39. EAS -Tagung "Extreme Atomic Systems"

19 – 22 February 2018, Riezlern/Kleinwalsertal

– list of abstracts –

Ghassan Abumwis, mpipks Dresden

Multi-excitons in flexible Rydberg aggregates

Flexible Rydberg aggregates are ensembles of Rydberg atoms that are allowed to move, they provide a platform to investigate quantum phenomena like energy transport and conical intersections. This can be achieved by doping the aggregate with an excitation, an excited state that is energetically higher but close to the primary Rydberg state, leading to the resonant dipole-dipole interaction becoming dominant. Consequently, the excitation is delocalized throughout the aggregate creating excitons.
We follow up on previous results and add a second excitation to the aggregate. We demonstrate that products of excitons can be used to express biexciton states for a chain with a dislocation at one end, a one-dimensional aggregate with equal spacing between atoms except for the last two. Moreover, we show that non-adiabatic effects can be made prominent in flexible Rydberg chains. Finally, we analyze the interaction between two excitation pulses based on the initial biexciton state and the presence of a dislocation. Our findings further enlarge the pool of Born-Oppenheimer surfaces for quantum transport that can be engineered in flexible Rydberg aggregates.

Miguel Angel Bastarrachea Magnani, Universität Freiburg

Dynamics of coherent states in the Dicke model

The Dicke Hamiltonian is a model that comes from quantum optics employed to describe the collective interactions of a set of N two-level atoms and a single-mode of radiation field inside a cavity. The model is well-known for its quantum phase transitions, as well as for its non-integrability. Besides, it is a simple and paradigmatic description of a spin-boson interaction. In this work we present the dynamics of coherent states under the unitary evolution of the Dicke Hamiltonian. In the regular part of the spectrum, the distribution of the coherent states in the eigenstate basis consists of quasi-harmonic sub-sequences of eigenstates with gaussian weights. This allows to derive analytical expressions for the survival probability of the coherent states. These expressions describe the time evolution in agreement with exact numerical results up to the decay of the survival probability oscillations. Furthermore, the analytical treatment can be extended to higher energies where interference terms between these sequences of eigenstates in the distribution of the coherent states mark the onset of chaos in the spectrum. Since most bounded Hamiltonians have regular regimes in the spectrum at low-energies, this approach has broad applicability.

Thomas Baumert, Universität Kassel

Multiphoton ionization of chiral molecules

Molecular chirality is widely recognized for its relevance to the building blocks of life and its vital role for medicine and health. Chiral recognition in the gas phase using electromagnetic radiation is an emerging research eld and promising for fundamental research as well as for applications due to the non-interacting nature of molecules in the gas phase. Photoelectron angular distributions after one photon or multiphoton ionization turned out to be especially sensitive to that end and are usually measured by velocity map imaging (VMI) techniques. The corresponding circular dichroism is termed photoelectron circular dichroism (PECD). Based on electric dipole interaction, its magnitude of up to a few ten percent typically surpasses that of other chiroptical techniques and can be turned into a highly sensitive analytic tool with respect to investigation of enantiomeric excess.
Resonance-enhanced multi-photon ionization (REMPI) gives access to electronic intermediates and, with the help of femtosecond laser excitation and ionization, PECD has been demonstrated on bicyclic ketones. As more angular momentum can be transferred in a multiphoton process in comparison to single photon ionization, higher order nodal structures were observed. An exploration of the nuclear and electron dynamics of the intermediate resonance may stimulate the development of laser driven purification schemes. In this talk I will present the field and our experiments.
References are compiled for example in our latest publication: Kastner et al. JCP 2017, Vol. 147, 013926 (9 pp)

Christopher Bentley, mpipks Dresden
Quantum simulation using Rydberg atoms

We consider an open quantum system of ultracold Rydberg atoms. The system part consists of resonant dipoledipole-interacting Rydberg states. The environment part is formed by 'three-level atoms': each atom has a ground state, a short-lived excited state, and a Rydberg state that interacts with the system states. The two transitions in the environment atoms are optically driven, and provide control over the environment dynamics. Appropriate choice of the laser parameters allows us to prepare a Boltzmann distribution of the system's eigenstates. By tuning the laser parameters and system-environment interaction, we can change the temperature associated with this Boltzmann distribution, and also the thermalization dynamics. Our method provides novel opportunities for quantum simulation of thermalization dynamics using ultracold Rydberg atoms.

Jens Biegert, ICFO - The Institute of Photonic Sciences, Castelldefels (Barcelona)
Molecular selfies

Alexander Blättermann, MPI für Kernphysik
Strong-field spectroscopy

Dana Bloß, Universität Kassel
Photon and electron impact induced luminescence spectroscopy of a liquid microjet

For investigations in atomic and molecular physics it is a common approach to prepare pure atomic and molecular samples to reveal their electronic structure without being affected by any environment. However, there is an abundance of effects which rely on the interaction of different molecules and atoms in loosely bound systems. For example, a variety of biochemical effects only take place in an aqueous surrounding. With the development of the liquid microjet technique the investigation of pure liquids or solutions after irradiation with synchrotron radiation became possible, which allows the exploration of the electronic structure of such complex systems. Here we present our recent results of dispersed luminescence from liquid water and demonstrate the possibilities of this detection method using this prototype system. As an outlook the experimental set-up for electron impact excitation will be presented, which will yield data for comparison with the photon-induced luminescence spectra.

Gergana Borisova, MPI für Kernphysik, Heidelberg
First results of XUV transient absorption spectroscopy in the ionization continuum of molecular hydrogen

In studies of the ionization dynamics in atoms and molecules after light-matter interaction, usually electrons and/or ions are detected, as they are the natural products of the ionization process. Investigating ionization dynamics in molecular hydrogen is therefore predominantly done by measuring charged particles [1]. Here, we experimentally consider the complementary approach of attosecond transient-absorption spectroscopy (ATAS) and aim at the energy region around the Qn doubly excited resonances. First results of this technically challenging experiment will be presented, with emphasis on a systematic study of various obstacles that arise when searching for weak and broadband spectral signatures in an ATAS experiment.
[1] Palacios et al., J. Phys. B: At. Mol. Opt. Phys. 48, (2015) 242001

Andreas Buchleitner, Universität Freiburg
Statistical signature of many body quantum interference

Quantum simulation needs certification - in particular when the implemented task cannot be verified by (deterministic) theoretical and/or numerical modelling. Much as in classical many-particle systems, when the number of particles renders a deterministic description impractical, statistics is the method of choice. We discuss how distinctive and robust features of many-particle interference upon transmission across a multi-mode, random scattering set-up can be used for *scalable, statistical* certification, without the (unsatisfiable, for sufficiently large particle and mode numbers) need of a complete measurement of the many-particle output state. We compare theoretical predictions and a recent experimental validation of the protocol, and also touch upon the potential of machine learning algorithms in identifying "optical" experimental observables.
[joint work together with T. Giordani, F. Flamini, M. Pompili, N. Viggianello, N. Spagnolo, A. Crespi, R. Osellame, N. Wiebe, M. Walschaers, F. Sciarrino, under review]

Laura Cattaneo, ETH Zürich
Attosecond nuclear-electronic coupled photoionization dynamics of H_2

Photoionization dynamics of the simplest molecule H_2 continues to be of strong scientific interest as still new physical insight into fundamental processes can be gained.
In this study, we investigate how the dissociative ionization of oriented H_2 molecule, i.e. $H_2 \rightarrow H + H^+ + e^-$, is influenced not only by electron correlation due to the presence of autoionizing states, but also by nuclear dynamics which takes place at comparable time scales as the electron dynamics. This investigation has been carried out exploiting the XUV pump/IR probe RABBITT interferometric technique combined with a coincidence detection using a COLTRIMS apparatus. This allows us to reconstruct the kinematics of the complete reaction, as the neutral H-fragment is reconstructed according to the total momentum conservation principle, retrieving the H_2 molecular frame orientation before dissociation.
Following the selection rules, we can further determine the final state of the photoemitted electrons. In particular the Q_1 and Q_2 series of autoionizing states can be populated only by molecules preferentially aligned parallel and perpendicular to the XUV polarization axis, respectively. In the parallel case we observed a clear modulation of the RABBITT-extracted photoionization phases between 29 and 32 eV attributable to the presence of the Q_1 states. Similarly, for the perpendicular case, Q_2 states are explicitly inducing a jump in the molecular phase above 32 eV. Notably a non-zero phase is measured below the Q_2-threshold at 32 eV. This is attributed to nuclear-electronic coupling degree of freedom.
These experimental results are confirmed and complemented by a complete ab initio theoretical study incorporating not only the electronic, but also the nuclear coordinates in the description of the molecular wave function.

Stefano Michele Cavaletto, MPI für Kernphysik, Heidelberg
Reconstruction of strong-field-excited systems for deterministic quantum control

Coherent-control methods exploiting femtosecond pulse-shaping technology have revolutionized our access to the quantum properties of matter. Measurement-driven techniques such as adaptive feedback control are widely used: femtosecond pulses are thus utilized to simultaneously control and interrogate the atomic system, with their shape being iteratively optimized based on the received experimental response. However, the complex reaction pathways followed by an optimally controlled system often remain concealed. For quantum control using intense time-dependent pulses, which dress the atomic level structure, only a limited number of effective pulse-shaping strategies have been identified. Here, we show that the action of an intense pulse on a quantum system, including the dependence upon possibly unknown pulse properties and atomic structures, can be fully characterized from absorption-spectroscopy measurements. An optimal sequence of intense pulses can then be designed based on this extracted information, providing a complete mapping of the available control options and facilitating manipulation and interpretation of the chosen control strategy [S. M. Cavaletto et al., Phys. Rev. A 95, 043413 (2017)]. Implemented at x-ray energies with intense pulses from free-electron lasers, the scheme would represent an effective route to x-ray quantum control.

Maximilian Dirkmann, Universität Freiburg
A Bosonic Josephson junction with an impurity

We study the dynamics of a Bose-Einstein condensate in a double-well potential, or bosonic Josephson junction, in the presence of a mobile impurity particle. This allows us to test the practicability of a quantum probe scheme, where measurements are performed on the impurity in order to obtain information about the rest of the system.
The system is described using a two-site Bose-Hubbard Hamiltonian which accounts for tunneling between the wells and on-site interactions between the particles. We observe a variety of dynamical regimes as the relative strength of tunneling and interactions is changed. In particular, we study the entanglement of the impurity particle with the rest of the system.

Mohammad Reza Eidi, mpipks Dresden

Simulation of one and two electron systems on the base of static grids of coherent states

Different ways of computing electronic states of one and two-electron systems using coherent states will be briefly reviewed. I will also talk about how to treat the nucleus in Hydrogen like systems dynamically by using classical motion equation. Moreover, the simulation results of electronic states of laser induced H2+ considering classical nuclear dynamics will be discussed.

Stephan Fritzsche, Helmholtz-Institut Jena & Universität Jena

A fresh computational approach to atomic structures, processes and time evolutions

A new toolbox for performing atomic computations is currently developed by us. Apart from accurate calculations of atomic level properties and processes, we wish to simulate atomic excitation and decay cascades as well as the time-evolution of density operators. — We do, what we often did in the past, but now (much) better.

Maxim Gelin, Technische Universität München

Femtosecond pump-probe spectroscopy: Why not to try strong pulses

Pump-probe is one of the key techniques in the arsenal of femtosecond molecular spectroscopy: The pump pulse excites molecular system, the probe pulse interrogates it, and the signal is recorded as a function of the time delay between the pump and probe pulses. Traditionally, femtosecond pump-probe spectroscopy is performed with weak pulses. The well-established method of the simulation of such signals is based on third-order perturbation theory in the light-matter interaction.
The idea of strong-field pump-probe spectroscopy is to induce additional (beyond the third order) responses of the molecular system. The result of the interaction of the molecular system with a strong pulse is determined by Rabi cycling rather than by Fermi golden rule. By varying the strength and/or the duration of the pump pulse, we may create a highly non-equilibrium vibrational wave packets in the electronic ground state and excited electronic states. After the pump pulse is over, the system evolves according to its field-free dynamics until it is probed by another (strong) probe pulse. The present talk advocates the use of strong pulses in pump-probe spectroscopy. By explicit calculations of pump-probe responses of selected model systems and by simulations of selected experiments, we show that strong pulses can be applied to enhance weak transitions, to provide time resolution beyond the pulse duration, to manipulate electronic & vibrational coherences, and to control contributions of vibrational wave packets. It can be concluded that strong-pulse (nonperturbative) pump-probe spectroscopy allows us to extract more information from complex material systems than is accessible with weak pulses.
1. M. F. Gelin, Jayachander B. Rao, M. Nest, and W. Domcke. Domain of validity of the perturbative approach to femtosecond optical spectroscopy. J. Chem. Phys. 139, 224107 (2013).
2. M. F. Gelin, D. Egorova, and W. Domcke. Strong-pump strong-probe spectroscopy: effects of higher excited electronic states. Phys. Chem. Chem. Phys. 15, 8119-8131 (2013).
3. M. F. Gelin, D. Egorova, and W. Domcke. Strong and Long Makes Short: Strong-Pump Strong-Probe Spectroscopy. J. Phys. Chem. Lett. 2, 114-119 (2011).
4. M. F. Gelin, A. K. Belyaev, and W. Domcke. Pump-probe spectroscopy with strong pulses as a tool to enhance weak electronic transitions. Phys. Rev. A 87, 063416 (2013).
5. J. B. Rao, M. F. Gelin, and W. Domcke. Resonant Femtosecond Stimulated Raman Spectra: Theory and Simulations. J. Phys. Chem. A 120, 3286-3295 (2016).

Panagiotis Giannakeas, mpipks Dresden

Ultracold heteronuclear three-body systems: How diabaticity limits the universality of recombination into shallow dimers

The mass-imbalanced three-body recombination process that forms a shallow dimer is shown to possess a rich Efimov-Stückelberg landscape, with corresponding spectra that differ fundamentally from the homonuclear case. A semi-analytical treatment of the three-body recombination predicts an unusual spectra with intertwined resonance peaks and minima, and yields in-depth insight into the behavior of the corresponding Efimov spectra. In particular, the patterns of the Efimov-Stückelberg landscape are shown to depend inherently on the degree of diabaticity of the three-body collisions, which strongly affects the universality of the heteronuclear Efimov states.

Nikolay Golubev, Universität Heidelberg
Molecular quantum dynamics based on exact factorization of the wavefunction

Quantum dynamics simulations are now established as an essential tool for understanding experiments that probe matter at the microscopic level and on fundamental time-scales. Most of the methods of the modern quantum chemistry are based on an ansatz for the molecular wavefunction which is known as the Born–Oppenheimer expansion. The major limitation of this standard way to treat non-adiabatic electron-nuclear dynamics is very unfavorable scaling with respect to the number of electronic states taken into account. To tackle situations beyond the reach of traditional methods, a new theoretical approach based on exact factorization of a molecular wavefunction was suggested. We propose a methodology allowing to solve equations of motion emerging from the wavefunction factorization approach. We argue that this new technique will allow to calculate electron-nuclear dynamics following ultrafast ionization of moderate size molecules.

Frank Grossmann, Technische Universität Dresden
A critical look at the Davydov Ansatz for finite temperatures

We investigate the Davydov Ansatz for the spin-boson problem in the case of finite temperatures. The equations of motion, which are derived from a variational principle, are carefully studied and are made explicit for ease of numerical implementation. Generalizations towards multiplicity greater than one are also discussed.

Andreas Hans, Universität Kassel
Charge redistribution in van-der-Waals clusters studied by photon spectroscopy

The environment of an atom significantly influences its possibilities for further autoionization and charge redistribution processes after ionization and possibly subsequent (local) Auger decay. A variety of such processes leads to or is accompanied by photon emission. Although photons are often not directly detected in multi-coincidence spectroscopy of charged particles, their occurrence can be deduced from energy conservation. However, the direct observation of emitted photons can be used as complementary method, beneficial for tracking processes in dense samples. Here we report showcases for the study of interatomic Coulombic decay (ICD) and radiative charge transfer (RCT) in van-der-Waals bound noble gas clusters using photon spectroscopy.

Anne Harth, MPI für Kernphysik, Heidelberg
Attosecond timing with spectral resolution near resonances

To directly observe the ultrafast motion of electrons in atomic or molecular systems is an aspect of fundamental physics and is achievable thanks to the generation of attosecond pulses in the XUV spectral range. A key advantage of attosecond pulse trains over isolated attosecond pulses is their high spectral resolution, while high temporal resolution is still retained [1]. I will introduce attosecond measurements using attosecond pulse trains near resonances and discuss the role of continuum-continuum transitions in attosecond time delay measurement within a perturbative approach.
In the future, these experiments will benefit substantially by the advent of high-repetition rate attosecond experiments based on optical parametric amplifier systems driving high-order harmonic generation [2].
[1] Isinger et al. Science 358, 893 (2017), [2] Harth et al. Journal of Optics 20, 014007 (2018)

Kilian Heeg, MPI für Kernphysik, Heidelberg
Controlling excitation dynamics of Mössbauer nuclei

Mössbauer nuclei with transitions in the hard x-ray regime are usually probed by single x-ray pulses only, such that advanced concepts in light-matter interaction which, e.g., require control fields, cannot be realized straightforwardly. Here, we generate a sequence of two pulses with controlled relative phase. Such tailored x-rays are employed in a two-step interaction scheme: preparation and subsequent control of the excitation dynamics in a resonant target of ^{57}Fe Mössbauer nuclei. Our experimental results confirm that the collective nuclear dipole response can indeed be manipulated and we find clear signatures of fundamental processes in light-matter interaction such as stimulated emission and absorption.

Jiri Hofbrucker, Helmholtz Institut Jena
Non-linear dichroism in atomic ionization

Dichroic behavior is usually associated with an interaction of polarized atomic or chiral molecular target and circularly polarized light. However, in a non-linear interaction regime, elliptically polarized light ionizing symmetric target also produces a dichroic photoelectron angular distributions. The fundamental origin of this asymmetry explains why is the elliptical dichroism strictly a feature of multi-photon processes only, and why it is never observed in the single photon ionization process. Being energy and system specific, this phenomena give us an opportunity to study many-electron effects as well as fundamentals of non-linear light-matter interaction. Observation of this phenomena in two-photon ionization of an inner-shell shell electron of a rare gas atom is proposed.

Andrew Hunter, mpipks Dresden
Rydberg molecules with multiple perturbers

Andrew Hunter, Alex Eisfeld, and Jan-Micheal Rost
A Rydberg atom in the presence of a neutral perturber is investigated using scattering theory. Due to a negative s-wave scattering length at low energies these perturbers can form a bound state with the Rydberg atom, known as a trilobite molecule [1]. These molecules interact strongly with their environment due to their large polarisability or dipole moment [2]. In particular, we study how such systems change with the addition of multiple perturbers.
[1] C. H. Greene, A. S. Dickinson, and H. R. Sadeghpour, Phys. Rev. Lett. 85, 2458 (2000)
[2] P. J. J. Luukko and J. M. Rost, Phys. Rev. Lett.119, 203001 (2017)

Doris Jakubassa-Amundsen, LMU München
Study of polarized eV to GeV electrons and positrons scattering elastically from atoms

Differential cross sections and spin asymmetries are calculated within the partial-wave analysis. For collision energies from 1 eV to 1 MeV, an optical model potential is used, and for the higher energies the phase shift analysis combined with the DWBA is applied. As test cases, a light target (23Na), a medium-heavy target (112Cd) and a heavy target (208Pb) are investigated. Theory is compared with available experimental data.
(This is joint work with A.K.F.Haque and B.C.Saha.)

Nikolay Kabachnik, Lomonosov Moscow State University
Angular streaking of Auger electrons by THz field

Rotational streaking by terahertz (THz) field of Auger electrons generated by a short extreme ultraviolet (XUV) or X-ray pulse is theoretically considered. The character of the streaking pattern depends on three main parameters: the duration of the XUV pulse, the Auger-decay time-of-life, and the period of the THz field. Different cases with various interrelations of these parameters will be discussed. Examples of the patterns are calculated within the strong field approximation.

Victor Kimberg, KTH Royal Institute of Technology, Stockholm
Frequency control over nuclear dynamics in RIXS

Resonant Inelastic X-ray Scattering (RIXS) is a well-established powerful tool for study of the electronic structure and nuclear dynamics in molecules, liquids and solids, surfaces. I would like to overview our resent theoretical and experimental results on spectroscopy of x-ray induced nuclear dynamics with spatial and time-resolution. Our theoretical approach based on a combination of high-level ab initio calculations of molecular electronic structure and quantum wave packet propagation formalism allows for an advance description of the nuclear dynamics beyond the independent mode approximations. I will discuss theoretical-experimental observation of selective gating effect in RIXS via different core-excited states enabling a disentanglement of different vibrational modes [Couto et al., Nat. Comm. 8, 12725, 2017] and frequency control of the nuclear dynamics in the water molecule [Vaz da Cruz et al., PCCP 19, 19573, 2017]. IR-pump RIXS-probe technique for advanced symmetry resolved studies will be introduced [Ignatova et al., Phys. Rev. A 95, 42502, 2017] and applied for observation of a gradual collapse of the vibrational wave functions in HDO molecule regulated by x-ray frequency [Ignatova et al., Sci. Rep. 7, 43891, 2017].

Felix Mackenroth, mpipks Dresden
Determining the duration of an intense laser pulse directly in focus

We propose a novel measurement technique capable of determining the temporal duration of an intense laser pulse directly in its focus at full intensity. We show that the electromagnetic radiation pattern emitted by an electron bunch with a temporal energy chirp colliding perpendicularly with the laser pulse exhibits a distinct dependence on the pulses duration. As the electrons emit radiation into an angular region determined by the ratio of their instantaneous energy to the lasers local field strength, the temporal change of the electrons energy imprints information about the lasers pulse duration onto the angular radiation distribution. We quantify the interaction by a simplified analytical model and confirm this models predictions by numerical simulations of the electrons dynamics inside a realistically focused laser field. Based on these findings the pulses duration can be determined to an accuracy of several percent.

Robert Moszynski, University of Warsaw
Ultracold chemistry and asymptotic physics with diatomic strontium molecules

During the last decade state-of-the-art ab initio methods of quantum chemistry have been applied with success to interpret precision experiments on two-body and many-body processes in atomic gases in the ultracold regime. In this talk I will present recent examples of successful applications of the ab initio methods to describe two-body processes in atomic optical lattices leading to the formation of unusual chemical bonds and to observations of exotic optical transitions in diatomic molecules [1-3]. I will also discuss the studies of ultracold chemistry enabled by photodissociation of diatomic strontium molecules [4-5], including the phenomena of resonant and nonresonant barrier tunneling, matter wave interference of reaction products, and forbidden reaction pathways. Finally, I will discuss possible applications of ultracold strontium molecules in the search for a new physics.
1. B. H. McGuyer, C. B. Osborn, M. McDonald, G. Reinaudi, W. Skomorowski, R. Moszynski, T. Zelevinsky, Phys. Rev. Lett. 111 (2013) 243003.
2. B. H. McGuyer, M. McDonald, G. Z. Iwata, W. Skomorowski, R. Moszynski, T. Zelevinsky, Phys. Rev. Lett. 115 (2015) 053001.
3. B. H. McGuyer, M. McDonald, G. Z. Iwata, M. G. Tarallo, W. Skomorowski, R. Moszynski, T. Zelevinsky, Nature Physics 11 (2015) 32.
4. M. McDonald, B. H. McGuyer, F. Apfelback, C. H. Lee, I. Majewska, R. Moszynski, T. Zelevinsky, Nature, 535 (2016) 122.
5. M. McDonald, I. Majewska, C.-H. Lee, S. S. Kondov, B. H. McGuyer, R. Moszynski, T. Zelevinsky, Phys. Rev. Lett. - in press; arXiv:1709.04527.

Robert Müller, Physikalisch-Technische Bundesanstalt, Braunschweig
Hyperfine structure of doubly charged ^{229}Th

Natalia Oreshkina, MPI für Kernphysik Heidelberg
Theoretical prediction of the fine and hyperfine structure of heavy muonic atoms

Precision calculations of the fine and hyperfine structure of muonic atoms are performed in a relativistic approach and results for muonic ^{205}Bi, ^{147}Sm, and ^{89}Zr are presented. The hyperfine structure due to magnetic dipole and electric quadrupole splitting is calculated in first-order perturbation theory, using extended nuclear charge and current distributions. The leading correction from quantum electrodynamics, namely vacuum polarization in Uehling approximation, is included as a potential directly in the Dirac equation. Also, an effective screening potential due to the surrounding electrons is calculated, and the leading relativistic recoil correction is estimated.

Christian Ott, MPI für Kernphysik Heidelberg
XUV-only nonlinear wave mixing and absorption spectroscopy

Huda Otto, Universität Kassel
Investigating the electronic structure of nitrogen clusters with photon-induced fluorescence spectroscopy

Interactions between van-der-Waals bound entities are relevant in various biological processes. With a cluster source it is possible to artificially synthesize molecular clusters that attract each other by van-der-Waals forces, e.g. form N2-clusters. N2-clusters have recently been under discussion because of a showcase ICD, which might be a candidate for future medical applications. Because the electronic states of molecular clusters strongly depend on its geometric formation, it is necessary to identify these states to explain processes like ICD accurately. Here, photon-induced fluorescence spectroscopy is introduced as a technique for investigating the electronic structure of nitrogen clusters, and first experimental results are presented.

Anton Peshkov, Helmholtz Institut Jena
Rayleigh scattering of twisted light by hydrogenlike ions

The elastic scattering of photons by bound electrons of atoms, commonly known as Rayleigh scattering, has attracted much interest in experiment and theory as one of the simplest second-order quantum electrodynamical process. In particular, the measurement of the linear polarization of the elastically scattered plane-wave radiation has been recently performed at the PETRA III synchrotron at DESY [1]. Until the present, however, very little is known about the scattering of twisted light. When compared to plane-wave photons, such twisted photons carry a well-defined projection of the orbital angular momentum [2]. Here we analyze theoretically the behavior of the polarization Stokes parameters of scattered photons for the elastic scattering of twisted Bessel light by means of the Diracs relativistic equation. Special attention was paid to the scattering on three different atomic targets: a single atom, a mesoscopic (atoms in a trap) and a macroscopic (foil) targets. Our calculations indicate that the Stokes parameters of the scattered twisted light may significantly differ from their behaviour for an incident plane-wave radiation.
[1] K.-H. Blumenhagen et al., New J. Phys. 18, 103034 (2016).
[2] A. A. Peshkov et al., Phys. Rev. A 96, 023407 (2017).

Thomas Pfeifer, MPI für Kernphysik Heidelberg
The transition from simple to complex strong-field quantum dynamics among bound states in the time domain

Ulf Saalmann, mpipks Dresden
Adiabatic passage to the continuum

Krzysztof Sacha, Jagiellonian University Krakow
Time crystals

Time crystals are many-body systems that, due to interactions between particles, are able to self-organize spontaneously their motion in a periodic way in time by analogy with the formation of crystalline structures in space in condensed matter physics. Research in time crystals can be divided into two branches. In the first branch, systems that can reveal spontaneous breaking of time translation symmetry are investigated. In the other branch, time crystals are modelled with the help of periodically driven systems similarly as space periodic potentials are used to model properties of space crystals in condensed matter physics. We show that discrete time translation symmetry can be spontaneously broken and the so-called discrete time crystals can form [1,2] - the phenomenon that has been demonstrated in the recent experiments [3]. We show also that a number of solid state phenomena can be observed in the time domain in periodically driven systems. That is, Anderson localization in the time domain induced by disorder in time, Mott insulator phase in the time domain, many-body localization caused by temporal disorder and time quasicrystal structures can realized experimentally [4,5].
[1] K. Sacha, Phys. Rev. A 91, 033617 (2015).
[2] V. Khemani et al, Phys. Rev. Lett. 116, 250401 (2016); D. V. Else et al., Phys. Rev. Lett. 117, 090402 (2016).
[3] J. Zhang et al., Nature 543, 217 (2017); S. Choi et al., Nature 543, 221 (2017).
[4] K. Sacha and J. Zakrzewski, "Time crystals: a review", Rep. Prog. Phys. (in press).
[5] K. Giergiel, M. Miroszewski, and K. Sacha, arXiv:1710.10087.

Horst Schmidt-Böcking, Johann Wolfgang Goethe-Universität Frankfurt
Zepto Second Pump and Probe experiments with ion beam methods

Giacomo Sorelli, Universität Freiburg
High dimensional entanglement of twisted photons in atmospheric turbulence

Spatial excitations of the electromagnetic field carrying orbital angular momentum (OAM), often called twisted photons, can be used to encode high dimensional quantum (entangled) states. These states are not only of fundamental interest, but also practically useful, since they can enhance channel capacity and security in quantum communication. However, transmission across a turbulent atmosphere introduces random phase fluctuations of the photons wavefront that destroy the information therein encoded. In this talk we consider the propagation of OAM entangled qutrit and ququart states. We show how phase front correction by methods of adaptive optics can significantly reduce crosstalk to OAM modes inside and outside the encoding subspace, and thereby improve stability of high dimensional entanglement in atmospheric turbulence.

Fabian Spallek, Universität Freiburg
Optimisation of photovoltaic upconversion in multi-layered photonic structures

Upconversion materials, which convert two low-energy photons into one photon with higher energy, combined with photonic structures, open promising possibilities to improve the efficiency of silicon solar cells by utilising the full range rather than only a fraction of the solar spectrum [1]. Quantum yield and the luminescence enhancement, which quantify the overall efficiency of the embedded upconverter material, are determined by the interplay of energy transfer processes, local irradiance and local density of (photonic) states - all of which can be influenced by photonic dielectric nanostructures.
By tuning the thickness of each individual layer in a multi-layered photonic structure, we show that it is possible to trap incident photons of a given wavelenght inside this structure, and thus considerably increase the local irradiance in those layers which contain the upconverter material [2].
Furthermore we derive the local density of states from macroscopic QED, for arbitrary finite multi-layered dielectric structures. This allows us to optimize the structure, such as to enhance desired, or to suppress unwanted spontaneous emission processes from distinct excited energy levels of the upconverter material.
We compare the achievable enhancement of the local irradiance, as well as its robustness under manufactoring errors, as obtained for the resulting optimal geometries to thus far experimentally implemented Bragg structures [1]. In combination with results for the local density of states in multi-layered structures, we also make predictions for the achievable luminescence and upconversion quantum yield of optimised structures as compared to the above mentioned Bragg structures.
[1] C. L. M. Hofmann et al., Opt. Express 24, 14895 (2016)
[2] F. Spallek et al., J. Phys. B: At. Mol. Opt. Phys. 50, 214005 (2017)

Vasily Tulsky, Universität Rostock
Optimization of THz currents induced in strong laser circularly polarized fields

Development of a powerful and compact source of terahertz (THz) radiation is one of the objectives of strong field laser physics due to the broad variety of possible applications of such sources. A promising scheme to achieve an effective conversion of infrared or optical laser pulses into THz radiation is based on the interaction of an intense two-color laser field with a gaseous medium. Recently it has been shown experimentally [1] that the THz output yield may be significantly increased if a circularly polarized laser field is applied. Meanwhile, most of the theoretical research (see, for example, [2-6] and Refs. therein) was aimed on the case of linear polarization. In this work we fill this gap in the theory by introducing a model of generation of THz in circular+circular and circular+linear configurations of the laser. Our model is based on the combination of a microscopic theory for the calculation of initial photoelectron spectra (using the time dependent Schroedinger equation and the strong field approximation) and a macroscopic part describing the evolution and radiation of the photoelectron plasma using the particle-in-cell simulations.
[1] C. Meng, W. Chen, X. Wang, Z. Lu, Y. Huang, J. Liu, D. Zhang, Z. Zhao, and J. Yuan, Appl. Phys. Lett. 109, 131105 (2016)
[2] I. A. Kotelnikov, A. V. Borodin, and A. P. Shkurinov, Zh. Eksp. Teor. Fiz. 139, 1081 (2011)

[3] D.S. Bagulov, I.A. Kotelnikov, Zh. Exp. Teor. Fiz. 143, 26 (2013)
[4] L. A. Johnson, J. P. Palastro, T. M. Antonsen, and K. Y. Kim, Phys. Rev. A 88, 063804 (2013)
[5] S. V. Popruzhenko and V. A. Tulsky, Phys. Rev. A 92, 033414 (2015)
[6] N. V. Vvedenskii, A. I. Korytin, V. A. Kostin, A. A. Murzanev, A. A. Silaev, and A. N. Stepanov, Phys. Rev. Lett. 112, 055004 (2014)

Sebastian Ulbricht, Physikalisch-Technische Bundesanstalt, Braunschweig
The free electron g - factor in a homogeneous gravitational field

Matthias Wollenhaupt, Universität Oldenburg
Supercontinuum electron vortices

Recently, the emergence of vortex structures in the momentum distribution of free electron wave packets from photoionization of atoms with sequences of two time-delayed counterrotating circularly polarized (CRCP) ultrashort laser pulses was predicted [1] and demonstrated experimentally [2]. Vortex-shaped photoelectron momentum distributions arise from the superposition of two time-delayed free electron wave packets with different magnetic quantum numbers. In our experiment three-dimensional (3D) electron vortices are generated by multiphoton ionization of potassium atoms using CRCP femtosecond laser pulses from a polarization-shaped supercontinuum source [3] and reconstructed tomographically from a set of velocity map imaging (VMI) measurements [4]. By variation of the time delay, the helicity and the spectral bandwidth of the CRCP pulse sequence we control the vortex shape [5]. Absorption of another photon in the continuum changes the c_6 azimuthal symmetry of the threshold vortex into c_8 for above threshold ionization (ATI). Electron vortices from non-perturbative excitation show c_4 azimuthal symmetry and a π-phase jump in the polar direction. Determination of the relative phase of the superposition state allows us to directly reconstruct free electron wave functions. Further studies on electron vortices, including the generation of vortices with an odd number of arms using bichromatic polarization-shaped CEP-stable supercontinua [3], are presented.

[1] J. M. Ngoko Djiokap, S. X. Hu, L. B. Madsen, N. L. Manakov, A. V. Meremianin, and A. F. Starace, Phys. Rev. Lett. 115, 113004 (2015).
[2] D. Pengel, S. Kerbstadt, D. Johannmeyer, L. Englert, T. Bayer, and M. Wollenhaupt, Phys. Rev. Lett. 118, 053003 (2017).
[3] S. Kerbstadt, D. Timmer, L. Englert, T. Bayer, and M. Wollenhaupt, Opt. Express 25, 12518 (2017).
[4] S. Kerbstadt, D. Pengel, D. Johannmeyer, L. Englert, T. Bayer, and M. Wollenhaupt, New J. Phys. 19, 103017 (2017).
[5] D. Pengel, S. Kerbstadt, L. Englert, T. Bayer, and M. Wollenhaupt, Phys. Rev. A 96, 043426 (2017).