thermal EIT medium. By rotating an additonal magnetic field in a cone and returning to the original field, the two mF levels of the dark state will acquire different Berry phases which depend on the cone angle. As in the dynamic phase experiment, a relative phase difference should manifest itself in a rise of the absorption signal. This feature is also predicted in our numerical simulation.

A 39.11 Thu 16:00 Empore Lichthof

Temporal dynamics in strong-field processes subjected to Coulomb correlations — •Maximilian Hollstein and Daniela Pfannkuche — Jungiusstraße 9, 20355 Hamburg

Common theoretical approaches for studying atomic strong-field processes such as tunnel and multiphoton ionization of atoms or atom-like systems (e.g. quantum dots) rely on an (effective) one-particle description as for example the single-active-electron approach or the time-dependent configuration-interaction singles (TD-CIS) method. Within these methods, Coulomb correlations are usually neglected. In contrast to these approaches we are investigating the temporal dynamics in strong-field processes subjected to Coulomb correlations on a model system by solving the time-dependent Schrödinger Equation numerically. We consider the time evolution of pair-correlation functions and investigate two-particle excitations which are exceeding the configuration-interaction singles approximation.

A 39.12 Thu 16:00 Empore Lichthof

Mass Effects on the Entanglement Features of an Exactly Soluble Quantum Few-Body System — •Peter Alexander Bouvrie[1], Malte Christopher Tichy[2], Ana Paula Majtey[1], Angel Ricardo Plastino[1], and Jesús Sánchez-Dehesa[1] — [1]Instituto *Carlos I* de Física Teórica y Computacional and Departamento de Física Atómica, Molecular y Nuclear, Universidad de Granada, 18071-Granada, Spain — [2]Lundbeck Foundation Theoretical Center for Quantum System Research, Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark

We explore the entanglement features [1] of the eigenstates of an exactly soluble many-particle model consisting of N_n “nuclei” and N_e “electrons” which interact harmonically in a confining harmonic trap. We investigate its dependence upon the different parameters characterizing the system such as the relative strength between the two-particle interaction and the confining harmonic force, the number of particles and their masses. Particular attention is paid to the dependence of the entanglement on the ratio of the masses of the constituent particles; we have found that the entanglement vanishes when the subsystems have very different masses. Since the validity of the Born-Oppenheimer approach is closely related to the mass of the particles, we have studied the validity region of this approach depending on the parameters of the model; so, shedding new light on the understanding of the vanishing bipartite entanglement with the different subsystems mass.

[1] Bouvrie P A, Majtey A P, Plastino A R, Sanchez-Moreno P and Dehesa J S 2012 Eur. Phys. J. D **66** 15.

A 39.13 Thu 16:00 Empore Lichthof

Electron dynamics in atoms and clusters driven by twisted light — •Koray Köksal[1,2], Yaroslav Pavlyukh[2], and Jamal Berakdar[2] — [1]Faculty of Arts and Science, Physics Department, Bitlis Eren University, 13000 Bitlis, Turkey — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Str. 4, 06120 Halle, Germany

We study the electron dynamics in atoms and clusters triggered by light carrying orbital angular momentum (or twisted light). It is shown that charge currents can be generated [1] in the system that may be utilized as a source for localized magnetic pulses. For a sizable current it is advantageous to have the system's size on the scale of the waist size of the laser. Hence, we are investigating the electron dynamics in metal clusters under the action of twisted light with analytical and numerical methods as we developed and presented in [1, 2].

[1] K. Köksal and J. Berakdar, Phys. Rev. A, **86**, 063812 (2012).

[2] Y. Pavlyukh and J. Berakdar, K. Köksal, Phys. Rev. B **85**, 195418 (2012).