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– list of abstracts –

David Bachmann, Albert-Ludwigs-University Freiburg

Eigenmodes of turbulence – Exploring new possibilities for free-space quantum communication

High-dimensional free-space quantum communication is an active, application-oriented, research area. So far, most implementations of high-dimensional spatial encoding have used photonic orbital angular momentum (OAM), but the phase fronts of the corresponding spatial modes are very fragile under atmospheric turbulence distortions. Much work has recently been dedicated to identify complete orthonormal sets of spatial modes (such as Laguerre-Gaussian or Bessel-Gaussian), but none of these bases are truly robust under atmospheric perturbations.
With our project, we strive to develop a new paradigm of high-dimensional encoding – into spatial eigenmodes of light in atmospheric turbulence. Since the associated eigenvalues determine the actual transmission fidelities, eigenmodes with large eigenvalues can be transmitted through the atmosphere with little loss and distortion. Furthermore, such eigenmodes are by construction mutually orthogonal and hence suitable for spatial encoding and entanglement distribution of high-dimensional quantum states. In this talk, I will elaborate how numerical methods allow us to simulate atmospheric propagation, determine optical eigenmodes and assess their properties. In particular, we will study their transmission through static as well as dynamic atmospheric turbulence.

Dr. Carlos Benavides-Riveros, Max-Planck-Institute for Physics of Complex Systems Dresden

Determining excited state properties of quantum many-body systems via purified ensembles

Unlike ground states of quantum many-body systems, the computation of their excited-state properties remains complex and rather expensive. By resorting to the generalization of the Ritz variational principle to ensemble states and to the double-state formulation of ensemble matrices, I will introduce a novel field theory that allows one to access to the excitation spectra of quantum many-body systems in a fully variational way [1]. Our method resembles a more standard pure-state ground-state calculation, and therefore allows one to reuse well-known ground-state methods (like couple-cluster ansätzen). Here, I will show how to compute the eigen-states and eigen-energies of correlated fermionic and bosonic systems, and perform an explicit application for the Fermi-Hubbard model. I will also discuss the implications of this approach for the quantum computation of excited states.

[1] C.L. Benavides-Riveros, L. Chen, S. Mantilla, and S. Pitallis, arXiv:2201.10974 (2022)

Dr. Andrei Benediktovitch, DESY Hamburg
Modeling of 3D paraxial x-ray superfluorescence based on stochastic differential equations

A focused X-ray Free Electron Lasers (XFEL) pulse can bring atoms to a highly excited transient core-hole state. Under such conditions amplification of the x-ray fluorescent radiation may take place, thus leading to x-ray superfluorescence or x-ray lasing. This phenomenon forms a basis for several nonlinear x-ray spectroscopic techniques and was recently proposed for creating a source of nearly transform-limited highly-coherent x-ray pulses – x-ray laser oscillator [1].

Quantitative description of x-ray superfluorescence requires quantum-mechanical treatment of the field – to describe the spontaneous emission that triggers the superfluorescence – as well as field propagation effects to describe spectral-angular properties of the amplified field. In this talk, we will present an approach to this challenging problem based on rigorously derived stochastic differential equations. For rod-like geometry of the XFEL-pumped medium – which is typical for x-ray superfluorescence experiments – a paraxial approximation enables effective numerical implementation, thus providing a 3D description of amplified field evolution out from spontaneous emission. The developed formalism can be used as a basis for calculations needed to design the x-ray laser oscillator.

[1] A. Halavanau, A. Benediktovitch, A. A. Lutman, D. DePonte, D. Cocco, N. Rohringer, U. Bergmann, and C. Pellegrini, "Population inversion x-ray laser oscillator", Proc. Natl. Acad. Sci.117, 15511–15516 (2020).

Dana Bloß, University of Kassel
Experimental investigation of X-ray-induced photochemistry of solvated metal ions

The investigation of microscopic radiation damage aims at the understanding of the response of biological systems to ionizing radiation on a molecular level. One particular aspect of the field are low-energy electrons (LEEs), which are known to be responsible for DNA double-strand breaks as well as for the creation of reactive species in the water surrounding the DNA[1]. Upon X-ray irradiation, these LEEs result mainly from secondary processes, like interatomic/intermolecular Coulombic decay (ICD) or electron-transfer-mediated decay (ETMD) subsequent to photoionization and Auger decay. Stumpf et al. predicted that X-ray ionization of microsolvated metal ions, e.g., Mg2+ or Ca2+, results in a multi-step cascade of ICD and ETMD processes[2]. We experimentally investigate the theoretically predicted LEE emission for Mg2+, Ca2+ and Al3+ solutions at different synchrotron facilities with a combination of coincident electron detection and liquid microjets.

[1] E. Alizadeh et al., Biomolecular damage induced by ionizing radiation: the direct and indirect effects of low-energy electrons on DNA. Annu Rev Phys Chem. 66, 379-398 (2015)
[2] V. Stumpf et al., The role of metal ions in X-ray-induced photochemistry. Nat. Chem. 8, 237-241 (2016)

Dr. Christina Bömer, DESY Hamburg
Visualizing the parametric conversion cone in the x-ray regime

Wavemixing and frequency conversion processes are well known in the optical regime and find their applications throughout a broad field of research and technology. Extending these effects into the x-ray domain remains challenging, however, mainly due to their low conversion efficiencies [1]. Yet, with the ascent of new generation synchrotrons and x-ray free electron lasers (FELs), these processes become progressively accessible. For example, in the process of x-ray parametric down-conversion, an x-ray photon (10 keV) can be converted into an x-ray signal photon at lower energy (10 keV – E) and an idler photon at the corresponding energy difference (E).

In the presented work, we focus specifically on extreme splitting ratios, i.e., the conversion of x-rays into lower energy photons (E at XUV to optical wavelengths). Intriguingly, this nonlinear conversion effect couples predominantly to the valence electrons of the irradiated matter, as Freund [2] noted almost 50 years ago. This selective coupling can be used to image the valence charges with atomic scale resolution – similar to conventional x-ray diffraction. In addition, this diffractive method is spectroscopically sensitive: By selecting the idler energy E accordingly, electronic transitions of the valence charges may be probed. Ultimately, this could provide access to transition charge densities at atomic scale resolution inside the bulk material. As such, parametric conversion could build the foundation of novel spectroscopy and imaging methods, which are selective to valence charges. We present an experimental setup based on bent-crystal x-ray optics, with which we are able to detect the complete parametric down-conversion cone for the first time. We find that this characteristic signature behaves according to (kinematic) predictions. Moreover, we present data for different splitting ratios and materials and compare them to our theoretical framework based on nonrelativistic Quantum electrodynamics [3]. Our new experimental approach to observe nonlinear x-ray conversion thus enables new insights into unexplored light-matter interactions.

[1] Boemer, et al. 'Towards novel probes for valence charges via X-ray optical wave mixing' Faraday Discussions (2021).
[2] Freund, 'Nonlinear X-ray diffraction. Determination of valence electron charge distributions', Chemical Physics Letters, 1972, 12, 583 – 588
[3] Krebs and Rohringer: 'Theory of parametric x-ray optical wavemixing processes', submitted 2021 (arXiv:2104.05838)

Eric Brunner, Albert-Ludwigs-University Freiburg
Many-body coherence and entanglement from randomized correlation measurements

We show that k-point correlation measurements on output of a non-interacting, multimode random unitary allow to quantify the k-particle coherence of $N \geq k$ identical (bosonic or fermionic) particles. We establish a strict monotonic relationship between k-particle coherence, the interference contrast in the experimentally accessible counting statistics, and the degree of the particles' mutual distinguishability, as controlled by their internal degrees of freedom, given separable many-particle input states. Non-separability on input can be unveiled by comparison of correlation measurements of different orders.

Dr. David Busto, Albert-Ludwigs-University Freiburg
Entanglement and decoherence in attosecond photoelectron spectroscopy

Photoelectron spectroscopy is a powerful tool to study the structure and dynamics of matter. While traditional techniques only measure the photoelectron yield, attosecond spectroscopic techniques such as attosecond streaking or reconstruction of attosecond beating by interference of two-photon transitions (RABBIT) also provide phase information. The interpretation of such measurements often relies on the assumption that the photoelectrons are in a pure state that can be described by a wavefunction. However, in some cases, as a result of entanglement between different degrees of freedom of the system ion+electron, the reduced density matrix of the photoelectron is in a mixed state. I will present RABBIT measurements in the vicinity of Fano resonances. We observe that, due to coupling between different resonances, the radial and angular degrees of freedom of the wavepacket are entangled, leading to a dynamic loss of purity of the photoelectron in angle-integrated measurements. I will then present a new interferometric method allowing to tomographically reconstruct the reduced density matrix of the photoelectrons.

Clément Canard, Albert-Ludwigs-University Freiburg
Simulating curved spacetimes using discrete quantum Hamiltonians

The application of quantum field theory to curved spacetimes allows for the prediction of fascinating phenomena, the most famous of them being Hawking radiation [1]. However these are in general hardly accessible for direct observation. For this reason, analogue models (e.g. acoustic black holes [2,3]) provide an interesting alternative to experimentally address these features. In this direction and following recent work by Yang *et al.* [4], we investigate the mapping of quantum wave equations in curved spacetime onto non-relativistic lattice models. Beyond the mapping, we aim to witness signatures of the original curvature through site-dependent couplings. This may establish an analogue for the horizon of the metric in consideration and a means to probe its dynamical behaviour.

[1] S. Hawking, "Particle Creation by Black Holes." Commun. math. Phys. 43, 199 (1975).
[2] W. G. Unruh, "Experimental Black-Hole Evaporation?", Phys. Rev. Lett. 46, 1351 (1981).
[3] J. R. M. de Nova *et al.*, "Observation of Thermal Hawking Radiation and Its Temperature in an Analogue Black Hole", Nature 569, 688–691 (2019).
[4] R.-Q. Yang *et al.*, "Simulating quantum field theory in curved spacetime with quantum many-body systems", Phys. Rev. Res. 2, 023107 (2020).

Dr. Giovanni Cerchiari, University of Innsbruck
Self-homodyne detection of trapped ions's motion

The study of levitated dipolar scatterers is a growing field in physics that promises to uncover the connection between quantum mechanics and gravity, to access the QED forces exert on atoms by external boundary conditions and to deliver future devices for ultra-precise force sensing.
We investigated a self-homodyne method to measure the position of these scatterers and tested it with trapped ions and trapped silica nanoparticles. The setup splits the solid angle surrounding the scatterer into two regions. From one side a spherical mirror is used to produces an image of the dipolar scatterer, which interferes with the primary emitted field on the opposite side. This configuration realizes the self-homodyne of the emitted field by self-interfering each emitted photon. Self-interference allows controlling the SE of the scatterer while obtaining superior mode-matching of the radiation fields for homodyne detection.

The new method is suitable to detect the motion of dipolar scatterers such as atoms and nanoparticles without requiring the existence of a complex electronic structure.

In this contribution, I will present the theoretical description of the detection method and our recent results of experiments performed with trapped atomic ions and trapped nanoparticles.

Stasis Chuchurka, DESY Hamburg
Stochastic methodology for light-matter interaction

Quantum mechanics has many interpretations aiming for a clear qualitative description of studied phenomena and cheap numerical simulations. A good example is the replacement of the density matrix for a bosonic system with a quasi-probability distribution [1]. If the studied process involves two-particle interaction, the equation for the quasi-probability distribution becomes a Fokker-Planck equation which allows sampling with stochastic Ito equations. There are various attempts to generalize this approach for fermions [2] or two-level atoms interacting with light [3]. However, the derivations typically require a lot of approximations and do not allow simple expansion to realistic conditions.

[1] Drummond, P. D., Hillery, M. (2009). The Quantum Theory of Nonlinear Optics. Cambridge University Press. https://doi.org/10.1017/cbo9780511783616
[2] Dalton, B. J., Jeffers, J., Barnett, S. M. (2016). Grassmann phase space methods for fermions. I. Mode theory. Annals of Physics, 370, 12–66. https://doi.org/10.1016/j.aop.2016.03.006
[3] Drummond, P. D., Raymer, M. G. (1991). Quantum theory of propagation of nonclassical radiation in a near-resonant medium. Physical Review A, 44(3), 2072–2085. https://doi.org/10.1103/physreva.44.2072
[4] Gross, M., Haroche, S. (1982). Superradiance: An essay on the theory of collective spontaneous emission. Physics Reports, 93(5), 301–396. https://doi.org/10.1016/0370-1573(82)90102-8

Dr. Giorgio Ciliberto, Albert-Ludwigs-University Freiburg
Analogue Hawking radiation in Analogue Black-Holes (Bose-Einstein condensates)

In an acoustic analogue system, as the ones obtained in Bose-Einstein condensates, a transonic fluid flow (i.e. a flow which is supersonic in a region of space, and subsonic elsewhere) is experimentally realized in order to model a gravitational black hole. Quantum fluctuations of the sound field induce emission of Hawking quanta away from the acoustic horizon. This radiation is correlated to a "partner" which falls inside the analogous black hole. This is why studying this phenomenon in Bose-Einstein condensates (BECs) allows for a better understanding of multipartite entanglement and information transport. The topic therefore belongs to the very active and stimulating area of research called "quantum simulators".

I will briefly present analogue black-holes in BECs and introduce the main questions (back-reaction and information transport) that are the current topics of my PhD research.

Alessandra Colla, Albert-Ludwigs-University Freiburg
Exact approach to strong-coupling quantum thermodynamics in open systems.

The formulation of a solid and consistent thermodynamic theory in the quantum regime has proven to be extremely challenging. Particularly in the case of strong system-reservoir interactions, agreement on how to properly define thermodynamic quantities such as work, heat, and entropy production has yet to be reached. Using the exact time-local quantum master equation for the reduced open system states, we develop an exact theory describing the thermodynamical behaviour of open quantum systems coupled to thermal baths [1]. We define an effective energy operator for the reduced system using a recent principle of minimal dissipation, which gives a unique prescription for decomposing the master equation into a Hamiltonian part (coherent evolution) and a dissipator part (decoherence). From this, we derive the first two laws of thermodynamics and investigate the relationship between violations of the second law and quantum non-Markovianity.

[1] A. Colla and H.-P. Breuer, arXiv:2109.11893 [quant-ph] (2021)

Dr. Christoph Dittel, Albert-Ludwigs-University Freiburg
Monogamy in the symmetry of many-body quantum states
TBA

Dr. Jonathan Dubois, Max-Planck-Institute for the Physics of Complex Systems Dresden
Phase space perspective of long-timescale non-stationary dynamics
Open quantum systems naturally relax to an equilibrium steady state. Once it has reached its steady state, the expectation value of observables is constant in time. Recently, it has been shown that there exist quantum conditions under which such systems exhibit non-stationary dynamics -or persistent oscillations- even at long-timescales, i.e., on timescales much longer than the relaxation timescale of the system. These conditions are global and require the determination of a ladder operator.

Here, we use the Moyal formalism and its semiclassical limit to study these conditions in phase space. We derive local necessary conditions for observing non-stationary long-timescale dynamics in open systems. We show that they also apply to near-integrable systems, where the system exhibits chaos in some regions of phase space.

Dr. Matthew Eiles, Max-Planck-Institute for the Physics of Complex Systems Dresden
Coherent delocalized states in ultracold Rydberg gases
The long-range dipole-dipole interaction can create delocalized states due to the exchange of excitation between Rydberg atoms. We show that even in a random gas many of the single-exciton eigenstates are surprisingly delocalized, composed of roughly one quarter of the participating atoms. We identify two different types of eigenstates, one which stems from strongly-interacting clusters and one which extends over large delocalized networks, and show how to excite and distinguish them via appropriately tuned microwave pulses. The extent of delocalization can be enhanced by degeneracies in the atomic states and can be controllably lifted by a magnetic field.

Janine Franz, Albert-Ludwigs-University Freiburg
Chiral resonant energy transfer in a medium

It has been shown that resonance energy transfer between chiral molecules can be used to discriminate enantiomers (1): the transfer rate between two molecules of the same handedness is slightly different from that between molecules of opposite chirality. Using macroscopic quantum electrodynamics, we can study how to enhance this effect by means of an intervening medium and hence propose a distinct but related way to discriminate between enantiomers by using a medium with known chirality. However, when embedding a donor or acceptor molecule in a macroscopic medium, the microscopic structure of the medium close to the embedded molecule needs to be taken into account, which can be achieved using the so-called local-field correction. This turns out to be quite challenging for a chiral medium where contributions from light of opposite circular polarisation need to be distinguished. In this talk I will outline the challenges encountered, propose a possible solution and predict the possible enhancement of the disriminatory power of resonance energy transfer.

[1] D. P. Craig, T. Thirunamachandran, J. Chem. Phys. 109 (1998)

Prof. Dr. Frank Großmann, Technical University Dresden
Strong coupling to a phonon bath enhances adiabatic population transfer

We present a study on the influence of an environmental heat bath on the rapid adiabatic passage scheme for optimal population transfer in a two-level system, originally invented in nuclear magnetic resonance [1].
To cope with strong coupling to an external phonon bath with superohmic spectral density, we are solving the time-dependent Schrödinger equation of the extended system, including a carefully chosen finite number of bath modes, using the multi-Davydov D2-Ansatz [2], which will briefly review. This Ansatz allows for the treatment of the non-Markovian reduced dynamics of the two-level subsystem. We find that strong system-bath coupling stabilizes the transition probability from the lower to the upper level as a function of the area under the laser pulse. This dissipative engineering effect could only be uncovered by a non-Markovian treatment. For strong coupling, the transition probability then becomes a monotonically increasing function of the pulse area at zero temperature of the heat bath. Finite temperatures break the monotonicity in the range of pulse areas that we studied but not the stability of the observed effect.

[1] M. Werther and F. Grossmann, Phys. Rev. A 102, 063710 (2020)
[2] M. Werther and F. Grossmann, Phys. Rev. B 101, 174315 (2020)

Dr. Peilun He, Max-Planck-Institute for Nuclear Physics Heidelberg
Nondipole time delay and double-slit interference in tunneling ionization

Recently two-center interference in a single-photon molecular ionization was employed to observe a zeptosecond time delay due to the photon propagation of the inter-nuclear distance in a molecule [Science 370, 339 (2020)]. We investigate whether the nondipole time delay exists in the tunneling ionization and decode the emerged time delay signal. With the newly developed Coulomb-corrected nondipole molecular strong-field approximation, we derive and analyze the photoelectron momentum distribution, the signature of nondipole effects, and the role of the degeneracy of the molecular orbitals. We show that the momentum shifts efficiently imprint information of the wave function, and its interpretation as a nondipole time delay significantly deviates from that in the single-photon ionization.

In particular, when the two-center interference in the molecule is destructive, the time delay is independent of the bond length. We also re-examine the tunneling ionization of atoms from a nonzero angular momentum state and show that the nondipole momentum shift manifests double-slit interference.

Emilia Heikura, University of Kassel
Mass spectroscopy and triple ion coincidence spectroscopy on argon, xenon and mixed argon-water clusters

Fundamentally clusters are studied since they lay a bridge between the atomic and macroscopic world. The interest of studying rare gas clusters, such as argon and xenon clusters, is that they are relatively easy to produce, and they can be regarded as a prototype for more complex systems. Water compounds are studied due to the water's obvious significance to life. Therefore, mixed argon water clusters are also of high interest in research. Here, the clusters under research are ionized and measured using a time of flight spectrometer. Mass spectra of argon and xenon clusters are measured both as a function of increasing cluster size and as a function of ionization energy. The results show interesting differences between xenon and argon cluster spectra. In addition, on argon clusters triple ion coincidence spectra was measured. Via triple ion coincidence measurements more detailed information about cluster fragmentation is achieved. Mixed argon-water clusters were studied as a function of increasing cluster size. To produce more detailed information about the structures and fragmentation, triple coincidence spectra was measured also for mixed clusters.

Tobias Heldt, Max-Planck-Institut for Nuclear Physics Heidelberg
Towards cavity-enhanced non-linear nuclear excitation of thorium-229

The first excited nuclear state of thorium-229 has a uniquely low energy of 8 eV [1], which allows in principle an excitation with vacuum ultraviolet light (VUV). Due to the long radiative lifetime, this narrow transition could be the basis of a nuclear optical clock [2], which promises high accuracy and potentially high sensitivity to the variation of fundamental constants. Up to now, the very large uncertainty of the transition energy in the order of 0.1 eV hinders the development of a suitable laser system in the VUV and no direct excitation of the isomer has been demonstrated so far. Here, we propose a technique for non-linear excitation of the 229Th nucleus with a frequency comb in a femtosecond enhancement cavity with additional plasmonic field enhancement. Successful excitation will result in emission of internal conversion electrons, which can be detected for direct frequency comb spectroscopy of the nuclear transition. To cover the full range of the current energy uncertainty, a novel dispersion-compensated multipass-cell has been developed, which can broaden the spectrum and shorten the pulses of the fundamental frequency comb.

[1] L. von der Wense and B. Seiferle, The European Physical Journal A, 56, 277, 2020
[2] E. Peik and C. Tamm, Europhys. Letters, 61, 2, 181-186, 2003.

Dr. Frederic Hummel, Max-Planck-Institute of Physics for Complex Systems Dresden
Precision measurement of negative ion resonances in rubidium

Slow electrons scattering off Alkaline atoms exhibit shape resonances in the P-wave channel that correspond to short lived negative ion states trapped above threshold behind the angular momentum barrier for $L = 1$. The small spin-orbit splitting within the ^3P_J triplet in rubidium prevented a resolved observation in electron scattering experiments. However, a single ultra-cold atom trapped inside the orbit of a Rydberg atom forming an ultra-long-range Rydberg molecule provides an atomic-scale system highly sensitive to electron-neutral scattering and allows extraction of the corresponding scattering parameters [1]. The measurements are based on a unique alignment process of the underlying Rydberg molecules in magnetic fields that is mediated by the spin-orbit coupling of the negative ion [2].

[1] Engel et al. Phys. Rev. Lett. 123, 073003 (2019)
[2] Hummel et al. Phys. Rev. A 99, 023401 (2019)

Dr. Victor Kimberg, KTH Royal Institute of Technology Stockholm
Dynamical phase shift in x-ray absorption and ionization spectra by two delayed x-ray laser fields

We study theoretically x-ray absorption and ionization spectra of an atom or molecule by two coherent x-ray pulses that show a relative phase shift resulting in a time delay of the pulse envelopes. We demonstrate that the phase modulation of the spectra is shifted with respect to the phase oscillation comb of the x-ray double pulse. The reason for this shift is the dynamics of the process defined by the interplay of the delay time, the pulse width, the detuning, and the lifetime of the core-excited state.

Dietrich Krebs, DESY Hamburg
Probing the nonlinear response of valence electrons (theoretically)

Over the past decade, free-electron lasers have been established as x-ray sources of unprecedented intensity. As such, they have enabled studying nonlinear phenomena in the x-ray regime and encourage transferring or extending concepts from conventional nonlinear optics.

Among the multitude of newly accessible processes, x-ray optical wavemixing (XOWM) phenomena are of particular interest. In this talk, I will focus on x-ray optical sum- and difference-frequency generation as well as x-ray parametric down-conversion. All of these processes could provide diffractive imaging capabilities similar to regular x-ray diffraction, yet with additional spectroscopic selectivity that is tuneable via the optical wave. Intriguingly, this selectivity would allow specific probing of valence responses.

In order to explore this potential further, we have derived a theoretical description of the above processes based on non-relativistic QED. I will present this approach and discuss the observable electronic response - illustrating its microscopic reconstruction from nonlinear analogues of crystallographic measurements.

Dr. Matthias Kübel, Friedrich-Schiller-University Jena
Imaging electronic structure variations using photoelectrons

I will present results of time-resolved coincidence experiments on atoms and molecules in intense laser fields. In a first experiment, a spin-orbit wave packet is prepared in the argon cation and probed using strong-field ionization. By isolating the second electron and detecting it in coincidence with the dication, a movie of the evolution of the valence electron density is recorded. In a second experiment, the approach is extended to molecules. Preliminary results on imaging the bond breaking process in H_2^+ will be presented.

Dr. Tim Laarmann, DESY Hamburg
Interferometry on extreme time and wavelength scales

Short-pulse metrology and dynamic studies in the extreme ultraviolet spectral range greatly benefit from interferometric measurements. In recent years my research team developed a Michelson-type all-reflective split-and-delay autocorrelator operating in a quasi-amplitude splitting mode. The common-path interferometer opens up new opportunities for short-wavelength femtosecond and attosecond pulse metrology and dynamic studies on extreme time scales in various research fields. ccc
In my talk I will discuss a few examples from atomic and molecular physics, where the experiments provide information on time-dependent electronic structure.

Fang Liu, Helmholtz-Institute Jena
The Quantitative re-scattering theory for NSDI with elliptically polarized laser beams

We show through simulation that an improved quantitative re- scattering model (QRS) [1] can successfully predict the nonsequential double ionization (NSDI) process by intense elliptically polarized laser pulses. Using the QRS model, we calculate the correlated two-electron and ion momentum distributions of NSDI of Ne exposed to intense elliptically polarized laser pulses with a wavelength of 788 nm at a peak intensity of $5.0 \times 10^{14}\, W/cm^2$.
We analyze the asymmetry in the doubly charged ion momentum spectra that were observed by H. Kang et al. [2] in the transition from linearly to elliptically polarized laser pulses. Our model reproduces their experimental data well. In addition, we find that this ellipticity-dependent asymmetry is due to the drift velocity along the minor axis of the polarization ellipse. It is indicated that the correlated electron momentum distributions along the minor axis provide access to the subcycle dynamics of recollision and distinguish recollisions before and after the zero crossing of the field. Futhermore, our results demonstrate that the NSDI process can be driven by varying the ellipticity.

[1] Z. Chen et at., Phys. Rev. Lett. 79, 033409 (2009).
[2] H. Kang et at., Phys. Rev. Lett. 120, 223204 (2018).

Dr. Črt Lozej, Max-Planck-Institute for Physics of Complex Systems Dresden
Exploring Quantum Chaos and Localization with Quantum Billiards with Quantum Billiards

Billiard systems are ideal test-beds for exploring concepts in classical and quantum chaos. In spite of the simplicity of the dynamics, many interesting dynamical regimes may be realized by considering the correct shape of the billiard table. I will present some recent numerical studies of spectral statistics and eigenfunctions of quantum billiards that explore dynamical localization of chaotic billiard eigenstates. The very efficient scaling method allows us to compute spectral samples of the order of 10^6 levels.

The stadium billiard is rigorously proven to be an ergodic, chaotic system. However, when considering small separation stadia, the intermediate level statistics arise due to dynamical localization. I will present some methodology developed to study localized states in billiards. The billiard states are represented with Poincaré-Husimi functions that serve as a means of defining localization measures in the phase space. Similar approaches could be applied to study dynamical localization in chaotic atomic systems, like for instance hydrogen atoms in strong magnetic fields or atoms with complex nuclei.

Nicola Mayer, Max-Born-Institute Berlin
Imprinting chirality on atoms using synthetic chiral light

Atoms are usually thought of as achiral objects. Yet, it is mathematically possible to construct superpositions of atomic states that are chiral. Here, we show how to excite such superpositions using light that is chiral in the dipole approximation. We use TDSE simulations to demonstrate the creation of a time-dependent chiral wavepacket in sodium atoms. We also show how the time-dependent handedness of this wavepacket can be probed by photoelectron circular dichroism. Finally, we use TDSE simulations to show how chirality can be directly imprinted on a photoelectron wavepacket created by a strong chiral field and introduce a chiral measure that allows us to characterize the handedness of the photo-electron wavepacket and the chiral field used for its generation.

Björn Minneker, Friedrich-Schiller-University Jena
Torus-knot angular momentum in high harmonic generation by bicircular Laguerre Gaussian beams

We provide a model which intuitively demonstrates the conservation of the torus-knot angular momentum (TKAM) in bicircular high-harmonic generation and describes where it maid be found within the process. Therefore, our model approach has a well-defined geometrical interpretation alongside the mathematical one. In particular, we demonstrate how the invariance parameters of the TKAM, τ, and γ, can be read from the spatial and temporal evolution of the high harmonic radiation. In addition, we discuss the relationship between both invariance parameters and demonstrate it within our geometrical approach. In the end, our model approach describes the different features of TKAM in bicircular high harmonic radiation and delivers a geometrical interpretation that is closely related to the underlying mathematics.

Niklas Neubrand, Albert-Ludwigs-University Freiburg
First detection time statistics of many partially distinguishable particles

We show how partial distinguishability between many identical bosons or fermions impacts the first detection time statistics after the particles' coherent evolution on a finite lattice. To this end, we generalize the formalism of stroboscopic projective measurements from the single-particle to the many-particle domain, and present numerical results for two non-interacting particles evolving on a one-dimensional lattice. We observe clear signatures of the particles' indistinguishability in the total detection probability and the first detection time. For particular evolution times between consecutive measurements, we find a discontinuous behavior of these quantities, which can be understood through degeneracies of the corresponding many-particle unitary evolution operator.

Jan-Hendrik Oelmann, Max-Planck-Institute for Nuclear Physics Heidelberg
Multiphoton studies and XUV comb generation at 100 MHz

To perform precision spectroscopy of cold highly charged ions (HCI) in the extreme ultraviolet (XUV), we have built an XUV frequency comb by transferring the coherence and stability of a near-infrared frequency comb to the XUV by means of high-harmonic generation (HHG) [1, 2]. Amplified femtosecond pulses from a 100 MHz near-infrared frequency comb are fed into an astigmatism-compensated femtosecond enhancement cavity inside an ultra-high vacuum chamber. In this cavity, consecutive pulses are coherently superimposed and intensities of $10^{14}\,W/cm^2$ are reached in the focus region. High harmonics up to the 35^{th} order (corresponding to 42 eV; 30 nm) are generated inside a gas jet and coupled out of the cavity [3]. This XUV light will be guided to trapped and sympathetically cooled highly charged ions [4, 5] in a superconducting Paul trap to perform direct XUV frequency comb spectroscopy.

At lower intensities ($10^{12}\,W/cm^2$), electron-energy spectra are collected by an intra-cavity velocity map imaging (VMI) spectrometer at rates several orders of magnitude higher than those of conventional high pulse energy laser systems [6]. Consequently, we can investigate rare events, while keeping acquisition times experimentally manageable. The coherence of the frequency comb laser pulses is transferred to the photoelectrons by the actively stabilized cavity. In a first experiment, we used the same enhancement cavity, which is now used for HHG. A novel polarization insensitive enhancement cavity enables polarization shaping of the incoming pulses, allowing tomographic reconstruction of photoelectron angular distributions [7]. Additionally, pulses are fed from both directions in the ring cavity enabling studies of strong field effects in standing waves. Furthermore, pulses in one propagation direction can be split into two pulses with variable intensity, delay and polarization permitting versatile (pump-probe) experiments.

[1] C. Gohle et al., Nature 436, 234-237 (2005).
[2] G. Porat et al., Nat. Photon 12, 387 - 391 (2018).
[3] J. Nauta et al., Opt. Express 29, 2624 - 2636 (2021).
[4] L. Schmöger et al., Science 347, 1233 (2015).
[5] P. Micke et al., Nature 578, 60–65 (2020).
[6] J. Nauta et al., Opt. Lett. 45(8), 2156-2159 (2020).
[7] D. Pengel et al., Phys. Rev. A 96(4) (2017).

Sophia Marie Ohnemus, Albert-Ludwigs-University Freiburg
Multiparticle Concurrence from Randomized Measurements

We investigate how multiparticle entanglement, a as relevant figure of merit for the characterization of multiparticle quantum states, can be measured on real quantum devices. To do so, we focus on methods based on randomized measurements which allow to extract correlation properties of the underlying states statistically via measurements in randomly selected local bases. In particular, we show how the multiparticle concurrence, a measure for multiparticle entanglement, can be obtained from second moments of these randomized measurements. Moreover, we analyze in detail the measurement resources required for estimating the multiparticle concurrence from randomized measurements, by exploiting numerical and analytical tools.

Dr. Natalia Oreshkina, Max-Planck-Institute for Nuclear Physics Heidelberg
"Photon-bridge" effect in the new-physics contributions to the energy levels in simple ions

The influence of hypothetical new interactions beyond the standard model on atomic spectra has attracted recent interest. In the present work, interelectronic photon-exchange corrections and radiative quantum electrodynamic corrections to the hypothetical contribution to the energy levels of few-electron ions from a new interaction are calculated. The ground states of H-like, Li-like, and B-like ions are considered, as motivated by proposals to use isotope shift spectroscopy of few-electron ions in order to set stringent constraints on hypothetical new interactions. It is shown that, for light Li-like and B-like ions, photon-exchange corrections are comparable to or even larger than, by up to several orders of magnitude, the leading one-electron contribution from the new interaction, when the latter is mediated by heavy bosons.

Shahram Panahiyan, Max-Planck-Institute for the Structure and Dynamics of Matter Hamburg
Two-photon absorption measurements in nonlinear interferometers

Nonlinear optics combined with non-classical sources of light has many potential applications in spectroscopy and metrology Schlawin. In this regard, we study the measurement of two-photon absorption cross sections of molecules Munoz in a nonlinear SU(1,1)-interferometer Chekhova. An SU(1,1)-interferometer is composed of two optical parametric amplifiers which are used to squeeze and (re-)un-squeeze an input state of light. This setup has proven very successful for phase estimation applications, and here we investigate its usefulness for spectroscopic applications, when a sample is placed in between the two parametric amplifiers.

A fundamental problem in the measurement of two-photon absorption is the inevitable presence of single photon losses, which can reduce the achievable measurement precision. To address this issue, we consider two sources of photon losses in our model: I) single-photon scattering originating from interaction with the sample (η_1), and II) imperfect detectors (η_2). To quantify the influences of these sources of photon loss, we investigate the sensitivity of the measurement of the expectation value of operators such as the photon number and quadrature measurements Munoz. Furthermore, we also calculate quantum and classical Fisher information and use Cramer-Rao bounds to assess the achievable sensitivity. We find that at large photon numbers ($n_r \gg 1$) for a balanced interferometer, the change of the photon number scales as $\propto \eta_1\eta_2 n_r^3$. The variation of the photon number would scale to $\propto \eta_1^2\eta_2^2 n_r^4$ which consequently results into sensitivity scaling to $\propto n_r^2$ and independent of the photon losses. For the field positions, we find that the change of the anti-squeezed q-quadrature scales as $\propto \sqrt{\eta_1\eta_2} n_r^2$ while its variance scales to $\propto \eta_1\eta_2 n_r^2$ which similarly indicates sensitivity scaling to $\propto n_r^2$.

Lukas Pausch, Albert-Ludwigs-University Freiburg
Chaos in the Bose-Hubbard model versus Gaussian orthogonal and embedded random matrix ensembles

We benchmark spectral and eigenvector statistics of the Bose-Hubbard Hamiltonian against those of the Gaussian orthogonal and the bosonic two-body embedded random matrix ensembles. The latter, in contrast to the Gaussian ensemble, mirrors the few-body nature of interactions and is therefore expected to better approximate chaotic quantum many-particle systems. Within the energy and parameter range where chaos fully unfolds, the expectation value and the eigenstate-to-eigenstate fluctuations of the fractal dimensions of Bose-Hubbard eigenstates show clear signatures of ergodicity and are well described by the two random matrix ensembles. On top, the bosonic embedded ensemble reproduces the energy dependence of the chaotic domain, and the boundaries of the chaotic phase are signalled by an increased asymmetry of the fractal dimension distribution.

Despite the agreement of the three models on the level of the fractal dimensions' lowest-order statistical moments, the models are ever more distinguishable from each other in terms of their full fractal dimension distributions as Hilbert space grows. These results provide evidence of a way to discriminate among different many-body Hamiltonians in the chaotic regime.

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Prof. Dr. Thomas Pfeifer, Max-Planck-Institute for Nuclear Physics Heidelberg
How quickly can we control two-electron states and their entanglement?

Natural quantum systems such as atoms and molecules exhibit correlated ground and excited states. If these correlated states can be turned into entangled states of two spatially separated particles, e.g. to allow subsequent control on each of them, they can turn into building blocks (e.g. quantum bits) of quantum-technological applications. With all current entanglement control operations limited to nanosecond timescales and above, the question arises as to how quickly one can create controlled entangled states.

To address this question, we experimentally observe the hydrogen molecule and it's dissociation into a neutral hydrogen and a proton after removal of one electron. For the latter, we employ a two-color field, composed of an extreme-ultraviolet attosecond-pulse train and a near-infrared laser pulse. Depending on the timing between the two fields, we observe substantial changes in the spatial localization of the bound electron on either one or the other proton with respect to the direction of the other free electron.

An analysis of this experimental observation in a multi-pathway model allowed us to assign the origin of this observation to the interference of at least two dissociation pathways. The wavefunction of the two electrons can be described as a Bell-type state —1,2¿ + exp(-i*phi) —2,1¿, where the phase phi can be controlled by the sub-femtosecond time-delay between the attosecond pulse train and the near-IR-laser field.

Our results show that it is possible to create entanglement from fundamental molecular systems on a femtosecond time scale, which can be controlled by tiny (attosecond time scale) variations of electric fields.

Prof. Dr. Maria Novella Piancastelli, Sorbonne University Paris
The photochemical ring-opening reaction of 1,3-cyclohexadiene: complex dynamical evolution of the reactive state

The photochemically induced ring-opening isomerization reaction of 1,3-cyclohexadiene (CHD) to 1,3,5-hexatriene (HT) is a textbook example of a pericyclic reaction, and has been amply investigated with advanced spectroscopic techniques. The generally accepted description of the isomerization pathway starts with a valence excitation to the lowest-lying bright state, followed by a passage through a conical intersection to a dark doubly excited state, and finally a branching between either the return to the ground state of the cyclic molecule or the actual ring-opening reaction leading to the open-chain isomer. It was traditionally assumed that the dark reactive state corresponds to the second excited state of CHD at the Franck-Condon geometry. Here in a joint experimental and computational effort we demonstrate that the evolution of the excitation-deexcitation process is much more complex than usually described. In particular, we show that an initially high-lying electronic state smoothly decreasing in energy along the reaction path plays a key role in the ring-opening reaction. The conceptual basis of our work is that the dynamics to consider here is determined by diabatic states, whose populations are the ones closely related to the observed photoelectron signal.

Yulong Qiao, Technical University of Dresden
Dynamics of SU(M) coherent state in optical lattice

We propose a variational approach to the dynamics of Bose-Hubbard model based on SU(M) coherent state. In contrast to the normal coherent state, our selected variational family can preserve the number of particles and also allow us to go beyond the mean-filed approximation. The numerical results show that the SU(M) coherent state is a suited ansatz for the dynamics of condensed states in shallow lattices.

Shreyas Ramakrishna, Friedrich-Schiller-University Jena
Excitation of atoms by vector twisted light beams

The photo-excitation of atoms with a single valence electron by cylindrically polarized Laguerre-Gaussian beams is analyzed within the framework of first-order perturbation theory. For cylindrically polarized Laguerre-Gaussian beams, we show that the magnetic components of the electric-quadrupole field varies significantly in the beam cross-section with beam waist and radial distance from the beam axis. Furthermore, we discuss the influence of varying magnetic components of the electric-quadrupole field in the beam cross-section on the sub-level population of a localized atomic target. In addition, we calculate the total excitation rate of electric quadrupole transition (4s $^2S_{1/2}$ - 3d $^2D_{5/2}$) in a mesoscopic target of Ca^+ ion. Our calculation shows that the cylindrically polarized Laguerre-Gaussian beams are more efficient in driving electric quadrupole transition in the mesoscopic atomic target than circularly polarized beams.

Prof. Dr. Nina Rohringer, DESY Hamburg
Hybridized states of extreme ultraviolet light and matter in the light of nonlinear x-ray scattering

Polaritons — hybridized states between light and matter — are quasiparticles that can be interpreted as photons that are dressed by a matter excitations and are usually discussed in the realm of strong light-matter coupling regime. Experimentally, this strong coupling regime is realized in a variety of set ups, ranging from atomic gases, to semiconductors enclosed in cavities. Strong light coupling can, however, also be achieved by light propagating through bulk matter with a frequency close to electronic transition energies. In the weak coupling regime, light and matter are treated as independent objects. If a photon is absorbed, the underlying electronic system undergoes an excitation. The excited state, however, is linked to an optical polarization, emitting an electromagnetic field that mixes with the incident electromagentic field. This mixed state of the electromagnetic field with the material polarization wave turns out to be quantized and thus can exchange energy with the photon field in vacuum only by integer numbers of its fundamental energy quantum - the polariton.

In our recent experiments of x-ray parametric down conversion (XPDC) in diamond samples into pairs of x-ray and extreme ultraviolet (EUV) photons, the peculiarities of our experimentally determined nonlinear x-ray scattering signals can be interpreted in terms of EUV polaritons in the bulk system. I will present a simple polariton model that in conjunction with our quantum electrodynamics theory of x-ray optical wave mixing qualitatively explains the findings of our experiment. The model motivates that by momentum-resolved nonlinear x-ray scattering, microscopic properties of these light-matter quasiparticles and its dispersion relation can be mapped out. Furthermore, by nonlinear x-ray scattering spatial characteristics of polaritons can be resolved on the scale of the x-ray wavelength.

Daniele Ronchetti, DESY Hamburg
X-ray diffraction from population inverted atoms

The advent of XFELs opened the path towards ways of controlling x-ray emission and exploring nonlinear and collective emission phenomena. Exploiting the intense x-ray radiation produced by FELs and building up on well consolidated effects such as x-ray lasing and x-ray superfluorescence in the soft [1] and hard [2] x-ray spectral domain we aim at investigate ways of controlling the elastic x-ray scattering response of individual atoms into crystals. Similarly to seeded x-ray stimulated emission, this is achieved by a two-color x-ray pump-probe scheme: the pump pulse prepares atoms in a state of population inversion between inner-shell levels by ionization of an inner electronic state. The probe pulse, tuned on the appropriate inner-shell transition, experiences strong resonant elastic scattering. Under favourable conditions, the atomic scattering factor can reach values few hundreds times larger compared to the unpumped atom. In this way, the scattering properties of an element specific sub-ensemble of the crystal can be controlled.

By means of this technique period 4 elements can be converted to scatterers with a large value of imaginary part of the anomalous dispersion correction, thus enabling high-resolution reference-free crystallographic structure solution for the phasing problem without the need for heavy-atom replacement.

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Emanuele Rossi, DESY Hamburg
Non-linear X-Ray spectroscopy as a tool for studying ultrafast chemical reactions

Ultrafast chemical reactions such as intramolecular charge transfer, can be described as the time evolution of a valence-electron wave-packet (WP). The reconstruction of the properties of the WP requires a pump-probe technique which allows to launch the WP on a specific atom within the molecular sample and probe its evolution on the attosecond time scale.A candidate technique for the element specific launch of a coherent WP is Stimulated Resonant Inelastic X-Ray Scattering (SRIXS). In my contribution i'll present my results on the theoretical description of the WP launched by SRIXS and discuss ideas and challenges behind the experimental observation of the time evolution of the launched WP.

Prof. Dr. Jan Michael Rost, Max-Planck-Institute for Physics of Complex Systems Dresden
Ultrashort laser-driven dynamics of massless Dirac electrons generating valley polarization in graphene

We identify and describe how intense short light pulses couple to massless Dirac fermions in two-dimensional systems. The ensuing excitation dynamics exhibits unusual scaling with the wavelength of the light due the linear dispersion of the band structure and the fact that light coupling is efficient only close to the Dirac points. We exploit these features to achieve valley polarization of more than 70% with simple pulse shapes. Quantitative results are given for pristine graphene.

Prof. Dr. Krzysztof Sacha, Jagiellonian University Kraków
Topologically protected localization of a Rydberg electron on a Kepler orbit

We show that it is possible to drive a Rydberg atom by a microwave field so that the electron is represented by a localized wave packet moving along a Kepler orbit and this phenomenon is protected by topology. The same mechanism can be used to create bound states of a pair of atoms which we dub topological molecules.

Prof. Dr. Horst Schmidt-Böcking, Goethe-University Frankfurt
One hundred years ago Alfred Landé unraveled the mystery of the Anomalous Zeeman Effect

In order to commemorate Alfred Landé's unraveling of the anomalous Zeeman Effect a century ago, we reconstruct his seminal contribution to atomic physics in light of the atomic models available at the time. Landé recognized that the coupling of quantized electronic angular momenta (called Drall in German) via their vector addition within an atom was the source of all the apparent mysteries of atomic structure. We show to which extent Landé's ideas influenced the development of quantum physics, particularly Wolfgang Pauli's path to the exclusion principle. We conclude with Landé's brief curriculum vitae.

Prof. Dr. Reinhold Schuch, Stockholm University
Extremely Short Times and Binding Energy "Snaphots" in Atomic Collisions

Transient molecule-like states are formed in heavy-ion (Z1) atom (Z2) collisions for extremely short times of typically 100 zs with atomic binding energies reaching the united atom limit (Z1 + Z2= Zua). Inner-shell vacancies in such a system can be marked and their decay by emitting X rays measured. By an experimental trick, interferences from such collisions can be detected and times of photon emission with the corresponding binding energies can be deduced[1,2]. These studies were nourished by the goal to "see" superheavy atoms Zua ¿ 1 and follow the diving of the strongest bound molecular state (1s) into the negative energy continuum. New activities in this area started now with the upcoming FAIR machines in Darmstadt.

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Prof. Dr. Marc Simon, Sorbonne University Paris
Double Core Hole dynamics on isolated Atoms and Molecules

Double Core Hole states of Atoms and Molecules is attracting Physicist since several decades because they have very short core-hole lifetimes, exhibit large chemical shifts and are extremely dissociative. I will show how photoemission using synchrotron radiation can give rich information on their spectroscopy [1].

I will show recent results measured at the SQS beamline of European XFEL on Double Core Hole H2O molecule illustrating the photoionization and nuclear dynamics.

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Romain Soguel, Helmholtz-Institute Jena
From single-particle picture to many electron QED

The redefined vacuum approach, which is frequently employed in the many-body perturbation theory, proved to be a powerful tool for formula derivation. Here, we elaborate this approach within the bound-state QED perturbation theory. In addition to general formulation, we consider the particular example of a single particle (electron or vacancy) excitation with respect to the redefined vacuum. Starting with simple one-electron QED diagrams, we deduce first- and second-order many-electron contributions: screened self-energy, screened vacuum polarization, one-photon exchange, and two-photon exchange. The redefined vacuum approach provides a straightforward and streamlined derivation and facilitates its application to any electronic configuration. Moreover, based on the gauge invariance of the one-electron diagrams, we can identify various gauge-invariant subsets within derived many-electron QED contributions.

The employment of the redefined vacuum approach allowed us to identify the gauge-invariant subsets, within the two-photon-exchange diagrams, at two- and three-electron diagrams and separate between the direct and exchange contributions at two-electron graphs. The gauge invariance of found subsets is demonstrated both analytically (for an arbitrary state) as well as numerically for 2s, 2p1/2, and 2p3/2 valence electron in Li-like ions.

Vladislav Sukharnikov, DESY Hamburg
Second quantization of an open quantum system in Liouville space

One of the most major challenges in theoretical physics is the description of interacting many-body quantum systems. A typical example is an ensemble of atoms interacting with a quantized field. Many applications require the inclusion of decoherence by coupling to the environment — a reservoir with infinitely many degrees of freedom. Thus, we have an intractable problem of modelling an open quantum many-body system with a large number of degrees of freedom.

Imposing a permutation invariance of atoms reduces the complexity of the problem. Commonly, the second quantization takes advantage of permutation symmetry and provides an efficient tool for analysis. However, the dissipation obstructs canonical quantization and generally breaks down the traditional second quantization. Thus, a proper extension of the concept of second quantization to open quantum systems is required.

In this talk, we discuss the second quantization of open quantum systems in the context of light-matter interactions. Nonetheless, our considerations are general and applicable to a variety of problems. We directly perform the second quantization in the Liouville space of density matrices. The only assumption is the conservation of the number of particles. We present the main features of our formalism: occupation number basis for density matrices and bosonic superoperators acting on them. We demonstrate the possible applications of formalism and show it to be a powerful and intuitive tool for the analytical and numerical analysis of various quantum master equations.

Evaldas Svirplys, Max-Born-Institute Berlin

High-harmonic generation in a strongly overdriven regime

High-harmonic generation (HHG) in gases is a well-established technique for generating extreme-ultraviolet (XUV) pulses for which good phase matching between the driving and generated XUV pulses is crucial [0]. This necessitates careful tuning of many system parameters such as gas pressure, medium length, laser intensity, etc. [0, 0]. Here, I will present a novel HHG scheme that shows self-regulation of the driving laser intensity and may be defined as strongly overdriven regime. This setup is similar to a compact intense XUV setup that was recently demonstrated [0]. Near-infrared (NIR) laser pulses are focused into a high-pressure atomic jet, leading to intensities of about 10^{16} W/cm^2, which is much higher than the optimal intensity for HHG. Substantial Spectral and spatial reshaping of the driving NIR 50-fs laser pulse was observed in each atomic species investigated (Xe, Kr, Ar, Ne, He), resulting in the observation of a ten-fold increase of the initial NIR bandwidth. Our experimental and numerical study shows that ionization-induced self-phase modulation is responsible for the spectral broadening, while plasma-induced defocusing results in a substantial decrease and self-regulation of the NIR intensity. This allows for the build-up of phase-matched HHG and results in the generation of continuous spectra ranging from 18-140 eV albeit using long driving laser pulses. This flexible and compact HHG scheme is ideally suited for absorption spectroscopy, allowing to access different spectral ranges without the need for tedious optimization procedures.

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Sebastian Ulbricht, Physikalisch-Technische Bundesanstalt Braunschweig

Non-idealized measurement of a quantum system with a classical apparatus

In modern quantum mechanics, we use an efficient but highly idealized formalism to theoretically describe the measurement of quantum systems. For instance, it is common to identify the measuring device and the property to be measured, and to express both in terms of operators acting on the initial quantum state. After interaction with the measuring device, the quantum system is then in the operator eigenstate corresponding to the operator eigenvalue that represents the measurement result. In a real measurement, however, things are not so idealized: The preparation of the quantum system as well as the initial conditions for the measuring device are limited by uncertainties and the measurement requires finite time. In addition, the measuring instrument is often a macroscopic apparatus, which we would like to describe within the framework of classical physics. However, a consistent theoretical description of interacting classical and quantum systems is a highly nontrivial task.

In this talk we use the formalism of ensembles on configurations space to describe a classical apparatus measuring the position of a delocalized quantum particle. The observation of the classical apparatus after interaction provides all the information needed to update the probability density of the quantum system. This update, i.e. the collapse of the wave function, gives the location and uncertainty of the quantum particle after measurement in functional dependence on the initial uncertainty and the measured location of the pointer of the classical apparatus. Furthermore, we are able to keep track of the uncertainties that are necessarily present during the measurement process.

Dr. Christopher Wächtler, Max-Planck-Institute for Physics of Complex Systems Dresden
Topological synchronization of coupled Van der Pol oscillators

When systems are coupled to external reservoirs a variety of phenomena with no counterpart in closed systems may be observed. One of these is synchronization, which is a hallmark of collective behavior in nonequilibrium systems. However, unavoidable defects, local deformations caused by ambient conditions as well as long-term degradation can have a large impact on the collective behavior or even destroy the synchronicity altogether. Especially at the nanoscale, it is desirable to investigate universal principles to enhance the robustness of synchronization. On the other hand, the application of topology has become an integral part in condensed matter physics leading to the discovery of phases characterized by global invariants rather than by local order parameters. These new phases of matter exhibit an unusual robustness to the adverse effects of impurities and defects. In this talk, we will show a possible route towards integrating topological concepts with nonlinear, open system dynamics. By adjusting the coupling in a network of Van der Pol oscillators, we realize topological models like the Sue-Schrieffer-Heeger chain or a kagome lattice. In the resulting systems, signatures of the underlying topology emerge as different synchronization mechanism between the bulk and the edges. Moreover, the synchronized edge states are topologically protected against local disorder demonstrating the availability of topological features even under open system conditions far away from equilibrium.

Prof. Dr. Matthias Wollenhaupt, Carl-von-Ossietzky-University Oldenburg
Multichromatic Photoelectron Vortices

Photoelectron vortices have received much attention in the last couple of years [1-3]. Experimental results on the generation and manipulation of photoelectron vortices by multiphoton ionization (MPI) have been reviewed recently in [4,5]. In our experiments, we combine supercontinuum polarization pulse shaping with high-resolution photoelectron tomography to map the atomic MPI dynamics. Recently, we have extended our previous scheme towards multichromatic polarization shaping. In this presentation, we discuss the physical mechanisms of the properties of multicolor free electron vortices and introduce a holographic method for extracting the phases in the photoelectron spectra [6,7].

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Weiyu Zhang, Max-Planck-Institute for Nuclear Physics Heidelberg
Fragmentation of CH4 in shaped laser fields

Ultrashort laser pulses are widely used to probe the dynamics of atoms and molecules. An intuitive and accessible way to control the laser pulses is always wanted. Limited by the electronic speed, temporal pulse shaping cannot be applied directly. Here, with the spatial liquid modulator, we exhibit one flexible and reliable way to compress and shape pulse. In this talk, the spectral Fourier setup will be introduced. Within the freedom to give and change pulse through amplitude, phase, and polarization, it is possible to better resolve dynamics. Here, we combine the pulse shaper with the Reaction Microscope (REMI) to carry out the real-time pump-probe measurement for methane. Spatially, the methane molecule is a regular tetrahedron structure, which can be distorted by the external laser field and be broken up into different fragments. Different ionization and dissociation channels are compared and analyzed.