Atomic Physics Division
Fachverband Atomphysik (A)

Marc Vrakking
Max Born Institut für Nichtlineare Optik und Kurzzeit-Spektroskopie
Max Born Strasse 2A
12489 Berlin
marc.vrakking@mbi-berlin.de

Overview of Invited Talks and Sessions

(Lecture rooms N 1, N 2, N3, and HS 20; Poster P OGs)

Invited Talks

A 1.1	Mon	14:30–15:00	HS 20	**Tunable entanglement resource in elastic electron-exchange collisions out of chaotic spin systems** — •Bernd Lohmann, Karl Blum, Burkhard Langer
A 2.1	Mon	14:30–15:00	N 1	**Towards Atomtronic Interferometry** — •Wolf von Klitzing
A 3.1	Mon	14:30–15:00	N 2	**Excited state molecular dynamics: new insights from x-ray spectroscopy and scattering** — •Markus Gühr
A 4.1	Mon	14:30–15:00	N 3	**Bound-electron g factor of highly charged ions** — •Andrey Volotka
A 6.1	Mon	17:00–17:30	HS 20	**Phase-modulated harmonic light spectroscopy** — •Lukas Bruder, Ulrich Bangert, Marcel Binz, Andreas Wituschek, Marcel Mudrich, Frank Stienkemeier
A 6.2	Mon	17:30–18:00	HS 20	**Amplitude and phase control of an atom's optical response** — •Alexander Blättermann, Andreas Kaldun, Veit Stooss, Thomas Ding, Christian Ott, Thomas Pfeifer
A 8.1	Mon	17:00–17:30	N 2	**Angular resolved inner-shell photoionization spectra of randomly oriented and fixed-in-space methane and methyloxirane** — •Philipp Demekhin
A 8.2	Mon	17:30–18:00	N 2	**Circular Dichroism in Multi-Photon Ionization of Oriented Helium Ions** — •Markus Ilchen, Nicolas Douguet, Tommaso Mazza, Klaus Bartschat, Alexei Grum-Grzhimailo, Nikolay Kabachnik, Michael Meyer
A 16.1	Tue	14:30–15:00	N 2	**High-power XUV frequency combs** — •Christoph M. Heyl, Gil Porat, Stephen Schoun, Craig Benko, Nadine Dörre, Kristan L. Corwin, Jun Ye
A 22.1	Wed	14:30–15:00	N 2	**Electron correlation dynamics in weak and strong fields** — •Christian Ott
A 23.1	Wed	14:30–15:00	N 3	**Surface-electrode traps for scalable quantum information processing with atomic ions** — •C. Ospelkaus, H. Hahn, M. Wahnschaffe, G. Zarantonello, T. Dubielzig, S. Grondkowski, J. Morgner, M. Kohnen, A. Bautista-Salvador
A 34.1	Fri	11:00–11:30	N 2	**3d-Photoelectron Momentum Distributions from Multi-Photon Ionization with Ultra Short Polarization-Shaped Laser Pulses** — •Matthias Wollenhaupt
A 35.1	Fri	11:00–11:30	N 3	**The Nanoplasma Oscilloscope** — •Christian Peltz, A. LaForge, B. Langbehn, R. Michiels, C. Callegari, M. Di Fraia, P. Finetti, R. Squibb, C. Svetina, L. Raimondi, M. Manfredda, N. Mahne, P. Piseri, M. Zangrando, L. Giannessi, T. Möller, R. Feifel, K. C. Prince, M. Mudrich, D. Rupp, F. Stienkemeier, T. Fennel
A 37.1	Fri	14:30–15:00	N 1	**Sympathetic cooling of OH- by means of a heavy buffer gas** — •Henry Lopez, Bastian Höltkemeier, Jonas Tauch, Tobias Heldt, Eric Endres, Roland Wester, Matthias Weidemüller
A 39.1	Fri	14:30–15:00	N 3	**Experimental studies of Interatomic Coulombic Decay** — •Till Jahnke

Invited talks of the joint symposium SYDD

See SYDD for the full program of the symposium.

SYDD 1.1	Mon	14:30–15:00	P 1	**Controlling (?) Quantum Dynamics with Open Systems** — •Dieter Meschede
SYDD 1.2	Mon	15:00–15:30	P 1	**Many-body physics of driven, open quantum systems: optically driven Rydberg gases** — •Michael Fleischhauer
SYDD 1.3	Mon	15:30–16:00	P 1	**Theorie getriebener dissipativer Quantensysteme / theory of driven dissipative quantum systems** — •Tobias Brandes
SYDD 1.4	Mon	16:00–16:30	P 1	**Calorimetry of a Bose-Einstein-condensed photon gas** — •Martin Weitz

Invited talks of the joint symposium SYAP

See SYAP for the full program of the symposium.

SYAP 1.1	Tue	11:00–11:30	P 1	**Electrons and ions meet ultracold atoms** — •Herwig Ott
SYAP 1.2	Tue	11:30–12:00	P 1	**Interrogating strongly bound electrons about fundamental physics** — •José R. Creso López-Urrutia
SYAP 1.3	Tue	12:00–12:30	P 1	**Strong-field effects in heavy-ion collisions** — •Andrey Surzhykov, Vladimir Yerokhin, Thomas Stöhlker, Stephan Fritzsche
SYAP 1.4	Tue	12:30–13:00	P 1	**Laser-based high photon flux XUV sources and applications in atomic physics** — •Jan Rothhardt, Robert Klas, Stefan Demmler, Maxim Tschernajew, Jens Limpert, Andreas Tünnermann

Invited talks of the joint symposium SYAD

See SYAM for the full program of the symposium.

SYAD 1.1	Wed	11:00–11:30	RW 1	**Exciton transport in disordered organic systems** — •Franziska Fennel
SYAD 1.2	Wed	11:30–12:00	RW 1	**Quantum dynamics in strongly correlated one-dimensional Bose gases** — •Florian Meinert
SYAD 1.3	Wed	12:00–12:30	RW 1	**Dynamics and correlations of a Bose-Einstein condensate of light** — •Julian Schmitt
SYAD 1.4	Wed	12:30–13:00	RW 1	**Circular dichroism and accumulative polarimetry of chiral femtochemistry** — •Andreas Steinbacher

Invited talks of the joint symposium SYAM

See SYAM for the full program of the symposium.

SYAM 1.1	Thu	11:00–11:30	P 1	**Buffer gas cooling of antiprotonic helium to T=1.5-1.7 K, and the antiproton to electron mass ratio** — •Masaki Hori
SYAM 1.2	Thu	11:30–12:00	P 1	**The BASE Experiment: High-precision comparisons of the fundamental properties of protons and antiprotons** — •C. Smorra, M. Besirli, K. Blaum, M. Bohman, M. J. Borchert, J. Harrington, T. Higuchi, H. Nagahama, Y. Matsuda, A. Mooser, C. Ospelkaus, W. Quint, S. Sellner, G. Schneider, N. Schoen, T. Tanaka, J. Walz, Y. Yamazaki, S. Ulmer
SYAM 1.3	Thu	12:00–12:30	P 1	**Antihydrogen physics at the ALPHA experiment** — •Niels Madsen
SYAM 2.1	Thu	14:30–15:00	P 1	**Muon g-2** — •Klaus Jungmann
SYAM 2.2	Thu	15:00–15:30	P 1	**Antihydrogen physics at ASACUSA and AEGIS** — •Chloé Malbrunot
SYAM 2.3	Thu	15:30–16:00	P 1	**An experiment to measure the anti-hydrogen Lamb shift** — •Paolo Crivelli

Invited talks of the joint symposium SYLG

See SYLG for the full program of the symposium.

SYLG 1.1	Fri	11:00–11:30	P 1	**Quantum Simulation of Lattice Gauge Theories with Cold Atoms and Ions** — •Peter Zoller

SYLG 1.2	Fri	11:30–12:00	P 1	**Quantum Simulations with Cold Trapped Ions** — Esteban A. Martinez, Christine A. Muschik, Philipp Schindler, Daniel Nigg, Alexander Erhard, Markus Heyl, Philipp Hauke, Marcello Dalmonte, Thomas Monz, Peter Zoller, •Rainer Blatt
SYLG 1.3	Fri	12:00–12:30	P 1	**Studies of hot and dense nuclear matter at the Large Hadron Collider** — •Boleslaw Wyslouch
SYLG 1.4	Fri	12:30–13:00	P 1	**Lattice gauge theory beyond QCD** — •Claudio Pica

Sessions

A 1.1–1.7	Mon	14:30–16:30	HS 20	**Collision Experiments**
A 2.1–2.7	Mon	14:30–16:30	N 1	**Ultracold atoms and BEC - I (with Q)**
A 3.1–3.7	Mon	14:30–16:30	N 2	**XUV/X-ray spectroscopy I**
A 4.1–4.7	Mon	14:30–16:30	N 3	**Precision Spectroscopy I**
A 5.1–5.7	Mon	14:30–16:30	P 104	**Precision Measurements and Metrology: Gravity (with Q)**
A 6.1–6.6	Mon	17:00–19:00	HS 20	**Time-resolved spectroscopy**
A 7.1–7.8	Mon	17:00–19:00	N 1	**Ultracold atoms and BEC - II (with Q)**
A 8.1–8.6	Mon	17:00–19:00	N 2	**XUV/X-ray spectroscopy II**
A 9.1–9.8	Mon	17:00–19:00	N 3	**Precision Spectroscopy II**
A 10.1–10.6	Mon	17:00–18:45	N 6	**Diffraction and Coherences (with MO)**
A 11.1–11.8	Mon	17:00–19:00	P 104	**Precision Measurements and Metrology: Optical Clocks (with Q)**
A 12.1–12.7	Tue	11:00–13:00	N 6	**Clusters I (with MO)**
A 13.1–13.8	Tue	11:00–13:00	P 104	**Precision Measurements and Metrology: Interferometry I (with Q)**
A 14.1–14.7	Tue	14:30–16:15	HS 20	**Highly Charged Ions**
A 15.1–15.8	Tue	14:30–16:30	N 1	**Ultracold atoms and BEC - III (with Q)**
A 16.1–16.7	Tue	14:30–16:30	N 2	**XUV/X-ray spectroscopy III**
A 17.1–17.7	Tue	14:30–16:15	N 3	**Rydberg atoms**
A 18.1–18.6	Tue	14:30–16:15	N 6	**Helium Droplets and Systems (with MO)**
A 19.1–19.9	Tue	14:30–16:45	P 104	**Precision Measurements and Metrology: Interferometry II (with Q)**
A 20.1–20.47	Tue	17:00–19:00	P OGs	**Poster Session I**
A 21.1–21.8	Wed	14:30–16:30	N 1	**Ultracold atoms and BEC - IV (with Q)**
A 22.1–22.7	Wed	14:30–16:30	N 2	**Attosecond Science**
A 23.1–23.7	Wed	14:30–16:30	N 3	**Trapped ions**
A 24.1–24.8	Wed	14:30–16:30	P 5	**Laser Development and Applications (Spectroscopy) (with Q)**
A 25.1–25.8	Wed	14:30–16:45	P 104	**Ultracold Plasmas and Rydberg Systems (with Q)**
A 26.1–26.48	Wed	17:00–19:00	P OGs	**Poster Session II**
A 27.1–27.4	Thu	11:00–12:15	P 5	**Laser Applications: Optical Measurement Technology (with Q)**
A 28.1–28.8	Thu	11:00–13:15	P 104	**Ultracold Plasmas, Rydberg Systems and Molecules (with Q)**
A 29.1–29.9	Thu	14:30–16:45	P 5	**Ultrashort Laser Pulses: Generation and Applications (with Q)**
A 30.1–30.7	Thu	14:30–16:30	P 104	**Ultracold Atoms I (with Q)**
A 31.1–31.48	Thu	17:00–19:00	P OGs	**Poster Session III**
A 32.1–32.8	Fri	11:00–13:00	HS 20	**Rydberg gasses I**
A 33.1–33.8	Fri	11:00–13:00	N 1	**Ultracold atoms and BEC - V (with Q)**
A 34.1–34.7	Fri	11:00–13:00	N 2	**Atoms in Strong Fields I**
A 35.1–35.7	Fri	11:00–13:00	N 3	**Clusters II (with MO)**
A 36.1–36.7	Fri	14:30–16:15	HS 20	**Rydberg gasses II**
A 37.1–37.5	Fri	14:30–16:00	N 1	**Ultracold atoms and BEC - VI (with Q)**
A 38.1–38.8	Fri	14:30–16:30	N 2	**Atoms in Strong Fields II**
A 39.1–39.7	Fri	14:30–16:30	N 3	**Clusters III (with MO)**
A 40.1–40.8	Fri	14:30–16:30	P 104	**Ultracold Atoms II (with Q)**

Annual General Meeting of the Atomic Physics Division

Friday 13.15–14.00 N 1

A 1: Collision Experiments

Time: Monday 14:30–16:30 Location: HS 20

Invited Talk A 1.1 Mon 14:30 HS 20

Tunable entanglement resource in elastic electron-exchange collisions out of chaotic spin systems — •Bernd Lohmann[1], Karl Blum[1], and Burkhard Langer[2] — [1]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Straße 9, 48149 Münster, Germany — [2]Physikalische Chemie, Freie Universität Berlin, Takustraße 3, 14195 Berlin, Germany

Elastic collisions between initially unpolarized electrons and hydrogen-like atoms are discussed aiming to analyze the entanglement properties of the correlated final spin system. Explicit spin-dependent interactions are neglected and electron exchange only is taken into account. It is shown that the final spin system is completely characterized by a single spin correlation parameter depending on scattering angle and energy. Its numerical value identifies the final spins of the collision partners to be either in the separable, entangled, or Bell correlated regions.

The symmetry of the scattering process allows for the construction of explicit examples applying methods of classical communication and local operations for illustrating the concepts of nonlocality versus separability.

It is shown that strong correlations can be produced violating Bell*s inequalities significantly. Furthermore, the degree of entanglement can be continuously varied simply by changing either the scattering angle and/or energy. This allows for the generation of tunable spin pairs with any desired degree of entanglement. We suggest to use such nonlocally entangled spin pairs as a resource for further experiments, for example in quantum information processes.

A 1.2 Mon 15:00 HS 20

Commissioning of a high-power electron gun for electron-ion crossed-beams experiments — •Benjamin Ebinger[1], Alexander Borovik Jr.[1], B. Michel Döhring[1], Tobias Molkentin[1], Alfred Müller[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

In an electron-ion crossed-beams experiment, the experimental sensitivity is mainly determined by the densities of both beams in the interaction region. Aiming at the extension of the available range of accessible electron energies and densities, a new high-power electron gun has been developed and built. It delivers a ribbon-shaped beam with high currents at all energies variable between 10 and 3500 eV [1,2]. The expected high electron currents and good beam transmission have already been shown.

Here, we report on the current status of commissioning of this electron gun. The electron gun is integrated into the experimental electron-ion crossed-beams setup in Giessen. Employing the *animated crossed-beams* technique [3], first cross sections for electron-impact ionization of xenon and helium ions were measured. The measurement of more cross sections is intended for the near future. Further investigations concerning, e.g., space-charge effects in the high-density electron beam are currently performed.

[1] Shi et al., Nucl. Instr. Meth. Phys. Res. B 205 (2003) 201-206
[2] Borovik et al., J. Phys.: Conf. Ser. 488 (2014) 142007
[3] Müller et al., J. Phys. B. 18 (1985) 2993-3009

A 1.3 Mon 15:15 HS 20

A new electron beam ion source as charge breeder for rare isotope beams — •Michael A. Blessenohl[1], Stepan Dobrodey[1], Zachary Hockenbery[2], Renate Hubele[1], Thomas Baumann[3], Jens Dilling[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]McGill, Montreal, Canada — [3]European XFEL, Hamburg — [4]TRIUMF, Vancouver, Canada

The 500 MeV cyclotron at TRIUMF bombards heavy-element targets with protons to generate rare isotopes for nuclear physics studies at the post-accelerators ISAC (Isotope Separator and Accelerator) I and II. The new Advanced Rare IsotopE Laboratory (ARIEL) will use a new electron beam ion source (EBIS) for charge breeding of those isotopes. At high charge states, the charge to mass ratio $^{A}/_{Q}$ can stay low, as required by ISAC I and II. For rare isotopes with half-lives down to 65 milliseconds and low abundances of down to 10^6 per bunch, the whole process of injection, charge breeding and extraction has to be as efficient as possible. At bunch repetition rates of 100 Hz fast high-voltage control and switching are needed, with a goal charge breeding efficiency of at least 20 %. We present the design including finite-element and Monte-Carlo simulations results, as well as concepts for both on-line diagnostics and control system.

A 1.4 Mon 15:30 HS 20

Towards ion-atom scattering in the ultracold regime — •Thomas Schmid[1], Christian Veit[1], Nicolas Zuber[1], Thomas Dieterle[1], Robert Löw[1], Tilman Pfau[1], Michal Tarana[2], and Michal Tomza[3] — [1]5th Physical Insitute & Center for Integrated Quantum Science and Technology, University of Suttgart, Stuttgart, Germany — [2]J. Heyrovský Institute of Physical Chemistry of the ASCR, Prague, Czech Republic — [3]Centre of New Technologies, University of Warsaw, Warsaw, Poland

We propose an experiment to extend the investigation of ion-atom collisions from the so far studied cold, but still essentially classical regime covered by hybrid ion-atom-trap experiments [1] to the ultracold, quantum regime. Reaching the quantum scattering regime is made possible, first, by the use of an ion-atom system (in our case $^{87}Rb^{+}$-^{6}Li) with a small reduced mass, and second, by employing a specific type of heteronuclear F-state Rb*-Li Rydberg molecules to initialize the scattering event. We present calculations on this type of heteronuclear Rydberg molecules together with quantum mechanical simulations showing how the initial wave function evolves in the presence of the ion-atom scattering potential. Finally, we outline how quantum scattering features could be extracted experimentally from the scattered wave function.

[1] A. Härter, and J. Hecker Denschlag; *Contemp. Phys.* **55**, 33 (2014).

A 1.5 Mon 15:45 HS 20

Towards Ultracold Li – Ba$^+$ Interactions — •Markus Debatin, Pascal Weckesser, Fabian Thielemann, Yannick Minet, Julian Schmidt, Alexander Lambrecht, Leon Karpa, and Tobias Schaetz — Physikalisches Institut, Universität Freiburg, Germany

Research on the interplay of atoms and ions allows to observe a large variety of interesting physics phenomena [1]. Optical trapping of ions [2] allows to overcome heating effects caused by technical and intrinsic micromotion, which is ubiquitous in Paul traps [3].

We are currently setting a novel experiment targeting ultracold interactions between Ba^+ ions and Li atoms. We give details on our strategy to combine an Ion trap with homogenous mangetic fields required for tuning Li interac- tions and good optical access necessary for optical trapping of Ba + Ions and imaging of both species.

[1] A. Haerter et al., Contemp. Phys., 55, 1, pp. 33-45 (2014).
[2] T. Huber et al., Nat. Comm. 5,5587 (2014).
[3] M.Cetina et al., Phys.Rev.Lett. 109,253201 (2012).

A 1.6 Mon 16:00 HS 20

Setup for studying Li-Yb+ mixtures in the quantum regime — •Henning Fürst[1], Jannis Joger[1], Norman Ewald[1], Thomas Feldker[1], Thomas Secker[2], and René Gerritsma[1] — [1]Institute of Physics, University of Amsterdam, Netherlands — [2]Institute for Coherence and Quantum Technology, TU Eindhoven, Netherlands

Mixtures of trapped atoms and ions form exciting new systems enabling the study of quantum chemistry, ultracold collisions and polaronic physics. Possible applications include sympathetic cooling of ions, ion-assisted detection of atoms and quantum simulation. In the ultracold regime the quantum dynamics of mixtures of fermionic atoms and ions and of fermion-phonon coupling may be studied [1]. We present our setup for realising a hybrid system of trapped Li atoms and Yb+ ions, where the large mass-ratio between ion and atom will allow us to reach the ultracold regime [2]. We discuss overlapping of magnetically trapped atoms with an ion crystal confined in the Paul trap and show first experimental results of atom-ion interactions and prospects for reaching the quantum regime.

[1] U. Bissbort et al., Phys. Rev. Lett. 111, 080501 (2013).
[2] M. Cetina et al., Phys. Rev. Lett. 109, 253201 (2012).

A 1.7 Mon 16:15 HS 20

Effective two-channel model for cold reactive collisions —

•Christian Cop and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

In a previous work experimental data [1] of cold collisions of metastable neon atoms (Ne*) has been analyzed theoretically in terms of a coupled two-channel model with realistic interaction potentials [2]. This model gave good agreement between theory and experiment.

Here we present an effective two-channel square well potential which contains all the features present in the coupled two-channel model of [2]. For the coupled square-well potential, the S matrix is analyzed analytically in the complex k plane. Based on a single pole expansion of the S matrix we derive analytic expressions for the two-body loss rates of the coupled square-well potential. These analytic expressions show good agreement of scattering rates in the coupled square-well model and the model with realistic interaction potentials. Thus, threshold collisions rates can be well approximated by a single pole expansion of an effective two-channel potential theory.

[1] J. Schuetz et al., *Heteronuclear collisions between laser-cooled metastable neon atoms*, Phys. Rev. A, **86**, 022713 (2012).

[2] C. Cop et al., *Penning ionization and elastic scattering in cold collisions of metastable neon atoms*, to be published.

A 2: Ultracold atoms and BEC - I (with Q)

Time: Monday 14:30–16:30 Location: N 1

Invited Talk A 2.1 Mon 14:30 N 1

Towards Atomtronic Interferometry — •Wolf von Klitzing — Institute of Electronic Structure and Laser, FORTH, 71110 Heraklion, Crete, Greece

Atom interferometers are some of the most sensitive instruments available to date. In order to avoid unwanted perturbations, most of the matterwave interferometers use atoms in free fall. This is largely due to the lack of appropriatly coherent matterwave guides. Here, we present a novel Sagnac interferometer based on state-dependent manipulation of atoms in waveguides using time-averaged adiabatic potentials (TAAP) [1,2]. In this clock-type matterwave interferometer the atoms are in different internal states in the two arms of the interferometer and can thus be manipulated nearly independently. In analogy to the magic frequency of the strontium lattice clocks, by carefully tuning the confining potential a magic-field strength can be found such that the linear dependence on the potential vanishes [3].

We will report the use of adiabatic potentials in the creation of ultra-bright atom lasers. And present initial experimental results towards the realization of this interferometer. Most notably the state-dependent manipulation and guiding of the atoms.

[1] P. Navez et al. N.J.Phys. **18**:7 075014 (2016)
[2] I. Lesanovsky and W. von Klitzing PRL **99**:8 083001 (2007)
[3] P. Treutlein et al. PRL **92**:20 203005 (2004)

A 2.2 Mon 15:00 N 1

Towards coherent beam splitting in a TAAP ring atom waveguide — •Hector Mas[1,2], Saurabh Pandey[2,3], Giannis Drougakis[2,3], Patrick Navez[1], Konstantinos Poulios[2], Georgios Vasilakis[2], Thomas Fernholz[4], and Wolf von Klitzing[2] — [1]Department of Physics, University of Crete, Heraklion 70113, Greece — [2]IESL-FORTH, Heraklion 70013, Greece — [3]Department of Materials, Science and Technology, University of Crete, Heraklion 70113 — [4]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom

Trapped atom interferometers are promising candidates for improving the sensitivity of cold atom based sensing devices by means of increasing the interaction time and decreasing the size of the devices. We present progress towards a Sagnac clock type interferometer employing the two hyperfine states (F=1 and F=2) of Rubidium 87 (Rb87) in a state-dependent time averaged adiabatic potential (TAAP) ring shaped waveguide. We report on experimental advances leading to the implementation of the full interferometric sequence with a focus on achieving coherent splitting, guiding and recombination of the atomic cloud inside the waveguide. A number of decoherence processes may arise during the interferometric cycle, e.g. fluctuations in the magnetic fields or rf/microwave excitation. We will introduce and discuss preliminary measurements on both the ring waveguide characterisation and the spectroscopy of cold atoms in TAAP potentials, focusing on the search for a magic frequency that will allow for much improved coherence times.

A 2.3 Mon 15:15 N 1

QUANTUS-2 - Ultra Low Expansion Atomic Source for Matter Wave Interferometry in Extended Free Fall — •Peter Stromberger[1], Alexander Grote[1], Andre Wenzlawski[1], Patrick Windpassinger[1], and the QUANTUS-Team[1,2,3,4,5,6,7] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz — [2]Institut für Physik, Humboldt-Universität zu Berlin — [3]Ferdinand-Braun-Institut, Leibniz Institut für Höchstfrequenztechnik Berlin — [4]Institut für Quantenoptik, Leibniz-Universität Hannover — [5]ZARM, Universität Bremen — [6]Institut für Quantenphysik, Universität Ulm — [7]Institut für angewandte Physik, TU Darmstadt

QUANTUS-2 is a mobile high-flux rubidium BEC source used for experiments under microgravity in the drop tower in Bremen. To further decrease the expansion rate of the BEC, magnetic lensing - also known as delta-kick cooling - is crucial for observations after long evolution times in the range of seconds. Long evolution times are desirable, because the sensitivity of atom interferometers enhances quadratically with the interrogation time. Here we present our results of a lens, which leads to an observability of the BEC of up to 2.7 s after free expansion. This expansion rate is equivalent to an expansion rate of a thermal ensemble with a temperature below 100 pK in all three dimensions.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economic Affairs and Energy under grant numbers DLR 50 WM 1552-1557.

A 2.4 Mon 15:30 N 1

Selfbound quantum droplets — •Matthias Wenzel, Matthias Schmitt, Fabian Böttcher, Carl Bühner, Igor Ferrier-Barbut, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Self-bound many-body systems are formed through a balance of attractive and repulsive forces and occur in many physical scenarios. Liquid droplets are an example of a self-bound system, formed by a balance of the mutual attractive and repulsive forces that derive from different components of the inter-particle potential. On the basis of the recent finding that an unstable bosonic dipolar gas can be stabilized by a repulsive many-body term, it was predicted that three-dimensional self-bound quantum droplets of magnetic atoms should exist.

Here we report on the observation of such droplets, with densities 10^8 times lower than a helium droplet, in a trap-free levitation field. We find that this dilute magnetic quantum liquid requires a minimum, critical number of atoms, below which the liquid evaporates into an expanding gas as a result of the quantum pressure of the individual constituents. Consequently, around this critical atom number we observe an interaction-driven phase transition between a gas and a self-bound liquid in the quantum degenerate regime with ultracold atoms.

A 2.5 Mon 15:45 N 1

Quantum droplets in one-dimensional dipolar Bose-Einstein condensates — •Daniel Edler, Falk Wächtler, and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

Recent experiments on dipolar Bose-Einstein condensates have reported the formation, due to quantum fluctuations, of a novel form of ultra-dilute stable droplets. We will show that in one-dimensional geometries these fluctuations lead to peculiar momentum dependence of the dipole-dipole interactions inducing an anomalous density dependence of the beyond-mean-field corrections. Further we will discussion the density distribution for different system parameters and the behaviour for included three-body losses.

A 2.6 Mon 16:00 N 1

Purity oscillations in coupled Bose-Einstein condensates —

•Jonathan Stysch, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

We investigate the many-body dynamics of two three-mode Bose-Einstein condensates (BECs) forming a six-mode system. Both three-mode subsystems are initially prepared as isolated, fully coherent BECs and are then rendered open systems by coupling them together. The dynamics induced by this coupling leads to a periodic loss and restoration of the coherence in each subsystem which is quantified by the purity of the single-particle density matrices of the respective subsystems. We show that these purity oscillations correspond with oscillations in the average contrast in interference experiments and are therefore linked to a quantity accessible in experiment.

A 2.7 Mon 16:15 N 1

Dynamical Instabilities in Trapped Bose-Einstein Condensates — •Torsten Victor Zache[1], Valentin Kasper[2], and Jürgen Berges[1] — [1]Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg — [2]Physics Department, Harvard University, Cambridge MA 02138, USA

We study the nonlinear phenomenon of secondary instabilities (secondaries), which was proposed in the context of inflationary particle production, with ultracold atom systems. Specifically, we consider a one-dimensional two-component Bose gas that can be realized in different experimental setups and show analytically that it exhibits a primary instability characterized by exponentially growing occupation numbers of certain momentum modes. The primary instability is triggered by initial quantum fluctuations and leads to an amplified occupation of primarily stable modes at later times. We demonstrate the existence of these secondary instabilities in trapped Bose-Einstein condensates numerically employing the classical-statistical approximation. The process underlying the generation of secondaries can be identified with a nonlinear loop correction, which leads to an interpretation in terms of Feynman diagrams and allows us to analytically estimate the secondary growth rates to be integer multiples of the primary one.

A 3: XUV/X-ray spectroscopy I

Time: Monday 14:30–16:30 Location: N 2

Invited Talk A 3.1 Mon 14:30 N 2

Excited state molecular dynamics: new insights from x-ray spectroscopy and scattering — •Markus Gühr — Institut für Physik und Astronomie, Universität Potsdam

The conversion of light energy into other energetic forms is accomplished via electronically excited states. Visible and ultraviolet light initially deposits energy in the molecular electronic degrees of freedom. The coupling between electronic and nuclear degrees of freedom on an ultrafast timescale determines the efficiency and selectivity of energy conversion into heat, chemical transformation or charge transfer. Understanding of the energy conversion processes therefore requires information on electronic and nuclear molecular degrees of freedom.
Time resolved spectroscopy using femtosecond x-ray pulses provides a new window into the molecular excited states dynamics. Due to the x-ray typical element and site selectivity, the method provides highly local information on nonadiabatic dynamics. I will discuss the progress in this field and present new experiments on the excited state decay from a $\pi\pi*$ state to an $n\pi*$ state, probed at the oxygen K-edge [1].
In addition, I will present recent approaches to directly image molecular dynamics using x-rays and relativistic electron pulses. For the latter I will show how electrons can be used to directly image vibrational wavepackets in an isolated molecule [2].

[1]T. Wolf, R Heilemann Myhre et al., arXiv:1610.08498 (2016)
[2]Yang, J., Guehr et al., Phys. Rev. Lett. 117, 173002 (2016)

A 3.2 Mon 15:00 N 2

Optical control of core hole relaxation dynamics in open shell atoms — •Alexander Achner[1], Tommaso Mazza[1], Carlo Callegari[2], Stefano Stranges[3], and Michael Meyer[1] — [1]European XFEL GmbH, 22869 Schenefeld, Germany — [2]Elettra-Sincrotrone Trieste, 34149 Basovizza, Trieste, Italy — [3]Università degli Studi di Roma La Sapienza, 00185 Rome, Italy

To explore the relaxation dynamics of resonantly excited core-hole states of atomic iodine, we used XUV pulses from the FERMI FEL in combination with a synchronized near-infrared (NIR) laser. The ionization process was characterized by ion time of flight spectrometry. After resonant 4d excitation by the XUV radiation the NIR laser field is used to probe the excited states as well as the final ionization products. The I^*4d^96p and the I^*4d^95p resonances (at 55.95 eV and 46.2 eV) were excited by the XUV photons and the dynamics of the electronic decay was probed by varying the relative delay between XUV and NIR. Using only XUV radiation, the resonant excitation is followed by an ultrafast resonant Auger decay leading mainly to singly charged states. Introducing the NIR laser pulses the ionization of the $4d^96p$ resonant state is possible, causing the production of higher charge states via normal Auger process. For the $4d^95p$ resonance the energy difference to the 4d ionization threshold is too high for further ionization with NIR intensities used in the experiment, and therefore only ionization of the excited singly charge states produced via resonant Auger decay was possible.

A 3.3 Mon 15:15 N 2

Site-selective x-ray photofragmentation of molecules — •Ludger inhester[1], Sang-Kil Son[1], and Robin Santra[2] — [1]Center for Free-Electron Laser Science, DESY, Hamburg — [2]Department of Physics, University Hamburg

For understanding the impact of radiation damage in biological processes it is important to know how a molecule fragments after x-ray absorption. After x-ray ionization of a core electron and subsequent Auger decay the molecular electronic structure is left in a two-valence hole configuration. This two-valence hole configuration typically initiates molecular dissociation. In contrast to the core electron, the valence holes are often delocalized over large parts of the molecule. Thus, ionization on a specific atomic site may lead to disruption of the molecule at remote parts, which makes it difficult to predict into which fragments the molecule breaks apart. Because of the large number of accessible two-hole configurations the quantitative theoretical prediction of molecular fragments is a challenging task.

We address this issue using our newly developed XMOLECULE toolkit(Y. Hao et al., Struct. Dyn. 2 (2015) 041707, L. Inhester et al., Phys. Rev. A, 94 (2016) 023422). Based on calculated Auger transition rates and Mayer's bond order analysis, we present a way to efficiently calculate the molecular fragments after x-ray absorption. Results for ethyl trifluoroacetate (CF3-CO-O-CH2-CH3, a.k.a the Siegbahn or the ESCA molecule) are compared with recent experiments. With these results we demonstrate that the abundance of certain molecular fragments is specific for x-ray ionization on a particular atomic site.

A 3.4 Mon 15:30 N 2

Calibration of the fluence of an x-ray free-electron laser using XATOM — •Koudai Toyota, Zoltan Jurek, Sang-Kil Son, and Robin Santra — CFEL, DESY, Hamburg

We report on a numerical procedure to calibrate the spatial intensity profile of x-ray free-electron laser pulses (XFELs). Extracting the reliable pulse parameters is indispensable to quantitatively analyze the experimental results and eventually to understand the non-linear physics in matter induced by high intensity XFELs. So far, we have conducted calibrations based on charge state distributions (CSDs) of atomic ions [1] calculated by XATOM toolkit [2]. Such a method has the advantage that the calibration is based on observables directly reflecting the experimental conditions within the interaction volume. By convolving theoretical CSDs with a spatial fluence distribution of a double Gaussian shape profile, which is defined by a few parameters, the experimental CSD was successfully recovered. However, our previous analysis was lacking a comprehensive framework and was manually implemented.

Our new procedure is now built with a well established optimization techniques in numerical analysis and fully automatized via computer codes. Therefore it offers a possibility of deeper investigations based on CSDs over a wide range of a parameter space. We discuss the procedure of optimization algorithms and test different pulse profile ansatz. We demonstrate the workflow and its practical importance on real experimental data. [1] B.F. Murphy et al., Nat. Commun. 5, 4281 (2014); [2] S.-K. Son and R. Santra, XATOM - an integrated toolkit for x-ray and atomic physics, CFEL, DESY, Hamburg, Germany, 2011

A 3.5 Mon 15:45 N 2

Auger cascades in resonantly excited neon — •Sebastian Stock[1,2], Randolf Beerwerth[1,2], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

Auger electron spectroscopy is an important tool for probing the inner-shell structure of atoms and ions. Over the past few decades, multi-electron coincidence spectroscopy has led to substantial progress in our understanding of multiple ionization via Auger processes.

We here present a theoretical study [1] of the Auger decay paths following resonant 1s $\rightarrow$ np ($n = 3, 4$) excitation of neutral neon. In contrast to the usual approach that often considers just a few transitions, we model the complete cascade decay paths from neutral to doubly ionized neon. By performing extensive MCDF calculations, we include the effects of electron correlation in the calculation of the transition rates of many possible decays. In addition, we also account for shake processes, which play a significant role in some of these transitions. In order to improve our results, especially for low-energy transitions, we employ experimental values for the energy levels of neutral, singly and doubly ionized neon.

By modeling the complete cascade, we are able to predict electron spectra, shake probabilities, ion yields, and the population of intermediate and final states. Our results are in good agreement with experimental findings, e.g. from Ref. [2].

[1] S. Stock, R. Beerwerth, and S. Fritzsche, to be published.

[2] Y. Tamenori and I. H. Suzuki, *J. Phys. B* **47**, 145001 (2014).

A 3.6 Mon 16:00 N 2

Relativistic calculations of the non-resonant two-photon K-shell ionization of neutral atoms — •Jiri Hofbrucker[1,2], Andrey Volotka[1,3], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Friedrich-Schiller-Universität, Jena, Germany — [3]St. Petersburg State University, Russia

The non-resonant two-photon one-electron K-shell ionization of neutral atoms is studied within the framework of relativistic second-order perturbation theory and independent particle approximation. The importance of relativistic and screening effects in the total as well as differential cross sections is investigated. Our results show that, at near two-photon ionization threshold energies, the account for the screening effects of the remaining electrons leads to occurrence of an unexpected minimum in the total two-photon ionization cross section [1] and to elliptical dichroism in the photoelectron angular distribution. For ionization of heavy atoms, relativistic effects result in a significant decrease of the total cross section [2], and in distortion of the angular distribution into forward direction.

[1]J. Hofbrucker, A. V. Volotka, S. Fritzsche, accepted in Phys. Rev. A.

[2]J. Hofbrucker, A. V. Volotka, S. Fritzsche, submitted to Nucl. Instr. Meth. Phys. Res.

A 3.7 Mon 16:15 N 2

State-of-the-art MMC detector arrays for X-ray spectroscopy — •D. Hengstler[1], F. Mücke[1], J. Geist[1], M. Keller[1], M. Krantz[1], C. Schötz[1], R. Pons[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], T. Gassner[2,3], K.H. Blumenhagen[2,3], R. Märtin[2,3], G. Weber[2,3], and Th. Stöhlker[2,3,4] — [1]KIP, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Darmstadt — [4]IOQ, Jena University

Metallic magnetic calorimeters (MMCs) are energy dispersive X-ray detectors which provide a very good energy resolution over a large dynamic range combined with an excellent linearity. MMCs are operated at millikelvin temperatures and convert the energy of an incoming X-ray into a temperature rise which is monitored by a paramagnetic temperature sensor. The resulting change of sensor magnetization is read out by a SQUID and serves as a measure for the energy input. We developed several micro-fabricated one- and two-dimensional detector arrays optimized for energies up to 20, 30 and 200 keV providing energy resolutions as good as 1.6 eV, 7 eV and 26 eV, respectively. The detectors are operated in a mobile dilution refrigerator. We discuss the performance of our detectors and show results of our most recent 8x8 pixel detector array providing an active detection area of 4 mm x 4 mm. We present promising results of first beamline experiments at ESR@GSI showing that MMCs are an ideal tool for future precision experiments at FAIR as well as new detector designs optimized for upcoming beamtimes at Cryring@ESR.

A 4: Precision Spectroscopy I

Time: Monday 14:30–16:30 Location: N 3

Invited Talk A 4.1 Mon 14:30 N 3

Bound-electron g factor of highly charged ions — •Andrey Volotka — Helmholtz-Institut Jena, D-07743 Jena, Germany

In recent years, remarkable progress in experimental and theoretical investigations of the bound-electron g factor of highly charged ions has been achieved. In particular, it has led to the determination of the electron mass [1], tests of the many-electron QED [2] as well as relativistic recoil [3] effects. Here, we summarize recent results in theoretical calculations of the bound-electron g factor of H-, Li-, and B-like ions. Moreover, we discuss possibilities for investigations of nuclear and nonlinear effects as well as fine structure constant determination from g factors of heavy ions.

[1] S. Sturm et al., Nature **506**, 467 (2014)

[2] A. V. Volotka et al., Phys. Rev. Lett. **112**, 253004 (2014)

[3] F. Köhler et al., Nat. Commun. **7**, 10246 (2016)

A 4.2 Mon 15:00 N 3

A Laser Ion Source for the ALPHATRAP experiment — •Tim Sailer[1,2], Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Andreas Weigel[1,2], Robert Wolf[1,3], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Fakultät für Physik und Astronomie, Universität Heidelberg — [3]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, NSW Australia

The Penning-trap experiment ALPHATRAP, located at the Max-Planck-Institut für Kernphysik, aims to measure the g-factor of bound electrons in highly charged ions up to hydrogen-like $^{208}Pb^{81+}$. In the resulting electrical field strength of the order of 10^{16} V/cm bound-state quantum electrodynamics can be tested with highest precision in extreme conditions.

A Laser Ion Source (LIS) based on a pulsed Nd:YAG laser will be designed and built to produce $^{9}Be^{1+}$ ions, which will subsequently be laser cooled inside the trap using a 313nm laser system. Highly charged ions, which cannot be directly addressed by the laser, will be sympathetically cooled by the beryllium ions. This will enable measurements beyond the current thermal limits. The LIS will be attached to the existing beamline, allowing the external production and insertion of the $^{9}Be^{1+}$ ions into the trap as well as enabling easy adjustments such as target material switching for future uses.

A 4.3 Mon 15:15 N 3

The ALPHATRAP *g*-Factor Experiment — •Andreas Weigel[1,2], Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Tim Sailer[1,2], Robert Wolf[1], José Ramon Crespo López-Urrutia[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg

The Penning-trap based experiment ALPHATRAP is currently in the commissioning phase at the Max-Planck-Institut für Kernphysik in Heidelberg. It is the follow-up to the Mainz g-factor experiment, which has performed the most sensitive test of bound-state quantum electrodynamics (BS-QED) by measuring the g-factor of the remaining electron bound in hydrogen-like $^{28}Si^{13+}$ at an uncertainty level of 10^{-11} [1]. ALPHATRAP aims for g-factor measurements on even heavier highly charged ions up to hydrogen-, lithium- and boron-like lead, with simultaneously improved accuracy. To achieve this, the ALPHATRAP experiment, consisting of an improved cryogenic double

Penning-trap setup, is coupled via an ultra-high vacuum beamline to various ion-sources including the Heidelberg Electron-Beam Ion Trap. In combination with currently conducted BS-QED calculations, the measurements are expected to further contribute to the exploration of the limits of BS-QED and also aim for an independent determination of the fine-structure constant α. The current status of the project will be presented.

[1] S. Sturm et al., Phys. Rev. Lett. 107, 023002 (2011)

A 4.4 Mon 15:30 N 3

Towards Laser Cooling of Highly Charged Ions at the ALPHATRAP Experiment — •Sandro Kraemer[1,2], Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], Tim Sailer[1,2], Andreas Weigel[1,2], Robert Wolf[1,3], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Fakultät für Physik und Astronomie, Universität Heidelberg — [3]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, NSW Australia

ALPHATRAP, a Penning-trap experiment currently being set up at the Max-Planck-Institut für Kernphysik, aims for a test of bound-state QED in very high field strengths by measuring the g-factor of highly charged ions (HCI) up to hydrogen-like $^{208}Pb^{81+}$. In existing systems the stored particles are cooled using resistive and electronic feedback cooling.

As a novel development, laser cooled beryllium ions will be used to sympathetically cool the HCIs stored in the same trap. A setup for laser cooling of Be^+-ions adressing the $^2S_{1/2} \leftrightarrow {}^2P_{3/2}$ transition at 313 nm is currently being developed. The lower achievable ion temperatures are expected to further increase the precision of the measurement. Additionally, new measurement schemes, such as simultaneous g-factor measurements on Coulomb crystallized ion pairs, become possible.

The laser system and the coupling into the trap will be discussed, and a current status of the project will be given.

A 4.5 Mon 15:45 N 3

Development of a Modified-Cyclotron Detection System for Resistively Cooling a Single Trapped Antiproton — •James Harrington[1,2], Mustafa Besirli[2], Matthias Borchert[2,4], Takashi Higuchi[2,5], Hiroki Nagahama[2,5], Stefan Sellner[2], Christian Smorra[2,3], Toya Tanaka[2,5], Matthew Bohman[1,2], Andreas Mooser[2], Georg Schneider[6,2], Natalie Schön[6], Klaus Blaum[1], Yasuyuki Matsuda[5], Christian Ospelkaus[4,7], Wolfgang Quint[8], Jochen Walz[6,9], Yasunori Yamazaki[10], and Stefan Ulmer[2] — [1]Max-Planck-Institut für Kernphysik, Germany — [2]Ulmer Initiative Research Unit RIKEN, Wako, Japan — [3]CERN, Geneva, Switzerland — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [5]Graduate School of Arts and Sciences, University of Tokyo, Japan — [6]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [7]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [8]GSI-Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [9]Helmholtz-Institut Mainz, Germany — [10]Atomic Physics Laboratory RIKEN, Wako, Japan

The development of an improved tuned circuit, for resistively cooling the modified-cyclotron mode of a single trapped antiproton, is described. Efficient cooling of the radial modified-cyclotron mode is of the utmost importance when performing single particle spin quantum-transition spectroscopy in Penning traps. This is because at low modified-cyclotron quantum states the radial heating rates are small, which improves axial frequency stability. This is necessary to improve the spin-flip identification fidelity, which is crucial for our planned high-precision measurement of the antiproton g-factor. This system has been developed as an upgrade for the BASE experiment, located at CERN's antiproton decelerator facility.

The instrument consists of a helical superconducting coil inside of a cylindrical copper shield which produces an unloaded Q-value on the order of 15000 at 29.774 MHz. When connected to the trap and active-amplifier electronics, a cooling time constant of $\tau \approx 18$ s is achieved – a 17-fold improvement compared to the resistive damping system currently used in the experiment.

A 4.6 Mon 16:00 N 3

Proof of concept of Precise High Voltage measurements by collinear laser spectroscopy — •Tim Ratajczyk[1], Kristian König[1], Christopher Geppert[2], Phillip Imgram[1], Bernhard Maass[1], Ernst Otten[3], Johannes Ullmann[1], Jörg Krämer[1], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt — [2]Institut für Kernchemie, Johannes Gutenberg Universität Mainz — [3]Institut für Physik, Johannes Gutenberg Universität Mainz

The ALIVE experiment at the TU Darmstadt is a new collinear laser spectroscopy setup. The goal of the experiment is the measurement of high voltages in the range of 10 to 100 kV using precise laser spectroscopy of ions with a well-known transition frequency as it has been suggested in [1]. The aim is to achieve an accuracy of 1 ppm, which is of interest for many applications.

First measurements have been performed to test collinear laser spectroscopy with a new two chamber approach as a high voltage standard. To show the feasibility of this concept the well-known 4s1/2 -> 4p3/2 transition of 40Ca+ was used to mark a velocity class with a narrow bandwidth laser, as the multiply excited ions decay into the meta stable 3d5/2 state. The marked ions are accelerated by the unknown static high voltage and can be probed by re-exciting them from the 3d5/2 state. The shift of the resonance frequency introduced by the Doppler effect is then used to refer the high-voltage measurement to a high accuracy frequency measurement. First results will be presented.

[1] O. Poulsen, Nuclear Instruments & Methods in Physics Research 202 (1982) 503.

A 4.7 Mon 16:15 N 3

Determination of ground-state hyperfine splitting energies in $Bi^{80+,82+}$ ions to test QED — •Johannes Ullmann[1,2], Zoran Andelkovic[3], Carsten Brandau[3,11], Andreas Dax[8], Wolfgang Geithner[3], Christopher Geppert[2], Christian Gorges[2], Michael Hammen[5,7], Volker Hannen[4], Kristian König[3], Simon Kaufmann[2], Yuri Litvinov[3], Matthias Lochmann[2], Bernhard Maass[2,3], Johann Meisner[6], Tobias Murböck[10], Rodolfo Sánchez[3], Stefan Schmidt[2,7], Matthias Schmidt[6], Markus Steck[3], Thomas Stöhlker[1,3], Richard C. Thompson[9], Christian Trageser[11], Jonas Vollbrecht[4], Christian Weinheimer[4], and Wilfried Nörtershäuser[2] — [1]Helmholtz Inst. Jena — [2]Inst. f. Kernphysik, TU Darmstadt — [3]GSI Darmstadt — [4]Inst. f. Kernphysik, Uni Münster — [5]Helmholtz Inst. Mainz — [6]PTB Braunschweig — [7]Inst. f. Kernchemie, Uni Mainz — [8]PSI, Villigen, Switzerland — [9]Imperial College London, UK — [10]Inst. f. Angew. Physik, TU Darmstadt — [11]I. Phys. Institut, Uni Gießen

The measurement of the ground state hyperfine splittings in Bi^{82+} and Bi^{80+} ions tests the theory of bound-state quantum electrodynamics (QED) in the strong field of the nucleus. Precise theoretical predictions use a specific difference of both splitting energies to cancel the large uncertainty of nuclear contributions. In the recent laser spectroscopy beamtime at the storage ring ESR at GSI Darmstadt, we reduced the largest experimental uncertainty by an order of magnitude. Systematic effects will be discussed and we will present the first high precision value of the specific difference, which deviates significantly from theory.

A 5: Precision Measurements and Metrology: Gravity (with Q)

Time: Monday 14:30–16:30 Location: P 104

Group Report A 5.1 Mon 14:30 P 104

The Laser Ranging Interferometer on GRACE Follow-On - current status and outlook — Germán Fernández Barranco, Alexander Görth, •Christoph Mahrdt, Vitali Müller, Daniel Schütze, Gunnar Stede, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut (AEI), Hannover

The Gravity Recovery and Climate Experiment (GRACE) is able to observe the Earth's dynamic gravitational field on a global scale. Changes due to mass transport within the Hydrosphere and Cryosphere, with unprecedented precision have been observed with a temporal resolution of one month. Long term monitoring of these changes is important for a better understanding of the processes causing these time variations. GRACE has been flying for nearly 15 years now, tripling it's targeted design lifetime. Due to the increasing risk of failure a rebuild of GRACE has been build and is currently under test for an anticipated launch as early as spring 2018. GRACE Follow-On carries an additional laser ranging interferometer as technology demonstrator for future gravity field missions which has the potential to enable improved spatial resolution. This talk will give an overview of the architecture of the laser ranging interferometer, a status update, and outlook towards the launch.

A 5.2 Mon 15:00 P 104

Precise measurement of pW laser powers for inter-satellite laser interferometry applications — •Sebastian Schreiber, Alexander Görth, Christoph Vorndamme, Nils Christopher Brause, Oliver Gerberding, Thomas Schwarze, Gerhard Heinzel, and Karsten Danzmann — Albert-Einstein-Institut Leibniz Universität Hannover

Future space missions like the Laser Interferometer Space Antenna (LISA) or the Gravity Recovery and Climate Experiment Follow-on mission (GRACE-FO) will make use of laser interferometry to measure precise distance changes between the spacecraft.

The huge distances between the SC reduce the received laser power to a few nW or even pW. To ease the alignment procedure of the SC an acquisition sensor will be installed on each SC.

To ensure the correct functionality of those sensors it is necessary to measure such light intensities on ground. Noise sources such as residual, scattered or reflected light as well as electronic readout noise are actually limiting the achievable results from common instruments.

This talk will present a general overview and first ideas of building a measuring instrument which is able to directly measure such low intensities. The focus lies on AC measurement techniques that involve optical chopper wheels or heterodyne interferometey

A 5.3 Mon 15:15 P 104

Deep Frequency Modulation Interferometry — •Christoph Vorndamme[1], Oliver Gerberding[2], Katharina-Sophie Isleif[1], Thomas S. Schwarze[1], Moritz Mehmet[2], Gerhard Heinzel[2], and Karsten Danzmann[1,2] — [1]Albert Einstein Institute, Leibniz Universität Hannover — [2]Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

Here we present the latest developments for the deep frequency modulation interferometry (DFMI) technique at the AEI. This technique is based on a Michelson setup with unequal armlength and a strong, or deep, frequency modulation applied to the input laser. The unequal armlength converts the laser frequency modulation into an effective deep phase modulation in the measurement arm, thus encoding the measurement phase in complex amplitudes of the modulation frequency harmonics. Unlike in a phase modulated setup, which already provides high precision and high dynamic range, the frequency modulated setup can be implemented with very compact optical heads for a scalable amount of degrees of freedom. This is due to the laser frequency modulation and reference noise measurement being kept seperate from the part of the optics that need high thermal and mechanical stability. Futhermore, the effective modulation depth includes the total delay in the measurement arm, thus yielding the possibility for absolute ranging. The presented efforts include the construction of optical hardware like a glued ultra-stable reference interferometer as well as the developement of fast phase readout electronics (phasemeter) based on a system on chip (SoC).

A 5.4 Mon 15:30 P 104

Interferometrischer Messkopf zur dynamischen Laser-Entfernungsmessung — •Oliver Mandel[1,2], Thilo Schuldt[2,3], Michael Chwalla[1], Dennis Weise[1], Ulrich Johann[1] und Claus Braxmaier[2,3] — [1]Airbus DS GmbH, Friedrichshafen — [2]Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation (ZARM), Bremen — [3]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Bremen

Die Laserinterferometrie gilt in der Raumfahrt als vielversprechende Technologie zur dynamischen Abstandsmessung zwischen Satelliten, besonders im Hinblick auf Missionen zur Erdbeobachtung, Detektion von Gravitationswellen und Formationsflügen. Verschiedene Konzepte für ein heterodynes, dynamisches Laser-Entfernungsmessgerät mit Nanometergenauigkeit wurden auf ihre Nutzbarkeit für Gravitations-Missionen der nächsten Generation untersucht und hinsichtlich ihrer Messgenauigkeit, Baugröße, Flexibilität und Komplexität verglichen. Darauf aufbauend wird ein monostatisches Instrumentendesign vorgestellt, bei dem sich die Laserstrahlen auf der direkten Sichtverbindung zwischen den Satelliten ausbreiten, wobei innerhalb des Instruments eine bi-statische Strahlführung Anwendung findet. Die tatsächliche Leistungsfähigkeit soll in einer eigens dafür entwickelten Testumgebung vermessen werden. Zur leichteren Unterbringung in zukünftigen Satellitenmissionen ermöglicht das Instrumentendesign einen frei wählbaren Abstand vom Messkopf zum Phasenzentrum und kann vollständig auf einer kompakten optischen Bank integriert werden. Zuwendung des DLR mit Mitteln des BMWi unter dem Förderkennzeichen 50EE1409.

A 5.5 Mon 15:45 P 104

A backlink for LISA: Pre-experiment and optical design — •Lea Bischof[1], Katharina-Sophie Isleif[1], Oliver Gerberding[2], Daniel Penkert[2], Stefan Ast[2], Gerhard Heinzel[2], Michael Winter[1], Jens Reiche[2], and Karsten Danzmann[1,2] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover — [2]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut)

The Laser Interferometer Space Antenna (LISA) is a planned space-based gravitational wave detector with arm-lengths of several million kilometers. To suppress laser frequency noise in this detector two or more arms have to be compared to synthesize a quasi Michelson interferometer. This is non-trivial due to an orbit induced breathing of the angle between the arms, which requires an adaptable link (so-called backlink) between two optical benches in one satellite. Therefore, a new experiment is currently being set-up at the AEI in Hannover to compare three different methods: a 'fiber backlink', a 'free beam backlink' and a 'frequency separated backlink'. All bonded on two baseplates that are fixed on two rotary stages to simulate a LISA like motion. We will present the current status of this, so called '3Backlink-experiment', the stray light mitigation strategies and the actual implementation of a pre-experiment that will analyze key issues for the free beam backlink. Highlights include first results with a free beam backlink, including angular steering control, and the IfoCAD based design of the highly complex three backlink interferometer.

A 5.6 Mon 16:00 P 104

Experiment to investigate collinear back-reflections of optical components — •Michael Winter[1], Oliver Gerberding[2], Katharina-Sophie Isleif[1], Daniel Penkert[2], Stefan Ast[2], Lea Bischof[1], Gerhard Heinzel[2], Jens Reiche[2], and Karsten Danzmann[1,2] — [1]Albert Einstein Institute Hannover, Leibniz Universität Hannover — [2]Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

The Laser Interferometer Space Antenna (LISA) is a planned space-based gravitational wave detector with arm lengths of some million kilometres. Due to orbital dynamics the angle between the arms changes. Thus an adaptable link (backlink) between the two optical benches inside each spacecraft is required. Previous experiments have shown that a fiber solution is limited by collinear ghost beams. Additional optical components can be used to avoid them or make them irrelevant, e.g. Faraday Isolators or AOMs. Collinear back-reflections of the components are designated to be the new limiting factors.

To investigate these back-reflections a simple cavity-like setup is used, whereby the component to be examined forms one half of an ultra-low finesse cavity. Deep Frequency Modulation (DFM) interferometry is then applied to generate self-interference at AC-frequencies for a quasi heterodyne detection.

This talk will give an overview of the operating principle and the characterization of the setup. Thereby the focus lies on reconciling theory and experiment to connect obtained signal and power reflectivity of the device-under-test, revealing collinear back-reflection properties.

A 5.7 Mon 16:15 P 104

Optical three-signal test for the LISA phasemeter — •Germán Fernández Barranco, Daniel Penkert, Thomas Schwarze, Oliver Gerberding, and Gerhard Heinzel — Max Planck Institute for Gravitational Physics, Callinstraße 38 30167 Hannover

The planned spaceborne gravitational wave detector LISA will allow the detection of gravitational waves at frequencies between 0.1 mHz and 1 Hz. It uses high-precision heterodyne laser interferometry as the main measurement technology. A breadboard model of the interferometric phase readout system (phasemeter) was developed in the scope of an ESA technology development project. This project was completed successfully fulfilling all performance requirements in an electrical two-signal test. Here we present the advances of an optical testbed for the phasemeter as well as measurements. The testbed is based on an ultra-stable hexagonal optical bench. This bench allows the generation of three unequal heterodyne beatnotes, thus enabling us to probe the phasemeter for nonlinearities in an optical three-signal test. The final goal is to show a performance in the microcycle/sqrt(Hz) regime for the upper part of the LISA measurement band (5 mHz to 1 Hz) with a dynamic range of about 7 orders of magnitude using beatnotes between 5 and 25 MHz. The measurements presented here fulfill this requirement down to 100 mHz including dynamic and beatnote ranges. Once full performane is achieved, other components of the LISA arm metrology chain (clock noise transfer and removal, inter-satellite ranging and communication) can be tested in this setup.

A 6: Time-resolved spectroscopy

Time: Monday 17:00–19:00 Location: HS 20

Invited Talk A 6.1 Mon 17:00 HS 20

Phase-modulated harmonic light spectroscopy — •Lukas Bruder, Ulrich Bangert, Marcel Binz, Andreas Wituschek, Marcel Mudrich, and Frank Stienkemeier — Physikalisches Institut, Universität Freiburg

Coherent time-resolved spectroscopy is a powerful tool to study ultrafast dynamics in complex systems. It is highly desirable to extend these techniques to the XUV spectral range. However, demands on phase stability increase significantly when going to short wavelengths and advanced pulse manipulation in the XUV is challenging. We suggest an approach based on acousto-optical phase modulation of the driving/seed laser combined with harmonic lock-in detection. In this approach, demands on phase stability are drastically reduced and signals are efficiently isolated and amplified. We demonstrate this concept in a proof-of-principle study with second harmonic generation. The concept is characterized in a femtosecond pump-probe experiment measuring electronic wave packet dynamics in atomic systems. Our results show promise for an implementation in HHG and HGHG light sources.

Invited Talk A 6.2 Mon 17:30 HS 20

Amplitude and phase control of an atom's optical response — •Alexander Blättermann, Andreas Kaldun, Veit Stooss, Thomas Ding, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The optical response of an atom to ultrashort bursts of light gives rise to a characteristic fingerprint of its electronic system - the atomic absorption spectrum. Originating from the superposition of quantum states, we are able to control the optical response by acting on the very same quantum states with an intense laser pulse. Varying the timing and intensity of this laser pulse allows us to modify the amplitude and phase of the optical response anytime during the decay of the excited state. These degrees of freedom enable a variety of experimental schemes, such as a static pulse configuration with tunable intensity up to a dynamic configuration with tunable delay. While the former scheme granted control over the Fano-q parameter of a spectral line [1], the latter recently enabled us to observe the formation of a Fano resonance in time [2]. A third scheme even allows for an in situ characterization of the NIR pulse providing helpful information for data analysis [3]. Our experiments are supported by an analytic model of the laser-controlled dipole moment [4], which establishes a direct link between time and frequency domain.

[1] Science 340, 716 (2013)
[2] Science 354, 738 (2016)
[3] Opt. Lett. 40, 3464 (2015)
[4] J. Phys. B: At. Mol. Opt. Phys. 47, 124008 (2014)

A 6.3 Mon 18:00 HS 20

Using strong-field spectroscopy to observe the ultrafast buildup of a Fano resonance — •Veit Stooss[1], Alexander Blättermann[1], Andreas Kaldun[1], Stefan Donsa[2], Hui Wei[3], Renate Pazourek[2], Stefan Nagele[2], Christian Ott[1], Chii-Dong Lin[3], Joachim Burgdörfer[2], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany, EU — [2]Institute for Theoretical Physics, Vienna University of Technology, Vienna, Austria, EU — [3]Department of Physics, Kansas State University, Manhattan, USA

High-harmonic generation and the resulting attosecond light pulses in the extreme ultraviolet (XUV) spectral range enables access to the dynamics of electrons in atomic and molecular systems. The method of strong-field spectroscopy uses these pulses to excite bound electronic states, which are subsequently perturbed in their natural evolution with a high-intensity ultrashort near-infrared (NIR) pulse. By observing the thus modified XUV absorption spectrum one gains insights into such strong-field-driven dynamics. Here, we use this method to create a controllable temporal gate between excitation and termination of a bound-bound transition to experimentally observe the emergence of an asymmetric Fano absorption resonance in helium [1]. The results shown are in good agreement with *ab-initio* calculations as well as analytical models describing the buildup of a Fano resonance.

[1] Observing the ultrafast buildup of a Fano resonance in the time domain - Science, Vol. 354, Issue 6313, pp. 738-741 (2016)

A 6.4 Mon 18:15 HS 20

Laser-induced grating spectroscopy with absolute time information — •Jan Reislöhner, Christoph G. Leithold, and Adrian N. Pfeiffer — Institute of Optics and Quantum Electronics, Abbe Center of Photonics, Friedrich Schiller University, Max-Wien-Platz 1, 07743 Jena

The nonlinear response function of transparent dielectrics is studied in time and spectral domain. A laser-induced grating is generated in a thin sample with short laser pulses (~5 fs, 700 nm) and imaged with a 2f-2f imaging system. The individual beams (the two fundamental beams and two orders of self-diffraction) are blocked consecutively in the imaging system while varying the pulse delay. From the absolute phase of the interference gratings, the delay between the fundamental pulses and the nonlinear optical response can be determined with subcycle precision. However, the optical path difference in the optical system is usually not known and inhibits the measurement of the absolute grating phase.

In a first step, the information contained in relative phase measurements (intensity dependence, material dependence) is examined. In a second step, a method is discussed for retrieving the absolute grating phase by stepwise translation and rotation of each element of the optical system.

A 6.5 Mon 18:30 HS 20

Two-electron dynamics in Helium driven by intense XUV radiation — •Lennart Aufleger[1], Thomas Ding[1], Marc Rebholz[1], Maximilian Hartmann[1], Alexander Magunia[1], David Wachs[1], Veit Stooss[1], Paul Birk[1], Gergana Borisova[1], Andrew Attar[2], Thomas Gaumnitz[3], Zhi Heng Loh[4], Stefan Düsterer[5], Christian Ott[1], and Thomas Pfeifer[1] — [1]MPI für Kernphysik, Heidelberg, Germany — [2]UC Berkeley, Berkeley, USA — [3]ETHZ, Zürich, Switzerland — [4]NTU Singapore, Singapore — [5]DESY, Hamburg, Germany

The measurement of laser-induced strong-field dynamics in few-electron systems provides a way to investigate their correlated nature. Using a lab-based HHG source we have studied such correlations that are imprinted on the XUV absorption line shape and investigated them by modification with strong fields in the near infrared and visible (VIS) spectral region. [C. Ott et al., Science 340, 716 (2013)]. Here, we present an extension of the strong-field modification scheme to the XUV-only spectral region. Using intense and partially coherent light of a FEL source (FLASH@DESY), the transition into the doubly-excited state 2s2p in Helium at 60.15 eV was driven. This excitation scenario represents a most basic two level system with a cooperative excitation of two electrons. The variation of pulse intensities between 10^{12} W/cm^2 and 10^{14} W/cm^2 induces a change in the experimentally observed XUV absorption line shape. A transformation from a Fano to a Lorentzian line shape is also confirmed by few-level simulations that were carried out.

A 6.6 Mon 18:45 HS 20

Time-Dependent Strong-Field Effects in Argon and Nitrogen — •Paul Birk, Veit Stooss, Maximilian Hartmann, Alexander Blättermann, Kristina Meyer, Christan Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Extreme ultraviolet (XUV) light pulses in the attosecond regime produced by high-harmonic generation of near-infrared (NIR) light are powerful tools to investigate intra-atomic and -molecular processes at ultra-high time resolution. With the help of an all-optical approach we gain access to bound-state dynamics and correlations between electronic states in atoms and molecules. In previous work we have investigated the laser-induced phase shifts and couplings of excited states in helium by measuring its perturbed polarization decay [1-2]. Based on this work on a two-electron system, we here study and compare time-dependent strong-field effects in argon and molecular nitrogen. Electronic and vibrational states of the target gases are excited by a weak XUV pulse and subsequently perturbed with a strong NIR pulse. We present first results and interpretations of XUV absorption spectra and their changes depending on both the time delay and intensity of the strong NIR pulse.

[1] Blättermann et. al., *J. Phys. B*, **47**, 124008 (2014)
[2] Blättermann et. al., *Optics Letters*, **40**, 3464 (2015)

A 7: Ultracold atoms and BEC - II (with Q)

Time: Monday 17:00–19:00 Location: N 1

A 7.1 Mon 17:00 N 1

Multiple BECs in a non-degenerate ring cavity — •Deepak Pandey[1,3], Grigor Kuyumjyan[1], Walid Cherifi[1], Naik Devang[1], Andrea Bertoldi[1], Arnaud Landragin[2], and Philippe Bouyer[1] — [1]LP2N, Université Bordeaux, IOGS, CNRS, Talence, France — [2]LNE-SYRTE, Observatoire de Paris, CNRS, UPMC, F-75014 Paris, France — [3]Presently at Institut für Angewandte Physik, Wegelerstr. 8, D-53115 Bonn, Germany

Quantum degenerate gases of neutral atoms are excellent systems with important applications in the study of many body quantum physics, condensed matter physics, precision measurements, and quantum information processing. We demonstrate the creation of multiple ^{87}Rb Bose-Einstein condensates (BECs) in the higher transverse modes of a bow-tie ring cavity at telecom wavelength 1560 nm. The non-degenerate character of the cavity allows splitting and merging of cold ensembles by deforming the trapping potentials inside the cavity. Another cavity resonance at 780 nm will allow us to realize the cavity aided quantum non-demolition measurements to generate measurement induced spin squeezed states.

A 7.2 Mon 17:15 N 1

Phase coherence and entanglement in Bose-Einstein condensates — •Tilman Zibold, Matteo Fadel, Roman Schmied, Baptiste Allard, Jean-Daniel Bancal, Nicolas Sangouard, and Philipp Treutlein — Department of Physics, University of Basel, Basel, Switzerland

We perform quantum enhanced metrology on an atom chip using internal states of Bose- Einstein condensed ^{87}Rb atoms. State dependent trapping potentials allow for the generation of entangled states such as squeezed states via interatomic interactions. By accounting for the atom number dependent phase shifts in the system we are able to produce strongly squeezed states. Our recent experiments demonstrate that these many-particle entangled states can exhibit Bell correlations [1]. We will discuss experiments on the limitations of phase coherence of squeezed atomic states and recent advances towards a Bell-test with split Bose-Einstein condensates.

[1] Schmied et al. Science 352, 441 (2016)

A 7.3 Mon 17:30 N 1

supersolidity in a Bose-Einstein condensate — •Andrea Morales, Julian Leonard, Philip Zupancic, Tilman Esslinger, and Tobias Donner — 1Institute for Quantum Electronics, ETH Zürich, Switzerland

Supersolidity is a paradoxical state of matter featuring both the crystalline order of a solid and the dissipationless flow typical of a superfluid. The realization of this state of matter requires the breaking of two continuous symmetries, the phase invariance of a superfluid and the translational invariance to form the crystal. Proposed for Helium almost 50 years ago, experimental verification of supersolidity remained elusive. Here we report on the realization of such a supersolid state of matter.

This state is realized by coupling a Bose-Einstein condensate (BEC) to the modes of two crossed optical cavity modes. Self-organization to individual cavities only breaks a discrete spatial symmetry and realizes a *lattice supersolid*. By equally coupling the BEC to both modes we enhance the symmetry of the system to a continuous one and observe simultaneous self-organization to the two cavities. We measure the high ground state degeneracy of the new supersolid state by measuring the crystal position over many realizations through the light fields leaking from the cavities. We also monitor real time fluctuations in the crystal position by the relative change in the light levels.

A 7.4 Mon 17:45 N 1

Realization of balanced gain and loss in a Bose-Hubbard model beyond the mean-field approximation — •Daniel Dizdarevic, Kirill Alpin, Johannes Reiff, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, Germany

In recent years there has been a growing interest in non-hermitian and especially $\mathcal{PT}$ symmetric quantum mechanics, since they allow for an effective description of open quantum systems. A quantum system exhibiting $\mathcal{PT}$ symmetry is given by a BEC in a double well with balanced particle gain and loss, which can be described in the mean-field limit by a Gross-Pitaevskii equation with a complex potential. Although a complex potential renders the Hamiltonian non-hermitian, $\mathcal{PT}$-symmetric stationary states with real eigenvalue spectra exist.

We present a possible experimental realization of such a system by embedding it into a hermitian time-dependent four-mode optical lattice, where additional potential wells act as reservoirs and particle exchange happens via tunneling [1]. Since particle influx and outflux have to be controlled explicitly, a set of conditions on the potential parameters is derived. In contrast to previous work, our focus lies on a full many-particle description beyond the mean-field approximation using a Bose-Hubbard model, where especially the differences arising are of interest. Furthermore, we examine whether $\mathcal{PT}$ symmetric stationary states still appear in the limit of low particle numbers.

[1] Kreibich et al., Phys. Rev. A 87, 051601(R) (2013)

A 7.5 Mon 18:00 N 1

A Homogeneous 2D Fermi Gas — •Klaus Hueck, Niclas Luick, Lennart Sobirey, Jonas Siegl, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Ultracold 2D Fermi gases in the BEC-BCS crossover provide a model system to investigate e.g. the Kosterlitz-Thouless transition to superfluidity. So far ultracold 2D Fermi gases have been studied in harmonic trapping potentials. This results in an inhomogeneous density distribution, which complicates the theoretical description of the system and only allows for the extraction of trap averaged quantities when utilizing non-local measurement methods such as time of flight imaging.

Here, we present our realization of an ultracold 2D Fermi gas trapped in a homogeneous disk-shaped potential. The radial confinement is realized by a ring-shaped blue-detuned beam with steep walls. Additionally a digital micro mirror device can be used to remove residual inhomogeneities and to imprint arbitrary repulsive potentials onto the system. This enables us to study systems in close analogy to e.g. gated 2D electron gases.

A 7.6 Mon 18:15 N 1

Non-equilibium BCS state Fermi gas — Alexandra Behrle, Timothy Harrison, •Kuiyi Gao, Martin Link, and Michael Koehl — Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany

Ultracold Fermi gases with tunable interactions have been widely used to investigate the BEC-BCS crossover in the last decade and superfluidity of Fermi gases with different interactions have shown a variety of rich physics. So far, the focus of research has mainly been on the equilibrium state of an attractive gas of cooper pairs. Non-equilibrium coherent dynamics of the BCS state was proposed for studying collective modes, pair formation and excitations in superconductivity, however, experimental realization has been hindered by the difficulty of performing fast enough perturbations to the system. In this talk, we will show our efforts in preparing and detecting a non-equilibrium BCS-superfluid of fermionic 6Li atoms. We focus on the coherent dynamics with fast modulation and quenched interactions using fast ramps across the Feshbach resonance.

A 7.7 Mon 18:30 N 1

Pairing in the normal phase of a 2D Fermi gas — •Puneet Anantha Murthy, Mathias Neidig, Ralf Klemt, Marvin Holten, Luca Bayha, Philipp Preiss, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universitaet Heidelberg

Paring of fermions is central to our understanding of superfluidity and superconductivity. In their celebrated work, Bardeen, Cooper and Schrieffer (BCS) describe how a pairing instability at sufficiently low temperatures at the Fermi surface leads to a transition from the normal phase to a superfluid for a weakly attractive Fermi gas. The formation of these Cooper pairs is a true many-body effect as it requires the presence of a Fermi sea and according to the BCS theory the pairing starts at the transition temperature. On this poster, we present evidence for pairing also in the normal phase of a two component 2D Fermi gas. We use spatially resolved radio-frequency (RF) spectroscopy to measure the onset of pairing at different interaction strengths across the 2D BEC-BCS crossover. We show that pairing occurs at temperatures significantly higher than the critical temperature for superfluidity. The spatially resolved RF spectroscopy allows us to separate the low- from the high-density regions of our inhomogeneous trap. As a result, we can identify regions where two-body physics is applicable and regions where many body effects take over. We map out a region in the strongly interacting regime, where paring is significantly influenced by the many-body nature of the system and cannot be explained purely by two-body physics.

A 7.8 Mon 18:45 N 1

Quantum Simulation of Mesoscopic Fermi Systems — •Philipp Preiss, Andrea Bergschneider, Vincent Klinkhamer, Jan-Hendrik Becher, Gerhard Zürn, and Selim Jochim — Universität Heidelberg, 69120 Heidelberg, Germany

Ultracold quantum gases in optical potentials have achieved spectacular progress in the experimental simulation of complex quantum systems. Complementary to many-body experiments, mesoscopic systems comprised of a small number of atoms offer the possibility to study highly entangled quantum states with an exceptional degree of versatility and control.

We are implementing a highly tunable platform to study such correlated few-fermion systems. As already demonstrated in our group, quantum states of 6Li atoms can be prepared with a deterministic atom number and spin configuration, and interactions are tunable via a magnetic Feshbach resonance. We are extending these techniques to a large range of trap geometries, including trap arrays as well as low-dimensional and toroidal systems. A novel readout scheme with single-particle and spin sensitivity allows us to measure spin- and momentum correlations.

The tunable few-fermion system will enable the realization of many novel mesoscopic systems, for example cylindrical optical lattices with unusual periodic boundary conditions. In two-dimensional traps, we will be able to study the formation of shell structure as well as the emergence of fermion pairing in the presence of interactions. I will discuss the status and prospects of our mesoscopic quantum simulator.

A 8: XUV/X-ray spectroscopy II

Time: Monday 17:00–19:00 Location: N 2

Invited Talk A 8.1 Mon 17:00 N 2

Angular resolved inner-shell photoionization spectra of randomly oriented and fixed-in-space methane and methyloxirane — •Philipp Demekhin — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

Recent progress in the development of experimental detection techniques enabled a set of new experiments on molecular photoionization in the angular-resolved mode. Interpretation of the results of such experiments requires development of new advanced nonstandard theoretical and computational approaches. In this talk, we first discuss theoretical background of the angular-resolved spectroscopy of molecules, and then consider two recent applications performed by the theoretical methods developed in our group. For core-to-Rydberg excited methane [1], we demonstrate that angular-resolved resonant Auger decay spectra provide very insightful information on the strength of the vibronic coupling effects. For O(1s) ionization of methyloxirane [2], we show that chiral asymmetry (photoelectron circular dichroism) can be significantly enhanced already by fixing one molecular orientation axis.

[1] A. Knie, et al., Phys. Rev. Lett. **116**, 193002 (2016).

[2] M. Tia, et al., arXiv:1609.03828v1 (2016).

Invited Talk A 8.2 Mon 17:30 N 2

Circular Dichroism in Multi-Photon Ionization of Oriented Helium Ions — •Markus Ilchen[1], Nicolas Douguet[2], Tommaso Mazza[1], Klaus Bartschat[2], Alexei Grum-Grzhimailo[3], Nikolay Kabachnik[3], and Michael Meyer[1] — [1]European XFEL GmbH, Schenefeld, Germany — [2]Drake University, Des Moins, USA — [3]Lomonosow Moscow State University, Moscow, Russia

The dichroic interaction of circularly polarized X-rays with matter is a multi-disciplinary field of science. With the advent of circularly polarized free-electron laser (FEL) radiation [1,2], the research field of circular dichroism phenomena in non-linear and ultrafast physics has been extended to the soft X-ray regime. Using high intensity, narrow bandwidth XUV pulses from FERMI in Italy, we were able to resonantly orient ionic helium in the 3p (m=+1) magnetic sub-state and to control the population of this state by a helicity dependent AC Stark shift generated by an overlapped near-infrared laser. The measured circular dichroism of electrons emitted via multi-photon ionization of the 3p state is intensity dependent to a surprisingly strong extent, therefore, allowing for an easily controllable and polarization selective transparency of such resonances. Potential applications in the general context of chirality research at FELs will be discussed. [1] E. Allaria et al., Phys. Rev. X, 4, 041040 (2014) [2] A. A. Lutman et al., Nature Photon., 10, 468 (2016)

A 8.3 Mon 18:00 N 2

X-ray laser spectroscopy with few-electron highly charged ions — •Sven Bernitt[1,2] and José R. Crespo López-Urrutia[2] — [1]IOQ, Friedrich-Schiller-Universität Jena, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Electronic transitions in few-electron highly charged ions are prominent in a variety of astrophysical and laboratory plasmas, and high precision spectroscopic data is indispensable for the interpretation of their X-ray spectra.

We have used a transportable electron beam ion trap (EBIT) to provide helium- and lithium-like ions of different elements as targets for monochromatized X-rays from synchrotron and free-electron laser light sources. By detecting resonantly excited fluorescence as a function of the photon energy, we were able to perform high precision spectroscopic studies, yielding transition energies, natural line widths and branching ratios.

This also serves as benchmark for the possible use of highly charged ions as future X-ray wavelength standards, and allows us to test current atomic theories, including electron-electron interactions, on the level of QED contributions.

A 8.4 Mon 18:15 N 2

Theoretical investigation of X-ray nonlinear Compton scattering — •Dietrich Krebs[1,2], David A. Reis[3], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Notkestrasse 85, 22607 Hamburg, Germany — [2]Department of Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany — [3]Stanford PULSE Institute, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA

Motivated by a recent experiment [1], we theoretically investigate the process of X-ray nonlinear Compton scattering. Our approach is based on the time-dependent Schrödinger equation for an atomic system subject to an intense X-ray pulse and explicitly accounts for the spontaneous scattering into a quantized photonic mode. To the best of our knowledge, this is the first time a time-dependent QED description has been attempted for a realistic system. We validate our implementation by calculating the linear Compton scattering signal for Helium at 500 eV photon energy and verify the dominance of the first-order A^2 mechanism. Subsequently, we explore the processes underlying X-ray nonlinear Compton scattering within the same framework. In contrast to the second-order mechanism that experience with linear Compton scattering would suggest, we find that X-ray two-photon Compton scattering in the soft X-ray regime is dominated by certain third-order processes. Moreover, our calculations demonstrate that the nonlinear Compton spectrum extends to much lower energies than would be expected from analogy with the sharply peaked linear case.

[1] M. Fuchs et al., Nature Physics 11, 964-970 (2015)

A 8.5 Mon 18:30 N 2

Inducing and detecting collective population inversions of Mössbauer nuclei — •Kilian P. Heeg, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Up to now, experiments involving Mössbauer nuclei driven by x-rays have been restricted to the low-excitation regime. In this talk, we propose a setup which promises significant excitation, ideally exceeding full inversion of the nuclear ensemble, at x-ray light sources under construction. We further introduce a method to experimentally verify such inversions, in which population inversions manifest themselves in symmetry flips of suitably recorded spectra. It neither requires per-shot spectra of the incoming x-ray pulses, nor absolute measurements of the scattered light intensity.

K. P. Heeg, C. H. Keitel, J. Evers, arXiv:1607.04116 [quant-ph] (2016).

A 8.6 Mon 18:45 N 2

Sub-envelope dynamics of slow electrons from non-adiabatic transitions — •Qi-Cheng Ning, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany

Ultra-short, intense and high-frequency laser pulses are able to release a bunch of slow electrons from atomic systems as the consequence of non-adiabatic transitions [1-3]. We find the formations of slow electrons peaks possess quite crucial dynamic origins which are intrinsic and have never been recognized. The previous observed peaks [1-3] should be comprehended as coherently combined outcomes of the continuum wavepackets launched by left hand side and right hand side of the laser envelope. The electron energy spectra exhibit oscillatory features and they are attributed to Stückelberg interferences, to achieve a profound understanding of the dynamic processes, we put forward numerical experiments using one single laser pulse which can be regarded as a pump-probe setup to reconstruct the quantum phases differences between wavepackets. As one other aspect of envelope dynamics, continuum-continuum non-adiabatic transitions are found appreciable to reshuffle distributions of electron energy spectra and they function oppositely at two sides of the pulse due to inverse slopes of the laser envelopes.

[1] M. Førre, S. Selstø, J. P. Hansen, and L. B. Madsen, Phys. Rev. Lett. **95**, 043601 (2005). [2] K. Toyota, O. I. Tolstikhin, T. Morishita, and S. Watanabe, Phys. Rev. Lett. **103**, 153003 (2009). [3] K. Toyota, U. Saalmann, and J. M. Rost, New J. Phys. **17**, 073005 (2015).

A 9: Precision Spectroscopy II

Time: Monday 17:00–19:00 Location: N 3

A 9.1 Mon 17:00 N 3

Laser spectroscopy of the heaviest elements — •Sebastian Raeder[1], Dieter Ackermann[2,3], Hartmut Backe[4], Michael Block[1,2,4], Bradley Cheal[6], Premaditya Chhetri[2,5], Christian Droese[2], Christoph E. Düllmann[1,2,4], Julia Even[7], Rafael Ferrer[8], Francesca Giacoppo[1,2], Stefan Götz[1,2,4], Fritz Peter Hessberger[2,5], Oliver Kaleja[2], Jadambaa Khuyagbaatar[1,2], Peter Kunz[9], Mustapha Laatiaoui[1,2], Felix Lautenschläger[2,5], Werner Lauth[4], Lotte Lens[2,4], Nathalie Lecesne[3], Andrew K. Mistry[1,2], Enrique Minaya Ramirez[10], Thomas Walther[5], Alexander Yakushev[1,2], and Zhiyuan Zhang[11] — [1]Helmholtz-Institut Mainz — [2]GSI, Darmstadt — [3]GANIL, Caen — [4]Universität Mainz — [5]TU Darmstadt — [6]University of Liverpool — [7]KVI-CART, Groningen — [8]KU-Leuven — [9]TRIUMF, Vancouver — [10]IPN Orsay — [11]IMP Lanzhou

Laser spectroscopy of the heaviest elements with $Z>100$ enables studying the influence of relativistic and QED effects on the atomic shell structure, but is hampered by the low production rates available. Applying the sensitive Radiation Detected Resonance Ionization Spectroscopy technique at the SHIP velocity filter in GSI, we identified optical transitions in the element nobelium ($Z=102$) for the first time. Besides the identification of a strong optical ground-state transition, the hyperfine structure splitting in the isotope ^{253}No was measured along with the isotope shifts in $^{252-254}$No. These results will be discussed and the prospects for first attempts in extending laser spectroscopy to the next of the heaviest elements, lawrencium, will be given.

A 9.2 Mon 17:15 N 3

Precision spectroscopy of Ba^+ isotopes in a Paul trap — •Nivedya Valappol, Elwin Dijck, Amita Mohanty, Klaus Jungmann, Lorenz Willmann, and Aswin Hofsteenge — Van Swinderen Institute, University of Groningen, The Netherlands

We perform precision spectroscopy on Ba^+ ions and precisely determine the $6s^2S_{1/2}$ - $6p^2P_{1/2}$, $6p^2P_{1/2}$ - $5d^2D_{3/2}$, $6s^2S_{1/2}$ - $5d^2D_{5/2}$ transition frequencies. We have achieved more than 100 times improved values using single trapped ion and frequency comb and I_2 line locked laser system. We have reached 10^{-11} relative accuracy, where these values test precisely the atomic wave functions. This is important input for a measurement of atomic parity violation in the alkaline earth atoms.

A 9.3 Mon 17:30 N 3

High-resolution In-source Laser Spectroscopy of Hyperfine Structures and Isotope Shifts on $^{163,165,166\mathrm{m}}$Ho Isotopes for the ECHo Project — •Reinhard Heinke[1], Tom Kieck[1], Tobias Kron[1], Sebastian Raeder[2], Marcel Trümper[1], Carsten Weichhold[1], and Klaus Wendt[1] — [1]Johannes Gutenberg-Universität, Mainz — [2]Helmholtz-Institut Mainz

The ECHo project aims for a measurement of the electron neutrino mass by precise analysis of the electron capture decay spectrum of ^{163}Ho. As part of this project, ^{163}Ho ions are implanted into metallic microcalorimeters, applying the highly selective laser resonance ionization technique at the RISIKO mass separator at Mainz University. In order to fully exploit the opportunities of isotope selective ionization, suppressing the interfering contamination of radioactive $^{166\mathrm{m}}$Ho even further, detailed knowledge of the hyperfine structure of the atomic transitions is mandatory. Therefore, high resolution laser spectroscopic investigations were performed on $^{163,165,166\mathrm{m}}$Ho isotopes, using a pulsed frequency doubled injection-locked high repetition rate titanium:sapphire laser system in combination with a newly developed dedicated ion source with perpendicular atom - laser beam interaction geometry in a radiofrequency quadrupole structure. First results on atomic and nuclear structure parameters are presented, including first-time optical measurements on $^{166\mathrm{m}}$Ho.

A 9.4 Mon 17:45 N 3

Towards Laser Spectroscopy of Boron-8 — •Bernhard Maass[1], Peter Müller[2], Jason Clark[2], Christian Gorges[1], Simon Kaufmann[1], Kristian König[1], Jörg Krämer[1], Anthony Levand[2], Rodney Orford[2], Rodolfo Sánchez[3], Guy Savard[2], Felix Sommer[1], and Wilfried Nörtershäuser[1] — [1]IKP,TU Darmstadt, DE — [2]ANL, Chicago, IL, USA — [3]GSI Darmstadt, DE

The BOR8 experiment aims at the determination of the nuclear charge radius of boron-8 with high-resolution laser spectroscopy. ^{8}B is perhaps the best candidate of a nucleus exhibiting an extended proton wave-function or one-proton-halo. The charge radius, which is directly correlated with the extent of the proton wave function, can be extracted from the measured isotope shift along the boron isotopic chain. Atomic theory calculations of the five-electron system, which were recently carried out, pave the way for targeting neutral boron atoms, whose spectroscopic properties are well suited for such measurements. In-flight production and preparation of sufficient yields of ^{8}B ions at low energies are provided by the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL). In a first off-line experiment, the isotope shift of the stable isotopes ^{10,11}B have been measured with resonance ionization mass spectrometry. This delivers a valuable test not only of atomic theory, but also of experimental equipment which will later be used at ANL.

This work is supported by the U.S. DOE, Office of Science, Office of Nuclear Physics, under contract DE-AC02-06CH1135, and by the Deutsche Forschungsgemeinschaft through Grant SFB 1245.

A 9.5 Mon 18:00 N 3

Atomic Parity Violation in Ytterbium and Dysprosium — •Anne Fabricant[1], Dionysios Antypas[2], Lykourgos Bougas[1], Nathan Leefer[3], Konstantin Tsigutkin[4], and Dmitry Budker[1,2,5] — [1]Johannes Gutenberg Universität-Mainz, Germany — [2]Helmholtz Institut-Mainz, Germany — [3]Nixie Labs, Mountain View, California, USA — [4]ASML, Veldhoven, The Netherlands — [5]University of California at Berkeley, USA

Atomic-parity-violation (APV) experiments enable us to probe fundamental electroweak and nuclear physics at low energies on a tabletop. Ytterbium (Yb) and dysprosium (Dy) are excellent candidates for APV measurements because of their particularly strong parity-violating effects (already confirmed experimentally for Yb) and the availability of many stable isotopes. Both systems are ideal for investigation of neutron distributions in the nucleus (the neutron skin), as well as of anapole moments arising from the weak interaction between nucleons. In addition, Dy is used to search for variation of fundamental constants. We report on the current status of our updated experimental setups in Mainz, present our latest results, and discuss future plans.

A 9.6 Mon 18:15 N 3

Nuclear transitions induced by atomic processes — Andrey V. Volotka[1], Andrey Surzhykov[2,3], Stephan Fritzsche[1,4], and •Robert A. Müller[2,3] — [1]Helmholtz-Institute Jena, Jena, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Technische Universität Braunschweig, Braunschweig, Germany — [4]Friedrich-Schiller-Universität Jena, Jena, Germany

The investigation of nuclei in isomeric (metastable) states gives important insight into their inner dynamics. Moreover the low lying nuclear excitation at a few eV in ^{229}Th has received strong interest because of its applicability for a nuclear clock [1]. For the majority of these studies the nuclear isomers are produced by neutron collisions or as products of the radioactive decay series of heavier elements. A direct photoexcitation seems possible as well but turns out to be a very difficult task due to the extremely narrow linewidths of the nuclear states. In contrast to photons, atomic electrons have a large overlap with the nucleus and, hence, are not only sensitive to nuclear properties but can also be used instead of photons to induce nuclear excitations [2]. In this contribution we will discuss different possible scenarios for the excitation of nuclei via electronic processes. We will especially concentrate on two-photon processes in highly charged ions and multi-step schemes in almost neutral systems, e.g. Th^{2+}, that can be realized using optical lasers.

[1] E. Peik and M. Okhapkin, C. R. Physique **16**, 516-523 (2015)
[2] R. A. Müller *et al.*, NIMB (2016) submitted

A 9.7 Mon 18:30 N 3

The first ionization potential of nobelium — •Premaditya Chhetri[1,2], Dieter Ackermann[2,3], Hartmut Backe[4], Michael Block[2,4,5], Bradley Cheal[6], Christian Droese[7], Christoph Emanuel Düllmann[2,4,5], Julia Even[8], Rafael Ferrer[9], Francesca Giacoppo[2,5], Stefan Götz[2,4,5], Fritz Peter Hessberger[2,5], Oliver Kaleja[2,4], Jadambaa Khuyagbaatar[2,5], Peter Kunz[10], Mustapha Laatiaoui[2,5], Felix Lautenschläger[1,2], Werner Lauth[4], Lotte Lens[2,4], Nathalie Lecesne[3], Andrew Kishor Mistry[2,5], Sebastian Raeder[2,5], Enrique Minaya Ramirez[11], Thomas Walther[1], Alexander Yakushev[2], and Zhiyuan Zhang[12] — [1]TU Darmstadt — [2]GSI — [3]GANIL — [4]Universität Mainz — [5]Helmholtz-Institut Mainz — [6]University of Liverpool — [7]Universität Greifswald — [8]KVI-CART — [9]KU-Leuven — [10]TRIUMF — [11]IPN Orsay — [12]IMP Lanzhou

Precision measurements of optical transitions of the heaviest elements can be used to test state-of-the-art atomic calculations which include relativistic effects and electron correlations, both affecting physical and chemical properties of these elements. Only recently, the first optical spectroscopy of element nobelium (Z=102) was reported [1], making use of the sensitive Radiation Detected Resonance Ionization Spectroscopy (RADRIS) technique. Several high lying Rydberg states were observed enabling the extraction of the first ionization potential of nobelium. In this talk, a report on the recent achievements in the RADRIS measurements on nobelium will be presented.

[1] M. Laatiaoui et al., Nature 538, 495-498 (2016)

A 9.8 Mon 18:45 N 3

High-precision theory of the bound-electron *g*-factor — •Bastian Sikora[1], Nikolay A. Belov[1], Natalia S. Oreshkina[1], Vladimir A. Yerokhin[2], Christoph H. Keitel[1], and Zoltán Harman[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia

The g-factor of bound electrons in H-like ions can be measured and calculated with high accuracy. Comparison between the theoretical and experimental values of the bound-electron g-factor allows precision tests of QED and the determination of fundamental constants such as the electron mass or the fine-structure constant α [1].

In order to achieve a high accuracy in theoretical predictions of the bound-electron g-factor in high nuclear charge states, the interaction with the nuclear potential needs to be taken into account to all orders in $Z\alpha$. We present all-order evaluations of QED contributions to the bound-electron g-factor such as two-loop corrections and the muonic vacuum polarization contribution [2]. – [1] V. A. Yerokhin, E. Berseneva, Z. Harman, *et al.*, PRL 116:100801 (2016) [2] N. A. Belov, B. Sikora, R. Weis, *et al.*, submitted; arXiv:1610.01340 (2016).

A 10: Diffraction and Coherences (with MO)

Time: Monday 17:00–18:45 Location: N 6

Invited Talk A 10.1 Mon 17:00 N 6

Single-shot coherent diffractive imaging of individual clusters using a high harmonic source — Nils Monserud[1], Daniela Rupp[2], Bruno Langbehn[2], Mario Sauppe[2], Julian Zimmermann[2], Yevheniy Ovcharenko[2], Thomas Möller[2], Fabio Frassetto[3], Luca Poletto[3], Andrea Trabattoni[4], Francesca Calgari[5], Mauro Misoli[4,5], Katharina Sander[6], Christian Peltz[6], Marc J.J. Vrakking[1], Thomas Fennel[6], and •Arnaud Rouzée[1] — [1]Max-Born-Institut, Berlin, Germany — [2]Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Germany — [3]CNR, Instituto di Fotonica e Nanotecnologie Padova, Padova, Italy — [4]Department of Physics, Politecnico di Milano, Milano, Italy — [5]CNR, Instituto di Fotonica e Nanotecnologie Milano, Milano, Italy — [6]Institut für Physik, Universität Rostock, Rostock, Germany

We present a single-shot coherent diffractive imaging (CDI) experiment based on high harmonic generation of individual He nanodroplets performed with a table-top femtosecond extreme ultraviolet (XUV) light source. Using a laser based HHG source, we are able to demonstrate for the first time the possibility to extract the shape, size, and orientation of free-flying nanoparticles. While most of the recorded diffraction patterns are assigned to the formation of spherical nanodroplets, we observed as well non-point symmetric diffraction patterns which are uniquely assigned to the formation of prolate, pill-shaped He-nanodroplets. Our experiment paves the way towards time-resolved imaging of ultrafast electron motion in individual clusters and nanoparticles with attosecond time resolution.

A 10.2 Mon 17:30 N 6

Numerical simulations for characterizing and optimizing an aerodynamic lens — •Nils Roth[1], Salah Awel[1,2], Daniel Horke[1,3], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Notkestrasse 85, 22607 Hamburg, Germany —

[2]Department of Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]The Hamburg Center for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

Atomic resolution single-particle coherent diffractive imaging requires reproducible samples to reconstruct three-dimensional molecular structures from isolated particles [1]. Currently one of the major limiting factors is the inefficient delivery of particles and the correspondingly low number of strong diffraction patterns, collected during typical beam times. We build a numerical simulation infrastructure capable of calculating the flow of gas and the trajectories of particles through an entire aerosol injector, aiming to increase the fundamental understanding and to enable optimization of injection geometries and parameters. The simulation results are compared to literature studies and also validated against experimental data taken in an aerosol beam characterization setup [2]. The simulation yields a detailed understanding of the radial particle distribution and highlights weaknesses of current aerosol injectors. With the aid of these simulations we develop new experimental implementations to overcome current limitations and increase particle densities available for diffractive imaging experiments.

[1] M. M. Seibert, et al, *Nature* **470**, 78 (2011).
[2] Salah et al, *Opt. Exp.* **24**, 6507-6521 (2016)

A 10.3 Mon 17:45 N 6

Femtosecond Diffractive Imaging of Coherent Nuclear Motion using Relativistic Electrons — Jie Yang[1], •Markus Gühr[2,3], Xiaozhe Shen[3], Renkai Li[3], Theodore Vecchione[3], Ryan Coffee[3], Jeff Corbett[3], Alan Fry[3], Nick Hartmann[3], Carsten Hast[3], Kareem Hegazy[3], Keith Jobe[3], Igor Makasyuk[3], Joseph Robinson[3], Matthew Robinson[1], Sharon Vetter[3], Stephen Weatherby[3], Charles Yoneda[3], Xijie Wang[3], and Martin Centurion[1] — [1]Department of Physics, University of Nebraska-Lincoln,Lincoln, NE, USA — [2]Institut für Physik und Astronomie,Universität Potsdam, Potsdam, Germany — [3]SLAC National Accelerator Laboratory, Menlo Park, CA, USA

Observing ultrafast changes in the molecular geometry after photoexcitation is crucial to understand the conversion of light energy into other energetic degrees of freedom within molecules. We present a time resolved electron diffraction study of a molecular vibrational wavepacket in photoexcited isolated iodine. We determine the time-varying interatomic distance with a precision 0.07 Å and a temporal resolution of 230 fs full width at half maximum. The method is not only sensitive to the position but also the shape of the nuclear wave packet.

A 10.4 Mon 18:00 N 6

Ultrashort polarization-tailored bichromatic fields — •Stefanie Kerbstadt, Lars Englert, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Straße 9-11, 26129 Oldenburg

Ultrashort bichromatic laser fields with commensurable center frequencies, have emerged as a powerful tool to coherently control the dynamics of free electron wave packets [1]. Here we present a novel scheme for the generation of polarization-tailored bichromatic laser fields based on ultrafast pulse shaping techniques. The scheme utilizes a 4f polarization pulse shaper equipped with a composite polarizer in the Fourier plane for independent amplitude and phase modulation of two spectral bands of a whitelight supercontinuum [2]. The setup allows us to sculpture the spectral amplitude, phase and polarization profile of both colors individually, offering an enormous versatility of producible bichromatic waveforms. In addition, the scheme features built-in dispersion management and the option for shaper-based pulse diagnostics. We demonstrate the fidelity of the generated bichromatic fields by optical characterization and present first results of quantum control of bichromatic photoionization of atoms employing photoelectron imaging tomography.

[1] D.B. Milosevic et al., Phys. Rev. A 61 (6) (2000), 063403.
[2] S. Kerbstadt et al., J. Mod. Opt., accepted (2016).

A 10.5 Mon 18:15 N 6

Electronic decoherence following photoionization: full quantum-dynamical treatment of the influence of nuclear motion — •Caroline Arnold[1,2,3], Oriol Vendrell[1,3,4], and Robin Santra[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Notkestrasse 85, 22607 Hamburg, Germany — [2]Department of Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [4]Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, 8000 Aarhus, Denmark

Photoionization using attosecond pulses can lead to the formation of coherent superpositions of the electronic states of the parent ion. However, ultrafast electron ejection triggers not only electronic but also nuclear dynamics—leading to electronic decoherence, which is typically neglected on time scales up to tens of femtoseconds. We propose a full quantum-dynamical treatment of nuclear motion in an adiabatic framework, where nuclear wavepackets move on adiabatic potential energy surfaces expanded up to second order at the Franck-Condon point. We show that electronic decoherence is caused by the interplay of a large number of nuclear degrees of freedom and by the relative topology of the potential energy surfaces. Application to H2O, paraxylene, and phenylalanine shows that an initially coherent state evolves to an electronically mixed state within just a few femtoseconds. In these examples, it is not the fast vibrations involving hydrogen atoms, but rather slow vibrational modes that destroy electronic coherence.

A 10.6 Mon 18:30 N 6

Optimisation of strong laser field-free alignment using tailored light fields — •Evangelos Thomas Karamatskos[1,2], Sebastian Raabe[4], Andrea Trabattoni[1], Terry Mullins[1], Sebastian Trippel[1,2], Arnaud Rouzee[4], and Jochen Küpper[1,2,3] — [1]DESY, Hamburg, Germany — [2]Universität Hamburg, Germany — [3]CUI, Hamburg, Germany — [4]Max-Born Institute, Berlin, Germany

Alignment of molecules with respect to the laboratory fixed frame [1] enables the realization of a large variety of experiments such as the determination of molecular frame photoangular distribution (MFPAD's) [2] or laser induced electron diffraction (LIED) where typically a strong degree of alignment is needed [3]. We present a combined theoretical and experimental effort to optimise the degree of laser field-free alignment of molecules in the gas phase. We start by solving the time-dependent rotational Schrödinger equation coupled to a non-resonant laser field and a static electric field and use an iterative learning-loop algorithm to determine the ideal pulse shape that optimises the degree of alignment. These calculations serve as a guide to complement the experiments where the alignment laser pulse form is optimally tailored. We discuss the simulation results and the experimental realization of two-pulse impulsive alignment on the example of the linear molecule carbonyl sulfide (OCS) and give an outlook for the use of pulse shaping techniques to achieve strongly aligned asymmetric top molecules.
[1] Stapelfeldt et al., Rev. Mod. Phys. 75, 543 (2003) [2] Hansen et al. Phys. Rev. Lett. 106, 073001 (2011) [3] Pullen et al., Nature Communications 6, 7262 (2015)

A 11: Precision Measurements and Metrology: Optical Clocks (with Q)

Time: Monday 17:00–19:00 Location: P 104

A 11.1 Mon 17:00 P 104

Decay channels of the ^{229}Th nuclear isomeric state involving atomic electrons — •Pavlo Bilous and Adriana Pálffy — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, D-69117 Heidelberg, Germany

The thorium isotope ^{229}Th is unique due to its nuclear isomeric (*i.e.* long living) excited state with the energy of $E_{\text{iso}} = 7.8$ eV typical for optical atomic transitions. Being a bridge between atomic and nuclear physics, this nuclear transition has very narrow width and high stability to external perturbations, so it can be a key to metrology applications such as a nuclear frequency standard. The excitation and decay channels of this transition may well involve the electronic shell due to the very low value of E_{iso}.

For the neutral atom ^{229}Th, the isomeric state may decay via internal conversion (IC). For ^{229}Th ions this is not the case as the energy E_{iso} is lower than the corresponding ionization thresholds. However, IC from excited electronic states remains energetically allowed. On the other hand, the energy can be transferred to the electronic shell with excitation of an electron to another bound state accompanied by the absorption or emission of a photon (so called electron bridge). This channel can be strongly enhanced if the electronic and the nuclear transitions are on resonance. Here we consider several channels of decay of the nuclear isomeric state involving the atomic electrons and carry out *ab initio* calculations of corresponding rates using multiconfigurational Dirac-Fock wave functions for the bound atomic electrons.

A 11.2 Mon 17:15 P 104

Entwicklung und Aufbau einer kompakten und hochstabilen optischen Frequenzreferenz für den Einsatz auf einer Höhenforschungsrakete — •Markus Oswald[1], Thilo Schuldt[1,2], Klaus Döringshoff[3], Markus Krutzik[3], Vladimir Schkolnik[3], Franz B. Gutsch[3], Achim Peters[3] und Claus Braxmaier[1,2] — [1]Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation (ZARM), Universität Bremen — [2]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Bremen — [3]Humboldt-Universität zu Berlin

Hochstabile optische Frequenzreferenzen spielen bei einer Vielzahl von Weltraumanwendungen eine entscheidende Rolle, wie beispielsweise bei der Detektion von Gravitationswellen, der Navigation oder der Erdbeobachtung. Hierbei stellen Frequenzreferenzen auf Basis von molekularem Jod unter Nutzung der dopplerfreien Sättigungs-Spektroskopie eine vielversprechende Technologie für zukünftige Missionen dar, insbesondere hinsichtlich ihrer Stabilität über lange Zeiträume. Im Rahmen des JoKARUS-Projekts (Jod-Kammresonator unter Schwerelosigkeit) soll erstmals ein Jod-Spektroskopiemodul auf einer Höhenforschungsrakete zum Einsatz kommen und so den Weg bereiten für zukünftige Weltraumeinsätze (z.B. NGGM, eLISA). Ausgehend von vorangegangenen Laboraufbauten wurde ein Instrumentendesign entwickelt und hinsichtlich der Anforderungen der Mission an Kompaktheit, Leistungsfähigkeit und Robustheit optimiert und unter Einbeziehung qualifizierter Klebeverfahren auf einer 246 mm x 145 mm Quarzglasplatte integriert. Finanziert durch das DLR aus Mitteln des BMWi (Förderkennzeichen 50WM1646).

A 11.3 Mon 17:30 P 104

Relative field sensitivities in ^{171}Yb^{+} transitions — •Richard Lange, Nils Huntemann, Christian Sanner, Christian Tamm, Burghard Lipphardt, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

The ^{171}Yb^{+} ion exhibits two transitions that are employed in our setup of a single-ion optical frequency standard, the $^2S_{1/2} \rightarrow {}^2D_{3/2}$ electric quadrupole (E2) [PRA **89**, 023820] and the $^2S_{1/2} \rightarrow {}^2F_{7/2}$ electric octupole (E3) [PRL **108**, 090801] transition. In order to provide a frequency standard with highest accuracy, deviations from the unperturbed transition frequencies due to external perturbations have to be taken into account and corrected for. In particular, the effects related to external magnetic and electric fields as well as field gradients need to be investigated. The significantly higher sensitivity of the E2 transition frequency to these perturbations allows for an examination of the E3 transition frequency shifts on a magnified scale.

With precise information about the relative field sensitivities, uncertainties in the E3 transition frequency due to field perturbations can be reduced: Shifts of the E3 transition frequency can be corrected more accurately analyzing changes in the E2 transition frequency than measuring the fields and field gradients directly. In this talk we present improved measurement results of the relative field sensitivities of the E2 and E3 transition frequencies and discuss the effects of these results on the uncertainty budgets of our frequency standards.

A 11.4 Mon 17:45 P 104

First campaigns with PTB transportable optical lattice clock — •J. Grotti[1], S. Koller[1], S. Vogt[1], A. Al-Masoudi[1], S. Dörscher[1], S. Herbers[1], S. Häfner[1], U. Sterr[1], C. Lisdat[1], H. Denker[2], M. Pizzocaro[3], P. Thoumany[3], B. Rauf[3], C. Clivati[3], M. Zucco[3], F. Levi[3], D. Calonico[3], A. Rolland[4], F. Baynes[4], and H. Margolis[4] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Erdmessung - Leibniz Universität Hannover, Schneiderberg 50, 30167 Hannover, Germany — [3]Istituto Nazionale di Ricerca Metrologica, Strada delle Cacce 91 , 10135 Torino, Italy — [4]National Physical Laboratory, Teddington, Middlesex TW11 0LW, UK

A transportable lattice clock based on ^{87}Sr atoms has been built at PTB and successfully tested in the laboratory. The clock showed a stability of $1.3 \cdot 10^{-15}/\sqrt{\tau}$ and a systematic uncertainty of $7.4 \cdot 10^{-17}$. Furthermore, its frequency is in agreement with the stationary system of PTB. The system has been placed inside a car trailer and used for two measurement campaigns: A proof of principle experiment of relativistic geodesy in the Frejus tunnel, at the Italy-France boarder, and a local measurement of the ^{171}Yb/^{87}Sr clock frequency ratio at Torino. These campaigns were performed in collaboration with INRIM, NPL and the Institut für Erdmessung (IfE), Leibniz University Hannover. Results will be shown in the talk. This work is supported by QUEST, DFG (RTG 1729, CRC 1128), EU-FP7 (FACT) and EMRP (ITOC). The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

A 11.5 Mon 18:00 P 104

A Sr lattice clock with $6 \cdot 10^{-17}/\sqrt{\tau/\mathrm{s}}$ frequency instability — •Roman Schwarz[1], Sören Dörscher[1], Ali Al-Masoudi[1], Sofia Herbers[1], Dan-Gheorghita Matei[1], Thomas Legero[1], Sebastian Häfner[1], Christian Grebing[1], Erik Benkler[1], Wei Zhang[2], Lindsay Sonderhouse[2], John M. Robinson[2], Jun Ye[2], Fritz Riehle[1], Uwe Sterr[1], and Christian Lisdat[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig — [2]JILA, National Institute of Standards and Technology and University of Colorado, Boulder, Colorado 80309, USA

Optical clocks represent the forefront of frequency metrology enabling applications in relativistic geodesy, tests of fundamental physics, and the search for dark matter. As their systematic uncertainty reaches the low 10^{-18} regime, reducing their frequency instability becomes even more important in order to exploit their potential. Here, we report on recent improvements of the Sr lattice clocks at PTB by phase-locking the interrogation laser to cryogenic Si resonators at 194 THz. Frequency instabilities of $6 \cdot 10^{-17}(\tau/\mathrm{s})^{-1/2}$ are inferred from clock self-comparisons.

This work is supported by QUEST, the DFG within CRC 1128 (geo-Q), CRC 1227 (DQ-*mat*) and RTG 1729, EMPIR within OC18. The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation program and the EMPIR Participating States.

A 11.6 Mon 18:15 P 104

Evaluation of a magnesium frequency standard and progress towards a frequency measurement — •Klaus Zipfel, Dominika Fim, Nandan Jha, Steffen Rühmann, Steffen Sauer, Waldemar Friesen, Pia Koopmann, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

State-of-the-art optical atomic lattice clocks with fermionic strontium already reached uncertainties in the low 10^{-18} regime [1,2]. In order to operate on that level, a high Q factor and hence a narrow observable linewidth of the clock transition is key for the evaluation of the systematics.

In this presentation, we report on spectroscopy with an observable linewidth of 100 Hz for the $^1S_0$ - $^3P_0$ clock transition in bosonic magnesium, which corresponds to the highest Q factor for an optical transition in that species so far. As a consequence, the resolution for evaluating the uncertainties like 2nd order Zeeman and lattice AC-Stark shift increases. We will show the latest results for our systematics and as well present the progress towards an absolute frequency measurement.

[1] B. J. Bloom et al., Nature **506**, 71 - 75 (2014)
[2] T.L. Nicholson et al., Nature Communications **6**, 6896 (2015)

A 11.7 Mon 18:30 P 104

Ion dynamics and systematic shifts in a multi-ion atomic clock — •Dimitri Kalincev, Jonas Keller, Tobias Burgermeister, Alexandre Didier, Jan Kiethe, André Kulosa, Tabea Nordmann, Thorben Schmirander, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

Single ion optical clocks have an estimated systematic fractional frequency uncertainty at the 10^{-18} level. The main limitation in measuring atomic frequencies is their statistical uncertainty due to the fundamental limit of quantum projection noise. In order to exploit the high accuracy, very long averaging times are required. We show that the statistical uncertainty of single-ion-clocks can be overcome with a multi-ion-approach while keeping excellent control of systematics. For mixed crystals, we analyze effects relevant at the 10^{-19} level and below. We identify crystal configurations that can be cooled efficiently while having low heating rates.

With a new chip-based linear Paul-trap, designed for low axial micromotion, we measure heating rates as a function of the ion secular frequency. We simultaneously measure micromotion across an ion Coulomb crystal. Based on experimental results on trap induced shifts and on our calculations, we present an estimated error budget for a multi-ion-clock.

A 11.8 Mon 18:45 P 104

High precision and high frequency sensing with a continuous drive utilizing the Nitrogen Vacancy center — •Daniel Louzon[1,2], Alexander Stark[1,3], Thomas Undnen[1], Nati Aharon[2], Alexander Huck[3], Ulrik L. Andersen[3], Alex Retzker[2], and Fedor Jelzko[1] — [1]Ulm University, Ulm, Germany — [2]Hebrew University, Jerusalem — [3]Technical University of Denmark, Kongens Lyngby, Denmark

Single defect centers in diamond and especially the nitrogen-vacancy (NV) show remarkable physical properties such as long spin coherence time and the emission of single photons. These properties make them ideal candidates for qubits and nano-scale magnetic field sensors [1].

High frequency sensing, using a two level system, is considered T_2^* limited, given dynamical decoupling techniques cannot be applied on a time scale shorter than the on-resonance signal being measured.

We present the implementation of a novel technique to measure a weak high frequency signal using a detuned two level system and a series of continuous driving fields prolonging the coherence time of the two level system in principle close to its T_1 time [2].

The technique is demonstrated on a single NV center in diamond as the two level system, measuring a weak high frequency signal, with a coherence time over an order of magnitude longer than its T_2^*.

[1] M. Doherty et al., Physics Reports 528, 1 (2013) [2] N. Aharon et al., arXiv: 1609.07812 (2016).

A 12: Clusters I (with MO)

Time: Tuesday 11:00–13:00 Location: N 6

Invited Talk A 12.1 Tue 11:00 N 6

Cryo Kinetics and Spectroscopy of 3d Metal Clusters and Alloys — Jennifer Mohrbach, Sebastian Dillinger, Matthias Klein, Amelie Ehrhard, and •Gereon Niedner-Schatteburg — Fachbereich Chemie, TU Kaiserslautern

The cluster surface analogy motivates us to utilize our hybrid tandem ion trap instrument (cryo-RF-hexapole and cryo-FT-ICR trap) for the study of adsorption and reaction kinetics of clusters under single collision conditions at 11 -30 K, and for IR Photon Dissociation (IR-PD) spectroscopy initially focusing on the one and two colour investigations of metal organic complexes[1] and lately extended towards their N_2 adsorption properties[2].

We have started a systematic study of N_2 and H_2 cryo adsorption on size selected Fe, Co, and Ni clusters, and their alloys[3]. Adsorption kinetics show mono layer like adsorbate shells. IR-PD spectra of cluster adsorbate complexes $[M_n(N_2)_m]^+$ reveal complex patterns - DFT modelling providing some support. There are adsorbate coverage dependent spectral shifts and splittings that report on the cluster and adsorbate geometries. We compare to our synchrotron X-ray based studies of spin and orbital contributions to the total magnetic moments of the clusters[4]. Supported by SFB **3MET.de**.

[1] Y. Nosenko et al. PCCP **15**, 8171 (2013); J. Lang et al. PCCP **16**, 17417 (2014). [2] J. Lang et al., Chem.Comm 2016 (in print). [3] S. Dillinger et al. PCCP **17**, 10358 (2015); J. Mohrbach et al. JPC A 2016 (submitted). [4] S. Peredkov et al. PRL **107**, 233401 (2011); J. Meyer et al. JCP **143**, 104302 (2015)

A 12.2 Tue 11:30 N 6

Unusual magic numbers in Si_n^+-Ar_m clusters — •Marko Förstel, Bertram Jaeger, Philipp Sporkhorst, and Otto Dopfer — Institut für Optik und Atomare Physik, Technische Universität Berlin, Hardenbergstrasse 36, D-10623 Berlin

Silicon ions are found in the interstellar medium and in Earth's atmosphere. They are also involved in semiconductor manufacturing processes. The fundamental chemistry, behavior, and structure of Si_n^+ ions are, however, still poorly understood. Here we probe the anisotropic electronic structure of the Si_n^+ ion in form of the Si_n^+-Ar_m potential energy surface by using argon ligands. Si_n^+-Ar_m clusters are produced in a laser vaporization source and then analyzed in a mass spectrometer. Depending on the cluster source conditions we observe unusual magic numbers that cannot be explained satisfyingly by assuming an icosahedric argon shell. We interpret our observations as an effect of the strong anisotropy in the interaction potential of the Si^+ ion caused by its unpaired electron. We present the observed magic numbers of Si_n^+-Ar_m clusters and discuss the underlying structures with the help of quantum chemical calculations.

A 12.3 Tue 11:45 N 6

Absorption of diamondoid-noble metal cluster hybrids studied with ion yield spectroscopy — •Tobias Bischoff[1], Andre Knecht[1], Andrea Merli[1], Vicente Zamudio-Bayer[2], Tobias Lau[3], Bernd von Issendorff[2], Merle Röhr[4], Jens Petersen[4], Roland Mitric[4], Thomas Möller[1], and Torbjörn Rander[1] — [1]TU Berlin, Germany — [2]U Freiburg, Germany — [3]Helmholtz-Zentrum Berlin, Germany — [4]U Würzburg, Germany

The study of the radiative emission rate enhancement of molecules near metal surfaces has led to important applications such as single molecule spectroscopy. While interaction-induced amplification rates as high as 14 orders of magnitude have been already observed, there is still debate about the fundamental processes responsible for the enhancement. On the molecular size scale, small metal clusters may be used to systematically study the interaction between a metal subunit and a fluorophore. Diamondoids, perfectly shape and mass selected sp^3 hybridized nanodiamonds, show intrinsic luminescence and can be selectively functionalized. We were able to synthesize hybrid systems of diamondoids and small metal cluster cations in the gas phase. This approach enables us to study the optical properties of tailored hybrid systems. Here, we present the UV/VIS absorption of adamantanethiol-Au_3/Ag_3 hybrid systems, measured through ion yield spectroscopy. An analysis of both the hybrid and single subunit absorptions shows significant differences in spectral composition depending on the type of metal cluster. We attribute these differences to charge transfer states in the hybrid systems.

A 12.4 Tue 12:00 N 6

Disentangling water cluster beams — •Helen Bieker[1,2], Daniel Horke[1,2], Daniel Gusa[1], Boris Sartakov[3], Andrey Yachmenev[1], and Jochen Küpper[1,2,4] — [1]Center for Free-Electron Laser Science, DESY — [2]The Hamburg Center for Ultrafast Imaging, University of Hamburg — [3]General Physics Institute, Russian Academy of Sciences — [4]Department of Physics, University of Hamburg

To unravel the microscopic details of intermolecular interactions in water, we prepare controlled samples of size- and isomer-selected water clusters. Inhomogeneous electric fields allow us to create pure samples of individual structural isomers or of size-selected molecular clusters and to disperse molecules in a beam according to their quantum states [1].

Here, we aim to develop an understanding of the structures of water clusters containing a few monomer units. We present our first results on the production of size-selected samples using supersonic expansions, subsequent dispersion of the various clusters in strong electric fields, extending previous studies [2]. We introduce a simple theoretical description of water dimer in an electric field. Future experiments aim at utilizing x-ray and electron diffractive imaging to study the structures and ultrafast dissociation dynamics of these polymolecular systems.

[1] Y.P. Chang, D. A. Horke, S. Trippel and J. Küpper, *Int. Rev. Phys Chem.* **34**, 557-590 (2015)

[2] R. Moro, R. Rabinovitch, C. Xia, and V.V. Kresin, *Phys. Rev. Lett.* **97**, 123401 (2006)

A 12.5 Tue 12:15 N 6

D-Dimensional Fourier Grid Hamiltonian Method with Potential-Adapted Grid for Hydrogen Isotopologue Cluster Computations — •Alexander Kraus, Robin Grössle, and Sebastian Mirz — Karlsruhe Institute of Technology, Institute for Technical Physics, Tritium Laboratory Karlsruhe

In order to determine the systematic effect of molecular hydrogen clusters on the neutrino mass measurement with KATRIN, a computational method is needed that can be used for a calculation of initial and final beta decay states.

For this purpose, the Fourier Grid Hamiltonian Method has been generalized to d dimensions. A grid generation algorithm has been introduced that chooses sparse sampling points which represent the potential sufficiently to save computation time. The d-dimensional inverse FFT is used for fast computation of matrix elements. Eigenvalues and Eigenstates are approximated by parallel Lanczos diagonalization.

An overview of the constructed algorithm is given and first results and benchmarks are shown in this talk.

This method could also be useful to infrared spectroscopy of liquid hydrogen isotopologues for a better quantitative understanding of cluster excitations.

A 12.6 Tue 12:30 N 6

Highly nonlinear optical response of organotin cluster molecules — •Nils W. Rosemann[1,3], Jens P. Eussner[2], Andreas Beyer[3], Stephan W. Koch[3], Kerstin Volz[3], Stefanie Dehnen[2], and Sangam Chatterjee[1] — [1]Institute of Experimental Physics I, Justus-Liebig-Universität Giessen, Heinrich-Buff Ring 16, D-35392 Giessen, Germany — [2]Faculty of Chemistry and Materials Sciences Center, Philipps-Universität Marburg, Hans-Meerwein-Straße, D-35043 Marburg, Germany — [3]Faculty of Physics and Materials Science Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany

Organotin-based cluster molecules exhibit a large variety of physical properties. These depend on the clusters chemical composition as well as the spatial arrangement of the constituents. Variation of these two parameters usually results in highly complex electronic landscapes. Consequently, such cluster molecules exhibit a very specific linear response and ultimately nonlinear optical properties.

Here, we present the extreme nonlinear optical response of a cluster molecule composed of a SnS cluster-core decorated with styryl-ligands. The ligands, on the one hand, prevent crystallization and provide delocalized electrons that are responsible for the nonlinear response on the other hand. These peculiarities result in low-threshold white-light generation. The latter is simulated numerically using an anharmonic oscillator model and experimental parameters only.

A 12.7 Tue 12:45 N 6

Infrared spectra and structures of boron-doped silicon clusters — •Bertram Klaus August Jaeger[1], Nguyen Xuan Truong[1], Sandy Gewinner[2], Wieland Schöllkopf[2], Andre Fielicke[1], and Otto Dopfer[1] — [1]IOAP, TU Berlin, Germany — [2]FHI, Berlin, Germany

Silicon-based nanostructures have gained interest for nanoelectronics and nanophotonics. Therefore, the investigation of controlled change of physical and chemical properties of silicon clusters by doping will aid in developing novel cluster-containing nanostructures. Here we study neutral silicon-rich silicon-boron clusters (Si_nB_m, n=3-8, m=1-2) via mass spectrometry, resonant infrared-ultraviolet two-color ionization (IR-UV2CI) spectroscopy and quantum chemical calculations [1]. The most stable isomers are found utilizing global energy optimization. Their linear IR absorption spectra are compared to the IR-UV2CI spectra, thus determining the geometries of the observed Si_nB_m clusters. Different physical properties such as charge distributions, ionization energies and bond energies will be discussed. As the B-B bond is stronger than the B-Si and Si-Si bonds, boron segregation is observed for Si_nB_m clusters with m=2.

[1] N.X. Truong et al., Int. J. Mass Spectrom., 2016, 395, 1-6

A 13: Precision Measurements and Metrology: Interferometry I (with Q)

Time: Tuesday 11:00–13:00 Location: P 104

A 13.1 Tue 11:00 P 104

Challenging Einstein with Very Long Baseline Atom Interferometry — •Etienne Wodey, Christian Meiners, Dorothee Tell, Dennis Schlippert, Christian Schubert, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

In the quest for a theory of quantum gravity, most of the theoretical attempts to reconcile two of physics' most successful theories, quantum mechanics (QM) and general relativity (GR), build upon a violation of Einstein's equivalence principle. Considerable experimental effort to detect potential violations of the universality of free fall (UFF) has therefore been delivered, first using classical test masses and more recently with genuine quantum objects.

Very Long Baseline Atom Interferometers (VLBAI) represent a new class of matter-wave sensors that extend the baseline from tens of centimeters to several meters, enabling free fall times on the order of seconds and a corresponding increase in the phase sensitivity which scales with the square of the free fall time. Using ultracold mixtures of rubidium and ytterbium atoms, this should not only enable quantum tests of the UFF challenging the current state of the art with classical test masses but also permit new experiments ranging from gravimetry and gradiometry with unprecedented resolution and stability to new probes of the intimate interplay between GR and QM.

The VLBAI facility is a major research equipment funded by the DFG. We also acknowledge support from the CRCs 1128 "geo-Q" and 1227 "DQ-mat" and the RTG 1729.

A 13.2 Tue 11:15 P 104

Operating an interferometer in a noisy environment — •Dipankar Nath, Henning Albers, Christian Meiners, Logan L. Richardson, Dennis Schlippert, Christian Schubert, Etienne Wodey, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Inertial sensitive devices such as atom interferometers are prone to seismic noise. Atom interferometers with longer baselines are particularly susceptible to very low frequency noise where vibration isolation platforms are not very efficient. Using a mechanical sensor like a seismometer, one can correct the contribution from residual vibrations [1]. We demonstrate seismic post correction in an atom interferometer with 2T=152 ms by correlating the atom interferferometer (operated using cold ^{87}Rb atoms) with a Guralp CMG-40T seismometer and show a two fold improvement in the short term stability using the post correction scheme. Such a scheme will also be implemented in the Very Long Baseline Atom interferometer (VLBAI) [2]. Seismic post correction will also be used to improve the test of the Universality of Free Fall in a dual species atom interferometer employing ^{87}Rb and ^{39}K as test masses [3,4]. Post correction schemes such as this will also be used in atom interferometry based transportable gravimeters in the future.

[1] L. Le Gouët et al., Appl. Phys. B 92, 133 (2008)
[2] J. Hartwig et al., New J. Phys. 17, 035011 (2015)
[3] D. Schlippert et al., Phys. Rev. Lett. 112, 203002 (2014)
[4] B. Barrett et. al., arXiv 1609.03598v1

A 13.3 Tue 11:30 P 104

Trade-off of atomic sources for extended-time atom interferometry — •Sina Loriani, Dennis Schlippert, Christian Schubert, Ernst Maria Rasel, and Naceur Gaaloul — Leibniz University of Hanover, Germany

Proposals for atom-interferometry based sensors designed to detect gravitational waves or testing the universality of free fall assume unprecedented sensitivity for long interferometry times [Hogan et al., Phys. Rev. A 94, 033632, (2016)]. These long drift times of several seconds can be achieved by operation in microgravity and by using phase-space-manipulation techniqes like the delta-kick-collimation(DKC), which drastically reduces the expansion rate of atomic samples [Müntinga, et al. Phys. Rev. Lett. **110**, 093602 (2013), T. Kovachy et al., Phys. Rev. Lett. **114**, 143004 (2015)]. We present a set of theoretical models that treat the impact of collisions and mean-field on the performance of the kick and compare the efficiency of the collimation for all possible temperature and density regimes. The theoretical study covers commonly used alkaline and alkaline-earth-like ensembles of atoms (Rb, Sr, Yb, etc.). The figure of merit is the size of the ensemble when being lensed as the atomic lenses are subject to aberrations depending on the spatial extent of the cloud and the potentials being used. The analysis shows a clear advantage when using condensed ensembles.

A 13.4 Tue 11:45 P 104

Infrasound gravitational wave detection with atoms — •Christian Schubert, Dennis Schlippert, Sven Abend, Naceur

Gaaloul, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Atom interferometry offers an interesting perspective for the detection of gravitational waves in a frequency band between eLISA and Advanced LIGO, resulting in an active field of research. Ground based setups with vertical or horizontal baselines were considered, satellite missions investigated, and interferometer topologies developed. We investigate a novel geometry for a ground based device combining several advantages as a horizontal baseline, enabling long baselines, a single axis laser link between the atom interferometers acting as phasemeters, and suppressing errors sources otherwise implying very strict requirements onto the atomic source. It is based on recent developments in symmetric large momentum beam splitters, relaunching techniques for suspending the atoms against gravity, and delta-kick collimation techniques to generate very slowly expanding atomic ensembles. The idea will be presented and the requirements discussed in comparison with previous proposals and the state of the art in atom optics. The work is supported by the CRC 1227 DQ-mat, the CRC 1128 geo-Q, the RTG 1729, the DFG Excellence Cluster QUEST, the QUEST-LFS, and by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under Grant No. 50WM1552-1557.

A 13.5 Tue 12:00 P 104

First gravity gradient measurements with the gravimetric atom interferometer GAIN — •Bastian Leykauf, Christian Freier, Vladimir Schkolnik, Matthias Hauth, Markus Krutzik, and Achim Peters — Institut für Physik, Humboldt-Universität zu Berlin

The gravimetric atom interferometer GAIN is based on interfering ensembles of laser-cooled ^{87}Rb atoms in a fountain setup, using stimulated Raman transitions. GAIN's rugged design allows for transports to sites of geodetic and geophysical interest while maintaining a high accuracy compatible with the best classical instruments. Its long-term stability of $0.5\,\mathrm{nm/s^2}$ and the effective control over systematic effects, including Raman beam wavefront aberrations, has previously been reported [1,2], demonstrating the unique properties of atomic sensors.

By using the juggling technique, we are able to perform gravity measurements on two atomic clouds simultaneously. Advantages include the suppression of common mode phase noise, enabling differential phase shift extraction without the need for vibration isolation. We will present the results of our first gravity gradient measurements.

[1] Schkolnik et al. *The effect of wavefront aberrations in atom interferometry*, Applied Physics B (2015)
[2] Freier et al. *Mobile quantum gravity sensor with unprecedented stability*, Journal of Physics: Conference Series (2016)

A 13.6 Tue 12:15 P 104

Transportable Quantum Gravimeter – QG-1 — •Maral Sahelgozin[1], Jonas Matthias[1], Nina Grove[1], Sven Abend[1], Waldemar Herr[1], Jürgen Müller[2], Wolfgang Ertmer[1], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Institut für Erdmessung, Leibniz Universität Hannover, Schneiderberg 50, 30167 Hannover

We present the design of our transportable Quantum Gravimeter – QG-1 and report on the progress of the implementation of an ultracold atomic ensemble loaded on our atom chip constituting the source for matter-wave interferometry. The characterization and optimization of our high flux double MOT system will be presented. In our gravimeter the narrow momentum width of the ensemble in combination with higher order Bragg type beamsplitters will be employed to improve the acceleration sensitivity. More crucially the extremely low momentum distribution of an ultracold atomic ensemble will reduce the systematic errors arising from wavefront inhomogeneities during the interrogation time. This is the major limitation to the accuracy of state-of-the-art atomic gravimeters and will be overcome by our absolute quantum gravimeter. By this our compact atom chip based source, miniaturized electronics and simplified telecom fiber based laser system provide a stable and accurate gravimeter for geodetic field applications.

This work is in the scope of the SFB 1128 geo-Q and supported by the Deutsche Forschungsgemeinschaft (DFG).

A 13.7 Tue 12:30 P 104

Laser-interferometric dilatometry from 100 K to 325 K — •Ines Hamann[1,2], Ruven Spannagel[1,2], Josep Sanjuan[2], Felipe Guzman[1], and Claus Braxmaier[1,2] — [1]University of Bremen, ZARM Center of Applied Space Technology and Microgravity, 28359 Bremen, Germany — [2]DLR German Aerospace Center, Institute of Space Systems, 28359 Bremen, Germany

To enable high precision optical measurements highly dimensionally stable materials are needed. Dimensional stability is an important material property describing the dependency of geometrical dimensions of an optical setup due to temperature fluctuations. Optical setups are often built with components made of glass-ceramics or composite materials which exhibit low coefficients of thermal expansion (CTE). These materials have to be characterized over the full operating temperature range to accurately predict the response of the optical system and the impact on its measurement performance.

Our laser dilatometer setup is designed to characterize these low expansion materials in a temperature range from 100 K to 325 K, using a heterodyne laser interferometer to measure the dimensional changes of a sample due to well-controlled temperature variations. In this talk, we present the current status of our test facility, and recent improvements to decrease the uncertainty budget to levels of 10 ppb/K over the temperature range from 100 K to 325 K.

A 13.8 Tue 12:45 P 104

JOKARUS: An iodine frequency reference for space-applications on a sounding rocket — •Vladimir Schkolnik[1,2], Klaus Döringshoff[1], Franz Gutsch[1], Markus Krutzik[1], Achim Peters[1,2], and The JOKARUS Team[1,2,3,4,5,6] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]FBH Berlin — [3]ZARM U Bremen — [4]DLR Bremen — [5]JGU Mainz — [6]Menlo Systems GmbH

Stable optical frequency references are a key component in future missions based on quantum sensors testing Einsteins equivalence principle or long baseline interferometers for gravitational wave detection. In this talk, we present JOKARUS: A simple and compact diode laser based frequency reference, stabilized to an optical transition in iodine at 532 nm. Our frequency reference aims to exceed the performance required for space missions such as LISA and GRACE follow on, and will be operated on a sounding rocket flight in Fall 2017 to demonstrate its technological maturity.

The design of our reference system, including diode laser source, gas cell assembly and electronics is presented in detail. JOKARUS is based on the heritage of three successful sounding rocket missions and is adaptable to various wavelengths to reach narrow optical transitions.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant numbers DLR 50WM 1646

A 14: Highly Charged Ions

Time: Tuesday 14:30–16:15 Location: HS 20

A 14.1 Tue 14:30 HS 20

Investigations of highly charged ions with applications for optical frequency standards and metrology — •Hendrik Bekker[1], Alexander Windberger[1,2], Nicky Potters[1], Julian Rauch[1], Julian Berengut[3], Anastasia Borchevsky[4], and Jose R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Advanced Research Center for Nanolithography, Amsterdam — [3]University of New South Wales, Sydney — [4]Van Swinderen Institute for Particle Physics and Gravity, Groningen

Many highly charged ions (HCI) have been proposed for use in next generation optical clocks for metrology purposes. But for these HCI, theory is not capable of predicting the energy level structures to the precision required for laser spectroscopy [1,2]. Therefore, we investigated several of the proposed HCI, which we produced, trapped, and collisionally excited in the Heidelberg electron beam ion trap. The wavelengths of subsequent fluorescence light were determined at the ppm-level using a grating spectrometer. We present our latest results for Ir^{17+}, which features transitions with extremely high sensitivity to variation of the fine-structure constant [2,3]. Furthermore, our latest results for Pr^{9+} and Pr^{10+} are discussed. All results are used to benchmark state-of-the-art atomic theory calculations. Our investigations aim to provide a deeper insight into the suitability for metrology of the proposed HCI, and to pave the way for future laser spectroscopy.

[1] J. C. Berengut *et al.*, Phys. Rev. Lett. 106, 210803 (2011)
[2] M. S. Safronova *et al.*, Phys. Rev. Lett. 113, 030801 (2014)
[3] A. Windberger *et al.*, Phys. Rev. Lett. 114, 150801 (2015)

A 14.2 Tue 14:45 HS 20

Status of the Penning-trap mass spectrometer PENTATRAP — •Alexander Rischka[1], José Ramón Crespo López-Urrutia[1], Sergey Eliseev[1], Pavel Filianin[1], Yuri Novikov[2], Rima Schüssler[1], Christoph Schweiger[1], Sven Sturm[1], Stefan Ulmer[3], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Petersburg Nuclear Physics Institute,188300 Gatchina, Russia — [3]RIKEN, Ulmer Initiative Research Unit, Japan

The Penning-trap mass spectrometer PENTATRAP is currently in the commissioning phase at the Max-Planck-Institute for Nuclear Physics in Heidelberg. We are aiming at measurements of mass ratios using highly charged ions with a relative uncertainty of better than 10^{-11}. This allows, among others, contributions to neutrino physics research by a sub-eV measurement of the Q-value of the electron capture in ^{163}Ho. Furthermore, for a precession test of the energy-mass equivalence $E = mc^2$ and thus of special relativity, the mass difference of ^{35}Cl and ^{36}Cl and the sum of energies of the gamma-rays emitted after the neutron capture in ^{35}Cl are needed. The former will be measured at PENTATRAP and the latter - at ILL. To reach trapping times of weeks for highly charged ions and to perform a full characterization of the Penning-trap system in order to start first precision measurements, a major revision of the cryogenic setup and the ion transfer beamline is presently prepared and will be commissioned soon.

A 14.3 Tue 15:00 HS 20

Dielectronic-recombination processes in highly-charged heavy ions — •Alexander Borovik[1,2,3], Joan Dreiling[2], Roshani Silwal[2,4], Dipti Dipti[2], Endre Takács[2,4], John Gillaspy[2,5], Ramaz Lomsadze[3,6], Vladimir Ovsyannikov[3], Kurt Huber[3], and Alfred Müller[3] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Quantum Measurement Division, National Institute of Standards and Technology, Gaithersburg MD, USA — [3]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen — [4]Department of Physics and Astronomy, Clemson University, Clemson SC, USA — [5]Division of Physics, National Science Foundation, Arlington VA, USA — [6]Department of Physics, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia

Dielectronic-recombination (DR) spectra of highly-charged W^{q+} and Ir^{q+} ions have been measured by employing the Electron-Beam Ion Trap (EBIT) at National Institute of standards and Technology [1] and the Main Magnetic Focus Ion Trap (MaMFIT) [2] at Justus-Liebig Universität Gießen, respectively, over wide ranges of electron-beam energies. A series of DR resonances involving transitions between $2l \rightarrow 3l'$ and $2l \rightarrow 4l'$ subshells in Na-like through Ar-like tungsten have been revealed in the NIST EBIT spectra, while in the MaMFIT, DR resonances involving transitions between $2l \rightarrow 3l'$ subshells in K-like through Ni-like iridium were seen. Detailed modeling of the observed spectra has been performed. [1] J. D. Gillaspy, AIP Conf. Proc. 1438 (2012) 97. [2] V. P. Ovsyannikov, arXiv:1403.2168 (2014)

A 14.4 Tue 15:15 HS 20

A superconducting resonator-driven linear radio-frequency trap for long-time storage of highly charged ions — •Julian Stark[1], Lisa Schmöger[1,2], Andrii Borodin[1], Janko Nauta[1], Dieter Liebert[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Cold, strongly localized highly charged ions (HCIs) are particularly interesting candidates for novel frequency standards at a potential 10^{-19} level of relative accuracy and the search for possible variations of fundamental constants. Motional cooling of HCIs down to the mK range can be achieved by sympathetic cooling with directly laser-cooled Be^{+} ions inside a cryogenic linear radio-frequency (RF) Paul trap [1,2]. For a stable localization of the trapped ions a high voltage RF field with low noise is required. Here, a novel superconducting RF resonator design with integrated Paul trap electrodes is presented. The high quality factor Q of the resonator will drastically reduce Paul trap heating rates as well as improve the overall stability of the trapping conditions. A normal-conducting prototype is currently being commissioned. First measurements yield a quality factor of 5816(23) at a resonance frequency of 29.772(4) MHz. In the superconducting version a much higher Q value will render electrodynamical losses of trapped ions negligible. This will enable precise localization of HCIs which is needed for high precision laser spectroscopy.

[1] M. Schwarz et al., Rev. Sci. Instrum. 83, 083115 (2012)
[2] L. Schmöger et al., Science 347, 6227 (2015)

A 14.5 Tue 15:30 HS 20

A novel off-axis gun for electron beam ion traps — •Steffen Kühn[1], Sven Bernitt[1,2], Thore M. Bücking[1], André Cieluch[1], Peter Micke[1,3], Thomas Stöhlker[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität Jena, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

In an electron beam ion trap (EBIT) highly charged ions (HCIs) are produced using an electron beam compressed to very high densities, which sequentially ionizes atoms. EBITs usually employ on-axis electron guns blocking the view along the trap axis. This can constitute a limitation for certain applications like laser spectroscopy where the photon beam is lost hitting the gun. A novel off-axis gun (OAG) was built with the cathode displaced from the central axis, which is therefore free of any obstacles and the photon beam is available for further experiments downstream. One of the envisaged applications is using HCIs as a new in situ calibration standard for high energy photon beams as provided e.g. by synchrotrons. First performance checks in a compact 0.86 T permanent magnet EBIT have shown stable operation with a 20 mA electron beam and up to 10 keV beam energy.

A 14.6 Tue 15:45 HS 20

Compact 0.86 T room-temperature electron beam ion traps — •Peter Micke[1,2], Sven Bernitt[1,3], Klaus Blaum[1], Lisa F. Buchauer[1], Thore M. Bücking[1], André Cieluch[1], Alexander Egl[1], James Harries[4], Steven A. King[2], Sandro Kraemer[1], Steffen Kühn[1], Tobias Leopold[2], Janko Nauta[1], Thomas Pfeifer[1], Lisa Schmöger[1,2], Rima X. Schüssler[1], Christoph Schweiger[1], Julian Stark[1], Thomas Stöhlker[3], Sven Sturm[1], Joachim Ullrich[2], Robert Wolf[1], Piet O. Schmidt[2,5], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Friedrich-Schiller-Universität Jena — [4]SPring-8, Hyogo, Japan — [5]Leibniz Universität Hannover

To facilitate accessibility to highly charged ions (HCI) for a wider physics community we have developed a novel type of high-performance room-temperature electron beam ion trap (EBIT). It is based on permanent magnets featuring low-maintenance operation. HCIs are bred and trapped by an electron beam, compressed by the strong, inhomogeneous magnetic field. A protoype proved successful operation and provided a 100 pA continuous beam of Xe ions and charge states of up to 36+ with a 4.6 mA 3 keV electron beam. A second generation of three more EBITs is under commissioning to supply HCIs for precision measurements in Paul and Penning traps as well as X-ray spectroscopy using synchrotron radiation and free-electron lasers. With a magnetic field of 0.86 T, stable operation of a 50 mA electron beam at 1.7 keV was demonstrated.

A 14.7 Tue 16:00 HS 20

Recent laser cooling and laser spectroscopy experiments at the ESR — •Danyal Winters[1], Oliver Boine-Frankenheim[1,2], Axel Buss[3], Christian Egelkamp[3], Lewin Eidam[2], Volker Hannen[3], Zhongkui Huang[4], Daniel Kiefer[2], Sebastian Klammes[2], Thomas Kühl[1,5], Markus Löser[6,7], Xinwen Ma[4], Fritz Nolden[1], Wilfried Nörtershäuser[2], Rodolfo Sanchez Alarcon[1], Ulrich Schramm[6,7], Mathias Siebold[6], Markus Steck[1], Thomas Stöhlker[1,5,8], Johannes Ullmann[2,8], Thomas Walther[2], Hanbing Wang[4], Weiqiang Wen[4], Christian Weinheimer[3], Daniel Winzen[3], and Michael Bussmann[6] — [1]GSI Darmstadt — [2]TU-Darmstadt — [3]Uni Münster — [4]IMP Lanzhou — [5]HI-Jena — [6]HZDR Dresden — [7]TU-Dresden — [8]Uni-Jena

Laser cooling is one of the most promising techniques for ion beam cooling at high energies. The fluorescence emitted during the cooling process can be used for both optical beam diagnostics and precision spectroscopy. We present results on experiments with $^{12}C^{3+}$ beams (122 MeV/u) stored in the experimental storage ring (ESR) in Darmstadt, Germany. To excite the cooling transition, a pulsed laser system with a high repetition rate, and a wide-scanning cw laser system have been used. To detect the fluorescence, a novel XUV detector system, installed inside the vacuum of the ESR, was used. We will present the experimental setup and preliminary data on the interaction of the lasers with the ion beam, and discuss it in the light of future experiments at the high-energy storage rings of FAIR in Germany and HIAF in China.

A 15: Ultracold atoms and BEC - III (with Q)

Time: Tuesday 14:30–16:30 Location: N 1

A 15.1 Tue 14:30 N 1

Efimov physics in ultracold atomic gases using finite-range potentials — •Thomas Secker, Paul Mestrom, and Servaas Kokkelmans — Eindhoven University of Technology, Eindhoven, The Netherlands

Three-body Efimov physics is relevant for the understanding of both dynamics and stability of ultracold gases. Efimov predicted the existence of an infinite sequence of three-body bound states, of which many properties scale universally, at diverging scattering length for a zero-range interaction potential. Experiments with ultracold atoms in which the scattering length is tuned through Feshbach resonances have also shown the universality of the negative three-body parameter. In order to investigate these universal aspects, we utilize a finite range interaction potential. We solve for this problem in a momentum-space treatment containing off-shell two-body scattering processes. To include the Feshbach formalism we have generalized it to an off-shell theory. First results show remarkable similarities with experimental data, especially in the case of broad resonances.

A 15.2 Tue 14:45 N 1

Novel states in a three-body system with a p-wave resonance — •Matthias Zimmermann[1], Santiago I. Betelu[2], Maxim A. Efremov[1], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, 89081 Ulm, Germany — [2]Department of Mathematics, University of North Texas, Denton, TX 76203-5017, USA

One of the most intriguing phenomena of few-body physics is the Efimov effect, which manifests itself in an infinite number of weakly bound three-body states if at least two of the three two-body subsystems exhibit a single s-wave resonance.

We present a novel class of purely quantum-mechanical bound states in the system of three particles in two dimensions provided: (i) the system consists of a light particle and two heavy bosonic ones, and (ii) the heavy-light short-range potential has a p-wave resonance. Within the familiar Born-Oppenheimer approach, the effective potential between the two heavy particles is shown to be attractive and of long-range, resulting in an infinite number of universal bound states corresponding to a vanishing total angular momentum of the three-body system.

In order to verify our analytical results we employ a numerical scheme utilizing spectral methods. This enables us to discretize the stationary Schrödinger equation in function space in order to achieve exponential convergence. We solve the resulting eigenvalue problem with the Data Vortex supercomputing system.

A 15.3 Tue 15:00 N 1

Impurities immersed in a BEC. Quantum simulator of the polaron? — •Luis Aldemar Ardila[1], Thomas Pohl[1], and Stefano Giorgini[2] — [1]Nöthnitzer Straße 38 01187 Dresden Germany — [2]Via Sommarive 14 I-38123 Povo, Italy

We investigate the properties of an impurity immersed in a Bose gas at zero temperature using both analytical and Quantum-Monte Carlo methods. The interaction between bosons are modeled by a hard-sphere potential with scattering length a, whereas the impurity-boson interaction is modeled by a short-range attractive square-well potential, where both the sign and the strength of the scattering length b can varied by adjusting the well depth. We characterize the repulsive and attractive [Fig. 1] polaron branch by calculating the binding energy and the effective mass [1]. Furthermore, we study the structure of the bosonic bath such as the boson-boson correlation function and the density profile around the impurity. For resonant interactions between the impurity and the bosonic bath, the Ground state properties are also investigated as well as Efimov Effects . The implication for the phase diagram of binary Bose-Bose mixtures is also discussed . We also discuss more complicated interactions between the impurity and the bosonic bath. For this case we consider a Quasi-2D Dipolar Bose gas at zero temperature. Furthermore, the impurity-Bose interaction is dipolar. Using perturbation theory, the Ground-state properties are investigated based on the low-energy Fröhlich Hamiltonian.

A 15.4 Tue 15:15 N 1

The Bose polaron in an ultracold Bose-Fermi mixture of Cs and Li — •Stephan Häfner, Binh Tran, Manuel Gerken, Melina Filzinger, Bing Zhu, Juris Ulmanis, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

An ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li is well suited for the investigation of the Bose polaron. In this scenario a single Li impurity is immersed in a Cs BEC and interacts with its phonon excitations, mimicking the Fröhlich polaron problem from solid-state physics. Tuning the sign and strength of the interaction between Li and Cs via Feshbach resonances enables us to study repulsive and attractive polarons. The observation of different polaron states, ranging from the Landau-Pekar polaron to the bubble polaron is within reach for the Li-Cs system.

In this talk we describe the production of a Cs BEC by forced evaporative cooling in an optical dipole trap. The phase-space density is enhanced by modifying the trapping geometry with an additional small-sized dipole trap. This is the first step for the study of the Bose polaron in the Li-Cs system.

A 15.5 Tue 15:30 N 1

Observation of individual tracer atoms in an ultracold dilute gas — •Felix Schmidt[1,2], Daniel Mayer[1,2], Tobias Lausch[1], Daniel Adam[1], Steve Haupt[1], Michael Hohmann[1], Farina Kindermann[1], Nicolas Spethmann[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern

Diffusion of particles in fluids and gases is an essential and omnipresent transport phenomenon in nature. While diffusion is well understood in the limit of a heavy particle in a dense gas (known as Brownian motion), much less is known, both theoretically and experimentally, about light particles diffusing in a dilute gas.

Here, we report on the experimental investigation of individual Cs atoms impinging on a dilute cloud of ultracold Rb atoms with variable density. We study the nonequilibrium relaxation of the initial nonthermal state of Cs and detect the effect of a of single collision, i.e. the fundamental building block of diffusion. We show that the diffusive motion of the single Cs atom in the Rb cloud is well described by a generalized Langevin equation with a velocity-dependent friction coefficient, an unfamiliar feature of the Langevin equation emerging for light particles.

A 15.6 Tue 15:45 N 1

angular self-localization of impurities rotating in a bosonic bath — •xiang li, mikhail Lemeshko, and robert seiringer — Institute of Science and Technology Austria, Am Campus 1, Klosterneuburg, Austria

The existence of a self-localization transition in the polaron problem has been under an active debate ever since Landau suggested it in 1933. Here we reveal the self-localization transition for the rotational analogue of the polaron - the angulon quasiparticle. The transition takes place at finite coupling strength already at the mean-field level, it is accompanied by a discontinuity in the first derivative of the angulon ground-state energy and a spherical-symmetry breaking of the angulon ground state. This symmetry breaking is demonstrated to be depend on the symmetry of the microscopic impurity-atom potential, which results in a number of distinct self-localized states. The predicted effects can potentially be addressed in experiments on cold molecules trapped in superfluid helium droplets and ultracold quantum gases, as well as on electronic excitations in solids and Bose-Einstein condensates.

[1] X. Li, R. Seiringer, M. Lemeshko, arXiv: 1610.04908

A 15.7 Tue 16:00 N 1

Rotation of cold molecular ions inside a Bose-Einstein condensate — •Bikashkali Midya[1], Michal Tomza[2], Richard Schmidt[3], and Mikhail Lemeshko[1] — [1]Institute of Science and Technology Austria, Am Campus 1, 3400 Klosterneuburg, Austria — [2]ICFO- The Barcelona Ins titute of Science and Technology, Barcelona, Spain — [3]ITAMP, Havard-Smithsonian Center for Astrophysics, Cambr idge, MA 02138, USA

We use recently developed angulon theory [1] to study the rotational spectrum of a cyanide molecular anion immersed into Bose-Einstein condensates of rubidium and strontium. Based on *ab initio* potential energy surfaces, we provide a detailed study of the rotational Lamb shift and many-body-induced fine structure which arise due to dressing of molecular rotation by a field of phonon excitations. We demonstrate that the magnitude of these effects is large enough in order to be observed in modern experiments on cold molecular ions. Furthermore, we introduce a novel method to construct pseudopotentials starting from the *ab initio* potential energy surfaces, which provides a means to obtain effective coupling constants for low-energy polaron models.

[1] R. Schmidt and M. Lemeshko, Phys. Rev. Lett. 114, 203001 (2015).

[2] B. Midya, M. Tomza, R. Schmidt, M. Lemeshko, Phys. Rev. A 94, 041601(R) (2016).

A 15.8 Tue 16:15 N 1

Numerical Simulation of a mobile Impurity in a BEC — •Tobias Lausch[1], Fabian Grusdt[3], Artur Widera[1,2], and Michael Fleischhauer[1] — [1]TU Kaiserslautern and Forschungszentrum OPTIMAS, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler Strasse 47, 67663 Kaiserslautern, Germany — [3]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Cooling atoms to ultracold temperatures, where quantum effects dominante, has become a standard approach in experimental quantum physics. An intriguing focus of research lies on impurity systems, aiming on elucidating microscopic properties of thermalization or quasiparticle formation in quantum systems. Recent experiments$^{(1,2)}$ shed light on the bose polaron and the interaction between impurities and a bose gas. We thoretically model the thermalization dynamics of a single impurity immersed into a BEC using Bogoliubov approximation. From the master equation, we derive the impurity's momentum resolved scattering and numerically simulate the ensuing cooling dynamics. We find a separation of relaxation time scales originating from the superfluid nature of the condensate, indicating a prethermalized state. Furthermore we discuss the possibuility to exploit the emerging non-thermal impurity states to realize low-entropy quantum states by applying external forces.

(1) Hu et al. PRL 117(2016), 055301

(2) Jørgensen et al. PRL 117 (2016), 055302

A 16: XUV/X-ray spectroscopy III

Time: Tuesday 14:30–16:30 Location: N 2

Invited Talk A 16.1 Tue 14:30 N 2

High-power XUV frequency combs — •Christoph M. Heyl[1,2], Gil Porat[1], Stephen Schoun[1], Craig Benko[1], Nadine Dörre[1,3], Kristan L. Corwin[1,4], and Jun Ye[1] — [1]JILA, NIST and the University of Colorado, 440 UCB, Boulder, CO 80309-0440, USA — [2]Department of Physics, Lund University, P. O. Box 118, SE-221 00 Lund, Sweden — [3]University of Vienna, Faculty of Physics, VCQ & QuNaBioS, Boltzmanngasse 5, A-1090 Vienna, Austria — [4]Department of Physics, Kansas State University, Manhattan, Kansas, USA

Frequency combs are nowadays routinely used for precision spectroscopy in the visible and near-IR spectral region. In contrast, the extreme ultraviolet (XUV) spectral region presents a barely explored area for precision spectroscopy studies with promising targets such as ground state transitions in helium, highly charged ions and possibly even nuclei. While XUV combs can reach sub-Hz coherence levels [1], the bottleneck is the limited power available in the XUV.

Here we discuss recent steps towards high-power XUV comb generation. These include down-scaling of efficient high-order harmonic conversion schemes [2] to adapt for intra-cavity operation as well as the exploration of intra-cavity plasma dynamics and their suppression. Our recent effort allowed us to generate high harmonics with average power levels in the mW range, setting a new record for XUV combs and more generally, for high-harmonic-based XUV sources.

[1] C. Benko, et al., Nature Photonics 8, 530 (2014).

[2] C. M. Heyl, et al., Optica 3, 75 (2016).

A 16.2 Tue 15:00 N 2

Towards XUV metrology with Highly Charged Ions using a HHG frequency comb — •Janko Nauta[1], Andrii Borodin[1], Julian Stark[1], Peter Micke[1,2], Lisa Schmöger[1,2], Maria Schwarz[1,2], José Crespo López Urrutia[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Highly charged ions (HCI) are atomic systems with only a few tightly bound electrons and offer many advantages over neutral and singly charged ions for probing fundamental physics. For example, HCI are intrinsically sensitive to a possible variation of the fine-structure constant α. Moreover, they have been recently proposed as candidates for novel frequency standards, because their low polarizability makes them insensitive to black body radiation and laser-induced shifts [1].

To this end, our project aims at studying trapped HCI, cooled down to mK temperatures [2], with ultra-high precision in the extreme ultraviolet (XUV) regime. We will use high harmonic generation (HHG) to coherently transfer the modes of an infrared frequency comb to the XUV, and then plan to perform direct frequency comb spectroscopy. To amplify the femtosecond pulses we are developing an enhancement cavity, with a focus waist size smaller than 15 μm in order to reach intensities of 10^{14} W/cm^2, enabling for intra-cavity HHG. The experimental approach and first results of the new enhancement cavity will be presented.

[1] A. Derevianko *et al.*, Phys. Rev. Lett. **109**, 180801 (2012)

[2] L. Schmöger *et al.*, Science **347**, 6227 (2015)

A 16.3 Tue 15:15 N 2

Electron correlation meets high-harmonic generation in He: Identifying plateaus beyond $3.17\,U_\mathrm{p}$ in the simulation — •Julius Rapp, Martins Brics, and Dieter Bauer — Institute of Physics, University of Rostock, 18051 Rostock, Germany

The harmonic radiation generated by an atom with ionization potential I_p^{n+} subjected to a laser field of ponderomotive energy U_p is classically expected to reproduce the cutoff energies of $3.17\,U_\mathrm{p} + I_\mathrm{p}^{n+}$ considering a single active electron (SAE) at each ionic charge number n. Beyond the SAE, electron correlation may give rise to new phenomena such as nonsequential double recombination [1] where—in simple man's picture—double ionization is followed by the simultaneous recombination of two electrons. Apart from those subtle yet qualitative additions, electron correlation may influence the ionization probabilities to such an extent that the contributions from different ionic charge states to the harmonic yield are significantly modified.

We present high-harmonic spectra of helium obtained by the numerical propagation of renormalized natural orbitals (RNOs) in 3D. Indeed, time-dependent RNO theory (TDRNOT) [2] applied to helium in full dimensionality produces harmonic-radiation plateaus which can not be explained in the SAE picture (confirming the prediction from 1D simulations [2]). We finally illustrate the disentanglement of different possible explanations by extended simple-man's modeling and time-frequency analyses.

[1] P. Koval, F. Wilken, D. Bauer, C. H. Keitel, *PRL* **98**, 043904 (2007)

[2] M. Brics, J. Rapp, D. Bauer, *PRA* **93**, 013404 (2016)

A 16.4 Tue 15:30 N 2

Optical and EUV spectroscopy of complex open $4d$-shell $\mathrm{Sn}^{7+..14+}$ ions — •Hendrik Bekker[1], Francesco Torretti[2,5], Alexander Windberger[1,2], Alexander Ryabtsev[3,4], Stepan Dobrodey[1], Wim Ubachs[2,5], Ronnie Hoekstra[2,6], Anastasia

Borschevsky[8], Emily V. Kahl[7], Julian C. Berengut[7], José R. Crespo López-Urrutia[1], and Oscar O. Versolato[2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Advanced Research Center for Nanolithography, Amsterdam — [3]Institute of Spectroscopy, Russian Academy of Sciences, Troitsk — [4]EUV Labs, Ltd., Troitsk — [5]Department of Physics and Astronomy, and LaserLaB, VU, Amsterdam — [6]Zernike Institute for Advanced Materials, University of Groningen — [7]School of Physics, University of New South Wales, Sydney — [8]The Van Swinderen Institute, University of Groningen

We present the analysis of the level structure of $Sn^{7+..14+}$ ions with their many-valence-electron open [Kr]$4d^m$ shell (m=7-0). These are essential in bright extreme-ultraviolet (EUV) plasma-light sources for next-generation nanolithography, but their complex electronic structure is an open challenge for both theory and experiment. We combine charge-state-resolved optical and EUV spectroscopy in an electron beam ion trap with state-of-the-art calculations using configuration-interaction many-body perturbation theory. Line identifications were performed employing semi-empirical calculations using the orthogonal parameters technique and COWAN code calculations. The results represent the most complete data available to date and suggest that some EUV line identifications in previous work need to be revisited.

A 16.5 Tue 15:45 N 2

High-precision X-ray spectroscopy of highly-charged ions at storage rings using silicon microcalorimeters — •Pascal Andree Scholz[1], Victor Andrianov[2], Artur Echler[3,4], Peter Egelhof[3,4], Oleg Kiselev[3], Saskia Kraft-Bermuth[1], and Damian Muell[1] — [1]Justus-Liebig-Universität, Giessen, Germany — [2]Lomonosov Moscow State University, Moscow, Russia — [3]GSI Helmholtz Center, Darmstadt, Germany — [4]Johannes-Gutenberg Universität, Mainz, Germany

High-precision X-ray spectroscopy of highly-charged heavy ions provides a sensitive test of quantum electrodynamics in very strong Coulomb fields. Silicon microcalorimeters, which detect the X-ray energy as heat rather than by charge production, have already demonstrated their potential to improve the precision of such experiments due to their excellent energy resolution for X-ray energies around 100 keV. Microcalorimeter arrays based on silicon thermistors and tin absorbers have already been successfully applied at the Experimental Storage Ring (ESR) of the GSI Helmholtz Center for Heavy Ion Research. Based on these experiments, a larger detector array with three times the active detector area in a new cryogen-free cryostat equipped with a pulse tube cooler is currently in preparation. Recently, a new compact detector design was applied in a test experiment at the ESR. In this presentation, we will introduce the detection principle, present the ESR test experiment following results, and discuss potential future applications.

A 16.6 Tue 16:00 N 2

The 3.5 keV X-ray line: a dark matter decay line or an unknown plasma line? — •Stepan Dobrodey[1], Chintan Shah[1], Sven Bernitt[1,2], René Steinbrügge[1], Liyi Gu[3], Jelle Kaastra[3], and José Ramón Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Friedrich-Schiller-Universität Jena, Jena, Germany — [3]SRON Netherlands Institute for Space Research, Utrecht, Netherlands

Speculations about a possible dark matter origin of an observed unidentified X-ray line feature at 3.5 keV from galaxy clusters have sparked an incredible interest in the scientific community and given rise to a tide of publications attempting to explain the possible cause for this line [1,2]. Motivated by this, we have measured the K-shell X-ray spectra of highly ionized bare sulfur ions following charge exchange with gaseous molecules in an electron beam ion trap, as a source of or contributor to this X-ray line. We produced S^{16+} and S^{15+} ions and let them capture electrons in collision with those molecules with the electron beam turned off while recording X-ray spectra. We observed a charge-exchange-induced X-ray feature at the Lyman series limit (3.47 ± 0.06 keV). The inferred X-ray energy is in full agreement with the reported astrophysical observations and supports the proposed novel scenario by Gu [2,3].

[1] E. Bulbul et al., ApJ, 13, 789 (2014)
[2] L. Gu et al., A&A, L11, 584 (2015)
[3] C. Shah et al., ApJ, in press (2016)

A 16.7 Tue 16:15 N 2

Nuclear excitation by electron capture in optical-laser-generated plasmas — •Jonas Gunst, Yuanbin Wu, Christoph H. Keitel, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

In the process of nuclear excitation by electron capture (NEEC), the energy gained when a free electron is recombining into a bound state of an ion is simultaneously transfered to the atomic nucleus which is thereby excited. Recently, we have shown that this process can play the leading role among the nuclear excitation channels in cold, high-density plasmas created by an x-ray free-electron laser (XFEL), even higher than direct nuclear excitation channel using the XFEL beam on resonance [1,2]. However, the actual nuclear excitation rates are still small, strongly constrained by the attainable plasma conditions.

In contrast to XFELs, optical petawatt (PW) lasers are able to create plasmas over a broad parameter region. Exploring the potential of these lasers for NEEC raises several interesting questions: Is it possible to find a point on the accessible density-temperature landscape where NEEC is maximized? How does the NEEC rate depend on the laser parameters? What are the benefits/drawbacks of using optical PW lasers instead of XFELs? In this contribution, we are going to discuss these questions at the example of ^{93m}Mo isomer triggering.

[1] J. Gunst, Yu. A. Litvinov, C. H. Keitel, A. Pálffy, Phys. Rev. Lett. **112**, 082501 (2014).
[2] J. Gunst, Y. Wu, N. Kumar, C. H. Keitel and A. Pálffy, Phys. Plasmas **22**, 112706 (2015).

A 17: Rydberg atoms

Time: Tuesday 14:30–16:15 Location: N 3

A 17.1 Tue 14:30 N 3

Trilobite Rydberg molecules in Rubidium — •Kathrin S. Kleinbach[1], Florian Meinert[1], Felix Engel[1], Woojin Kwon[1], Sebastian Hofferberth[1], Robert Löw[1], Tilman Pfau[1], and Georg Raithel[2] — [1]5. Physikalisches Institut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart,Germany — [2]Department of Physics, University of Michigan, Ann Arbor, Michigan 48109, USA

Rydberg atoms exhibit extreme properties due to their large size and high polarizability. Moreover, in the ultracold regime, the interaction of the Rydberg electron with a neutral ground-state atom gives rise to long-range bound molecular states. A class of such homonuclear dimers, so called "trilobite molecules", have been shown to possess huge electronic dipole moments exceeding hundreds of Debye, which arise from interaction-induced admixing of high angular momentum Rydberg states. However, direct photo-association of such states is hindered by the required angular momentum transfer.

Here, we devise a novel method for two-color photo-association of Rb^{87} trilobite Rydberg molecules with large permanent dipole moment employing remote spin flips. More specifically, strong mixing of singlet and triplet scattering channels mediated by the ground-state hyperfine interaction couples the s-wave molecular state 50S↓+5S↑ and the trilobite state 47Trilobite↑+5S↓. This mixing allows for direct laser excitation of trilobite molecules, which we demonstrate via photo-association spectroscopy. Also, the the dipole moment is measured and the data is compared to predictions from calculated potential energy curves.

A 17.2 Tue 14:45 N 3

Rydberg molecule-induced remote spin-flips — •Carsten Lippe[1], Thomas Niederprüm[1], Oliver Thomas[1,2], Tanita Eichert[1], and Herwig Ott[1] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz

We have performed high resolution photoassociation spectroscopy of ^{87}Rb Rydberg molecules in the vicinity of the $25P$ state. These exotic states originate from the scattering interaction between a ground state atom located within the electronic wave function of a second atom in a highly excited Rydberg state and the Rydberg electron.

We have investigated two different types of molecular states: Butterfly Rydberg molecules originate from a shape resonance in the p-wave scattering channel and are thus much more deeply bound than the second type, ultra-long range molecules. For the former, we measured bond lengths in the range of $100\,a_0$ to $350\,a_0$ and permanent electric dipole moments of around 500 Debye.
For the latter, we find potentials containing contributions of both hyperfine states of the ground state perturber atom due to the hyperfine interaction. Depending on the relative strength of the scattering interaction compared to the hyperfine splitting we identify two distinct regimes where entanglement and spin-flips occur, respectively. Remote spin-flips in the perturber atom can be induced by excitation of Rydberg molecules when the hyperfine interaction dominates the scattering interaction, leading to a possible implementation of long-range spin-dependent interactions for ultracold atoms.

A 17.3 Tue 15:00 N 3

Strong light-matter coupling in Rydberg excitons — •Peter Grünwald[1], Julian Heckötter[2], Marc Assmann[2], Dietmar Fröhlich[2], Manfred Bayer[2], Heinrich Stolz[1], and Stefan Scheel[1] — [1]Institut für Physik, Universität Rostock, Rostock, Germany — [2]Experimentelle Physik 2, TU Dortmund, Dortmund, Germany

Rydberg systems show strong light-matter coupling due to the long life times and large dipole moments of states with high principal quantum number n. In Rydberg excitons [1], the single-exciton light-matter coupling is weak. However, due to collective excitation, strong coupling occurs even for low laser intensities ($\sim \mu$W/mm^2). Additionally, the high-n exciton states display little pure dephasing [2], making them interesting for quantum-optical research. We will discuss the optical properties of Rydberg excitons, and their implications for the Rydberg exciton fluorescence. In particular, nonclassical effects and their detection will be addressed. Because of the limited detection efficiency, homodyne correlation measurements [3] are required.

[1] T. Kazimierczuk *et al.*, Nature **514**, 343 (2014).
[2] P. Grünwald *et al.*, Phys. Rev. Lett. **117**, 133003 (2016).
[3] W. Vogel, Phys. Rev. A **51**, 4160 (1995).

A 17.4 Tue 15:15 N 3

Ionization spectra of highly Stark shifted Rubidium Rydberg states — •Jens Grimmel, Markus Stecker, Manuel Kaiser, Lara Torralbo-Kampo, Andreas Günther, and József Fortágh — Center for Quantum Science, Physikalisches Institut, Universität Tübingen, Germany

Rydberg atoms are extremely sensitive to electric fields and consequently have a rich Stark spectrum. At sufficiently high electric fields these states start to ionize due to tunneling through the potential barrier as well as direct coupling to the continuum. This region is of particular interest for tailoring the ionization process to certain needs, for example in order to create cold ions and electrons for microscopy applications.

In our previous work, we calculated Stark maps including the transition strength from low lying states to Stark shifted Rydberg states [1]. By adding a complex absorbing potential (CAP), we are now able to accurately predict the ionization spectra of Rydberg states beyond the classical ionization threshold. The CAP is adjusted to the external electric field, which allows us to calculate a whole range of the spectrum with only one free parameter. The results from these calculations are compared to experimental data of Stark maps for Rubidium Rydberg atoms with principal quantum numbers up to 70.

[1] J. Grimmel, M. Mack, F. Karlewski, F. Jessen, M. Reinschmidt, N. Sándor and J. Fortágh, N. J. Phys. 17, 053005 (2015).

A 17.5 Tue 15:30 N 3

High resolution ion microscopy of cold atoms — •Raphael Nold, Markus Stecker, Andreas Günther, and József Fortágh — Center for Quantum Science, Physikalisches Institut, Universität Tübingen, Germany

We report on an ion-optical system serving as a microscope for ultracold ground state and Rydberg atoms. The system is designed to achieve a magnification of up to 1000 and a spatial resolution in the 100nm range, thereby surpassing many standard imaging techniques for cold atoms. This allows the observation of trapped quantum gases with single atom sensitivity and high temporal and spatial resolution.

We present the ion optics setup and the corresponding simulations, which show the theoretical limits of the system in terms of magnification and resolution. We also show the experimental implementation in an ultra-cold atom setup. Using spatially patterned 480nm laser light, atoms are ionized out of a magneto-optical trap in order to characterize the imaging quality. Furthermore, we present excitation and detection of Rydberg atoms with this system.

A 17.6 Tue 15:45 N 3

Magnetoexcitons in cuprous oxide — •Frank Schweiner, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, 70550 Stuttgart, Germany

Excitons are often regarded as the hydrogen analog of the solid state due to their hydrogen-like spectrum. In particular, excitons in cuprous oxide (Cu_2O) have recently attracted lots of attention due to the observation of giant Rydberg excitons [1].

However, the spectra of magnetoexcitons cannot be understood from a simple hydrogen-like model. We present the theory of magnetoexcitons in Cu_2O and show that it is indispensable to account for the complex valence band structure and the cubic symmetry of the solid in a quantitative theory. We especially discuss the dependence of the spectra on the direction of the external magnetic field and present a comparison of theoretical and experimental results [2].

Due to the band structure, fundamental differences between magnetoexcitons and the external fields hydrogen atom regarding the symmetry and the line statistics can be observed. While in atomic physics only GOE statistics can be observed, we show that magnetoexcitons break all antiunitary symmetries and thus show GUE statistics [3,4].

[1] T. Kazimierczuk et al, Nature 514, 343, 2014
[2] F. Schweiner et al, arXiv:1609.04275, 2016
[3] M. Aßmann et al, Nature Mater. 15, 741, 2016
[4] F. Schweiner et al, arXiv:1609.04278, 2016

A 17.7 Tue 16:00 N 3

Towards a shotnoise limited optogalvanic vapor cell — •Johannes Schmidt[1,2], Ralf Albrecht[1], Patrick Schalberger[2], Holger Baur[2], Robert Löw[1], Harald Kübler[1], Norbert Frühauf[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut, IQST, University of Stuttgart — [2]Institute for Large Area Microelectronics, IQST, University of Stuttgart

We show how we want to integrate a shotnoise limited ion current detection into an optogalvanic vapor cell. Such a device can be used as a sensitive detector for electric and magnetic fields as well as highly excited atoms and molecules. We excite Alkali Rydberg atoms in an electrically contacted vapor cell [1,2]. These atoms are ionized due to collisions with the background gas. A voltage directs these charges towards the electrodes on the inside of the cell, where they are detected with an amplification circuit based on thin film technology [3]. Requirements for such a circuit are among others, that it is low noise, provides a stable amplification under changing environmental conditions and is chemically inert against the content of the cell. Different implementation schemes are proposed, compared and first results will be presented.

[1] D. Barredo, et al., *Phys. Rev. Lett.* **110**, 123002 (2013)
[2] R. Daschner, et al., *Opt. Lett.* **37**, 2271 (2012)
[3] P. Schalberger, et al., *JSID* **19**, 496-502 (2011)

A 18: Helium Droplets and Systems (with MO)

Time: Tuesday 14:30–16:15 Location: N 6

Invited Talk A 18.1 Tue 14:30 N 6

Cluster Studies with the BerlinTrap — •Pablo Nieto, Alan Günther, David Müller, Alex Sheldrick, and Otto Dopfer — Institut für Optik und Atomare Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany

The first experiments using a novel tandem mass spectrometer (BerlinTrap) which combines an electrospray ion source, a quadrupole mass spectrometer, a cryogenic 22-pole ion trap (4-300 K), and an orthogonal reflectron time-of-flight mass spectrometer [1] are presented. First, the generation of small He clusters around cold metal ions (He_nM^{q+}) by successive aggregation of He atoms is presented. The attraction between a positive charge and the surrounding He leads to the formation of a shell of strongly bonded atoms around the ion often called snowball. The study of He snowballs has been carried out in the last years by photo- or electron impact ionization of the atom or molecule embedded in relatively large He droplets. This study constitutes the first bottom-up approach to the formation of He snowballs around an ion using a gentle growth scheme. The formation of some clusters with a given (magic) number of He atoms is greatly enhanced signaling a high relative stability. In the second part of the talk structure and optical absorption properties of metalated flavins in the gas phase are discussed. The present results illustrate the broad variety of atomic and molecular ionic clusters which can be studied with the BerlinTrap by mass spectrometry and spectroscopy.

[1] A. Günther, P. Nieto, D. Müller, A. Sheldrick, D. Gerlich, and O. Dopfer, J. Mol. Spectrosc., in press, DOI:10.1016/j.jms.2016.08.017

A 18.2 Tue 15:00 N 6

Libration of strongly-oriented polar molecules inside a superfluid — •Elena Redchenko and Mikhail Lemeshko — IST Austria (Institute of Science and Technology Austria), Am Campus 1, 3400 Klosterneuburg, Austria

Recently, it was shown that molecular rotation inside a superfluid, such as a helium nanodroplet or a Bose-Einstein condensate, leads to formation of a quasiparticle of a new kind – the angulon. The angulon represents a quantum rotor dressed by a field of many-particle excitations. In this work, we demonstrate that in the strong-field limit the angulon turns into the 'pendulon' – a quantum spherical librator, whose pendular motion is altered by the field of phonon excitations, and study the properties of the pendulon quasiparticle. We have shown that an electric field relaxes the selection rules on the angular momentum exchange between the molecule and the bath, which results in a series of instabilities absent in the field-free case of the angulon quasiparticle. In other words, a field renders the instabilities universal, i.e. independent on the details of the molecule-boson potential energy surface. Furthermore, a field acts as an additional knob for altering the positions of the instabilities in the molecular rotational spectrum, thereby opening the door for detailed experimental studies of redistribution of orbital angular momentum in many-particle systems.

[1] Redchenko E.S., Lemeshko M., Chemphyschem. 2016 Nov 18;17(22):3649-3654.

A 18.3 Tue 15:15 N 6

Fingerprints of the angulon quasiparticle in spectra of molecules in superfluid helium droplets — •Igor Cherepanov and Mikhail Lemeshko — Institute of Science and Technology Austria (IST Austria), Am Campus 1, 3400 Klosterneuburg, Austria

The recently developed angulon theory [1] represents a powerful tool to study interactions between a rotating molecular impurity and a macroscopically large number of helium atoms in a superfluid helium nanodroplet. The comparison of the experimental data on the renormalization of rotational constants for a wide range of different molecules and the predictions of the angulon theory [2] provides a strong evidence for angulon formation in superfluid ^{4}He.

Here we demonstrate that angulon theory is also able to explain some features observed in the ro-vibrational spectra of the ν_3 band of the methyl radical [3] and the ammonia molecule [4] solvated in superfluid ^{4}He. We found that one of the largest anisotropic terms in the CH_3(NH_3)-He potential expansion induces a transfer of one quantum of angular momentum from the molecule to the many-body bath. As a consequence, the spectral line corresponding to the $^RR_1(1)$ transition becomes significantly broadened and suppressed compared to the gas phase. This amounts to an experimental confirmation of the angulon instabilities, recently predicted in Ref. [1].

[1] R. Schmidt, M. Lemeshko, Phys. Rev. Lett. **114**, 203001 (2015)
[2] M. Lemeshko, arXiv:1610.04908 (2016)
[3] A. Morrison et al., J. Phys. Chem. A **117**, 11640 (2013)
[4] M. Slipchenko, A. Vilesov, Chem. Phys. Lett. **412**, 176 (2005)

A 18.4 Tue 15:30 N 6

Gold doped helium nanodroplets: Electronic spectroscopy from atoms to nanoparticles — •Florian Lackner, Maximilian Lasserus, Roman Messner, Martin Schnedlitz, Alexander Volk, Philipp Thaler, and Wolfgang E. Ernst — Institute of Experimental Physics, TU Graz

The isolation of nanoparticles in helium nanodroplets offers low temperature confinement for a dopand size regime ranging from single atoms and molecules to large clusters and elongated wire-structures. Excitation spectra of gold atoms, residing inside the droplets, appear strongly blue shifted due to the repulsive Pauli interaction of excited electrons with the He environment. Consequently, for the $5d^{10}6p$ $^2P^o_{1/2} \leftarrow 5d^{10}6s$ $^2S_{1/2}$ transition in Au-He$_N$ we observe a broad structure extending more than 800 cm^{-1} to the blue of the bare atom line located at 37,359 cm^{-1}. This feature is superimposed by a peak around 37,950 cm^{-1} attributed to atoms that have relaxed into the $5d^96s^2$ ^{2}D manifold, a pathway enabled by the droplet environment and forbidden in the free atom. Absorption spectra of larger nanoparticles can be recorded ex-situ after deposition on fused silica substrates. First results on Au nanoparticles prepared by helium nanodroplets show a characteristic surface plasmon resonance peaking around 530 nm. We expect that the formidable doping capabilities provided by helium nanodroplets will allow for the study of the electronic structure of a large variety of mono- and bi-metallic nanoparticles ranging from single atoms and molecules to large nanoparticles.

A 18.5 Tue 15:45 N 6

Far-Infrared Spectroscopy of Molecules and Aggregates in Helium Nanodroplets at FELIX — •Gerhard Schwaab[1], Raffael Schwan[1], Devendra Mani[1], Nitish Pal[1], Britta Redlich[2], Lex van der Meer[2], and Martina Havenith[1] — [1]Physikalische Chemie 2, Ruhr-Universität Bochum — [2]FELIX Laboratory, Radboud University Nijmegen

Helium nanodroplets provide the opportunity to study molecules and molecular aggregates at temperatures of 0.37 K in a suprafluid matrix. Recently we have moved one of our helium droplet machines to the free electron laser facility FELIX in Nijmegen. First test molecules included SF_6, water, water clusters and water-HCl clusters.

The high output energy and broad frequency coverage of the FELIX I and FELIX II beamlines allows access to the low frequency ($\nu > 100$cm^{-1}) far-infrared range in spite of the low energy per photon. Esecially the spectrum of small water clusters in this region is astonishingly rich. An overview of the experimental setup and the results of our latest micro-solvation studies will be given.

A 18.6 Tue 16:00 N 6

Infrared spectroscopy of HCl dissociation at 0.37K using free electron lasers. — •Devendra Mani[1], Raffael Schwan[1], Theo Fischer[1], Arghya Dey[1,2], Matin Kaufmann[1], Britta Redlich[2], Lex van der Meer[2], Gerhard Schwaab[1], and Martina Havenith[1] — [1]Lehrstuhl für Physikalische Chemie II, Ruhr Universität Bochum, Germany. — [2]Institute for Molecules and Materials (IMM), Radboud University Nijmegen, Nijmegen, Netherlands

Dissociation of HCl in presence of few water molecules has recently been studied theoretically as well as spectroscopically. [1,2] These studies suggest that 4 water molecules are sufficient to dissociate one HCl molecule, forming a solvent separated $H_3O^+(H_2O)_3Cl^-$ dissociated cluster. Until now, attempts to observe this dissociated species had been focused on the O-H and H-Cl stretch regions. However, the results were obscured by the presence of vibrational bands of different $(HCl)_m - (H_2O)_n$ undissociated clusters in this spectral range. From the recent theoretical calculations [3], the umbrella type motion of the H_3O^+ moiety (prediction: broad band, 1300-1360 cm^{-1}) appears to be a fingerprint signature for the dissociated cluster. We have studied this dissociation reaction in helium droplets, in the frequency range of 900-1700 cm^{-1}, using free electron lasers at FELIX. A weak broad band, spanning from 1000 to 1450 cm^{-1}, could be observed on specific mass channels. The results will be discussed in detail in the talk.

References: 1) H. Forbert et al., J. Am. Chem. Soc., **133**, 4062 (2011). 2) A. Gutberlet et al., Science, **324**, 1545 (2009).3) J. M. Bowman et al., Phys. Chem. Chem. Phys., **17**, 6222 (2015).

A 19: Precision Measurements and Metrology: Interferometry II (with Q)

Time: Tuesday 14:30–16:45 Location: P 104

A 19.1 Tue 14:30 P 104

Theoretical study of Bose-Einstein condensates in optical lattices towards large momentum transfer atom interferometers — •Jan-Niclas Siemss[1], Ernst Maria Rasel[2], Klemens Hammerer[1], and Naceur Gaaloul[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Highly sensitive atom interferometers require the two interferometer arms to enclose a large area in spacetime.

In parallel to the implementation of large interrogation times in microgravity [1] and fountains [2], a larger spatial separation with large momentum transfer (LMT) enhances the sensitivity of atomic sensors. A promising method to realize these novel schemes is to combine Bragg pulses and Bloch oscillations in optical lattices to coherently split and recombine the atomic wave packets. However, the finite momentum width of the atomic ensemble or the damping of Bloch oscillations due to tunneling constrain the fidelity of the LMT.

We theoretically analyze the coherent acceleration of BECs in 1D optical lattices to understand and optimize pioneering experiments performed in the QUANTUS collaboration. To this end, a 1D-reduced Gross-Pitaevskii model [3] is adapted to interpret and propose realistic novel LMT schemes.

[1] H. Müntinga et al. Phys. Rev. Lett. 110, 093602 (2013)
[2] S. M. Dickerson et al. Phys. Rev. Lett. 111, 083001 (2013)
[3] L. Salasnich et al. Phys. Rev. A 66, 043613 (2002)

A 19.2 Tue 14:45 P 104

Fast BEC transport with atoms chips for inertial sensing — •Robin Corgier[1], Sirine Amri[2], Eric Charron[2], Ernst Maria Rasel[1], and Naceur Gaaloul[1] — [1]Leibniz University of Hanover, Germany — [2]Université Paris-Sud, France

Recent proposals in the field of fundamental tests of foundations of physics assume Bose-Einstein condensates (BEC) as sources of atom interferometry sensors. Atom chip devices have allowed to build transportable BEC machines with high repetition rates as demonstrated in the QUANTUS project. The proximity of the atoms to the chip surface is, however, limiting the optical access and the available interferometry time necessary for precision measurements. In this context, a fast and perturbation-free transport of the atoms is required. Shortcuts to adiabaticity protocols were proposed and allow in principle to implement such sequences with well defined boundary conditions. In this theoretical study, one can engineer suitable protocols to move atomic ensembles trapped at the vicinity of an atom chip by tuning the values of the realistic chip currents and external magnetic fields. Experimentally applicable trajectories of the atomic trap optimizing the transport time and reducing detrimental effects due to the offset of atoms positions from the trap center are found using a reverse engineering method. We generalize the method in order to optimize the size evolution and the center of a BEC wave packet in phase space. This allows an efficient delta-kick collimation to the pK level as observed in the Quantus 2 experiment. With such low expansion rates, atom interferometry experiments with seconds of drift time are possible.

A 19.3 Tue 15:00 P 104

Symmetric scalable large momentum transfer beam splitter — •Martina Gebbe[1], Sven Abend[2], Matthias Gersemann[2], Hauke Müntinga[1], Holger Ahlers[2], Wolfgang Ertmer[2], Claus Lämmerzahl[1], Ernst M. Rasel[2], and The QUANTUS Team[1,2,3,4,5,6] — [1]ZARM, Uni Bremen — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Physik, HU Berlin — [4]Institut für Quantenoptik, Uni Ulm — [5]Institut für angewandte Physik, TU Darmstadt — [6]Institut für Physik, JGU Mainz

Due to their small spatial and momentum width ultracold Bose-Einstein condensates (BEC) or even delta-kick collimated (DKC) atomic ensembles are very well suited for high precision atom interferometry. We generate such an ensemble in a miniaturized atom-chip setup where BEC generation and delta-kick collimation can be performed in a fast and reliable way. We present a symmetric double Bragg diffraction technique offering interesting new features for atom interferometry. The coherent manipulation is directed along the horizontal axis and combined with Bloch oscillations in order to realize symmetric scalable large momentum beam splitters. We employ this new type of beam splitter to study the performance of scalable Mach-Zehnder interferometers whose sensitivity increases linearly with velocity separation. This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under grant numbers DLR 50WM1552-1557 (QUANTUS-IV-Fallturm).

A 19.4 Tue 15:15 P 104

A sensitive electrometer based on a Rydberg atom in a Schrödinger-cat state — •Eva-Katharina Dietsche, Arthur Larrouy, Adrien Facon, Serge Haroche, Jean-Michel Raimond, Michel Brune, and Sebastien Gleyzes — Laboratoire Kastler Brossel, College de France, ENS-PSL, UPMC-Sorbonne Universite, CNRS, Paris France

The Rydberg atoms are highly excited states where the electron is orbiting far from the nucleus. As a result, they have a huge electric dipole, making them ideal probes of the electric field. Rydberg states are highly degenerated. However, in the presence of a small electric field, this degeneracy is lifted and it is possible to drive transitions between the different Stark sublevels by applying radiofrequency fields. It is then possible to manipulate the state of the atom inside the manifold. We have recently shown that by using a radiofrequency field with a well-defined polarization it is possible to restrict the evolution of the atom to a subspace of the manifold where it behaves like a large angular momentum J. We have prepared non-classical states, similar to Schrödinger cat states, that allowed us to measure small variations of the electric field with a sensitivity beyond the standard quantum limit [1]. We are now investigating more complex manipulations of the atom to take advantage of the full richness of the Rydberg manifold. By using a combination of radiofrequency fields of different polarizations we can explore a larger part of the level structure. This opens the way to schemes that give access to higher moments of the electric field.

[1] A. Facon et al. Nature 535, 262-265 (2016)

A 19.5 Tue 15:30 P 104

Using Schrödinger cat states of Rydberg atoms to measure fast electric fields — •Eva-Katharina Dietsche, Arthur Larrouy, Adrien Facon, Serge Haroche, Jean-Michel Raimond, Michel Brune, and Sebastien Gleyzes — Laboratoire Kastler Brossel, College de France, ENS-PSL, UPMC-Sorbonne Universite, CNRS, Paris France

We present a quantum-enabled measurement of the electric field using Rydberg atoms. We prepare the atom in a quantum superposition of two circular states with principle quantum number n=50 and n=51. Using a radiofrequency field resonant with the Stark transition in the n=50 manifold we transfer the n=50 part of the wave function from its horizontal circular orbit to a tilted elliptical trajectory. This creates a Schrödinger cat superposition of two states with very different polarizabilities whose relative phase is highly sensitive to variations in the amplitude of the electric field. Detecting this phase change using Ramsey interferometry allows us to measure the electric field with a precision below the standard quantum limit (SQL) [1]. This allows using the Rydberg atom as a microscopic electrometer that can perform time-resolved field measurements with a very high bandwidth.

[1] A. Facon et al. Nature 535, 262-265 (2016)

A 19.6 Tue 15:45 P 104

Fock state metrology — •Fabian Wolf[1], Chunyan Shi[1], Jan Christoph Heip[1], Marius Schulte[3], Klemens Hammerer[3], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität, 30167 Hannover, Germany — [3]Institute for Theoretical Physics, Leibniz Universität, 30167 Hannover, Germany

The field of quantum metrology promises measurements with unprecedented accuracies and sensitivities using non-classical states. The idea behind quantum metrology is to prepare the investigated system or the measurement probe in a quantum states to reduce certain types of noise. In particular shot noise or quantum projection noise represents the major limitation for stability in state-of-the-art precision experiments ranging from gravitational wave detection to optical atomic clocks. The most prominent examples for states with non-classical features, previously investigated for this purpose are Schrödinger cat states and squeezed states and metrological gain compared to classical states has been demonstrated. Recently, investigations started to focus on the properties of states with negative Wigner function. However, so far the metrological gain of these states has not been verified experimentally. Here, we demonstrate that force measurements on an ion, trapped in a linear Paul trap can beat the classical limit, if the ion is initially prepared in a motional Fock state. Our scheme does not include any entanglement or squeezing and therefore illustrates the power of quantum interference due to negative Wigner functions for quantum metrology.

A 19.7 Tue 16:00 P 104

Phase magnification for robust atom interferometry beyond the SQL — •Fabian Anders — Institut für Quantenoptik, LUH Hannover, Deutschland

The two-axis counter-twisting interaction provides the possibility for detection noise robust atom interferometry beyond the standard quantum limit. Our scheme complements recent approaches based on one-axis twisting to magnify the interferometric phase.

In both concepts, the non-linear interaction is not only applied before the interferometer to generate entanglement, but also afterwards to amplify the signal. We compare both squeezing-echo approaches in their optimal performance as well as for experimentally feasible parameters. We find that varying the echo strength can further improve the robustness against detection noise. We obtain simple analytical results for the one-mode approximation of the scheme. Additionally, we investigate spin dynamics in a spinor condensate as suitable interaction to effectively implement this technique.

A 19.8 Tue 16:15 P 104

Random bosonic states for robust quantum metrology — Michał Oszmaniec[1], Remigiusz Augusiak[1,2], •Christian Gogolin[1,3], Janek Kołodyński[1], Antonio Acín[1,4], and Maciej Lewenstein[1,4] — [1]ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain — [2]Center for Theoretical Physics, Polish Academy of Sciences, Aleja Lotników 32/46, 02-668 Warsaw, Poland — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [4]ICREA-Institució Catalana de Recerca i Estudis Avançats, Lluis Companys 23, 08010 Barcelona, Spain

We study how useful random states are for quantum metrology, i.e., whether they surpass the classical limits imposed on precision in the canonical phase estimation scenario. We prove that random pure states drawn from the Hilbert space of distinguishable particles typically do not lead to super-classical scaling of precision. Conversely, we show that random states from the symmetric subspace typically achieve the optimal Heisenberg scaling. Surprisingly, the Heisenberg scaling is observed for states of arbitrarily low purity and preserved under the loss of fixed number of particles. Moreover, we prove that for such states a standard photon-counting interferometric measurement suffices to typically achieve the Heisenberg scaling of precision for all values of the phase at the same time. Finally, we demonstrate that metrologically useful states can be prepared with short random optical circuits.

A 19.9 Tue 16:30 P 104

The First Sounding Rocket Flight with an Atom Interferometer — •Stephan T. Seidel[1], Maike D. Lachmann[1], Dennis Becker[1], Wolfgang Ertmer[1], Ernst M. Rasel[1], and QUANTUS Collaboration[2] — [1]Institut für Quantenoptik, Universität Hannover — [2]LU Hannover, U Bremen, JGU Mainz, U Hamburg, HU Berlin, FBH, TU Darmstadt, U Ulm

The possibility of precise measurements of inertial forces using atom interferometry has led to a multitude of proposals for future satellite missions. These include missions aimed at geodetic measurements like a characterization of earth's gravitational field gradient and fundamental physics like a test of the universality of free fall.

Current ground based experiments are not suitable for the use on a satellite mission and a series of new technological and experimental techniques are required. This creates the necessity for pathfinder missions to test atom interferometer setups in relevant environments. To bridge this gap three sounding rocket missions are currently being prepared. The launch of the first mission is aimed at both the first creation of Bose-Einstein Condensates (BEC) and first demonstration of light atom interferometry in space.

Its payload can create BECs of 10^5 atoms from ^{87}Rb within two seconds. Therefore 70 experiments can be performed within the microgravity time including an observation of the phase transition and the characterization of the BECs after long free evolution times using atom interferometry. The system was qualified for the flight in a series of vibration tests and is currently in wait for favorable wind conditions.

A 20: Poster Session I

Time: Tuesday 17:00–19:00 Location: P OGs

A 20.1 Tue 17:00 P OGs

Towards quantum many-body physics with Sr in optical lattices — •Annie Jihyun Park[1], André Heinz[1], Stephan Wissenberg[1], Stepan Snigirev[1], Jean Dalibard[2], Immanuel Bloch[1], and Sebastian Blatt[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85784 Garching, Germany — [2]Laboratoire Kastler Brossel, Collège de France, ENS-PSL Research University, CNRS, UPMC-Sorbonne Universités, 11 place Marcelin Berthelot, 75005 Paris, France

Within the last decade, fermionic alkaline earth atoms in optical lattices have become a platform for precision measurements, culminating in the realization of an atomic clock with the currently highest stability and accuracy at the 2e-18 level. In the meantime, quantum degenerate gases of all bosonic and fermionic isotopes of Sr have been realized. With the extension of the quantum gas microscopy technique to fermionic alkali metal atoms, experiments with quantum degenerate gases in optical lattices have taken another step towards full control over the internal and external degrees of freedom of fermions in optical lattices.

Here, we report on the construction of a new experiment with quantum degenerate gases of Sr in optical lattices. Our experiment aims to combine the high spatial control over the atomic degrees of freedom from quantum gas microscopy with the precision control over the internal degrees of freedom enabled by optical lattice clock techniques.

A 20.2 Tue 17:00 P OGs

Disspative processes in interacting bosonic systems — •Arya Dhar, Andreas Geissler, Tao Qin, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany

Rydberg atoms in recent years have emerged as an efficient tool to engineer long-range interactions and simulate a variety of spin Hamiltonians. Off-resonant coupling to Rydberg states creates 'Rydberg dressing' leading to great flexibility of tuning the interaction strengths. The interplay between the kinetic energy and the interactions gives rise to a number of novel quantum phases in the equilibrium scenario such as the Devil's staircase, and supersolid phases [A. Geißler et al., arXiv:1509.06292]. But in realistic situations in the experiment, there are always dissipative processes present such as spontaneous emission from the excited Rydberg states or intermediate states and dephasing due to black-body radiation. In this work we demonstrate progress on the development of a novel numerical method to study dissipative effects in Rydberg-dressed many-body systems. The goal is to combine dynamical mean field theory (DMFT) with the Lindblad formalism using the auxiliary master equation approach proposed recently [I. Titvinidze et al, Phys. Rev. B 92 , 245125 (2015)]. Using this method, we study the effects of dissipation on the various ordered states already predicted in the equilibrium case. Our studies are relevant for current experiments, which can also control the different dissipation processes to some degree.

A 20.3 Tue 17:00 P OGs

Real-space Floquet DMFT study of spectral functions of time-periodically driven systems — •Tao Qin and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt/Main, Germany

Time-periodically driven cold atom systems are versatile toolboxes for realizing artificial gauge fields in quantum simulations. Great progress has been made in simulating topologically non-trivial models such as the Hofstadter- and Haldane-Hamiltonians. Up to now most experiments focus on the non-interacting regime. Introducing interactions into systems with artificial gauge fields will be of high interest. Floquet DMFT is a non-perturbative method to study the non-equilibrium steady state in interacting time-periodically driven systems. Using its generalization to real-space Floquet DMFT for inhomogeneous systems we studied the spectral function of the Hofstadter-Falicov-Kimball Hamiltonian and its realization in a time-periodically driven system. We calculated the effect of interactions on edge states in this system and discuss possible ways to observe them in experiments. We also discuss the possibility to study spectral functions of the Hofstadter-Hubbard Hamiltonian in time-periodically driven systems.

A 20.4 Tue 17:00 P OGs

Towards a Bose polaron in an ultracold Fermi-Bose mixture of ^{6}Li and ^{133}Cs — •Binh Tran, Stephan Häfner, Manuel Gerken, Melina Filzinger, Bing Zhu, Juris Ulmanis, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

In our experiment we are working towards the creation of a Bose polaron in an ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li atoms with a large mass imbalance. The Bose polaron is a quasiparticle that describes a single Li impurity which is immersed into a Cs BEC and interacts with its phonon excitations. Therefore, this scenario is similar to the Fröhlich polaron from condensed matter physics. Via Li-Cs Feshbach resonances we can tune the interparticle interaction strength and change the sign of interaction, thus enabling us to investigate both attractive and repulsive polarons.
We describe the creation of a Cs BEC by means of evaporative cooling in an optical dipole trap, after the atoms have been brought to a temperature of around 1 μK in previous cooling stages. In order to reach a high phase-space density we modify our trapping potential by adding a second dipole trap with a smaller waist and applying two consecutive evaporation steps. Furthermore, we give an overview of our approach towards the experimental investigation of the Bose polaron, its energy spectrum and dynamic properties.

A 20.5 Tue 17:00 P OGs

Diatomic and triatomic ultra long-ranged Rydberg molecules — •Frederic Hummel[1], Christian Fey[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg

We present recent results of our study of ultra long-range Rydberg molecules (ULRM), which include polyatomic molecules with spin dependent interactions as well as their stretching and bending dynamics. An ULRM is the manifestation of a novel molecular binding mechanism occuring in ultra cold atomic quantum gases due to the scattering of an exited Rydberg electron with neutral ground state atoms in its vicinity. The diverse potential energy landscapes arising from Born-Oppenheimer approximation gives way to a plethora of molecular states, partly with, for all practical purposes, large permanent electric dipole moments in the kilo Debye magnitude, even for homonuleic systems. Typical binding energies range from 10 up to 10^4 MHz for so called Butterfly molecules. Inculsion of fine- and hyperfine structure can lead to longrange spin-spin interaction between the Rydberg and neutral atom with typical separations of 400-1000 atomic units.

A 20.6 Tue 17:00 P OGs

Mode coupling of interaction quenched ultracold bosons in periodically driven lattices — •Simeon Mistakidis[1] and Peter Schmelcher[1,2] — [1]Zentrum fuer Optische Quantentechnologien, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The out-of-equilibrium dynamics of interaction quenched finite ultracold bosonic ensembles in periodically driven one-dimensional optical lattices is investigated. It is shown that periodic driving enforces the bosons in the outer wells of the finite lattice to exhibit out-of-phase dipole-like modes, while in the central well the atomic cloud experiences a local breathing mode. The dynamical behavior is investigated with varying driving frequency, revealing a resonant-like behavior of the intra-well dynamics. An interaction quench in the periodically driven lattice gives rise to admixtures of different excitations in the outer wells, an enhanced breathing in the center and an amplification of the tunneling dynamics. We observe then multiple resonances between the inter- and intra-well dynamics at different quench amplitudes, with the position of the resonances being tunable via the driving frequency. Our results pave the way for future investigations on the use of combined driving protocols in order to excite different inter- and intra-well modes and to subsequently control them.

A 20.7 Tue 17:00 P OGs

Experimental studies of the disordered Bose-Hubbard model in two dimensions — •Jae-yoon Choi[1], Antonio Rubio-abadal[1], Johannes Zeiher[1], Simon Hollerith[1], Sebastian Hild[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopermann straße 1, 85748 Garching, Germany — [2]Fakultät für physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

The study of disordered systems with ultracold atoms has been extended by the advent of quantum gas microscopy, making it possible to prepare an out-of-equilibrium initial state and measure local quantities rather than bulk properties. In this poster, we summarize our recent experimental work on two-dimensional disordered optical lattice systems. Studying relaxation dynamics of out-of-equilibrium initial states, we observe a many-body localized phase and investigate the phase transition in the 2D system. Moreover, motivated by recent proposals, we probed the Bose glass phase locally by measuring an Edward-Anderson parameter analogue. Our measurements provide a chemical resolved characterization of the disordered Bose-Hubbard model in the low energy limit.

A 20.8 Tue 17:00 P OGs

Commensurate-incommensurate transition in optical cavities — •Andreas Alexander Buchheit[1], Haggai Landa[2], Cecilia Cormick[3], Thomas Fogarty[4], Vladimir Stojanovic[5], Eugene Demler[5], and Giovanna Morigi[1] — [1]Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]LPTMS, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay, France — [3]IFEG, CONICET and Universidad Nacional de Cordoba — [4]Okinawa Institute of Science and Technology, Japan, — [5]Department of Physics, Harvard University, Cambridge, MA 02138, USA

In this work we report on the optomechanical dynamics of chains of trapped ions, which couple to the high-Q mode of an optical standing-wave cavity. Their dynamics results from the interplay between the trapping potential, long-range Coulomb repulsion and the cavity-induced interactions. The latter are due to multiple scatterings of laser photons inside the cavity and become relevant when the laser pump is sufficiently strong to overcome photon decay. We study the stationary states of the ions as a function of the cavity and laser parameters, when the typical length scales of the two self-organizing processes, Coulomb crystallization and photon-mediated interactions, are almost commensurate. We analyze the phase diagram as a function of the ratio between the two wavelengths and recover the commensurate-incommensurate transition when cavity backaction can be neglected. We discuss the features of the emerging phases and analyse how they can be detected in the radiation emitted by the cavity.

A 20.9 Tue 17:00 P OGs

Quantum phases of ultracold dipolar molecules in low dimensions — Florian Cartarius[1,2], •Lukas Himbert[1], Anna Minguzzi[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Université Grenoble-Alpes, CNRS, LPMMC, BP166, 38042 Grenoble, France

We consider ultracold dipolar bosonic molecules in a 1D optical lattice in tight anisotropic harmonic confinement, leading to a quasi one-dimensional geometry. If the confinement along one of the directions perpendicular to the optical lattice is relaxed, the system undergoes a structural linear-zigzag transition. We show that close to the transition this system can be mapped onto a multi-orbital extended Bose-Hubbard model, where the coefficients can be determined by means of a low-energy theory. The system displays a rich phase diagram resulting from the interplay between tunneling, on-site repulsion, the external confinement and dipolar interaction and we determine the ground state at the linear-zigzag structural instability by means of exact diagonalization. This study sets the basis for a systematic investigation on the interplay between structural and quantum order in interacting quantum gases.

A 20.10 Tue 17:00 P OGs

Spectroscopy of discrete solitons in Coulomb crystals — •Miriam Bujak[1], Jonathan Brox[1], Philip Kiefer[1], Haggai Landa[2], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]LPTMS, Université Paris Sud, Orsay, France

We study structural defects (solitons) which are formed during laser triggered first order phase transition from a cloud of Mg-ions to a Coulomb crystal in a Paul trap [1]. The formation of kink configurations as well as the lifetime of such structural defects are experimentally investigated. We study the dependence on parameters, such as laser cooling ($-\Gamma/2$) and heating ($+\Gamma/10$) rate, the duration of the process to optimize the kink creation propability and explore the relevant time scales of the formation mechanism during the phase transition. We present first results of kink spectroscopy, i.e. of localized vibrational eigenmodes of the Coulomb crystal [2].

[1] M. Mielenz et al., Phys. Rev. Lett. 110, 133004 (2013)
[2] J. Brox et al., in preparation

A 20.11 Tue 17:00 P OGs

Sympathetic cooling of OH- ions using Rb atoms in a MOT — •Jonas Tauch[1], Henry Lopez[1], Bastian Höltkemeier[1], Tobias Heldt[1], Eric Endres[2], Roland Wester[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut Heidelberg, INF 226, 69120 Heidelberg — [2]Institut für Ionenphysik und Angewandte Physik, Technikerstraße 25/3, 6020 Innsbruck

In this poster I will present the current status and first results of our hybrid atom-ion trap (HAITrap) experiment. Our setup combines an octupol radio frequency ion trap and a magneto optical trap (MOT). We can store up to 500 OH^- anions in the radio frequency trap, which provides sufficient optical access to superimpose laser cooled rubidium atoms in the MOT on the anion cloud. A dark spontaneous force optical trap (darkSPOT) configuration is used to bring most rubidium to the ground state, hence avoiding ion loss by inelastic collisions, as well as allowing higher densities up to $3 \cdot 10^{11}$ atoms/cm^3. This setup allows us to investigate sympathetic cooling of molecular anions with five times heavier buffer gas atoms, which is predicted to be possible by localizing the ultracold buffer gas atoms in the center of the anion cloud.

A 20.12 Tue 17:00 P OGs

Dynamical Instabilities in Trapped Bose-Einstein Condensates — •Torsten Victor Zache[1], Valentin Kasper[2], and Jürgen Berges[1] — [1]Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg — [2]Physics Department, Harvard University, Cambridge MA 02138, USA

We study the nonlinear phenomenon of secondary instabilities (secondaries), which was proposed in the context of inflationary particle production, with ultracold atom systems. Specifically, we consider a one-dimensional two-component Bose gas that can be realized in different experimental setups and show analytically that it exhibits a primary instability characterized by exponentially growing occupation numbers of certain momentum modes. The primary instability is triggered by initial quantum fluctuations and leads to an amplified occupation of primarily stable modes at later times. We demonstrate the existence of these secondary instabilities in trapped Bose-Einstein condensates numerically employing the classical-statistical approximation. The process underlying the generation of secondaries can be identified with a nonlinear loop correction, which leads to an interpretation in terms of Feynman diagrams and allows us to analytically estimate the secondary growth rates to be integer multiples of the primary one.

A 20.13 Tue 17:00 P OGs

QUANTUS-2 - Towards a Dual-Species Matter-Wave Interferometer in Free Fall — •Merle Cornelius[1], Tammo Sternke[1], Sven Herrmann[1], Claus Lämmerzahl[1], and The QUANTUS-Team[1,2,3,4,5,6] — [1]ZARM, Universität Bremen — [2]Institut für Quantenoptik, Leibniz Universität Hannover — [3]Institut für Physik, Humboldt-Universität zu Berlin — [4]Institut für Physik, Johannes Gutenberg Universität Mainz — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt

The goal of the QUANTUS-2 experiment is to perform dual-species matter-wave interferometry in microgravity at the drop tower in Bremen. Aiming for precision measurements to test the equivalence principle, long interferometer times in the range of seconds are crucial to increase the sensitivity of the measurement. Therefore ultra-low residual expansion rates of the used atomic ensembles are required, which can be achieved by magnetic lensing - also known as delta-kick cooling. Here we present our results of a magnetic lens to collimate a rubidium BEC in microgravity, enabling the observation of the ensemble after 2.7s of free evolution time. Optimization of the lens to reduce the aberrations lowers the expansion rate further and will thus provide an ideal source for precision atom interferometry in microgravity. Resulting future prospects will be discussed.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number DLR 50WM1555-1557.

A 20.14 Tue 17:00 P OGs

State selective probing of weakly bound molecular products after three-body recombination — •Joschka Wolf[1], Artjom Krükow[1], Amir Mohammadi[1], Amir Mahdian[1], Markus Deiss[1], Johannes Hecker Denschlag[1], and Eberhard Tiemann[2] — [1]Institut für Quantenmaterie, Universität Ulm, 89069 Ulm, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

Three-body recombination in an ultra-cold atomic cloud is a fundamental reaction process. Until now, it has mainly been studied as a particle loss phenomenon limiting the lifetime of dense atomic clouds and Bose-Einstein condensates. However, the underlying reaction channels and product states remained unexplored. In a recent experiment we were able to measure the population distribution of diatomic molecular reaction products for the regime of lowest binding energies and to extract absolute numbers for the fractions of molecules produced in the individual states. Our method allows us to determine the vibrational, rotational and partially also the hyperfine quantum numbers. In this poster we focus on the experimental technique and summarize the results.

A 20.15 Tue 17:00 P OGs

Ion source development for PIPE — •Alexander Perry-Sassmannshausen, Ticia Buhr, and Stefan Schippers — Justus-Liebig-Universität Gießen

We report on the development of a new ion source for measurements with the Photon-Ion-Spectrometer (PIPE) at beam line P04 of PETRA III at DESY in Hamburg. The new source is a Middleton type versatile negative ion source (VNIS) [1]. It produces intense negative ion currents by sputtering of caesium ions on a target material. Negative ions are prominent in low temperature plasmas like the upper atmosphere oder the interstellar medium. The main difference to positive ions is the way the additional electron is bound to the atom. Instead of by the coulomb force the electron is bound by polarization of the atomic core. Another interesting topic within respect is the study of inner shell ionization processes [2]. The design of the source was originally developed at Max-Planck-Institut für Kernphysik (MPI-K) at Heidelberg [3]. The new source was built in Gießen where also the tests will be performed at an ion source testbench. We will present mass spectra of ions produced in the source and show the behaviour of the source under various conditions.

[1] R. Middleton, A Negative-Ion Cookbook, 1990
[2] S. Schippers et al., Phys. Rev. A 94 (2016) 041401(R)
[3] J. Meier, Diploma thesis, University of Heidelberg, 2007

A 20.16 Tue 17:00 P OGs

Multi-electron processes in K-shell double and triple photodetachment of oxygen anions — •Stefan Schippers[1], Randolph Beerwerth[2,3], Levente Abrok[4], Sadia Bari[5], Ticia Buhr[1], Michael Martins[6], Sandor Ricz[4], Jens Viefhaus[5], Stephan Fritzsche[2,3], and Alfred Müller[1] — [1]Justus-Liebig-Universität Gießen — [2]Helmholtz-Institut Jena — [3]Friedrich-Schiller-Universität Jena — [4]ATOMKI, Debrecen, Hungary — [5]DESY, Hamburg — [6]Universität Hamburg

The photon-ion merged-beams technique was used at a synchrotron light source for measuring absolute cross sections of double and triple photodetachment of O^- ions [1]. The experimental photon energy range of 524–543 eV comprised the threshold for K-shell ionization. Using resolving powers of up to 13000, the position, strength and width of the below-threshold $1s\,2s^2\,2p^6\;{}^2S$ resonance as well as the positions of the $1s\,2s^2\,2p^5\;{}^3P$ and $1s\,2s^2\,2p^5\;{}^1P$ thresholds for K-shell ionization were determined with high-precision. In addition, systematically enlarged multi-configuration Dirac-Fock calculations have been performed for the resonant detachment cross sections. Results from these *ab initio* computations agree very well with the measurements for the widths and branching fractions for double and triple detachment, if *double* shake-up (and -down) of the valence electrons and the rearrangement of the electron density is taken into account. For the absolute cross sections, however, a previously found discrepancy between measurements and theory is confirmed.

[1] S. Schippers et al., Phys. Rev. A **94** (2016) 041401(R).

A 20.17 Tue 17:00 P OGs

X-Ray Quantum Optics with Novel Light Sources — •Jeremy Gallant, Kilian P. Heeg, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Theoretically and experimentally, x-ray quantum optics has been studied using Mössbauer nuclei in the single photon excitation regime. In this theoretical work we study multi-photon effects that will be accessible with novel x-ray sources [1]. We discuss methods for inducing Kerr-type non-linearities in Mössbauer nuclei excited by fluctuating free electron laser pulses and we describe a method to detect these effects interferometrically. Such methods could be used to produce electromagnetically induced transparency in the x-ray regime. [1] K. P. Heeg, C. H. Keitel, and J. Evers, arXiv:1607.04116 [quant-ph] Inducing and detecting collective population inversions of Mössbauer nuclei

A 20.18 Tue 17:00 P OGs

Towards coherent time-resolved all-XUV spectroscopy — •Andreas Wituschek[1], Lukas Bruder[1], Ulrich Bangert[1], Tim Laarmann[2,3], and Frank Stienkemeier[1] — [1]Universität Freiburg, Physikalisches Institut, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging CUI, Luruper Chaussee 149, 22761 Hamburg, Germany

Coherent time-resolved spectroscopy is a powerful tool to study ultrafast dynamics in complex systems. Extending these techniques to the XUV spectral region would allow studying core excitations, thus providing site specific information. However, demands on phase stability increase significantly when going to short wavelengths and advanced pulse manipulation in the XUV is challenging. Recent experiments have shown that in seeded HGHG free electron lasers (FEL) the emitted XUV pulses inherit the coherence properties of the seed pulses [1]. We suggest an approach based on acousto-optical phase modulation on the seed laser with subsequent seeding of the FEL and lock-in detection at the harmonics of the seed modulation. In this way, pulse manipulation can be performed with standard optics. Moreover, demands on phase stability are drastically reduced and signals are efficiently isolated and amplified. We present the first step towards this approach: extending the phase modulation scheme towards UV wavelengths (260nm) and high intensity femtosecond laser pulses in combination with detection in dilute samples.

[1] Gauthier et al., PRL 116, 024801 (2016)

A 20.19 Tue 17:00 P OGs

Observation of strong non-dipole effects in sequential multiphoton ionization using VUV FEL radiation — •Gregor Hartmann[1,2], Markus Ilchen[3], Michael Meyer[3], and Jens Viefhaus[2] — [1]Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg, Germany — [3]European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany

One of the fundamental principles of light-matter interaction is the dipole approximation that is commonly assumed to be valid at low photon energies including the soft X-ray region. Although it has been shown at synchrotron radiation facilities that this approximation has limitations, it has been unclear how they impact the ionization characteristics of ions. Recently, ultrafast and ultra-intense Vacuum UltraViolet pulses from free-electron lasers such as FERMI have been used to efficiently study photoionization properties of noble gas ions by angle resolved photoelectron spectroscopy. We present evidence of a forward-backward symmetry breakdown in such a sequential ionization process in the vicinity of the Cooper Minimum of argon, at 46 eV excitation energy. In particular, we show that the electron angular distribution of ionic argon gains a pronounced forward-backward asymmetry with respect to the beam by interference between the electric dipole and the electric quadrupole amplitudes.

A 20.20 Tue 17:00 P OGs

The Small Quantum Systems - SQS Instrument at the European XFEL — •Patrik Grychtol, Alexander Achner, Thomas M. Baumann, Alberto De Fanis, Markus Ilchen, Tommaso Mazza, Yevheniy Ovcharenko, Jones Rafipoor, Haiou Zhang, Pawel Ziolkowski, and Michael Meyer — Small Quantum System Group, European XFEL, 22869 Schenefeld

This contribution will present the Small Quantum System (SQS) scientific instrument, which is one of six experimental end stations at the European XFEL planned to open for user operation in autumn 2017. This experimental platform is designed for investigations of atomic and molecular systems, as well as clusters, nano-particles and small bio-molecules. It is located behind the SASE 3 soft x-ray undulator, which will provide horizontally polarized FEL radiation in a photon energy range between $260\,eV$ and $3000\,eV$ ($4.8\,nm$ to $0.4\,nm$) with 0.1 to 2×10^{14} photons per pulse and up to 27000 pulses per second. Two high-quality elliptical mirrors in Kirkpatrick-Baez configuration will focus the FEL beam to a FWHM spot size of approximately $1\,\mu m$ diameter. This is going to result in an intensity of more than $10^{18}\,W/cm^2$ within the interaction region, which will allow for studying non-linear multi-photon processes. Furthermore, the short FEL pulse duration between $2\,fs$ and $100\,fs$ in combination with a synchronized optical femtosecond laser will enable time-resolved studies of dynamic processes, thus capturing the motion of electrons and nuclei with unprecedented resolution in space on ultrafast time scales.

A 20.21 Tue 17:00 P OGs

X-ray lasing via K-shell ionization of highly charged ions — •Chunhai Lyu, Stefano M. Cavaletto, Christoph H. Keitel, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

X-ray lasing by inner-shell stimulated emission of highly charged ions (HCIs) is considered in theoretical simulations. Spiky, partially coherent x-ray free-electron lasers pulses are used to pump the lasing by ionizing K-shell electrons. Because there is no cavity to choose a specific frequency from the HCI's amplified spontaneous emission spectrum, the linewidth of the x-ray laser approximates the gain profile of the HCI medium. A frequency-dependent gain is calculated by means of time-dependent density-matrix simulations. Compared to similar approaches with neutral atoms in former experiments, certain HCIs promise a much narrower bandwidth of x-ray laser light.

A 20.22 Tue 17:00 P OGs

IR-assisted XUV multiphoton ionization of N2 at FLASH — •yifan liu[1], kirsten schnorr[1], georg schmid[1], sven augustin[1], severin meister[1], hannes lindenblatt[1], yuhai jiang[2], thomas ding[1], rolf treusch[3], stefan düsterer[3], kamal p singh[4], mathieu gisselbrecht[5], thomas pfeifer[1], and robert moshammer[1] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117, Heidelberg, Germany — [2]Shanghai Advanced Research Institute, Zhangjiang, 201210, Shanghai, China — [3]Deutsches Elektronen-Synchrotron, Notkestrasse 85, 22607, Hamburg, Germany — [4]Indian Institutes of Science Education and Research, Sector 81, 140306, Manauli, Indian — [5]Lund University, Lund, Post Box 118, 22100, Sweden

IR-assisted XUV multiphoton experiments on molecule N2 were performed at the free-electron-laser in Hamburg(FLASH). Within an XUV-pump/IR-probe scheme, the fragmentation and Multiple Ionization dynamics of N2 has been investigated using a dedicated Reaction-Microscope(ReMi). By adjusting the delay between the optical laser and XUV pulse, the ionization yields as a function of delay were recorded. By tracing the kinetic energy release of coincidence channels N(1,1) and N(2,1)as a function of delay in different laser fields, we find an enhanced yield of coincident fragments produced by XUV multiphoton absorption with the presence of a delayed NIR pulse. Sequential ionization is to be the dominant process. The enhanced ionization process is as well related to the polarization direction of the NIR laser pulse.

A 20.23 Tue 17:00 P OGs

Spectral characterization of SASE bunch trains — •Philipp Schmidt, Philipp Reiss, Gregor Hartmann, Christian Ozga, Martin Wilke, André Knie, and Arno Ehresmann — Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

The recent availability of short wavelength Free-Electron-Lasers (FELs) enabled the investigations of the nonlinear response of matter in the X-ray wavelength regime, i.e. at photon energies where the dominant interaction involves the strongly bound core electrons. Streak camera-type detectors are ideally suited to analyze the spontaneous and stimulated photon emissions after an target excitation driven by FELs. In combination with a suitable spectrometer they are able to spectrally and temporally resolve a single X-ray flash on the picosecond time scale. The inclusion of the spectral distribution of the laser pulse allows for an explicit selection of desired beam parameters that can vary greatly due to the statistical nature of the underlying SASE effect. This also applies to FEL sources like the FLASH facility in Hamburg and the upcoming European XFEL that employ long bunch trains of up to 3000 individual bunches to achieve high repetition rates. Here we want to present first results using an x-ray streak camera at FLASH to investigate the spectral and temporal correlations between SASE bunches in these bunch trains in realtime and for each shot.

A 20.24 Tue 17:00 P OGs

Observing Ultrafast Dissociation of CH3Cl with a COLTRIMS-Reaction Microscope — •Gregor Kastirke, Miriam Weller, Kilian Fehre, Markus S. Schoeffler, and Reinhard Dörner — Institut für Kernphysik, Universität Frankfurt, Max-von-Laue-Str.1, 60438 Frankfurt, Germany

Ultrafast Dissociation can be observed after resonant photoexcitation of an innershell electron of a small molecular system like CH3Cl. Because of populating a strongly repulsive potential energy curve, the dissociation of the molecule takes place within a few femtoseconds. At some point during the dissociation, the molecule deexcites as an Auger Decay occurs. The emitted Auger Electron carries information on the internuclear distance of the molecular fragments at the instant of the decay. By measuring the momenta of the electron and ionic fragment in coincidence, different scenarios can be observed: An emission of the electron from a molecular orbital at early decay times, emission during the bond breakage and emission from an atomic orbital in cases the molecule completely dissociated into separated fragments. In order to investigate ultrafast dissociation in CH3Cl we performed the above mentioned experiment at the SOLEIL Synchrotron, France using a COLTRIMS setup. From the coincidence measurement of the Auger electron and the fragment ion, it is possible to yield molecular frame angular emission distributions of the electron. By furthermore exploiting the measured Auger electron energy, snapshots of the temporal evolution of a decaying orbital of a molecule fragmenting into separated atoms are obtained.

A 20.25 Tue 17:00 P OGs

Control of X-Ray Interferences with Nuclei via Magnetic Switching — Gregor Ramien, •Jonas Gunst, Xiangjin Kong, Christoph H. Keitel, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

While Moore's law predicts the fast evolution of miniaturization, for future photonic devices the optical diffraction limit will emerge as bottleneck. This motivates the investigation of information carriers or flying qubits with particularly short wavelengths, e.g., x-ray photons, which range on the energy scale of low-lying nuclear transitions. Versatile control of the basic properties of such photons is the key requirement for short wavelength photonic qubits. Nuclear forward scattering, as it occurs with ^{57}Fe Mössbauer nuclei, presents a great basis for exerting coherent control on x-ray photons. The nuclear response can be controlled by subjecting the sample to a hyperfine magnetic field and to fast variations, i.e., switchings, of the latter. For instance, a timed on-/off-switching can lead to a coherent storage of the x-ray photon over a period of several dozen nanoseconds [1]. In this work, we investigate the implementation of periodic switching sequences: the switching affects the behaviour of the interference pattern of the nuclear forward scattering signal, the so-called quantum beat. Our focus lies on the field variation effects on the time and frequency spectrum, and identifying emerging patterns herein.

[1] W. Liao, A. Pálffy, C. H. Keitel, Phys. Rev. Lett. **109**, 197403 (2012).

A 20.26 Tue 17:00 P OGs

Fragmentation Dynamics of Argon Dimers studied by XUV-IR Experiments at FLASH — •Georg Schmid[1], Kirsten Schnorr[1], Sven Augustin[1], Hannes Lindenblatt[1], Severin Meister[1], Patrick Paluch[1], Yifan Liu[1], Thomas Ding[1], Defu Luo[1], Ann-Sophie Hilkert[1], Lutz Fechner[1], Kamal P. Singh[2], Mathieu Gisselbrecht[3], Harald Redlin[4], Stefan Düsterer[4], Rolf Treusch[4], Claus-Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]IISER, Mohali, India — [3]Lund University, Sweden — [4]DESY, Hamburg

XUV-IR pump-probe experiments on Argon dimers (Ar_2) were performed at the free-electron laser in Hamburg (FLASH).

Different XUV ($\hbar\omega$ = 27eV) multiphoton ionization pathways such as interatomic coulombic decay (ICD), radiative charge transfer (RCT), or frustrated multiple ionization could be identified by measuring the kinetic-energy release of the Coulomb-exploded dimer fragments using a reaction microscope. By applying an intense IR probe pulse ($I_{\mathrm{IR}} \sim 10^{14}$ W/cm^2), we were able to follow the dynamics of those fragmentation pathways in real time. Amongst other things, we could deduce an average RCT lifetime for excited $\mathrm{Ar}^{2+}(3\mathrm{p}^{-3}nl)-\mathrm{Ar}$ states.

A 20.27 Tue 17:00 P OGs

Multiphoton double ionisation of Neon studied at FLASH2 — •Hannes Lindenblatt[1], Kirsten Schnorr[1], Sven Augustin[1], Georg Schmid[1], Severin Meister[1], Florian Trost[1], Yifan Liu[1], Sandra Erbel[1], Markus Braune[2], Rolf Treusch[2], Thomas Pfeifer[1], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]DESY, Hamburg

The ionisation of Neon was studied by an XUV pump-probe experiment at the new Reaction-Microscope endstation at FLASH2. The variable gap undulators provide the opportunity to quickly change the central wavelength of the FEL photons. Combined with the Online Photoionisation Spectrometer (OPIS) for single-shot monitoring of the wavelength, this allows sampling of processes sensitive to the photon energy at the high intensity provided by a free-electron laser.

The production of doubly charged Ne^{2+} yield is analysed as a function of the photon intensity and energy around the Ne^+ $2s^22p^5 \rightarrow 2s2p^6$ transition energy of 26.9 eV.

A 20.28 Tue 17:00 P OGs

The Reaction Microscope at FLASH2: First Experiments at a versatile AMO Endstation — •Florian Trost[1], Kirsten Schnorr[1], Sven Augustin[1], Georg Schmid[1], Severin Meister[1], Hannes Lindenblatt[1], Yifan Liu[1], Sandra Erbel[1], Markus Braune[2], Marion Kuhlmann[2], Stefan Düsterer[2], Rolf Treusch[2], Thomas Pfeifer[1], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]DESY, Hamburg

A reaction microscope was set up and commissioned as a permanent user endstation at the free-electron laser in Hamburg (FLASH2). First XUV pump-probe experiments including ICD observation of neon-dimers were carried out at this endstation with a back-reflecting split-mirror. We varied the delay between pump and probe pulse to find the temporal overlap of the pulses and to obtain the average pulse duration via autocorrelation measurements of Ne^{2+} and Ar^{2+} ion rates.

Part of the setup is a newly designed jet source using supersonic expansion for target production. Being able to process both gaseous and liquid substances as well as a combination of both, the new source greatly expands the range of available targets. We used the new source to trace proton transfer in water-dimers, which were produced by seeding light and heavy water with helium.

A 20.29 Tue 17:00 P OGs

Resonance-enhanced ICD in Neon Dimers — •Severin Meister[1], Kirsten Schnorr[1], Georg Schmid[1], Sven Augustin[1], Hannes Lindenblatt[1], Florian Trost[1], Yifan Liu[1], Viktor Adam[1], Sandra Erbel[1], Claus Dieter Schröter[1], Thomas Pfeifer[1], Robert Moshammer[1], Rolf Treusch[2], Marion Kuhlmann[2], and Markus Braune[2] — [1]Max-Planck-Institut für Kernphysik — [2]Deutsches Elektron Sychrotron

Interatomic Coulombic Decay (ICD) is an efficient de-excitation mechanism in weakly bound environments. The released ICD-electron has a distinct energy and could possibly trigger successive processes. A first step towards the control of ICD, is to intentionally switch it on and off. For this, we employed the 2s-2p transition at 26.9eV (46.1nm) in Neon dimers.

In the two-photon absorption process, the first photon creates a 2p outer valence vacancy, while the second photon resonantly drives the transition $\mathrm{Ne}^+(2\mathrm{p}^{-1}) \rightarrow \mathrm{Ne}^+(2\mathrm{s}^{-1})$ within the same atom. The following relaxation leads to the emission of a 2p ICD-electron in the

neighboring Neon atom. Finally the two $Ne^{+}(2p^{-1})$ ions Coulomb-explode.
As one of the first experiments at FLASH2, we used the variable-gap undulators to quickly tune the photon wavelength. By scanning the resonance, we found an enhancement of a factor 2.5 for coincident $Ne^{+}(2p^{-1})$+$Ne^{+}(2p^{-1})$ ions. Full momentum resolved, coincidence measurements were performed with a reaction microscope (FLASH-REMI).

A 20.30 Tue 17:00 P OGs

XUV-pump—XUV-probe transient absorption experiments in small halogenated hydrocarbons — •Marc Rebholz[1], Thomas Ding[1], Maximilian Hartmann[1], Lennart Aufleger[1], Alexander Magunia[1], David Wachs[1], Veit Stooss[1], Paul Birk[1], Gergana Borisova[1], Kristina Meyer[1], Andrew Attar[2], Thomas Gaumnitz[3], Zhi Heng Loh[4], Sebastian Roling[5], Marco Butz[5], Helmut Zacharias[5], Stefan Düsterer[6], Christian Ott[1], and Thomas Pfeifer[1] — [1]MPI für Kernphysik, Heidelberg, Germany — [2]UC Berkeley, Berkeley, USA — [3]ETHZ, Zürich, Switzerland — [4]NTU Singapore, Singapore — [5]WWU Münster, Münster, Germany — [6]DESY, Hamburg, Germany

We present preliminary results of an XUV-pump-XUV-probe transient absorption experiment at the free-electron laser FLASH in Hamburg. The goal of our experiment is to determine how charge-rearrangement dynamics influence the dissociation of a molecule. In the experiments, we used small halogenated hydrocarbon molecules containing two iodine sites. We resonantly excited the 4d -> σ^* transition with the first XUV pulse. This induces a breaking of one C-I bond. Shortly thereafter the exact same transition was probed with the second XUV pulse to investigate how the modified electronic environment can be accessed via the absorption spectrum of the dissociating molecule. To drive the experimental scheme the XUV pulses were split into two identical copies and the time delay between them was varied from -1 ps to +3 ps. In addition, we varied the intensity of the FEL pulses by attenuating the full beam with a nitrogen gas absorber.

A 20.31 Tue 17:00 P OGs

Shake-up Processes in Auger Cascades of Light and Medium Elements — •Randolf Beerwerth[1,2] and Stephan Fritzsche[1,2] — [1]Helmholtz Institut Jena, Fröbelstieg 3, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

In recent years, coincidence spectroscopy of photo and Auger electrons helped to investigate the de-excitation of atoms, molecules and solids after the creation of inner shell holes. The kinetic energies of the emitted electrons allow to obtain information not only about the spectrum and population of the final states, but also about the decay pathways of an Auger cascade.

Our studies reveal that many Auger cascades are strongly affected by shake-up (or down) transitions, in which the two-electron Auger process is accompanied by an additional (de-)excitation of a valence electron. For example, in the de-excitation of resonantly excited negative oxygen ions [1], complex electron correlation effects lead to a strong contribution of shake transitions to the total decay width. Furthermore, the population of higher lying intermediate states also enables the occurrence of three-step Auger cascade decays that are otherwise not possible due to energetic reasons.

We will discuss the effects of shake-up transitions on Auger cascades of different elements and the theoretical models that are needed to account for the underlying electron correlation effects.

[1] S. Schippers et al., Phys. Rev. A **94**, 041401 (2016).

A 20.32 Tue 17:00 P OGs

Tunneling time in attosecond experiments, Time in Quantum Mechanics and the realization of the Bohr-Einstein photon box Gedanken experiment. — •Ossama Kullie — Institute of Physic, University of Kassel, Germany

Tunneling time in attosecond and strong field experiments is one of the most controversial issues in today's research, because of its importance to the theory of time, the time operator and the time quantum mechanics. In [1,2] I present a theoretical model of the tunneling time for attosecond experiment of the He atom [3]. The model offers a relation which performs an excellent estimation for the tunneling time in attosecond and strong-field experiments (for the He atom [3]). The tunneling time estimation is found by utilizing the time-energy uncertainty relation and represents a quantum clock. The tunneling time is also featured as the time of passage through the barrier similar to Einsteins photon-box Gedanken experiment [1]. This work tackles an important case study for the theory of time in quantum mechanics and is very promising for the search for a (general) time operator in quantum mechanics [4]. The work can be seen as a fundamental step in dealing with the tunneling time in strong-field and ultrafast science and is appealing for more elaborate treatments using quantum wave-packet dynamics and especially for complex atoms and molecules [2,4].

[1] O Kullie 2015 Phys. Rev. A 92 052118. [2] O Kullie 2016 J. Phys. B 49, 095601. [3] P Eckle et al 2008 Nat.phys. 4 565. [4] M. Bauer, arxiv1608.03492v1 (2016).

A 20.33 Tue 17:00 P OGs

Attosecond Transient Absorption Spectroscopy of Molecular Core-to-Valence Transitions — •Lorenz Drescher, Geert Reitsma, Martin Galbraith, Tobias Witting, Oleg Kornilov, Marc Vrakking, and Jochen Mikosch — Max-Born-Institut, Berlin, Germany

Transient absorption spectroscopy with attosecond pulses and pulse trains from high harmonic generation has recently become a versatile tool to study ultrafast phenomena, from photochemical dynamics on the femtosecond scale [1] to electron wave-packet dynamics in atoms [2] and molecules [3] on the few-femtosecond to attosecond scale.

Besides the intriguing potential of combining both high spectral and temporal resolution in an attosecond experiment, the study of core-to-valence transitions in the extreme ultraviolet (XUV) to soft X-ray absorption offers a local view into the valence shell dynamics, due to the localization of the initial state's core orbital. This paves the way to study ultrafast correlation driven phenomena from a site-specific point of view.

Here, we present first results and interpretations from our recent study of the attosecond transient absorption spectrum of core-to-valence transitions in a molecular system manipulated by a strong few-cycle near infrared (NIR) laser pulse.

[1] L. Drescher et al., J. Chem. Phys. 145, 011101 (2016); [2] E. Goulielmakis et al., Nature 466, 739-743 (2010); [3] M. Reduzzi et al., J. Phys. B 49, 065102 (2016)

A 20.34 Tue 17:00 P OGs

Transition rates of E1, M1, E2 and M2 transtions in Ni XII — •Moazzam Bilal[1,2], Randolf Beerwerth[1,2], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Friedrich-Schiller-Universität, Jena, Germany

Lines from Cl-like Ni XII have been observed in soft X-rays and EUV range from n = 3 → 3 transitions in spectra of sun and many solar type stars. These lines are also important in the Tokamak plasma. We report systematically enlarged calculations for allowed E1 and optically forbidden transitions (M1, E2, M2) among the fine structure levels of $3s^23p^5$, $3s3p^6$ and $3s^23p^43d$ configurations. We incorporated QED effects along with the effects of relativity, electron correlation and rearrangement of the electron density. We found that Breit interactions and leading QED corrections have reasonable effects on Dirac Hartree Fock wave-functions. Our calculated energy levels are in excellent agreement with experiments wherever available. Additionally emission rates, wavelengths and oscillator strength are reported for all E1, M1, E2 and M2 transitions among lowest 31 levels. From transition probabilities, lifetimes of lowest 31 levels are derived and compared with experiments. We believe that our extensive *ab initio* calculations are helpful for plasma physics community to identify the fine structure levels and plasma diagnostics. [1] Del Zanna, G. and Badnell, N. R., 2016 *A&A* **585** A118. [2] Mattioli, M. et al., 2004 *J. Phys. B: At. Mol. Opt. Phys.* **37** 13. [3] Jönsson, P., Gaigalas, G. et al., 2013 *Comput. Phys. Commun.* **184** 2197.

A 20.35 Tue 17:00 P OGs

The ALPHATRAP Double Penning-Trap Experiment — •Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Tim Sailer[1,2], Andreas Weigel[1,2], José Ramón Crespo López-Urrutia[1], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg

The ALPHATRAP double Penning-trap apparatus is a high-precision experiment that aims for the most stringent test of bound state quantum electrodynamics (BS-QED) in the strong field regime of 10^{16} V/cm. These fields are provided by the nucleus of a heavy highly charged ion (HCI), such as hydrogen-like $^{208}Pb^{81+}$. Determining the g-factor of the bound electron to the desired precision not only creates the means required for high-precision tests of BS-QED but also enables the determination of fundamental constants such as the fine structure constant α. The setup includes several ion creation possibilities for offline ion production, complementary to the online injection of heavy HCI from the Heidelberg Electron Beam Ion Trap. The latter is coupled, via an ion beam-line, to the cryogenic double Penning-trap system which consists of the so called Precision Trap for high-precision measurements in a homogeneous magnetic field and the Analysis Trap for spin state determination in a magnetic bottle configuration. The setup as well as the current status of the experiment will be presented.

A 20.36 Tue 17:00 P OGs

Gamma spectroscopy to measure the ^{229}Th isomer energy using a 2-dimensional array of metallic magnetic microcalorimeters — •P. Schneider[1], D. Hengstler[1], J. Geist[1], M. Krantz[1], C. Schötz[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], G.A. Kazakov[2], S.P. Stellmer[2], and T. Schumm[2] — [1]Heidelberg University — [2]Vienna University of Technology

The isotope ^{229}Th has a nuclear isomer state with the lowest presently known excitation energy, which possibly allows to connect the fields of nuclear and atomic physic with a potential application in a nuclear clock. In order to verify and improve the accuracy of the currently most accepted energy value, (7.8 ± 0.5) eV, we want to resolve the 29.18 keV doublet in the γ-spectrum following the α-decay of ^{233}U, corresponding to the decay into the ground and isomer state, to measure the isomer transition energy without additional theoretical input parameters.

We developed the detector array maXs-30 consisting of 8x8 metallic magnetic calorimeters with an expected energy resolution below 6 eV, providing a large detection area of 16 mm^2 to face the low rate of the 29.18 keV transitions.

In first measurements we observed the 29.18 keV transitions as a single peak with an instrumental resolution of 33 eV. A strong background contribution due to β-radiation from accumulated decay products in the ^{233}U-source was discovered. We present the experimental setup and the obtained results. We discuss the present sensitivity to the isomer energy and how this will improve in a next experiment based on a cleaned source and dc-SQUIDs with improved flux noise.

A 20.37 Tue 17:00 P OGs

High-precision X-ray spectroscopy of highly-charged ions at storage rings using silicon microcalorimeters — •Damian Müll[1], Artur Echler[2,3], Saskia Kraft-Bermuth[1], and Pascal Scholz[1] — [1]1. Physikalisches Institut, Justus-Liebig-Universität, Giessen, Germany — [2]GSI Helmholtz Center, Darmstadt, Germany — [3]Institute of Physics, Johannes-Gutenberg University, 55099 Mainz, Germany

The precise determination of the energy of the Lyman-α lines in hydrogen-like heavy ions provides a sensitive test of quantum electrodynamics in very strong Coulomb fields. Silicon microcalorimeters, which detect the X-ray energy as heat rather than by charge production, have already demonstrated their potential to improve the precision of such experiments due to their excellent energy resolution for X-ray energies around 100 keV. The application of microcalorimeters for hard X-rays, based on silicon thermistors and tin absorbers, has been pursued by our collaborating groups for more than two decades. Two detector arrays have been successfully applied in two experiments at the Experimental Storage Ring (ESR) of the GSI Helmholtz Center for Heavy Ion Research. In order to improve the energy resolution, parts of the electronics have to be changed. In this contribution the results of measurements on the characteristics of the junction field transistors, implemented on a newly designed printed circuit board, will be presented.

A 20.38 Tue 17:00 P OGs

Doppler Laser Cooling of ^{9}Be^{1+} for the ALPHATRAP g-Factor Experiment — •Alexander Egl[1,2], Ioanna Arapoglou[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Tim Sailer[1,2], Andreas Weigel[1,2], Robert Wolf[1,3], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik, Universität Heidelberg — [3]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, NSW Australia

The Penning-trap experiment ALPHATRAP at the Max-Planck-Institut für Kernphysik is currently being set up. It aims to test bound-state quantum electrodynamics by determining the g-factor of the bound electron in the electric field of heavy highly-charged ions with unprecedented precision. The accuracy achieved in previous experiments using established techniques can be improved by further cooling of the trapped ion, which also leads to a reduction of unwanted systematic shifts due to the magnetic inhomogeneities and the relativistic mass increase. Therefore ALPHATRAP will employ sympathetic laser cooling to the stored highly-charged ions using ^{9}Be^{1+} ions stored adjacent to the ion of interest. To this end a setup for the creation and Doppler laser cooling of ^{9}Be^{1+} is in development. An overview and the current status of this project will be presented.

A 20.39 Tue 17:00 P OGs

Formation studies of mesocsopic ion Coulomb crystals at SpecTrap — •Stefan Schmidt[1,2], Tobias Murböck[3], Zoran Andelkovic[4], Gerhard Birkl[3], Wilfried Nörtershäuser[1], Richard Thompson[5], and Manuel Vogel[4] — [1]Institut für Kernphysik, TU Darmstadt — [2]Institut für Kernchemie, Johannes Gutenberg Universität Mainz — [3]Institut für Angewandte Physik, TU Darmstadt — [4]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [5]Imperial College London, SW7 2AZ

We have investigated the formation and geometric structure of mesoscopic Coulomb ion crystals of singly charged magnesium ions stored in a Penning trap [1]. For this purpose, a combination of buffer-gas cooling and Doppler laser cooling was used for rapid crystallization of a sample of externally produced magnesium ions. The presented studies include detailed information of the evolution and dynamics of these ion crystals. In addition, two-species ion crystals were investigated over a large range of charge-to-mass ratios. These results represent an important step towards high-precision laser spectroscopy of highly charged ions as a fundamental test of bound-state QED.

Further, we present the design and concept of a dedicated low-noise charge amplifier [2] for non-destructive single-pass detection of charged particles in a beamline. In our setup, the detector is used as both a sensitive charge counter as well as a timing circuit.

[1] T. Murböck et al.: Phys. Rev. A 94, 043410 (2016)
[2] S. Schmidt et al.: Rev. Sci. Intr. 86, 113302 (2015)

A 20.40 Tue 17:00 P OGs

Influence of the nuclear shape on the hyperfine splitting of heavy muonic ions — •Niklas Michel, Natalia S. Oreshkina, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

When a muon is bound by a heavy atomic nucleus, it is located much closer to the nucleus than the corresponding electrons, thus the muonic wave function has a considerable overlap with the nuclear one and the transition energies in muonic atoms can provide information on the nuclear structure. Therefore, we aim at an accurate description of the energy levels of heavy muonic atoms in the framework of relativistic quantum mechanics with an extended nuclear charge distribution. In addition, we also take into account the screening correction due to the interaction of the muon with the electrons and the leading corrections for the bound muon from quantum electrodynamics.

A 20.41 Tue 17:00 P OGs

ARTEMIS: A Penning trap experiment for measurements of the electron magnetic moment in highly-charged ions via double-resonance spectroscopy — •Zhexi Guo[1,2], Marco Wiesel[1,3], Mohammad Sadegh Ebrahimi[1,4], Wolfgang Quint[1,4], Gerhard Birkl[3], and Manuel Vogel[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Institut für Angewandte Physik, TU Darmstadt, Darmstadt, Germany — [4]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

The ARTEMIS experiment at GSI Darmstadt currently aims to precisely measure the electron magnetic moment of Ar^{13+} ions using laser and microwave spectroscopy within a 7 T magnetic field at pressures down to 10^{-14} mbar. In the first of two Penning traps, we have been able to produce ion charge-states up to Ar^{16+} via electron impact ionisation and achieve storage times of more than three days. With the stored waveform inverse Fourier transform technique, we can attain a high relative concentration of Ar^{13+} before transportation to a second Penning trap dedicated to storing the ions for spectroscopy. These measurements are projected to be performed on much heavier ions, such as Bi^{82+}, extracted from the HITRAP facility at GSI eventually. Results herein would enable fine assessments of the theoretical propositions of bound-state QED.

A 20.42 Tue 17:00 P OGs

The *g*-factor of highly charged ions — •Halil Cakir[1], Bastian Sikora[1], Natalia S. Oreshkina[1], Nikolay A. Belov[1], Vladimir A. Yerokhin[2], Christoph H. Keitel[1], and Zoltán Harman[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia

Recent high-precision measurements on the *g*-factor of highly charged ions with Penning traps, together with a correspondingly accurate theoretical description, allow detailed tests of QED in strong fields. Furthermore, fundamental constants such as the electron mass and the fine-structure constant α can be extracted in such studies.

Due to their comparably simple structure, one-electron ions are most suited for testing strong-field QED effects (see e.g. [1]). A determination of α however also necessitates an accurate description for three-electron ions, as discussed recently in [2], because employing a specific weighted difference of the *g*-factors of both ions, the detrimental nuclear structural effects can be effectively suppressed. Therefore, we present recent theoretical calculations for one- and three-electron ions. – [1] N. A. Belov *et al.*, submitted; arXiv:1610.01340 (2016); [2] V. A. Yerokhin *et al.*, Phys. Rev. Lett. 116, 100801 (2016).

A 20.43 Tue 17:00 P OGs

Precision description of the atomic structure. Example of the odd configuration system of La I — •Jerzy Dembczyński[1], Magdalena Elantkowska[2], and Jarosław Ruczkowski[1] — [1]Institute of Control and Information Engineering, Poznan University of Technology, Piotrowo 3A, 60-965 Poznań, Poland — [2]Institute of Materials Research and Quantum Engineering, Poznan University of Technology, Piotrowo 3, 60-965 Poznań, Poland

We developed the method, which allows to analyze a complex electronic system composed of the configuration of up to four open shells, taking into account all electromagnetic interactions expected in an atom, in accordance with the second-order perturbation theory [1,2].

In order to show the effectiveness of our method, we decided to choose the odd configuration system of lanthanum atom, with a large amount of new experimental data [3].

The hyperfine structure constants were calculated using the fine structure eigenvectors and adjusting radial integrals in a least-squares procedure which compare the calculated constants with the experimental values. Moreover, the values of energy for the levels up to now unidentified and their hyperfine structure constants were predicted.

This work was supported by the Research Projects of the Polish Ministry of Sciences and Higher Education: 04/45/DSPB/0148

[1] J. Dembczyński et al., J Phys B 43, 06500 (2010)

[2] M. Elantkowska, J. Ruczkowski, J. Dembczyński, Eur Phys J Plus 130, 14 (2015)

[3] Gü. Başar et al., J Quant Spectrosc Radiat Transf 187, 505 (2017)

A 20.44 Tue 17:00 P OGs

Laser photodetachment of radioactive ions - towards the electron affinity of astatine — •S Rothe[1,2,3], J Sundberg[1,2], J Welander[2], K Chrysalidis[1,4], T Day Goodacre[1,3], V Fedosseev[1], O Forstner[5], R Heinke[4], K Johnston[1], T Kron[4], U Köster[6], Y Liu[7], B Marsh[1], A Ringvall-Moberg[1,2], R E Rossel[1,4], Ch Seiffert[1], D Studer[4], K Wendt[4], and D Hanstorp[2] — [1]CERN, Geneva, Switzerland — [2]Department of Physics, Gothenburg University, Sweden — [3]School of Physics and Astronomy, The University of Manchester, UK — [4]Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — [5]Friedrich Schiller Universität, Jena, Germany — [6]Institut Laue-Langevin (ILL), Grenoble, France — [7]Physics Division, Oak Ridge National Laboratory (ORNL), Tennessee, USA

Negatively charged ions are mainly stabilized through the electron correlation effect. A measure of the stability of a negative ion is the electron affinity, which the energy gain by attaching an electron to a neutral atom. This fundamental quantity is, due to the almost general lack of bound excited states, the only atomic property that can be determined with high accuracy for negative ions. We will present the results of the first laser photodetachment studies of radioactive negative ions at CERN-ISOLDE. The photodetachment threshold for the radiogenic iodine isotope ^{128}I was measured successfully, demonstrating the performance of the upgraded GANDALPH experimental beam line. The first detection of photo-detached astatine atoms marks a milestone towards the determination of the EA of this radioactive element.

A 20.45 Tue 17:00 P OGs

First results of a high-precision high-voltage measurement based on laser spectroscopy — •Phillip Imgram[1], Christopher Geppert[2], Kristian König[1], Jörg Krämer[1], Bernhard Maass[1], Ernst Otten[3], Tim Ratajczyk[1], Johannes Ullmann[1], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt — [2]Institut für Kernchemie, Johannes Gutenberg-Universität Mainz — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz

The ALIVE experiment at the TU Darmstadt is a new collinear laser spectroscopy setup. The purpose of the experiment is the measurement of high voltages in the range of 10 to 100 kV using precise laser spectroscopy of ions with a well-known transition frequency. Our aim is to achieve an accuracy of 1 ppm, which is of interest for many applications.
First experiments were done with a $^{40}Ca^+$ beam. Here, the well-known $4S_{1/2} \rightarrow 4P_{3/2}$ transition was driven with a diode-laser based system to pump the atoms to the metastable $3D_{5/2}$ state to mark a velocity class. Probing was achieved by reexcitation to the $4P_{3/2}$ level with a Ti:Sa laser which was stabilized to a frequency comb and subsequent detection of fluorescence light from the decay to the ground state. In order to evaluate the laser-based high-voltage measurements, their results are compared to a direct measurement with a voltage divider that has an active thermal stabilization and reaches a relative precision of 10^{-5}. We will present the current status of the experiment with results from the measurements with $^{40}Ca^+$ and an outlook for the future measurements with indium ions.

A 20.46 Tue 17:00 P OGs

Experimental setup for quantum logic inspired cooling and detection of single (anti-)protons — •Johannes Mielke[1], Teresa Meiners[1], Malte Niemann[1], Anna-Greta Paschke[1,2], Matthias Borchert[3,1], Amado Bautista-Salvador[2,1], Juan Manuel Cornejo[1], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch Technische Bundesanstalt, Braunschweig — [3]Ulmer Initiative Research Unit, RIKEN

We present concepts for cooling and manipulation of an (anti-)proton in a Penning trap using a co-trapped laser-cooled atomic ion, inspired by the proposal by Heinzen and Wineland [1]. Within the BASE collaboration [2], these techniques could be applied to *g*-factor based tests of CPT invariance with trapped (anti-)protons.

We discuss trap geometries, laser systems and imaging optics for loading, cooling, manipulation and detection of the trapped atomic ion and report on the current status of the experiment. We acknowledge funding by ERC StG "QLEDS" and DFG SFB DQ-mat and support by the BASE collaboration.

[1] Heinzen and Wineland, PRA **42**, 2977 (1990)

[2] C. Smorra *et al.*, EPJ-ST **224**, 3055 (2015)

A 20.47 Tue 17:00 P OGs

Laser spectroscopic investigation of singly and doubly charged thorium ions — •Johannes Thielking, David-Marcel Meier, Przemyslaw Glowacki, Maksim V. Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

The ^{229}Th isotope possesses a unique, low-energy nuclear isomeric state at about 7.8(5) eV. This fact has stimulated the development of novel ideas in the borderland between atomic and nuclear physics, for example the use as an optical nuclear clock. Since the required precise information on the isomer energy is not yet available, it is intensely searched for using different experimental approaches.

For the excitation of the nuclear isomer via electronic bridge or NEET processes, we plan to use two-photon laser excitation of highlying electronic levels in Th^+. We recently expanded our search range to higher energies and measured 38 previously unknown energy levels in the range from 7.8 eV to 8.7 eV.

We also prepare to study the nuclear structure of the isomeric state in cooperation with the Maier-Leibnitz-Laboratorium at LMU Munich, using trapped recoil ions, where the isomeric state is populated via α-decay from ^{233}U. For this purpose we investigate the hyperfine structure of suitable transitions of Th^{2+}.

A 21: Ultracold atoms and BEC - IV (with Q)

Time: Wednesday 14:30–16:30 Location: N 1

A 21.1 Wed 14:30 N 1

Bosonic many-body systems with topologically nontrivial phases subject to gain and loss — •Felix Dangel, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Topology has emerged as a powerful tool leading to deeper insights into the classification of phases of matter. Ultracold atoms in optical lattices provide a toolbox for engineering and investigating various models with interesting topological properties. We focus on Bosonic many-body systems such as the one-dimensional superlattice Bose-Hubbard model, which exhibits topologically nontrivial phases. Edge states at open boundaries are an indicator of such phases and numerical evidence for their occurrence in the topologically nontrivial Mott-insulating phase with half-integer filling as well as a possible experimental realization have been provided in a recent work [1]. Addressing the question how edge-states are influenced when the system is extended to an open quantum system, we combine the one-dimensional superlattice Bose-Hubbard model and non-Hermitian $\mathcal{PT}$-symmetric potentials which are capable of effectively describing quantum systems with balanced gain and loss.

[1] Grusdt et al., Phys. Rev. Lett. **110**, 260405 (2013)

A 21.2 Wed 14:45 N 1

Characterization and investigation of topologically nontrivial states in $\mathcal{PT}$-symmetric many-body systems — •Marcel Wagner, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

$\mathcal{PT}$-symmetric quantum mechanics allows for an effective description of open quantum systems with variable particle numbers. $\mathcal{PT}$-symmetry of the quantum state ensures a purely real energy spectrum. Topologically nontrivial phases are known to occur in such many-body systems. However, their characterization is not yet well understood and raises open questions. We investigate ways to characterize topologically nontrivial phases in $\mathcal{PT}$-symmetric quantum systems. The purpose of our work is to classify these phases by searching for appropriate topological invariants.

A 21.3 Wed 15:00 N 1

Exotic energy bands and topological phases in systems with oscillatory long-range potentials — Beatriz Olmos Sánchez[1,2], Robert J. Bettles[3], Igor Lesanovsky[1,2], and •Jiří Minář[1,2] — [1]School of Physics and Astronomy, University of Nottingham, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Non-equilibrium Quantum Systems, University of Nottingham, United Kingdom — [3]Joint Quantum Center (JQC) Durham-Newcastle, Department of Physics, Durham University, United Kingdom

The effective interaction between neutral atoms mediated by virtual photon exchange in general leads to a non-trivial long-range potential featuring both attractive and repulsive interaction [1,2] which goes beyond the typically considered simple power-law (dipolar, Van der Waals) potentials. Considering the full potential in two dimensions (which becomes relevant for atomic separations comparable to the atomic transition wavelength, situation achievable e.g. with strontium atoms), we show that it gives rise to energy spectrum with one-sided divergences in the Brillouin zone. This apparently unphysical situation is a consequence of the superextensivity of the potential and the thermodynamic limit. We perform a study for finite size systems and find new topological phases absent in the dipolar case. Moreover, the shape of the potential leads to a novel situation where energy peaks in the spectrum of arbitrary height and position can be created. Finally, we discuss the relation between the bulk and the edge states in case of square and hexagonal lattice. [1] R. H. Lehmberg, Phys. Rev. A **2** 883 (1970), [2] D. F. V. James, Phys. Rev. A **47** 1336 (1993)

A 21.4 Wed 15:15 N 1

An Optical Quasicrystal for Ultracold Atoms — •Konrad Viebahn[1], Matteo Sbroscia[1], Edward Carter[1], Michael Höse[1], Max Melchner[1], and Ulrich Schneider[1,2] — [1]University of Cambridge, Cavendish Laboratory, JJ Thomson Ave, Cambridge CB3 0HE, UK — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstrasse 4, 80799 Munich, Germany

We will present our experimental progress towards realising an optical quasicrystal.

A quasicrystal is a long-range ordered structure with no translational symmetry. Correspondingly, quasicrystals lie at the interface between ordered and disordered systems. On the one hand, ultracold atoms in regular (periodic) optical lattices have been studied extensively in the past years. Major achievements in this field include the first observation of the superfluid-Mott insulator transition, the realisation of the Fermi-Hubbard model, and the realisation of topological models, such as the Haldane model. On the other hand, the recent observation of many-body localisation in quasi-random optical lattices triggered another area of interest: interacting disordered systems. Now, we hope to bridge the gap between ordered and disordered systems using ultracold atoms in an optical quasilattice.

Interestingly, quasicrystals often have high rotational symmetries, five-fold or eight-fold, for example, which are forbidden in periodic crystals by the crystallographic restriction theorem. Optical lattice experiments lend themselves to realising these special geometries by superimposing lattice beams in a rotationally symmetric fashion.

A 21.5 Wed 15:30 N 1

Quantum and thermal phase transitions in a bosonic atom-molecule mixture in a two-dimensional optical lattice — •laurent de Forges de Parny[1,4], valy rousseau[2], and tommaso roscilde[3,4] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder Straße 3, D-79104, Freiburg, Germany — [2]Physics Department, Loyola University New Orleans, 6363 Saint Charles Ave., LA 70118, USA — [3]Institut Universitaire de France, 103 bd Saint-Michel, 75005 Paris, France — [4]Laboratoire de Physique, CNRS UMR 5672, École Normale Supérieure de Lyon, Université de Lyon, 46 Allée d'Italie, Lyon, F-69364, France

Recent progress in ultracold gases have allowed the study of multiple component bosonic systems, such as atomic and molecular mixtures. We will show that the coherent coupling of the atomic and molecular state, can lead to a novel insulating phase - the Feshbach insulator - for bosons in an optical lattice close to a narrow Feshbach resonance. This new phase appears around the resonance, preventing the system from collapsing when the effective atomic scattering length becomes negative. Surprisingly enough, the transition from condensate to Feshbach insulator has a characteristic first-order nature, due to the simultaneous loss of coherence in the atomic and molecular components. Our realistic numerical study shows that these features appear clearly in the ground-state phase diagram of e.g. rubidium 87 around the 414 G resonance, and they are therefore directly amenable to experimental observation. We also observe unconventional Berezinskii-Kosterlitz-Thouless transition when heating the superfluids.

A 21.6 Wed 15:45 N 1

Approaching non-Abelian Lattice Gauge Theories with Quantum Information Methods — Mari Carmen Bañuls[1], Krzysztof Cichy[2,3], J. Ignacio Cirac[1], Karl Jansen[4], and •Stefan Kühn[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Goethe-Universität Frankfurt am Main, Institut für Theoretische Physik, Max-von-Laue-Straße 1, 60438 Frankfurt am Main, Germany — [3]Faculty of Physics, Adam Mickiewicz University, Umultowska 85, 61-614 Poznań, Poland — [4]NIC, DESY Zeuthen, Platanenallee 6, 15738 Zeuthen, Germany

Originally developed in the realm of quantum information theory, Tensor Network States and in particular Matrix Product States have proven themselves as promising candidates for the numerical exploration of lattice gauge models in recent years. In this talk, we explore a family of 1+1 dimensional SU(2) lattice gauge models, where the color electric flux is truncated at a finite value, with this method. We show how on finite lattices with open boundary conditions the gauge field can be integrated out, thus greatly reducing the degrees of freedom present in the system. This formulation might be suitable for a potential future quantum simulator and, moreover, allows to efficiently address the model numerically with Matrix Product States. Using this approach, we explore the low lying spectrum of these models and systematically study the effect of truncating the color electric flux at a finite value.

A 21.7 Wed 16:00 N 1

Multipulse interaction quenched ultracold few-bosonic ensembles in finite optical lattices — •Simeon Mistakidis[1], Jannis Neuhaus-Steinmetz[1], and Peter Schmelcher[1,2] — [1]Zentrum fuer Optische Quantentechnologien, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The correlated non-equilibrium dynamics following a multipulse interaction quench protocol in few-bosonic ensembles confined in finite optical lattices is investigated. The multipulse interaction quench gives rise to the cradle and a global breathing mode, which are generated during the interaction pulse and persist also after the pulse. The tunneling dynamics consists of several channels accompanying the dynamics. The majority of the tunneling channels persist after the pulse, while only a few occur during the pulse. The induced excitation dynamics is also explored and a strong non-linear dependence on the delayed time of the multipulse protocol is observed. Moreover, the character of the excitation dynamics is also manifested by the periodic population of higher-lying lattice momenta. To solve the underlying many-body Schroedinger equation we employ the Multi Configuration Time-Dependent Hartree method for Bosons (MCTDHB) which is especially designed to treat the out-of-equilibrium quantum dynamics of interacting bosons beyond the mean field and linear response approximations. The above mentioned findings pave the way for future investigations on the direct control of the excitation dynamics.

A 21.8 Wed 16:15 N 1

Superfluidity and relaxation dynamics of a laser-stirred 2D Bose gas — •Vijay Pal Singh[1,2], Christof Weitenberg[2], Jean Dalibard[3], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]Laboratoire Kastler Brossel, Collège de France, ENS-PSL Research University, CNRS, UPMC-Sorbonne Universités, 11 place Marcelin Berthelot, 75005 Paris, France

We study the superfluid behavior of a two-dimensional (2D) Bose gas of ^{87}Rb atoms. In the experiment by R. Desbuquois *et al.*, Nat. Phys. **8**, 645 (2012) a 2D quasicondensate in a trap is stirred by a blue-detuned laser beam along a circular path around the trap center. Here, we study this experiment from a theoretical perspective. The heating induced by stirring increases rapidly above a velocity v_c, which we define as the critical velocity. We identify the superfluid, the crossover, and the thermal regime by a finite, a sharply decreasing, and a vanishing critical velocity, respectively. A direct comparison of our results to the experiment shows good agreement, if a systematic shift of the critical phase space density is included. We relate this shift to the absence of thermal equilibrium between the condensate and the thermal wings in the experiment, which were used to extract the temperature. We expand on this observation by studying the full relaxation dynamics between the condensate and the thermal cloud. Analytical results on the vortex formation are also discussed.

A 22: Attosecond Science

Time: Wednesday 14:30–16:30 Location: N 2

Invited Talk A 22.1 Wed 14:30 N 2

Electron correlation dynamics in weak and strong fields — •Christian Ott — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

This talk gives an overview of recent progress in the experimental investigation of correlated electron dynamics by means of all-optical absorption spectroscopy. Turning to the most fundamental system to investigate such processes, the helium atom with two active electrons, asymmetric Fano absorption line shapes are identified as a direct view into the multi-channel interaction of different two-electron configurations [1]. In response to few-cycle near-infrared laser fields of tunable strength, these channels can be selectively altered, which can be measured and understood as a change in the absorption profile [2]. This concept also enables the controlled steering of a two-electron wave packet [3], where the correlated position of both electrons with respect to the helium core can be reconstructed from theoretical calculation of the corresponding two-electron states. A new approach to correlated electron dynamics in solids is then gained with the discussion of recent experimental results on the ultrafast electronic phase transition in vanadium dioxide [4], which is investigated via attosecond transient absorption spectroscopy.

[1] U. Fano, Phys. Rev. 124, 1866 (1961).
[2] C. Ott et al., Science 340, 716 (2013).
[3] C. Ott et al., Nature 516, 374 (2014).
[4] M. F. Jager et al., manuscript in preparation (2016).

A 22.2 Wed 15:00 N 2

Attosecond spectroscopy using XUV-initiated high harmonic generation — •Michael Krüger[1], Doron Azoury[1], Gal Orenstein[1], Henrik R. Larsson[2], Sebastian Bauch[2], Barry D. Bruner[1], and Nirit Dudovich[1] — [1]Weizmann Institute of Science, 76100 Rehovot, Israel — [2]University of Kiel, D-20489 Kiel, Germany

In XUV-initiated high harmonic generation (XiHHG), tunneling ionization is replaced by photoionization with an attosecond XUV pulse [1,2]. The resulting electron wavepacket is driven by an IR laser field and recollides with the parent ion, leading to coherent frequency upconversion of the incoming XUV light. The emitted radiation carries the spectroscopic fingerprint of the full light-matter interaction. Here we demonstrate XiHHG in helium by irradiating the gas with XUV light at photon energies mostly below the atomic ionization threshold. We observe a strong dependence of the intensity of the generated XiHHG light on the temporal delay of XUV and IR. With the help of a strong-field model we are able to reconstruct the full quantum dynamics of the process and determine the initial electron wavepacket in amplitude and phase. Our approach combines the accuracy of high harmonic spectroscopy with the flexibility of XUV-IR pump-probe techniques and can address a wide range of ultrafast phenomena, e.g. inner-shell dynamics of complex molecules.

[1] K. Schafer et al., PRL 92, 023003 (2004).
[2] G. Gademann et al., NJP 13, 033002 (2011).

A 22.3 Wed 15:15 N 2

Attosecond Electron Scattering in Dielectrics — •L. Seiffert[1], Q. Liu[2,3], S. Zherebtsov[2,3], A. Trabattoni[4,5], P. Rupp[2,3], M. C. Castrovilli[6], M. Galli[4,6], F. Süssmann[2,3], K. Wintersperger[2], J. Stierle[2], G. Sansone[4,6], L. Poletto[6], F. Frassetto[6], I. Halfpap[7], V. Mondes[7], C. Graf[7], E. Rühl[7], F. Krausz[2,3], M. Nisoli[4,6], T. Fennel[1,8], F. Calegari[5,6,9], and M. Kling[2,3] — [1]Universität Rostock — [2]MPQ Garching — [3]LMU München — [4]Politecnico di Milano — [5]Center for Free-Electron Laser Science, DESY — [6]National Research Council of Italy — [7]FU Berlin — [8]MBI Berlin — [9]University of Hamburg

Scattering of electrons in dielectrics is at the heart of laser nanomachining, light-driven electronics, and radiation damage. Accurate theoretical predictions of the underlying dynamics require precise knowledge of the low-energy electron transport involving elastic and - even more important - inelastic collisions. Here, we demonstrate real-time access to electron scattering in isolated SiO_2 nanoparticles via attosecond streaking [1]. Utilizing semiclassical Monte-Carlo trajectory simulations [2,3] we identify that the presence of the field inside the dielectric cancels the influence of elastic scattering, enabling selective characterization of the inelastic scattering time [4].

[1] R. Kienberger et al., Nature 427, 817-821 (2004)
[2] F. Süßmann et al., Nat Commun. 6, 7944 (2015)
[3] L. Seiffert et al., Appl. Phys. B 122, 1-9 (2016)
[4] L. Seiffert et al., submitted

A 22.4 Wed 15:30 N 2

Localized High-Harmonic Generation in Semiconductor Nanostructures — •Murat Sivis[1,2], Marco Taucer[2], Kyle Johnston[2], Giulio Vampa[2], André Staudte[2], Andrei. Yu. Naumov[2], David. M. Villeneuve[2], Paul B. Corkum[2], and Claus Ropers[1] — [1]4th Physical Institute - Solids and Nanostructures, Georg-August University, Göttingen, Germany — [2]Joint Attosecond Science Laboratory, National Research Council of Canada and University of Ottawa, Ottawa, Canada.

High-harmonic generation (HHG) in solid-state systems, as recently demonstrated in semiconductors[1−3], enables the transfer of gas-phase attosecond spectroscopy techniques to condensed matter. In general, HHG is sensitive to the electronic structure of the generation medium and the local driving laser field. Both of these properties can be routinely tailored in solids by modifying the chemical composition and the microstructure. Here, we study HHG in nanostructured zinc oxide and silicon crystals. We use wavelength-selective microscopic imaging to characterize the harmonics (at 2 μm driving wavelength) and find enhanced emission in nanofabricated grating structures as well as in gallium-implanted patterns. Our results illustrate novel means to control HHG and to use the harmonic emission as a unique local probe to investigate structural, chemical or electronic dynamics in solid-state systems.

[1]S. Ghimire *et al.* Nat. Phys. **7**, 138-141 (2011).
[2]O. Schubert *et al.* Nat. Photon. **8**, 119-123 (2014).
[3]G. Vampa *et al.* Nature **522**, 462-464 (2015).

A 22.5 Wed 15:45 N 2

Time Delay in Photoionization with Light Carrying Orbital Angular Momentum — •Jonas Wätzel and Jamal Berakdar — Institut für Physik, Martin-Luther Universität Halle-Wittenberg, Karl-Freiherr-Von-Fritsch Str. 3, 06120 Halle (Saale)

The pioneering experiment of Schultze *et al.* on time delay in photoemission triggered substantial experimental and theoretical activities with the aim to understand and quantitatively reproduce the results of the measurements. Up to date various mechanisms and calculation techniques were put forward.

Here we add yet a qualitatively new aspect to this topic. I will present our recent research considering an atom irradiated by a twisted light beam, also called optical vortex. Such a beam carries orbital angular momentum (OAM) which can be transferred to an electron and is controllable by the topological charge. The use of an OAM XUV laser beams to trigger photoionization implies a complete new set of optical selection rules with the consequence that the optical transitions are tuneable by the choice of the beam topological charge.

I will present the analytical and numerical results for the atomic time delay of the photoionization process of the argon 3*p* subshell initiated by a twisted light XUV pulse demonstrating that in different asymptotic directions either the co-rotating electron (relative to the field) or the counter rotating electron dominates photoionization amplitude. Furthermore the corresponding time delays are completely different in magnitude and sign, and depend sensitively on the position of the atom in the laser beam spot.

A 22.6 Wed 16:00 N 2

Tunneling time in attosecond experiments, how to understand the measurement of time and the tunneling process in attosecond experiments. — •Ossama Kullie — Institute of Physic, University of Kassel, Germany

The measurement of the tunneling time (T-time) in today's attosecond and strong field (low-frequency) experiments, despite its controversial discussion, offers a fruitful opportunity to understand time measurement, and the importance issue of the theory of time, the time operator and the time-energy uncertainty relation in quantum mechanics. In [1] I derived an estimation and a relation of the (real) tunneling time, which shows an excellent agreement with the time measured in attosecond experiments of the He atom case [2]. This tunneling model, and the experiment [2], offers a realization of the Bohr-Einstein photon box Gedanken experiment. This has an important consequence to the time operator [3]. Some models used to calculate the T-time will be also discussed in relation to my model, where I showed that the important question is a more general one: How to understand the time and the measurement of the time of a quantum system [4]. The tunneling process itself is still not well understood, but I am arguing that a scattering mechanism offers a possibility to understand the tunneling process in the tunneling region [5].

[1] O Kullie 2015, Phys. Rev. A 92 052118. [2] P Eckle et al 2008, Nat.phys. 4 565. [3] M. Bauer, arxiv1608.03492v1 (2016). [4] O Kullie 2016, J. Phys. B 49, 095601. [5] O Kullie (2016), J. Phys. B, submitted.

A 22.7 Wed 16:15 N 2

The ion microscope as a tool for quantitative measurements in the extreme ultraviolet — •Nikolaos Tsatrafyllis[1,2], Boris Bergues[3], Hartmut Schröder[3], László Veisz[3,4], Emmanouil Skantzakis[1], David Gray[1], Bálazs Bodi[1,5], Sergei Kühn[6], George Tsakiris[3], Dimitris Charalambidis[1,2,6], and Paraskevas Tzallas[1,6] — [1]Foundation for Research and Technology - Hellas, Institute of Electronic Structure & Laser, Heraklion (Crete), Greece — [2]Department of Physics, University of Crete, Heraklion (Crete), Greece — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany — [4]Department of Physics, Umea University, Umeå, Sweden — [5]Wigner Research Center for Physics, Budapest, Hungary — [6]ELI Attosecond Light Pulse Source, Szeged, Hungary

We demonstrate a tool for quantitative measurements in the extreme ultraviolet (EUV) spectral region measuring spatially resolved atomic ionization products at the focus of an EUV beam. The ionizing radiation is a comb of the 11th-15th harmonics of a Ti:Sapphire femtosecond laser beam produced in a Xenon gas jet. The spatial ion distribution at the focus of the harmonics is recorded using an ion microscope. Spatially resolved single- and two-photon ionization products of Argon and Helium are observed. From such ion distributions single- and two-photon generalized cross sections can be extracted by a self-calibrating method. The observation of spatially resolved two-EUV-photon ionization constitutes an initial step towards future single-shot temporal characterization of attosecond pulses.

A 23: Trapped ions

Time: Wednesday 14:30–16:30 Location: N 3

Invited Talk A 23.1 Wed 14:30 N 3

Surface-electrode traps for scalable quantum information processing with atomic ions — •C. Ospelkaus[1,2], H. Hahn[1,2], M. Wahnschaffe[2,1], G. Zarantonello[1,2], T. Dubielzig[1], S. Grondkowski[1], J. Morgner[1,2], M. Kohnen[2,1], and A. Bautista-Salvador[2,1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Surface-electrode traps have emerged as a scalable platform for quantum information processing with trapped ions. We describe concepts and experiments aimed at implementing multi-qubit operations in such structures using near-fields from embedded microwave conductors rather than the commonly used focsed laser beams. We describe the design and operation of a trap structure allowing the implementation of entangling quantum logic gates and spin-spin interactions for quantum simulations with $^{9}Be^{+}$ ions. We demonstrate agreement between simulations of the near-field and measurements using a single ion as a quantum sensor at the sub-micron and few-degree level. We demonstrate motional sideband transitions as a prerequisite for entangling quantum logic operations and show microwave sideband cooling. We have set up a cryogenic ion trap system based on an ultra-low vibration ($< 20\,$nm 0-pk) closed cycle cryostat. This will eliminate the main source of infidelities in recent experiments, which was anomalous motional heating. Furthermore, we have extended our fabrication capability to include multiple metal layers with interconnects and discuss how such multi-layer structures would allow the realization of quantum simulations in scalable surface-trap arrays.

A 23.2 Wed 15:00 N 3

Nuclear magnetic resonance signal detection for the Cosmic Axion Spin Precession Experiment (CASPEr-Wind) — •Gary Centers[1], John Blanchard[1], Nataniel Figueroa[1], Marina Gil Sendra[1], Arne Wickenbrock[1], Dmitry Budker[1], Antoine Garcon[1], and CASPEr Collaboration[2] — [1]Helmholtz Institute Mainz, Johannes Gutenberg University, 55128 Mainz, Germany — [2]Various locations

The Cosmic Axion Spin Precession Experiment (CASPEr), particularly the CASPEr-Wind, is a detection scheme searching for light particles that have a coupling to nuclear spin; some examples being dark matter candidates like the axion/axion-like particles, hidden photons, or any pseudo-Goldstone boson. The coupling induces precession of the nuclear spin about the axion momentum which will be detected using Nuclear Magnetic Resonance (NMR) techniques.

Using a sample of hyperpolarized liquid xenon to monitor the transverse magnetization is different from the application of short radio-frequency pulses typical in NMR. From this perspective, an analysis for detecting the wind-induced NMR signal is presented using transient, steady state, and closed form solutions of the Bloch equations in different limits. Considerations will include, but are not limited to, different schemes of varying the leading field, effects of radiation damping, different relaxation limits, and noise considerations.

A 23.3 Wed 15:15 N 3

First data analysis schemes for the Global Network of Optical Magnetometers for Exotic physics searches (GNOME) — •Hector Masia-Roig[1], Vincent Dumont[2], Arne Wickenbrock[1], Chris Pankow[3], Samer Afach[1], and Dmitry Budker[1] — [1]Helmholtz Institute, Johannes Gutenberg University, Mainz — [2]University of California, Berkeley, USA — [3]Northwestern University, Evanston, USA

This presentation is prepared on behalf of the GNOME collaboration. GNOME is a novel experimental scheme which enables the investigation of couplings between nuclear spins and exotic fields generated by astrophysical sources. It consists of a network of geographically separated, time synchronized, ultrasensitive ($\sim$ fT/$\sqrt{\text{Hz}}$) optical atomic magnetometers that measure atomic spin precession in multilayer magnetic shielding. Such a configuration enables the study of global transient effects due to non-magnetic interactions.

Currently, there are six magnetometers placed around the world which are able to measure synchronously. This presentation discusses the first techniques used for the analysis of time synchronized data and the results obtained. The algorithm is based on an excess power analysis. It surveys the data looking for regions in the time-frequency space where the power density exceeds the noise floor. This method enables one to find weak signals in a noisy environment without a specific wavelet shape. A 24 h coordinated run is analyzed and the excess power regions are identified. This information is then cross-correlated between the different magnetometers in the network.

A 23.4 Wed 15:30 N 3

On the magnetic interaction between two bound electrons of two separate ions — •Biplab Goswami[1], Andrey Volotka[1], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, D-07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, D-07743 Jena, Germany

The magnetic interaction between bound electrons of two separate ions is investigated with the help of Breit equation. A special attention is paid to the effects beyond the leading order spin-spin interaction. The magnetic dipole-dipole interaction between two ions have been recently studied experimentally [1,2]. In present work, it is found that the spin-orbit interaction, which is usually neglected in an experimental analysis, could play a key role at the distances between ions of about 0.2 μm or smaller.

[1] S. Kotler, N. Akerman, N. Navon, Y. Glickman, and R. Ozeri, Nature **510**, 376 (2014).
[2] F. Dolde, I. Jakobi, B. Naydenov, N. Zhao, S. Pezzagna, C. Trautmann, J. Meijer, P. Neumann, F. Jelezko, and J. Wrachtrup, Nature Phys. **9**, 139 (2013).

A 23.5 Wed 15:45 N 3

Photoexcitation of atoms by Laguerre-Gaussian beams — •Anton Peshkov[1], Daniel Seipt[2,3], Andrey Surzhykov[4,5], and Stephan Fritzsche[1,3] — [1]Helmholtz-Institut Jena, Germany — [2]Lancaster University, United Kingdom — [3]Friedrich-Schiller-Universität Jena, Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [5]Technische Universität Braunschweig, Germany

With the recent experimental advances in optics, it is possible to produce Laguerre-Gaussian (LG) light beams with a non-zero projection of the orbital angular momentum (OAM). During the last few years, it was shown that the OAM may affect the fundamental light-matter interaction processes. In a recent experiment, in particular, it was demonstrated for an atom placed on the axis of the incident LG light beam that the sublevel population of excited atomic states is determined by the beam's OAM [1]. Following this experiment, we investigate theoretically the sublevel population of atoms with an arbitrary position with regard to the axis of the beam. We show that the sublevel population may vary significantly when the atoms are moved away from the beam axis. The population of the excited atoms is also found sensitive to the polarization, radial index, as well as the OAM of the incident LG beam; these effects can be observed experimentally by measuring the angular distribution of the subsequent fluorescence radiation.

[1] C. T. Schmiegelow *et al.*, Nat. Commun. 7, 12998 (2016).
[2] A. A. Peshkov *et al.*, Phys. Scr. 91, 064001 (2016).

A 23.6 Wed 16:00 N 3

State flip at exceptional points in spectra of the hydrogen atom in parallel electric and magnetic fields — •Lukas Oberreiter, Jan Burkhardt, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, Germany

Resonances, which are unbound and decaying states, can be found in spectra of non-Hermitian Hamiltonians. If the system depends at least on two real parameters, exceptional points can be found at parameter values, where eigenvalues form a branch point singularity, and hence eigenvalues and eigenfunctions coalesce. If exceptional points are encircled on a closed loop in parameter space eigenvalues commute their positions.

A well-suited quantum system to study these effects is the hydrogen atom in parallel electric and magnetic fields due to its theoretical and experimental accessibility. A two-dimensional parameter space is set up by the field strengths. By continuous variation on a closed loop around an exceptional point two resonance states commute. Here it will be investigated whether this commutation behavior of eigenvalues is extendable to population interchange. Therefore the system gets initially prepared in one of the two resonances and the population dynamics for a time dependent parameter loop is calculated. Since these calculations are numerically expensive an approximation method based on a 2×2 matrix will be introduced which only considers the two commuting resonances. The population transfer can be maximized by variation of the loop trajectory's shape and the duration of the encircling.

A 23.7 Wed 16:15 N 3

Transmission Resonance Through a Periodically Driven Impurity — •Christoph Dauer, Axel Pelster, and Sebastian Eggert — State Research Center OPTIMAS and Fachbereich Physik, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Recently a one-dimensional tight-binding chain with a temporally oscillating on-site potential acting as an impurity was investigated [1]. Using the Floquet theory a steady-state solution was found, whose transmission shows a non-monotonic behavior with respect to potential strength, driving frequency, and particle energy. For special parameter values a complete vanishing of the one-particle transmission occurs. Such a transmission resonance can be related to the Fano-effect and the interaction with dynamically created bound states in the continuum [2]. Here we perform the continuum limit of a vanishing lattice constant, where we obtain a qualitative similar nontrivial dependence of the transmission coefficient on the respective parameters. Furthermore, we show that the transmission coefficient can not vanish below a critical frequency.

[1] D. Thuberg, S.A. Reyes, and S. Eggert, Phys. Rev. B **93**, 180301(R) (2016)
[2] A.E. Miroshnichenko and Y.S. Kivshar, Phys. Rev. E **72**, 056611 (2005)

A 24: Laser Development and Applications (Spectroscopy) (with Q)

Time: Wednesday 14:30–16:30 Location: P 5

A 24.1 Wed 14:30 P 5

A pulsed single-mode Ti:sapphire laser for high-resolution resonance ionization spectroscopy — •Dominik Studer[1], Tobias Kron[1], Sebastian Raeder[2], Volker Sonnenschein[3], Pascal Naubereit[1], and Klaus Wendt[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]GSI Darmstadt — [3]Department of Quantum Engineering, Nagoya University

Resonance ionization spectroscopy (RIS) is a well-established technique for both atomic and nuclear research. Through the stepwise excitation and ionization of an atom individual transitions can be probed, allowing the extraction of fundamental parameters, such as isotope shifts and nuclear moments, provided an adequately narrow experimental linewidth is realized. Due to their high reliability and stability, pulsed Ti:sapphire lasers as designed at JGU Mainz are used at on-line laser ion sources worldwide. The standard design features a Z-shaped standing wave cavity, pumped by a frequency-doubled Nd:YAG laser with a repetition rate of 10 kHz. The output power reaches up to 4 W with pulse lengths of 40 ns. Frequency selection is achieved by a combination of a Lyot-Filter and a thin Etalon, resulting in a spectral linewidth of ≈5 GHz. Operation on a single longitudinal mode can be achieved using a ring cavity design featuring an additional air-spaced etalon, resulting in ≈50 MHz linewidth. Compared to the previously used technique of injection-locking, this design implies an unseeded single-mode operation, greatly reducing the complexity of the system. Moreover the wavelength range is not constrained by a master laser, allowing easy set-up and scanning operation.

A 24.2 Wed 14:45 P 5

Quantum metamaterials as an active lasing medium: Effects of disorder — •Martin Koppenhöfer[1,2], Michael Marthaler[2], and Gerd Schön[2] — [1]University of Basel, Basel, Switzerland — [2]Karlsruhe Institute of Technology, Karlsruhe, Germany

A metamaterial formed by artificial atoms, e.g., superconducting circuits or quantum dots, can serve as an active lasing medium when coupled to a microwave resonator. For these artificial atoms, in contrast to real atoms, variations in their parameters cannot be avoided. We examine the influence of disorder on such a multiatom lasing setup. We find that the lasing process evolves into a self-organized stationary state that is quite robust against disorder. The reason is that photons created by those atoms which are in or close to resonance with the resonator stimulate the emission also of more detuned atoms. Not only the number of photons grows with the number of atoms but also the width of the resonance as a function of the detuning. Similar properties are found for other types of disorder such as variations in the individual coupling. We present relations on how the allowed disorder scales with the number of atoms and confirm it by a numerical analysis. We also provide estimates for the sample-to-sample variations to be expected for setups with moderate numbers of atoms.

A 24.3 Wed 15:00 P 5

Laser System Technology for Quantum Optics Experiments in Space — •Kai Lampmann[1], Moritz Mihm[1], André Wenzlawski[1], Ortwin Hellmig[6], Markus Krutzik[2], Achim Peters[2], Patrick Windpassinger[1], and The MAIUS Team[1,2,3,4,5] — [1]Institut für Physik, JGU Mainz — [2]Institut für Physik, HU Berlin — [3]FBH, Berlin — [4]IQO, LU Hannover — [5]ZARM, Bremen — [6]ILP, UHH Hamburg

Numerous applications of quantum optics demand for operating experiments in extreme environments. Leaving the lab poses strict requirements to the experimental systems, especially the laser systems, in terms of miniaturization, power consumption, and mechanical and thermal stability. We follow a hybrid approach to build laser systems that can overcome these issues.

Optical bench systems using a set of specially designed freespace optics based on glass ceramics are combined with fiberintegrated components like splitters, modulators or resonators. Our systems fulfill all different functions such as laser frequency stabilization, switching and distribution of laser light.

Successful sounding rocket missions show that our systems can overcome the extreme loads of a rocket launch and that we are able to bring laser systems into space.

Our work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) under grant numbers 50 WP 1433 and 50 WM 1345, 1646.

A 24.4 Wed 15:15 P 5

Dy^{3+}:Lu_2O_3 as a promising gain material for mid-infrared lasers — •Alexander M. Heuer[1,2], Patrick von Brunn[1,2], and Christian Kränkel[1,2] — [1]Institut für Laser-Physik, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging

The cubic sesquioxide Lu_2O_3 is a suitable host material for mid-infrared laser applications due to its high thermal conductivity and low phonon energy. We report on the first growth from the melt and spectroscopic analysis of monocrystalline Dy^{3+}:Lu_2O_3 in the mid-infrared spectral range. Absorption and emission cross-sections in the wavelength range between 2 μm and 3.8 μm were determined. Gain cross-sections in the same wavelength region were derived and point towards possible laser action at 3256 nm and 3388 nm. The most suitable pump wavelengths for in-band pumping directly into the emitting multiplet were found to be 2713 nm and 2776 nm. This allows for pumping by an erbium-based mid-infrared laser. From the emission cross-sections the lifetime of the emitting $^6H_{13/2}$ multiplet has been calculated to be in the order of 20 ms. Corresponding measurements are in progress. Compared to the values reported for the mid-infrared laser material Dy:ZBLAN the cross-sections of Dy^{3+} in Lu_2O_3 are about 50 % higher. This reveals that Dy^{3+}:Lu_2O_3 is a promising candidate for the first mid-infrared oxide host material based on the Dy^{3+}-ion.

A 24.5 Wed 15:30 P 5

Low drift cw-seeded high-repetition-rate optical parametric amplifier for fingerprint coherent Raman spectroscopy — •Joachim Krauth[1], Tobias Steinle[1], Bowen Liu[2], Moritz Floess[1], Heiko Linnenbank[1], Andy Steinmann[1], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart — [2]Ultrafast Laser Laboratory, Tianjin University

We introduce a broadly tunable robust source for fingerprint (170 - 1620 cm^{-1}) Raman spectroscopy. A cw thulium-doped fiber laser, gap-free tunable from 1770 - 2030 nm, seeds an OPA, which is pumped by a 7-W, 450-fs Yb:KGW bulk mode-locked oscillator with 41 MHz repetition rate. The OPA is designed in double-pass configuration for power scaling and delivers a signal output power of around 1 W over most of the tuning range. The output radiation of the OPA signal is frequency doubled in a PPLN crystal and generates 0.7 - 1.3-ps-long narrowband pump pulses for the subsequent Raman spectroscopy that are tunable between 885 and 1015 nm with >80 mW average power. The Stokes beam is delivered by a part of the oscillator output, which is sent through an etalon to create pulses with 1.7 ps duration. We demonstrate a stimulated Raman gain measurement of toluene in the fingerprint spectral range. Here we use an acousto-optic modulator to modulate the pump pulse, while the Stokes intensity is detected using a single silicon photodiode, which is connected to a high-frequency lock-in amplifier. Our system combines the simplicity and the robustness of an OPA with the ultra-low intensity noise of a solid-state oscillator. Furthermore, the cw seeding intrinsically ensures low spectral drift.

A 24.6 Wed 15:45 P 5

Spatial Nonuniformity and Photochemical Doping in exfoliated WS2 Monolayers — •Ioannis Paradisanos — N. Plastira 100, Heraklion, Crete, Greece

Monolayers of transition metal dichalcogenides (TMDs) are promising new materials for future 2D nanoelectronic systems. With their tunable direct gap in the visible range of the optical spectrum and high surface-to-volume ratio, these 2D semiconducting systems are ideal for field-effect transistors, photovoltaics, light-emitting diodes, single-atom storage, molecule sensing and quantum-state metamaterials.

Here we report on the extraordinary photoluminescence (PL) and Raman properties, not only of the physical but also of intentionally created via femtosecond laser ablation, boundaries of mechanically exfoliated WS2 monolayers. In particular, it is shown that the edges of such monolayers exhibit significant Raman shifts as well as remarkably increased PL efficiency compared to their respective central area with the emission channels being of different origin. Moreover, by exploiting the interaction of UV nanosecond pulses with WS2 monolayers in rich Cl2 environment, a fine control of the crystal*s carrier density can be achieved. This is confirmed by micro-PL measurements at 78K that show significant energy shifts of the neutral and charged exciton*s emission. At the same time, micro-Raman experiments reveal systematic shifts of the -doping sensitive- A1* vibrational mode.

We envisage that these novel findings could find diverse applications in the development of TMDs-based optoelectronic devices.

A 24.7 Wed 16:00 P 5

Mid-IR laser-based FTIR imaging using a broadband fs laser source at 73 MHz repetition rate — •Florian Mörz, Rostyslav Semenyshyn, Tobias Steinle, Frank Neubrech, Andy Steinmann, and Harald Giessen — 4th Physics Institute and Research Center SCOPE, University of Stuttgart, 70550 Stuttgart,Germany

We demonstrate FTIR imaging of sub-wavelength layers of C60 and Pentacene at 7 μm using a broadband laser source. Imaging has been conducted by using aperture sizes as small as 10 x 10 μm with a 36x microscope objective. A 100 x 100 μm image of the molecule layers has been measured. A signal-to-noise ratio that exceeds common FTIR light sources, such as globars or synchrotrons, due to a several orders of magnitude higher brilliance has been observed. The applied laser source is based on the ffOPO system presented in [1, 2]. Here, a commercially available Yb:CALGO laser, providing 98 fs pulses at 73 MHz repetition rate, is used as a pump oscillator. The post-amplified ffOPO system converts the pump light to the 1.4 - 4 μm wavelength range. By difference frequency generation between signal and idler in $AgGaSe_2$ up to 1 mW average power at 7 μm with 446 nm (93 cm^{-1}) bandwidth ($1/e^2$) is generated. The system exhibits superior long term stability over several hours. In conclusion, this laser based FTIR setup enables applications such as single nano-antenna measurements or protein sensing based on surface-enhanced infrared absorption (SEIRA).

[1] F. Moerz et al., Opt. Exp. **23**, 23960 (2015)
[2] T. Steinle et al., Opt. Lett. **41**, 4863 (2016)

A 24.8 Wed 16:15 P 5

Towards Precision Infrared Spectroscopy on Small Molecules — •Arthur Fast[1], John E. Furneaux[2], and Samuel A. Meek[1] — [1]Max Planck Institute for Biophysical Chemistry, Germany — [2]University of Oklahoma, USA

Our goal is a high resolution measurement of the two-photon v = 2 ← v = 0 vibrational transitions in the hydroxyl (OH) radical with a relative accuracy of 10^{-14}. These transitions can be used for a test of a possible time variation of the electron-proton mass ratio. The core of this endeavor is a laser beam in the mid infrared region at 2.9 μm with a narrow optical linewidth below 1 kHz. This is the idler wavelength of an optical parametric oscillator (OPO) pumped at 1064 nm by a Nd:YAG laser. The same laser is also frequency-doubled and locked to a molecular iodine transition at 532 nm. By doing this, the Nd:YAG laser obtains a high short term stability, around 10^{-14} at the one-second timescale. To transfer this stability to the idler wavelength of the OPO at 2.9 μm we make use of an optical frequency comb. The frequency comb is stabilized to the Nd:YAG laser, and the OPO is stabilized to the frequency comb by controlling its cavity length with a piezo mirror. The frequency comb is also used to compare the measured absolute frequencies of the various lasers to a GPS-linked radio frequency reference. In this way, we obtain a long-term stability and absolute accuracy for our spectroscopic measurements.

A 25: Ultracold Plasmas and Rydberg Systems (with Q)

Time: Wednesday 14:30–16:45 Location: P 104

Group Report A 25.1 Wed 14:30 P 104

Non-equilibrium dynamics of dipolar interacting Rydberg spins — •Adrien Signoles[1], Miguel Ferreira-Cao[1], Asier Pineiro Orioli[2], Renato Ferracini Alves[1], Vladislav Gavryusev[1], Gerhard Zürn[1], Jürgen Berges[2], Shannon Whitlock[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Germany

Rydberg atoms in ultracold gases constitute controllable systems to experimentally study non-equilibrium phenomena, like thermalization of isolated quantum systems or relaxation after quenches. Of specific interest is the possibility to introduce resonant dipolar exchange interactions, providing new opportunities for investigating the dynamics of strongly correlated many-body quantum systems with beyond nearest-neighbour coupling.

We present an experimental realization of a prototypical dipolar spin model by coupling two strongly interacting Rydberg states by a microwave field. At low Rydberg density where interactions are negligible, we show that our system can be mapped into a spin-1/2 model, in which full control and readout are achieved by using arbitrary single-spin rotations. By driving the system out-of-equilibrium for higher densities we report the observation of coherent spin oscillations with interaction-induced damping, which can be described in terms of a dipolar XX-model in effective magnetic fields. The comparison with theoretical calculations allows us to identify the primordial quantum fluctuations as a source of relaxation.

A 25.2 Wed 15:00 P 104

Towards a strongly interacting gas of cold strontium Rydberg atoms — Ingo Nosske[1], Luc Couturier[1], Chang Qiao[1], Fachao Hu[1], •Jan Blume[1,2], Canzhu Tan[1], Peng Chen[1], Yuhai Jiang[1,3], and Matthias Weidemüller[1,2] — [1]University of Science and Technology of China, Shanghai Institute for Advanced Studies, Xiupu Road 99, 201315 Shanghai, China — [2]Physikalisches Institut, Universität Heidelberg, Germany — [3]Shanghai Advanced Research Institute, Chinese Academy of Sciences,

We aim to create a gas of ultracold strontium Rydberg atoms. Our laser cooling strategy, with the goal of reaching temperatures and densities close to quantum degeneracy [1], involves a side-loaded 2D MOT followed by 3D broad-band and narrow-band MOTs. The strontium atoms will be excited to triplet Rydberg states via a narrow singlet-triplet intercombination line.

Here we present our latest experimental progress including the realization of our strontium 2D MOT, as well as a characterization of the locking scheme of our cooling laser which addresses the broad $5s^2\ ^1S_0 - 5s5p\ ^1P_1$ transition of strontium at 461 nm. The locking scheme is based on a commercial wavelength meter (HighFinesse WSU10) with which an absolute frequency stability of a few MHz has been achieved.

[1] Simon Stellmer, Rudolf Grimm, and Florian Schreck. "Production of quantum-degenerate strontium gases." Physical Review A 87.1 (2013): 013611.9.5 571-586 (2014)

A 25.3 Wed 15:15 P 104

Spectroscopy of Rydberg states in ultra cold ytterbium — •Christian Halter, Mustafa Jumaah, Laura Sucke, Tobias Franzen, Bastian Pollklesener, Cristian Bruni, and Axel Görlitz — Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Deutschland

In recent years Rydberg atoms with their special features, like dipole-dipole interaction or van-der-Waals blockade, have become more and more important for quantum optics. Particularly ultra cold Rydberg atoms are of great interest for the investigation of long range interaction. A special feature of ytterbium is that due to its two valance electrons atoms in Rydberg state can be easily manipulated and imaged using optical fields. A first step towards studies of ultra cold ytterbium is to gain precise knowledge on the Rydberg states. Here we present a spectroscopy study of the Rydberg states of ultra cold ytterbium. For the detection of the Rydberg states we are using the induced loss of atoms in a MOT when atoms are excited to a Rydberg state. Using this method we could measure several energy levels of Rydberg states.

A 25.4 Wed 15:30 P 104

Simulating Rydberg dressing of a one-dimensional Bose-Einstein condensate — •Graham Lochead[1,2], Marcin Plodzien[3], Julius de Hond[2], N. J. van Druten[2], and Servaas Kokkelmans[3] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimerfeld 226, 69120 Heidelberg — [2]van der Waals-Zeeman Institute, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands — [3]Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

Rydberg dressing is the process of weakly admixing strongly interacting Rydberg-character into an otherwise weakly interacting ground state. These systems have the benefit of having strong, controllable, long-range interactions while still maintaining relatively long lifetimes. These properties have lead to many proposals for exotic many-body states/phases. In this talk I will present simulations of the influence of Rydberg dressed interactions on a 1D Bose-Einstein condensate, and show the advantages of 1D geometries over 3D for experimental observation. I will also describe a current experimental setup investigating Rydberg dressing in a 1D BEC.

A 25.5 Wed 15:45 P 104

Photon propagation through dissipative Rydberg medium at large input rates — •Ivan Mirgorodskiy[1], Christoph Braun[1,2], Florian Christaller[1,2], Christoph Tresp[1,2], Asaf Paris-Mandoki[1], and Sebastian Hofferberth[1,2] — [1]5. Phys. Inst. and Center for Integrated Quantum Science and Technology, Stuttgart University, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Department of Physics, Chemistry and Pharmacy, University of Southern Denmark, 5230 Odense M, Denmark

In our experiment we study the propagation of photons through cold atomic ensemble of 87Rb. Coupling photons to a Rydberg state via Electromagnetically Induced Transparency (EIT) leads to excitation of hybrid atom-photon states called Rydberg polaritons. Rydberg polaritons propagate through the atomic medium with vastly reduced speed and therefore strong Rydberg-Rydberg interaction can be mapped onto the photons. Thereby dissipative Rydberg-EIT media reveal a rich physics, understanding of which is of a high necessity.

In this work we investigate the particular case of large input photon rates and study quantum many-body dynamics of a dissipative Rydberg-EIT medium. We discuss effects of polariton propagation resulting in the change of photon transmission through the medium and an effect of "Rydberg pollution" consisting in a drastically increased rate of production of stationary Rydberg excitations inside of the medium.

A 25.6 Wed 16:00 P 104

Rydberg excitation of cold atoms in hollow core fiber — •Mohammad Noaman, Maria Langbecker, Chantal Voss, Maik Selch, Florian Stuhlmann, and Patrick Windpassinger — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Cold atoms confined inside hollow-core fibers represent a promising candidate to study strongly coupled light-matter systems. Combined with the long range Rydberg interaction which is controlled through an EIT process, a corresponding experimental setup should allow for the generation of a strong and tunable polariton interaction. Due to dipole blockade polaritons are restricted to a quasi one dimensional structure. Using this scheme, novel photonic states, eg crystallization of photons can be observed with possible applications in quantum information and simulation. This talk will review the current status of our experimental setup where laser cooled Rubidium atoms are transported into a hollow-core fiber using optical lattice. We present the first result of Rydberg EIT of cold atoms inside a hollow core fiber and discuss the progress towards physics in a quasi-one-dimensional geometry of Rydberg atoms.

A 25.7 Wed 16:15 P 104

Mixed spin character bound states in ultra-long range giant dipole molecules — •Thomas Stielow, Markus Kurz, and Stefan Scheel — Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18059 Rostock

An exotic species of Rydberg atoms in crossed eletric and magnetic fields are so-called giant-dipole atoms [1]. They are characterized by an electron-ionic core separation in the range of several micrometers, leading to huge permanent dipole moments of several hundred thousand Debye. Recently, diatomic molecular states formed by the binding of a giant-dipole atom with a neutral ground-state perturber have been analyzed within the framework of a triplet dominated S-wave Fermi-pseudopotential approach [2]. In this work, we expand this analysis by including both S- and P-wave scattering potentials along with the hyperfine-structure coupling of the ground-state perturber. We discuss the effects of these couplings on the adiabatic molecular potentials. In addition to the Fermi-pseudopotential ansatz we provide a comparative study based on a Green's function approach [3].

[1] Dippel O., Schmelcher P. and Cederbaum L. S., *Phys. Rev. A*, **49** (1994) 4415.
[2] Kurz, M., Mayle, M. and Schmelcher, P., *Europhys. Lett.*, **97** (2012) 43001.
[3] Fey, C., Kurz, M., Schmelcher, P., Rittenhouse, S. T., Sadeghpour, H. R., *New J. Phys.* **17** 055010 (2015).

A 25.8 Wed 16:30 P 104

Strong coupling of a Rydberg super atom to a propagating light mode — •Jan Kumlin[1], Asaf Paris-Mandoki[2], Christoph Braun[2], Christoph Tresp[2], Sebastian Hofferberth[2], and Hans Peter Büchler[1] — [1]Institut für Theoretische Physik III and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany — [2]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany

Strong coupling of a single atom to a light mode is at the heart of quantum optics. Such systems have so-far been realised experimentally in optical cavities, but recent experimental progress in coupling propagating photons to an atomic cloud with Rydberg states enables the realisation of strong interactions between individual photons in free space and opens up a novel toolbox for quantum optics.

In this talk, we present the exact input-output formalism to describe the phenomenon of collective Rabi oscillations in a single Rydberg two-level superatom coupled to a photon field. The photonic mode defines an effective one-dimensional system, while the large size of the atomic cloud provides a chiral coupling. Using a master equation approach and the quantum regression theorem, we calculate the intensity as well as the second-order correlation function for the outgoing field by numerically solving the quantum master equation. Finally, we compare our findings with recent experimental results.

A 26: Poster Session II

Time: Wednesday 17:00–19:00 Location: P OGs

A 26.1 Wed 17:00 P OGs

Quench-induced resonant tunneling mechanisms of bosons in an optical lattice with harmonic confinement — •Georgios Koutentakis[1,2], Simeon Mistakidis[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

The non-equilibrium dynamics of small boson ensembles in a one-dimensional optical lattice is explored upon a sudden quench of an additional harmonic trap from strong to weak confinement. We find that the competition between the initial localization and the repulsive interaction leads to a resonant response of the system for intermediate quench amplitudes, corresponding to avoided crossings in the many-body eigenspectrum with varying final trap frequency. In particular, we show that these avoided crossings can be utilized to prepare the system in a desired state. The dynamical response is shown to depend on both the interaction strength as well as the number of atoms manifesting the many-body nature of the tunneling dynamics.

A 26.2 Wed 17:00 P OGs

A reaction microscope for few-body Rydberg dynamics — •Philipp Geppert, Dominik Arnold, Cihan Sahin, Andreas Müllers, and Herwig Ott — Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

On the basis of our deterministic ion source experiment (see talk of C. Sahin), we are developing a reaction microscope that is inspired by the well-known MOTRIMS technique. For this, a sample of 10^6 ^{87}Rb atoms will be prepared in a crossed dipole trap. Using a 3-level excitation scheme, some atoms can be excited to atomic or molecular Rydberg states and photoionised by a short laser pulse from a high power CO_2 laser after a variable evolution time. Following small homogeneous electric fields generated by Wiley-McLaren-type ion optics, the produced ions are subsequently detected by a time and position sensitive micro channel plate detector. By analysing the trajectories of the recoil ions, we aim to measure momentum distributions of Rydberg molecule wave functions. In this context, special focus lies on butterfly and trilobite molecules, which can be addressed efficiently due to the opportunity of exciting Rydberg p- and f-states. As a next step, stroboscopic monitoring of the internal decay of Rydberg molecules as well as measurements regarding forces between pairs of Rydberg atoms will be performed.

A 26.3 Wed 17:00 P OGs

Towards Quantum Link Models in Ultracold Atoms — •Alexander Mil, Fabian Olivares, Pradyumna Paranjape, Markus Oberthaler, and Fred Jendrzejewski — Kirchhoff Institute for Science, 69120, Heidelberg, Germany

We discuss possible experimental realizations of dynamical gauge fields in ultracold atoms. The goal is to built an analog quantum simulator for quantum electrodynamics through quantum link models. We suggest a realization comprised of bosonic 23Na and fermionic 6Li atoms in an optical lattice. The bosonic sodium atoms are located at the link position between the fermionic lattice sites and lead to correlated hopping through well tuned interspecies interactions. We present first steps towards the experimental implementation.

A 26.4 Wed 17:00 P OGs

Dark-bright Soliton Dynamics and Interactions Beyond the Mean-Field approximation — Garyfallia Katsimiga[1], Georgios Koutentakis[1,2], •Simeon Mistakidis[1], Panagiotis Kevrekidis[3], and Peter Schmelcher[1,2] — [1]Zentrum fuer Optische Quantentechnologien, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003-4515, USA

The dynamics of dark bright solitons beyond the mean-field approximation is investigated. We first examine the case of a single dark-bright soliton and its oscillations within a parabolic trap. Subsequently, we move to the setting of collisions, comparing the mean-field approximation to that involving multiple orbitals in both the dark and the bright component. Fragmentation is present and significantly affects the dynamics, especially in the case of slower solitons and in that of lower atom numbers. The employed multi-orbital approximation allows for bipartite entanglement between the distinguishable species to be also generically observed. The above mentioned interplay leads to the decay of the initial mean-field dark-bright solitons into fast and slow fragmented dark-bright structures. A variety of excitations including dark-bright solitons in multiple orbitals is observed. Dark-antidark states and domain wall-bright soliton complexes arise spontaneously possessing an important role in the interpretation of the dynamics.

A 26.5 Wed 17:00 P OGs

Single Cesium Atoms Interacting with an Ultracold Rubidium Bath — •Steve Haupt[1], Daniel Mayer[1,2], Felix Schmidt[1,2], Tobias Lausch[1], Daniel Adam[1], Michael Hohmann[1], Farina Kindermann[1], Nicolas Spethmann[1], and Artur Widera[1,2] — [1]Department of Physics, University of Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern , Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Str. 42, 67663 Kaiserslautern, Germany

We immerse single neutral Cesium (^{133}Cs) atoms into an ultra cold Rubidium (^{87}Rb) cloud and study their dynamics. Tight external control over the Cs atoms' degrees of freedom as well as high-resolution single atom imaging allows studying various quantum phenomena and applications. This includes cooling dynamics of impurity atoms employed as quantum bits or the realisation of polaronic quasi-particles.

We will review the recent developments in gaining further independent control over the two species, including species-selective optical trapping as well as various measures to deduce the temperature of single atoms. This allows employing single atoms as local, non-destructive temperature probes for an ultracold gas, yielding access to the local thermalisation dynamics within the bath.

A 26.6 Wed 17:00 P OGs

Towards Ultracold Ba$^+$-Li - Interactions: The Lithium setup — •F. Thielemann, P. Weckesser, Y. Minet, A. Lambrecht, J. Schmidt, L. Karpa, M. Debatin, and T. Schaetz — Albert-Ludwigs-Universitaet Freiburg

The interplay of ultracold atoms and ions has recently gained interest in the atomic community [1], due to its wide applications in quantum chemistry [2] and quantum control [3]. To control the atom-ion interaction it is necessary to prepare the mixture at ultracold temperatures. Optical trapping of ions [4,5] provides a new pathway to achieve ultracold atom-ion mixtures, as it overcomes the intrinsic micromotion heating effects of a conventional Paul trap [6], currently limiting experiments to collision energies on the order of a few mK.

We present our novel setup aiming to combine Ba$^+$ ions and Li atoms in an optical dipole trap. On this poster we focus on the Li branch of the setup. Our design of the oven, the Zeeman slower and the MOT laser system will be introduced in more detail.

[1] A. Haerter et al., Contemporary Physics, volume 55, issue 1, pages 33-45 (2014).
[2] R.Cote et al. Phys.Rev.Lett. 89.093001 (2002).
[3] Idziaszek et al., Physical Review A 76.3 (2007): 033409.
[4] T.Huber et al., Nat. Comm. 5,5587 (2014).
[5] A. Lambrecht et al., arXiv preprint arXiv:1609.06429 (2016).
[6] M.Cetina et al., Phys.Rev.Lett. 109,253201 (2012).

A 26.7 Wed 17:00 P OGs

Towards Ultracold Ba$^+$ – Li Interactions: The Barium Setup — •P. Weckesser, F. Thielemann, Y. Minet, A. Lambrecht, J. Schmidt, L. Karpa, M. Debatin, and T. Schaetz — Albert-Ludwigs-Universitaet Freiburg

The interplay of ultracold atoms and ions has recently gained interest in the atomic community [1], due to its wide applications in quantum chemistry [2] and quantum control [3]. To control the atom-ion interaction it is necessary to prepare the mixture at ultracold temperatures. Optical trapping of ions [4,5] provides a new pathway to achieve ultracold atom-ion mixtures, as it overcomes the intrinsic micromotion heating of conventional Paul traps [6], currently limiting experiments to collision energies on the order of a few mK.

Here we present our novel experimental setup combining Ba$^+$ ions and Li atoms. On this poster we focus on the Barium branch of the experiment. We present the Barium laser setup, including a home build frequency doubler, generating laser light at 615nm. Furthermore we discuss a new ion trap suitable to transfer and detect Ba$^+$ ions and Li atoms in an optical dipole trap.

[1] A. Haerter et al., Contemporary Physics, volume 55, issue 1, pages 33-45 (2014).
[2] R.Cote et al. Phys.Rev.Lett. 89.093001 (2002).
[3] Idziaszek et al., Physical Review A 76.3 (2007): 033409.
[4] T.Huber et al., Nat. Comm. 5,5587 (2014).
[5] A. Lambrecht et al., arXiv preprint arXiv:1609.06429 (2016).
[6] M.Cetina et al., Phys.Rev.Lett. 109,253201 (2012)

A 26.8 Wed 17:00 P OGs

Ablation Loading and Tuning Techniques for the electrical potential in Surface-Electrode Ion Traps — •Leonard Nitzsche, Frederick Hakelberg, Philip Kiefer, Henning Kalis, Ulrich Warring, and Tobias Schaetz — Atom-, Molekül- und optische Physik, Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

Precise and individual control of motional degrees of freedom of trapped ions is needed for the advent of larger scale quantum simulations and computations in microfabricated trap arrays. Key techniques include, e.g., reduction of aging effects such as contamination of the trap surfaces as well as tuning of mirco potentials adressing single ions without affecting the overall performance of the array. Here we present preliminary results in optimising laser ablation loading of Mg$^+$ and shaping the trap potential adressing individual ions via control potentials up to the fourth order.

A 26.9 Wed 17:00 P OGs

Characterization and Control of Anharmonic Trapping Potentials in Surface-Electrode Ion Traps — •Frederick Hakelberg[1], Philip Kiefer[1], Leonard Nitzsche[1], Henning Kalis[1], Ulrich Warring[1], and Tobias Schaetz[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — [2]Freiburg Institute for Advanced Studies

Trapped ions present a promising system for quantum simulations [1].

However scaling the systems to larger size and dimension presents a major challenge. Surface-electrode traps offer a promising approach towards scalable ion traps [2, 3]. With decreasing length scales of trap electrodes and ion-electrode distances higher order terms of electric potentials become relevant. This includes contributions to the confining radio-frequency potential as well as to static control and stray potentials. Building on previous work [4] we present methods using motional excitation measurements to control higher order, anharmonic contributions and stray potentials. Furthermore we show how anharmonic radio-frequency potentials lead to a position dependent trace of the local curvature tensor that can be derived from established measurements of the motional frequencies. We present experimental results for both methods including the variation of anharmonic contributions using dedicated control potentials.

[1] Ch. Schneider *et al.*, Rep. Prog. Phys. **75**, 024401 (2012)
[2] T. Schaetz *et al.*, New J. Phys. **15**, 085009 (2013)
[3] M. Mielenz *et al.*, Nature Communications **7**, 11839 (2016)
[4] H. Kalis *et al.*, Phys. Rev. A **94**, 023401 (2016)

A 26.10 Wed 17:00 P OGs

Structural Defects in Anharmonic Trapping Potentials — •Philip Kiefer[1], Jonathan Brox[1], Miriam Bujak[1], Frederick Hakelberg[1], Leonard Nitzsche[1], Henning Kalis[1], Ulrich Warring[1], Haggai Landa[2], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]LPTMS, Université Paris Sud, Orsay, France

We study topological defects [1], so called kinks, in Coulomb crystals consisting of Mg-Ions. We demonstrate that the appearance of such defects, as well as the normal mode spectrum of the crystal and escape directionalities depend on the trap potential. Depending on defect type and anharmonic contributions to the trap potential, the defects get a preferred escape direction [2].

Linear surface electrode traps offer one possibility to control the trapping potential up to higher orders. We present numerical calculated control potentials, that are modifiable on relevant time scales of the crystal. This system offers a promising platform to further study and exploit the properties of such topological defects.

[1] Ch. Schneider et al., Rep. Prog. Phys. **75**, 024401 (2012)
[2] J. Brox et al., publication in preparation

A 26.11 Wed 17:00 P OGs

Impurity Atoms as a Quantum Probe Using Radiofrequency-Dressed Adiabatic Potentials — •Kathrin Luksch, Tiffany Harte, Elliot Bentine, Adam Barker, Benjamin Yuen, and Christopher Foot — Clarendon Laboratory, Parks Road, Oxford, OX1 3PU

Ultracold atoms can be confined in adiabatic potentials formed by radiofrequency (RF) dressing of magnetically trapped atoms. We demonstrate this approach can be extended by using multiple RFs to generate versatile trap geometries, such as a double-well potential generated by three distinct RFs.

In a new approach to probing complex quantum systems for quantum simulations, we plan to probe the dynamics of a BEC using a second impurity species to look at non-equilibrium phenomena.

Utilising the species-selectivity of the multi-RF dressed adiabatic potentials, we will immerse impurity atoms trapped in a double-well (^{85}Rb) into a bath of atoms of another species (^{87}Rb). The tunnelling rate of the impurity in the double-well will then be correlated to excitations in the bath.

An optical dipole trap combined with a 2D-acousto-optic deflector setup allows further shaping of the trapping potentials. Imaging of the small number of impurity atoms will be achieved using fluorescence imaging in a near-detuned optical lattice.

A 26.12 Wed 17:00 P OGs

A Homogeneous 2D Fermi Gas — •Niclas Luick, Klaus Hueck, Lennart Sobirey, Jonas Siegl, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Ultracold 2D Fermi gases in the BEC-BCS crossover provide a model system to investigate e.g. the Kosterlitz-Thouless transition to superfluidity. So far, ultracold 2D Fermi gases have been studied in harmonic trapping potentials. This results in an inhomogeneous density distribution, which complicates the theoretical description of the system and only allows for the extraction of trap averaged quantities when utilizing non-local measurement methods such as time of flight imaging.

Here, we present our realization of an ultracold 2D Fermi gas trapped in a homogeneous disk-shaped potential. The radial confinement is realized by a ring-shaped blue-detuned beam with steep walls. Additionally, a digital micromirror device can be used to remove residual inhomogeneities and to imprint arbitrary repulsive potentials onto the system. Technical details about the generation of optical potentials as well as the current status of our experiment will be presented.

A 26.13 Wed 17:00 P OGs

Three-body losses in Dysprosium — •Fabian Böttcher, Matthias Schmitt, Matthias Wenzel, Carl Bühner, Igor Ferrier-Barbut, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Strongly dipolar quantum gases enable the observation of many-body phenomena with anisotropic, long-range interactions. These interactions lead to a spectrum with a background of chaotic distributed narrow Feshbach resonances, as well as some universal broad resonances [1]. With Feshbach resonances it is well known that the scattering length can be tuned and that at the same time also the three-body recombination rate changes.

Motivated by the fact that the lifetime of the selfbound quantum droplets [2] is limited by the three-body loss rate, we present an extensive study of the three-body loss rate.

[1] T. Maier et al., Phys. Rev. A 92, 060702 (2015)
[2] M. Schmitt et al., Nature 539, 259-262 (2016)

A 26.14 Wed 17:00 P OGs

Trapped ions in strongly polarizable atomic media — •Norman Ewald[1], Henning Fürst[1], Jannis Joger[1], Thomas Secker[2], Thomas Feldker[1], and René Gerritsma[1] — [1]Institute of Physics, University of Amsterdam, Netherlands — [2]Institute for Coherence and Quantum Technology, TU Eindhoven, Netherlands

We report on our experiment which aims at studying trapped ions interacting with ultra-cold atoms that are coupled to Rydberg states. Since the polarizability of the Rydberg-dressed atoms can be very large, the interactions between the ions and atoms will increase dramatically as compared to the ground state case. Such interactions may be mediated over micrometers and could be used to entangle atoms and ions, to mediate spin-spin interactions or to study spin-phonon couplings [1]. Furthermore, we discuss how to employ Rydberg dressing on a dipole-forbidden transition to generate a repulsive atom-ion potential. This prevents collision-induced heating of the ions, typically limiting attainable temperatures in hybrid atom-ion experiments. We discuss our experimental approach for Rydberg excitation of Li atoms as well as a detailed theoretical analysis of Rydberg atom-ion interaction.

[1] T. Secker et al., Phys. Rev. A 94, 013420 (2016).

A 26.15 Wed 17:00 P OGs

Bichromatic control of multi-photon ionization — •Daniela Johannmeyer, Stefanie Kerbstadt, Dominik Pengel, Lars Englert, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Straße 9-11, 26129 Oldenburg

Polarization-shaped bichromatic laser fields have attracted much interest for the control of coherent electron dynamics. In view of quantum control, the benefit of bichromatic fields lies in the ability to disentangle different quantum pathways. Recently, we introduced a novel technique for the shaper-based generation of ultrashort bichromatic fields with freely adjustable spectral amplitude profile, phase and polarization state of each color [1]. Here we combine bichromatic polarization shaping with angular resolved photoelectron spectroscopy using velocity map imaging. The 3D photoelectron angular and energy distribution (PAD) is retrieved by tomographic methods. We study resonance enhanced multi-photon ionization of atoms as a prototype scenario for multi-path coherent control. In a bichromatic pump-probe scheme, we study the time evolution of a resonantly excited spin wave packet in the PAD.

[1] S. Kerbstadt, L. Englert, T. Bayer, M. Wollenhaupt, J. Mod. Opt., accepted (2016)

A 26.16 Wed 17:00 P OGs

Carrier-envelope phase stability and control of shaped few-cycle laser pulses from a $4f$ white light shaper — •Daniel Timmer, Stefanie Kerbstadt, Lars Englert, and Matthias Wollenhaupt — Institut für Physik, Carl von Ossietzky Universität Oldenburg, Carl-von-Ossietzky-Straße 9-11, 26129 Oldenburg

Few-cycle IR laser pulses are a well-established tool for control of coherent electron dynamics on the sub-fs timescale. For successful realization of such experiments stabilization and control of the carrier envelope phase (CEP) are essential. In order to exploit advanced coherent control strategies, the availability of tailored few-cycle pulses is highly desirable. Here we use a liquid crystal based $4f$ whitelight shaper to control the CEP of a supercontinuum from a gas-filled hollow-core fiber compressor. Using a home-built f-$2f$-interferometer capable of single shot measurements we verify both the CEP stability behind the setup and the CEP changes introduced by the shaper. In addition to the control over the temporal shape of the laser electric field, the shaper-based approach provides built-in dispersion management and pulse diagnostics. We present initial results of CEP-stable shaped few-cycle waveforms from our setup.

A 26.17 Wed 17:00 P OGs

Combining absorption and photoelectron spectroscopy on ultrashort timescales — •Maximilian Hartmann, Alexander Blättermann, Paul Birk, Veit Stooss, Gergana Borisova, Christian Ott, and Thomas Pfeifer — Max-Planck- Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Femtosecond laser pulses (1fs = 10^{-15}s) have enabled the study of electron dynamics in atoms, molecules and solids on their natural time scale.

Two techniques for these studies—namely transient absorption spectroscopy (TAS) and photoelectron spectroscopy (PES)—make use of such laser pulses to drive high-harmonic generation in rare gases in order to produce attosecond bursts of XUV radiation for pump probe-type experiments. The two methods are complementary in the sense that TAS is most sensitive to bound state dynamics, while PES has direct access to ionization dynamics.

Using TAS we have studied the evolution and manipulation of inner-valence transitions and autoionizing states in noble gases [C. Ott et al., Science 340, 716 (2013); A. Kaldun et al. Phys. Rev. Lett. 112, 103001 (2014); T.Ding et al., Opt. Lett. 41, 709 (2016)]. Here we present the integration of an electron time-of-flight spectrometer into our setup to be able to perform TAS and PES simultaneously. With this new dual approach we aim to gather complementary information of the electron dynamics in atoms and molecules.

A 26.18 Wed 17:00 P OGs

Spin-dependent rescattering in strong-field ionization of Helium — •Danilo Zille[1,2], Daniel Seipt[3,4], Max Möller[1,2], Stephan Fritzsche[2,3], Stefanie Gräfe[5,6], Carsten Müller[7], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena, 07743 Jena, Germany — [2]Helmholtz Institut Jena, 07743 Jena, Germany — [3]Theoretisch-Physikalisches Institut, Friedrich Schiller University Jena, 07743 Jena, Germany — [4]Physics Department, Lancaster University, Lancaster LA1 4YB, United Kingdom — [5]Institute for Physical Chemistry, Friedrich Schiller University Jena, 07743 Jena, Germany — [6]Abbe Center of Photonics, Friedrich Schiller University Jena, 07743 Jena, Germany — [7]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

We investigate the influence of singlet and triplet spin states on rescattered photoelectrons in strong-field ionization of excited helium. Choosing either a symmetric or antisymmetric spatial wave function as the initial state results in different scattering cross sections for the $1s2s$ ^1S and ^3S states. These cross sections are used in the semi-classical model of strong-field ionization. Our investigations show that the photoelectron momentum distributions of rescattered electrons exhibit a significant dependence on the relative spin state of the projectile and the bound electron which should be observable in experiments. The proposed experimental approach can be understood as a testbed for probing the spin dynamics of electrons during strong-field ionization and the presented results as a baseline for their identification.

A 26.19 Wed 17:00 P OGs

Two-timescale Kramers-Henneberger Bloch-Floquet approach for low frequency pulsed laser fields — •Lukas Medišauskas, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems Nöthnitzer Straße 38 D-01187 Dresden

An efficient numerical method to solve large Floquet problems in Kramers-Henneberger reference frame is proposed. A two-timescale formulation is used that enables to apply the Floquet picture for pulsed laser pulses. The approach is applied to the dynamics of atoms in strong and low frequency laser fields, where explicit treatment of few hundred Floquet states is necessary. Typical strong field effects like high harmonic generation and above threshold ionization are demonstrated. Finally, the existence of the so-called Kramers-Henneberger atom in strong laser field is addressed.

A 26.20 Wed 17:00 P OGs

Laser-solid interaction using time-dependent density functional theory — •Tobias Deffge and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Strong-field physics in solid targets is of fundamental interest because the dispersion relation of the electrons (and all the quasi particles involved) can be tailored via the field-dressed band structure. Applications in ultrafast electronics or novel radiation sources are conceivable. Much of the recent, pioneering theoretical work on the subject is based on the single-active-electron approximation and the assumption that only a few bands are important for the dynamics. Further, surface effects are difficult to take into account in momentum-space approaches.

In our work, we consider a one-dimensional model of a solid slab interacting with a laser field. The band structure is calculated self-consistently using density functional theory. The laser-induced dynamics is studied by solving the time-dependent Kohn-Sham equation in local spin-density approximation. By freezing and unfreezing the Kohn-Sham potential the influence of electron-electron interaction on Bloch oscillations and harmonic generation is investigated. Surface effects are identified.

A 26.21 Wed 17:00 P OGs

Two-color laser pulses and the phase of the phase — •Mohammad Adel Almajid and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Phase of the phase (PoP) spectroscopy using two-color colinearly polarized laser pulses has been introduced and applied to the tunneling regime of strong-field ionization [1]. Briefly, the momentum-resolved photoelectron yield as a function of the relative phase between the strong ω and weak 2ω component of a colinearly polarized two-color pulse is measured and Fourier-transformed. This tells us how much and with which phase lag the yield changes with varying relative phase. We present results for the multiphoton regime. We find that the alternating PoP along the above-threshold ionization rings generates a characteristic checkerboard pattern in the PoP spectra. In the case of counter-circularly polarized ω-2ω. laser pulses a three-fold symmetry in the PoP spectra is obtained, as previously found in "ordinary" photoelectron spectra. There is a jump in the PoP signature at a particular radial photoelectron momentum.

[1] S. Skruszewicz *et al.*, Phys. Rev. Lett. 115, 043001 (2015).

A 26.22 Wed 17:00 P OGs

How classical physics emerges from quantum tunneling: Experimental evidence for Wigner tunneling time — •E. Yakaboylu, N. Camus, L. Fechner, M. Klaiber, M. Laux, Y. H. Mi, K. Z. Hatsagortsyan, T. Pfeifer, C. H. Keitel, and R. Moshammer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The classically forbidden tunneling process has intrigued scientists for decades. Recently, the invention of high-precision attoclock techniques in strong laser ionization as well as so-called reaction microscopes for high-resolution momentum measurements have allowed to raise the fundamental question on how classical dynamics emerges in quantum tunneling. Combining experimental and theoretical investigations, we confirm that the leading quantum mechanical Wigner treatment of tunneling in strong field ionization reveals a nonzero tunneling delay time as well as a nonvanishing longitudinal momentum [1].

[1] arXiv preprint arXiv:1611.03701 (2016)

A 26.23 Wed 17:00 P OGs

Isotopic shift of $^{36}Ar/^{40}Ar$ measured with a spin-orbit wave packet — •Sofia Botsi, Nicolas Camus, Lutz Fechner, Thomas Pfeifer, and Robert Moshammer — 1 Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

High precision measurements of isotopic shifts in noble gases can provide a very good test of relativistic and quantum electrodynamic effects. In our experiment, we measured the isotopic shift between ^{36}Ar

and ^{40}Ar for the $3s^2 3p^5$ ($^2P_{3/2} \rightarrow {}^2P_{1/2}$) transition for singly ionized argon atoms. We measured the shift by implementing a Ramsey scheme using two ultra-short ($\sim$ 6fs) laser pulses. The first laser pulse excites the system in a coherent superposition of the aforementioned states. This superposition leads to a spin-orbit wave packet whose dynamics can be investigated by applying a second delayed probe pulse. A Mach-Zehnder interferometer was built, introducing a 3.97ns time delay between the two pulses.To detect the different argon isotopes we used a reaction microscope spectrometer (REMI). The isotopic shift is found to be $(1.22 \pm 0.12) \cdot 10^{-7}$eV and it is the first time it has been measured for this transition to the best of our knowledge.

A 26.24 Wed 17:00 P OGs

VMI spectrometer for studying interaction of atoms and molecules with Terahertz radiation — •Patrick Fross, Yonghao Mi, Nicolas Camus, Lutz Fechner, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Thanks to the advancements in strong laser technologies, generation and detection of strong Terahertz (THz) radiation has become possible in the recent years. Because of their low frequencies, they appear as ideal to study ultrafast phenomena in atoms and molecules without disturbing/interacting with the interrogated systems. In order to investigate the effect of THz and their imprint on particles arising from ionization with visible light, we build a dedicated spectrometer. First, this spectrometer has focusing optics which overcome the difficulties due to a low THz power inherent from the low power conversion efficiency of current pulsed THz generation. Second, the spectrometer frame is such that the voltage settings can be changed between Reaction Microscope (ReMi) settings allowing coincident measurement of all charged particles and VMI settings in which the multi-hit limitation of usual ReMis is overcome allowing to record statistics faster. An MCP-phosphor-screen-detector records a collective image of the charged particles that can mathematically be transformed to get the original 3D-momentum-distributions. The particle trajectories were simulated to find a potential configuration with optimal VMI-properties for the ReMi-spectrometer frame. First experimental results were obtained from photoionization of Argon with 25fs-IR-laser-pulses.

A 26.25 Wed 17:00 P OGs

Optical control of electron emission direction at a gold nanotip on a chip — •Constanze Sturm, Takuya Higuchi, Peyman Yousefi, Christian Heide, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen

Electron pulses from a sharp metal nanotip triggered by ultrashort laser pulses via multiphoton and above-threshold photoemission are extremely confined both in space and time. Employing these short-pulsed electrons as carriers in electronic devices may drastically improve their operation speed [1]. We propose and demonstrate an experiment to steer the electron emission direction at two dimensional nanotips fabricated with lithography on top of a substrate. This is achieved by illuminating the tip with a pair of two laser pulses with orthogonal polarizations. By tuning the relative delay between the two pulses, we change the near-field distribution at the surface of the tip, resulting in a modification of the electron emission sites on the tip. The resultant shift in emission direction is measured as a current difference of two detecting electrodes.

Numerical simulations and the current status of the experiment will be presented.

[1] T. Higuchi et al., Appl. Phys. Lett. 106, 051109 (2015).
[2] H. Yanagisawa et. al., Phys. Rev. Lett. 103, 257603 (2009).

A 26.26 Wed 17:00 P OGs

Strong-Field Approximation with Twisted Light Beams — •Birger Böning[1], Willi Paufler[1], and Stephan Fritzsche[1,2] — [1]Friedrich-Schiller-Universität, Jena, Germany — [2]Helmholtz-Institut Jena, Germany

The strong-field approximation has successfully been used to theoretically describe a variety of phenomena related to atoms in strong laser fields, e. g. above-threshold ionization and high-harmonic generation. Usually these studies are performed for the case of plane wave fields. On the other hand, the interaction of light beams with a more complex spatial structure (e. g. Bessel beams) with atomic systems has only been treated perturbatively and has, for example, been shown to lead to a modification of the selection rules of atomic transitions and photoelectron momentum spectra. We discuss the possibility to study the photoionization of atoms by intense Bessel beams beyond perturbation theory. To this extend, we adapt the strong-field approximation to include these light fields.

[1]: D. B. Milosevic et al., J. Phys. B: At. Mol. Opt. Phys. 39, R203–R262 (2006)
[2]: O. Matula et al., J. Phys. B: At. Mol. Opt. Phys. 46, 205002 (2013)

A 26.27 Wed 17:00 P OGs

Dynamic interference in atomic hydrogen — •Mehrdad Baghery, Ulf Saalmann, and Jan-Michael Rost — MPIPKS, Dresden, Germany

In the double-slit experiment two incoming wavepackets interfere due to their spatially varying relative phase. A similar phenomenon occurs if the relative phase varies with energy.

The goal is to ionise the electron wavepacket into identical continuum states at two different times. This can be done in multiple ways, 1. using two consecutive laser pulses of moderate intensity, 2. using one ultra strong laser pulse well into the stabilisation regime, 3. using one laser pulse below the stabilisation threshold but strong enough to induce a noticeable Stark shift.

This poster focuses mainly on the third alternative, which proves much more involved than perceived at first glance. In contrast to many previously published results, we show that this is only possible at frequencies in the x-ray regime.

A 26.28 Wed 17:00 P OGs

Sudden regime of laser-nucleus interaction — •Sergei Kobzak, Adriana Pálffy, and Hans Weidenmüller — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Recent experimental developments in laser physics and laser-driven acceleration promise to deliver coherent photon beams with energies ranging up to several MeV. The prospect of a laser beam with photon energies comparable to typical nuclear excitation energies raises a number of questions and opens new unexplored avenues for nuclear physics [1,2].

In this work we investigate theoretically the interaction between coherent gamma-ray laser pulses and medium-weight or heavy nuclei in the case of sudden regime. In this regime the compound nucleus statistical equilibration rate is slower than the average photon absorption rate. Consequently, nucleons are excited independently and are expelled from the common average potential. Multiple photon absorptions may lead to complete evaporation of the nucleus if the duration of the laser pulse of several MeV per photon is long enough. The time evolution of such processes is studied with help of master equations which take into account neutron decay and feeding, dipole absorption and emission and the nucleon-nucleon interaction.

[1] A. Pálffy and H. A. Weidenmüller, Phys. Rev. Lett. 112, 192502 (2014).
[2] A. Pálffy, O. Buss, A. Hoefer and H. A. Weidenmüller, Phys. Rev. C 92, 044619 (2015).

A 26.29 Wed 17:00 P OGs

Time-resolved photoelectron spectroscopy of IR-driven electron dynamics in a charge transfer model system — Mirjam Falge[1], •Friedrich Georg Fröbel[2], Volker Engel[1], and Stefanie Gräfe[2] — [1]Institut für Physikalische und Theoretische Chemie, Universität Würzburg — [2]Institut für Physikalische Chemie und Abbe Center for Photonics, Universität Jena

We numerically investigate the coupled nuclear and electronic dynamics induced by a moderately intense IR-pulse in a charge transfer model system. We examine two limiting cases, one, where the Born-Oppenheimer approximation is valid, and a second, where it breaks down. Calculating the time-resolved photoelectron momentum distributions, a pronounced difference is found. In the case of weak coupling, electrons adiabatically adjust to the nuclear motion. Strong coupling on the other hand leads to diabatic electron dynamics. The IR-pulse may modify the electron dynamics in the respective situation and thus influence the charge-transfer dynamics. Using an ultrashort XUV pulse as a probe, we illustrate that the electron-nuclear dynamics is reflected in the asymmetry of the photoelectron momentum distribution.

A 26.30 Wed 17:00 P OGs

Coulomb-corrected strong-field quantum orbits beyond the dipole approximation — •Thomas Keil and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Small nondipole effects in photoelectron spectra of rare gas atoms have been recently observed in experiments using 3.4-micron radiation at 2–8 $\times 10^{13}$ W/cm^2 [1]. Taking nondipole effects into account in 3D simulations based on the time-dependent Schrödinger equation (TDSE), let alone the Dirac equation, are extremely demanding and do not yield much insight into the underlying physics. The plain strong-field approximation (SFA), on the other hand, is oversimplified because it lacks the very essential effect of the Coulomb potential on the outgoing electrons. As a result, differential photoelectron momentum spectra obtained with the plain SFA are in very poor agreement with experiment and TDSE. Coulomb corrections can be incorporated via quantum orbits [2–4], and the equations of motion for these quantum orbits can be easily corrected for taking the $\vec{v} \times \vec{B}$-force into account as well. We analyze the effect of this correction and compare with the experimental findings.

[1] A. Ludwig *et al.*, Phys. Rev. Lett. 113, 243001 (2014).
[2] S.V. Popruzhenko and D. Bauer, J. Mod. Opt. 55, 2573 (2008).
[3] S.V. Popruzhenko *et al.*, Phys. Rev. A 77, 053409 (2008).
[4] Tian-Min Yan *et al.*, Phys. Rev. Lett. 105, 253002 (2010).

A 26.31 Wed 17:00 P OGs

Strong field dissociation of small heteronuclear molecules into excited fragments — •Sven Meise, Henri Zimmermann, and Ulrich Eichmann — Max-Born-Straße 2a, 12489 Berlin

We investigate the dissociation processes of small molecules in intense short laser fields which yield excited fragments. Recently, experimental coincidence measurements revealed that a fraction of H_2−molecules undergoing Coulomb explosion (CE) fragment into an excited H-atom and an proton [1]. The underlying physical process can be understood by applying the semi-classical model of frustrated tunneling ionization (FTI). Here, we present experimental results of strong field dissociation of small heteronuclear molecules (CH_4, CO_2) into excited fragments which proves that the excitation mechanism (FTI) is not unique to H_2 or other homonuclear molecules. Calculations based upon the CE which lead to excited fragments exhibit main features of the experimental results. Further insight is gained by looking at the excited state distribution of the molecular fragments using pulsed field ionization.

[1] B. Manschwetus *et al.*; PRL **102** 113002 (2009)

A 26.32 Wed 17:00 P OGs

Robust enhancement of high harmonic generation via attosecond control of ionization — Barry D. Bruner, •Michael Krüger, Oren Pedatzur, Doron Azoury, Gal Orenstein, and Nirit Dudovich — Weizmann Institute of Science, 76100 Rehovot, Israel

Advancements in high harmonic generation (HHG) have led to the development of table-top XUV and soft x-ray light sources for attosecond science. However, the very low conversion efficiency from the strong driving laser fields to short wavelength HHG light poses a significant practical limitation for the use of these sources in experimental applications. We show that a two colour driving field produces a considerable enhancement of the ionization rate compared to that of a single colour field, leading to huge increases in the HHG efficiency. We use a tunable mid-IR (1300-1600 nm) source as a driving field and a weaker 800 nm beam as an assisting field. By systematically varying the field parameters we can observe increases in HHG efficiency of over two orders of magnitude. The enhancement is achieved via sub-cycle control of the tunnel ionization dynamics in the bichromatic driving field. Most schemes for increasing the HHG efficiency rely on phase matching and involve careful control of a large number of experimental parameters. However, our scheme is robust to phase matching effects and requires control of just a single parameter, namely the ionization rate. The robustness of this approach makes great strides toward improving the simplicity and practicality of high flux HHG sources.

A 26.33 Wed 17:00 P OGs

XUV-Pump-Probe Transient Absorption Spectroscopy on Neon at the Free Electron Laser in Hamburg (FLASH) — •Thomas Ding[1], Marc Rebholz[1], Lennart Aufleger[1], Maximilian Hartmann[1], Kristina Meyer[1], Alexander Magunia[1], David Wachs[1], Veit Stooss[1], Paul Birk[1], Gergana Borisova[1], Andrew Attar[2], Thomas Gaumnitz[3], Zhi Heng Loh[4], Sebastian Roling[5], Marco Butz[5], Helmut Zacharias[5], Stefan Düsterer[6], Rolf Treusch[6], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck Institut für Kernphysik, Heidelberg, Germany — [2]University of California Berkeley, Berkeley, USA — [3]Eidgenössische Technische Hochschule Zürich, Zürich, Switzerland — [4]Nanyang Technological University Singapore, Singapore — [5]Westfälische Wilhelms-Universität Münster, Münster, Germany — [6]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

We present first transient-absorption spectroscopy experiments with extreme ultraviolet (XUV) pump and probe pulses delivered by FLASH. Applying our pump-probe scheme at photon energies around 50 eV and pulse durations of about 50 fs to neon, we traced strong-field-induced spectral modifications in the bound-electron response of the neutral and the ionized atom. The method also provides in-situ temporal diagnostics of self-amplified spontaneous emission (SASE) FEL pulses from the measured spectral cross-correlation signatures. In the near future, this scheme will be extended to a multi-pulse nonlinear spectroscopy technique to probe the excitation transfer and electronic redistribution dynamics among different sites of a molecule.

A 26.34 Wed 17:00 P OGs

Modification of Coulomb focusing of tunneled electrons in intense elliptically polarized mid-IR laser fields — •Jiří Daněk[1], Karen Z. Hatsagortsyan[1], Jochen Maurer[2], Benjamin Willenberg[2], Benedikt W. Mayer[2], Christopher R. Phillips[2], Lukas Gallmann[2,3], Ursula Keller[2], and Christoph H. Keitel[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]Department of Physics, ETH Zurich, Switzerland — [3]Institute of Applied Physics, University of Bern, Switzerland

Photoelectron momentum distributions (PMD) in the tunneling regime of ionization in an elliptically polarized laser field (3.4 μm) are investigated using classical-trajectory Monte-Carlo simulations. The signatures of the Coulomb field of the atomic core are identified and explained. In addition to the known Coulomb effect on the rotation of the PMD ellipse due to the Coulomb momentum transfer at the tunnel exit along the laser instantaneous polarization direction, we find the effect of the recollisions in the PMD at small values of the ellipticity. The recollisions are essentially modified in the elliptically polarized laser field, as the Coulomb focusing (CF) is very sensitive to all forces acting on the tunneled electrons. However, similarity of the CF in a linearly polarized case and in a case of a small ellitpicity can be found. The appearance and visibility of new features of PMD depend strongly on ellipticity and regimes can be identified where different features dominate. We focus on the theoretical analysis and investigate the PMD modifications analytically in the recollision picture, and present a qualitative analysis via the modified classical trajectories.

A 26.35 Wed 17:00 P OGs

The Effect of Electron Correlation on the Ionisation of Helium in Strong and Short Laser Pulses — •Gergana Borisova, Veit Stooss, Andreas Fischer, Alexander Blättermann, Thomas Ding, Andreas Kaldun, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Here, we present theoretical results from our study of the electron dynamics in the helium atom interacting with strong laser fields (XUV-excitation and NIR-perturbing pulse) on the attosecond timescale.
We investigate the role of electron-electron correlation dynamics to explain the experimentally observed abrupt ionisation of N = 2 doubly excited states in helium above a certain critical NIR-laser intensity. For this we employ a numerical quantum-mechanical model based on solving the one-dimensional time-dependent Schrödinger equation for two electrons. The theoretical method ensures direct access to the time-dependent population of the relevant atomic states during and right after the laser pulse. The simulation results obtained confirm our experimental observations and give important clues to the role of the electron-electron interaction in the ionisation processes.

A 26.36 Wed 17:00 P OGs

Direct Observation and Characterization of Multiple Strong-Field Ionization Continua Participating in Electron Rescattering — •Felix Schell, Timm Bredtmann, Serguei Patchkovskii, Marc Vrakking, Claus Peter Schulz, and Jochen Mikosch — Max Born Institute, Berlin, Germany

In laser-driven electron rescattering, the field of an intense fs laser pulse first ionizes a molecule and then accelerates the released electron back to the core, from which it scatters elastically. For polyatomic molecules, multiple ionization continua originating from the homo and

lower-lying states are known to be populated and thus expected to contribute to the signal of rescattered electrons. In this study, we separate electron rescattering correlated to different ion states in the strong-field ionization of 1,3-butadiene molecules. We extend the CRATI technique [1] to the recollision regime using a reaction microscope. We measure the channel-resolved rescattering yield as a function of ellipticity and - for laser-aligned molecules - in the molecular frame. The observed trends are rationalized by the anticipated nodal structure of the continuum electron wavepackets originating from the respective Dyson orbitals. These qualitative expectations are confirmed by multi-orbital TD-RIS [2] calculations.
[1] Science **335**, 1336 (2012).
[2] Phys. Rev. A **80**, 063411 (2009).

A 26.37 Wed 17:00 P OGs

Simulation of CEP-dependent above-threshold ionization with few-cycle laser pulses at 1800 nm — •Yinyu Zhang[1,2], Danilo Zille[1,2], Philipp Kellner[1], Daniel Adolph[1,2], Daniel Wüzler[1,2], Philipp Wustelt[1,2], Max Möller[1], Arthur Maxwell Sayler[1,2], and Gerhard G. Paulus[1,2] — [1]Institut für Optik und Quantenelektronik, Max-Wien-Platz 1, 07743, Jena, Germany — [2]Helmholtz Institut Jena, Fröbelstieg 3, 07743, Jena, Germany

The carrier-envelope(CE)-phasemeter, which is based on a stereographic above-threshold ionization (ATI) measurement, has been proven to be a precise, real-time, single-shot CEP tagging and pulse length characterization technique at 800 nm [1]. However, for longer wavelengths, the higher ponderomotive energy increases electron return energies. This reduces the scattering probability and thus reduces the corresponding yield of the high energy back-scattered electrons detected by the CE-phasemeter, which makes the measurements challenging. Nevertheless, recent preliminary results have shown that determination of the CEP of 1800 nm pulses using stereo-ATI of Xenon is possible. Here, the stereo-ATI spectra in few-cycle pulses at 1800 nm are simulated using the semi-classic three-step model of strong-field ionization and are compared with experimental results. The simulation results provide guidelines for optimizing CE-phasemeter technology to allow measurements at longer wavelength with increased precision.
[1]T.Rathje et al.J.Phys.B:At.Mol.Opt.Phys.45(2012)074003

A 26.38 Wed 17:00 P OGs

Charge Redistribution in Clusters revealed by XFEL Photoelectron Spectra — •Abraham Camacho Garibay, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS, Dresden

Photoelectron spectroscopy in the sequential regime is usually expected to produce a plateau in the energy spectra for direct electrons of sufficiently high energy. This has been shown to be no longer the case if the cluster potential is high enough to trap the innermost emitted photoelectrons, but this effect appears to be hard to measure. We study a new case where field ionization sets in due to a deep cluster potential, this makes the charge distribution inhomogeneous, showing itself in the photoelectron spectra.

A 26.39 Wed 17:00 P OGs

Sum rules for the polarization correlations in electron-nucleus bremsstrahlung — •Doris Jakubassa-Amundsen[1] and Richard Pratt[2] — [1]Mathematisches Institut, LMU Munich, Germany — [2]Department of Physics and Astronomy, University of Pittsburgh, USA

The knowledge of polarization transfer from a spin-polarized beam electron to the emitted bremsstrahlung photon is important for beam diagnostics or for the production of polarized positrons in conversion targets. Allowing for an arbitrary direction of the electron spin, the polarization transfer is characterized by seven parameters in the case of coplanar geometry. The squares of these parameters obey a strict sum rule, irrespective of the atomic or nuclear interaction potential, which can be used to test the accuracy of the calculations. Approximate sum rules connecting only three parameters can help to determine one particular polarization correlation if the other two are known. Examples for light and heavy nuclei bombarded with electrons in the MeV region will be given, based on the partial-wave Dirac theory for bremsstrahlung.

A 26.40 Wed 17:00 P OGs

Collision energies in inelastic electron-ion interaction at the CSR — •Sunny Saurabh[1], Arno Becker[1], Roman Čurík[2], Claude Krantz[1], Chris Greene[3], Oldřich Novotný[1], Marius Rimmler[1], Stephen Vogel[1], Patrick Wilhelm[1], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Academy of Sciences of the Czech Republic, Prague, Czech Republic — [3]Purdue University, Indiana, United States of America

In the Cryogenic Storage Ring (CSR) at MPIK, molecular ions are stored over 1000 s in a low blackbody radiation field environment of ~10 K. Under these conditions molecular ions can radiatively relax toward the ro-vibrational ground state. To facilitate electron-ion collision experiments, a new electron cooler device is being implemented at the CSR. The electrons are produced at cold photocathode and magnetically guided and merged with ion beam in the CSR orbit. The merged beam geometry of the electron cooler is envisaged giving us tunable center of mass (COM) frame collision energies from 0 to several eV. The geometry of the merging and de-merging region of cooler, temperature of electrons and space-charge effects in the electron-ion interaction region cause a position dependence of the COM collision energy with also non-zero values for velocity matched electron-ion mean collision velocities. To understand this, detailed studies have been carried out. Lastly the role of electron induced excitation and de-excitation of HeH^+ ions will be presented for the first time in cold environment (~10 K). Electron induced excitation and cooling enter in competition with destruction and neutralization processes.

A 26.41 Wed 17:00 P OGs

(e, 2e + ion) study of electron-impact ionization and fragmentation of tetrafluoromethane at low energies (E0 =35.7 eV, 38 eV, 45 eV and 67 eV) — •Khokon Hossen[1,3], Xueguang Ren[1], S. V. K. Kumar[2], and Alexander Dorn[1] — [1]Max Planck Institute for Nuclear Physics, 69117 Heidelberg, Germany — [2]Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Mumbai 400 005, India — [3]University of Santiago de Compostela,15782 Santiago de Compostela, Spain

We present our recent results for the ionization and fragmentation dynamics of tetrafluoromethane (CF4) molecules induced by low-energy electron impact (E0 = 35.7 eV, 38 eV, 45 eV, and 67 eV). One goal of this experiment is to clarify the origin of a resonance structure for the CF2+ fragment channel around 36 eV impact energy. Experimentally, we use a reaction microscope and a pulsed photoemission electron beam [1]. The momentum vectors of the two outgoing electrons (energies E1, E2) and one fragment ion are detected in triple coincidence (e, 2e + ion). After dissociation, the fragment products from CF4 are CF3+, CF2+, CF+, F+ and C+. For all fragmentation channels, we observe the ionized orbital binding energy (BE) [E0 - E1 - E2], the kinetic energy release (KER) of the fragments and two-dimensional (2D) correlation map between BE and KER. E.g., from binding energy spectra, we can conclude which molecular orbitals are responsible to form the fragments of CF4. [1] X. Ren et al, J. Chem. Phys. 141 134314 (2014).

A 26.42 Wed 17:00 P OGs

Coulomb- and quantum-corrected strong-field approximation — •Michael Klaiber[1], Jiří Daněk[1], Enderalp Yakaboylu[2], Karen Z. Hatsagortsyan[1], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]IST Austria, Wien

Signatures of the Coulomb quantum corrections in the photoelectron momentum distribution during laser-induced ionization of atoms or ions in tunneling and multiphoton regimes are investigated analytically in the case of an 1D problem. Extended Coulomb corrected strong-field approximation (SFA) is applied, where the exact continuum state in the S-matrix is approximated by the eikonal Coulomb-Volkov state including quantum corrections. Although, without quantum corrections our theory coincides with the known analytical R-matrix (ARM) theory, we propose a simplified procedure for the matrix element derivation. Rather than matching the eikonal Coulomb-Volkov wave function with the bound state to remove the Coulomb singularity, as it was carried out in ARM theory, we calculate the matrix element via the saddle-point integration method by time as well as by coordinate which is avoiding the Coulomb singularity. The momentum shifts in the photoelectron momentum distribution with respect to the ARM-theory due to quantum corrections are analyzed for tunneling and multiphoton regimes.

A 26.43 Wed 17:00 P OGs

Investigation of two-frequency Paul traps for antihydrogen production — Nathan Leefer[1,2], •Kai Krimmel[1,3], William Bertsche[4,5], Dmitry Budker[1,3,2,6], Joel Fajans[2], Ron Folman[7], Hartmut Häffner[2], and Ferdinand Schmidt-Kaler[1,3]

— [1]Helmholtz-Institut Mainz, Mainz 55128, Germany — [2]Department of Physics, University of California at Berkeley, Berkeley, CA 94720 — [3]QUANTUM, Institut für Physik, Johannes Gutenberg-Universit\"at Mainz, Mainz 55128, Germany — [4]University of Manchester, Manchester M13 9PL, UK — [5]The Cockcroft Institute, Daresbury Laboratory, Warrington WA4 4AD, UK — [6]Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 — [7]Department of Physics, Ben-Gurion University of the Negev, Be'er Sheva 84105, Israel

Radio-frequency (rf) Paul traps operated with multifrequency rf trapping potentials provide the ability to independently confine charged particle species with widely different charge-to-mass ratios. In particular, these traps may find use in the field of antihydrogen recombination, allowing antiproton and positron clouds to be trapped and confined in the same volume without the use of large superconducting magnets. We explore the stability regions of two-frequency Paul traps and perform numerical simulations of small samples of multispecies charged-particle mixtures of up to twelve particles that indicate the promise of these traps for antihydrogen recombination.

A 26.44 Wed 17:00 P OGs

Pros and cons of time-dependent renormalized-natural-orbital theory — •Martins Brics, Julius Rapp, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Recently introduced time-dependent renormalized-natural-orbital theory (TDRNOT) is a promising approach to describe correlated electron quantum dynamics, even beyond linear response. It has been shown [1-4] that TDRNOT is capable of describing correlated phenomena such as doubly excited states, autoionization, and Fano profiles in absorption and photoelectron spectra, nonsequential double ionization, single photon double ionization, high-harmonic generation and Rabi oscillations.

In this work, we compare how TDRNOT performs against standard methods such us multiconfiguration time-dependent Hartree-Fock (MCTDHF). The main focus is the truncation error, which is a consequence of the fact that numerical calculations necessarily require a truncation of the number of natural orbitals/configurations.

[1] M. Brics, D. Bauer, Phys. Rev. A 88, 052514 (2013).
[2] J. Rapp, M. Brics, and D. Bauer, Phys. Rev. A 90, 012518 (2014).
[3] M. Brics, J. Rapp, and D. Bauer, Phys. Rev. A 90, 053418 (2014).
[4] M. Brics, J. Rapp, and D. Bauer, Phys. Rev. A 93, 013404 (2016).

A 26.45 Wed 17:00 P OGs

Comparison of three modes of operation for an optical magnetometer for exotic physics searches. — •Hector Masia-Roig, Arne Wickenbrock, and Dmitry Budker — Helmholtz Institute, Johannes Gutenberg University, Mainz

GNOME is a novel experimental scheme which enables the investigation of couplings between nuclear spins and exotic fields generated by astrophysical sources. It consists of a network of geographically separated, time synchronized, ultrasensitive ($\sim$ fT/$\sqrt{\text{Hz}}$) optical atomic magnetometers that measure atomic spin precession in multilayer magnetic shielding. Such a configuration enables the study of global transient effects due to non-magnetic interactions.

Currently, there are six magnetometers placed around the world which are able to measure synchronously. Here is presented a comparison between three different modes of operation of an atomic magnetometer. The bandwidth and sensitivity is analyzed for an open loop, phase lock loop and self-oscillating configurations. The outcome points the phase lock loop configuration as optimal for the GNOME network. With this configuration an optimal compromise between sensitivity and bandwidth is reached.

A 26.46 Wed 17:00 P OGs

CASPEr: The Cosmic Axion Spin Precession Experiment — •Nataniel Figueroa Leigh[1], Gary Centers[1], Marina Gil Sendra[1], Arne Wickenbrock[1], John Blanchard[1], Dmitry Budker[1], and CASPEr Collaboration[2] — [1]Helmholtz Institute, Johannes Gutenberg University, Mainz — [2]Various Locations

Out of all the mass in the universe, no one knows what $\sim$ 85% of it is made of; this makes dark matter one of the biggest open questions in physics. In this context, the axion rises as a prime candidate that could account for the dark matter content of the universe. The CASPEr experiment seeks to exclude parameter space of (or find) axions by using a spin ensemble that transduces the usually inert axion wind field into a measurable magnetic signal, which can then be detected using conventional methods. What makes this challenging is that the coupling of the axions to the spin “antenna" -and thus, the signal- is small, which must be accounted for by using techniques that enhance the signal. This poster presents the overall CASPEr experiment and recent advances towards a working CASPEr-Wind experiment in Mainz.

A 26.47 Wed 17:00 P OGs

Progress towards hyperpolarized liquid xenon for the Cosmic Axion Spin Precession Experiment (CASPEr-Wind) — •Gary Centers[1], John Blanchard[1], Nataniel Figueroa[1], Marina Gil Sendra[1], Arne Wickenbrock[1], Dmitry Budker[1], and CASPEr Collaboration[2] — [1]Helmholtz Institute Mainz, Johannes Gutenberg University, 55128 Mainz, Germany — [2]Various locations

The Cosmic Axion Spin Precession Experiment (CASPEr), particularly the CASPEr-Wind, is a detection scheme searching for light particles that have a coupling to nuclear spin; some examples being dark matter candidates like the axion/axion-like particles, hidden photons, or any pseudo-Goldstone boson[1,2,3].

Current progress towards the condensation of hyperpolarized xenon (Xe) gas as the main sample for the CASPEr is presented. Included will be an overview of condensation process, a review of gas and liquid Xe relaxation processes, components designed for maintaining polarization during the condensation, and preliminary process/component characterizations.

[1] D. Budker et al., Phys. Rev. X 4, 021030 (2014).

[2] P. W. Graham and S. Rajendran, Phys. Rev. D 88, 035023 (2013).

[3] P. W. Graham et al., Annu. Rev. Nucl. Part. Sci. 65, 485514 (2015).

A 26.48 Wed 17:00 P OGs

Characterization of Xenon polarizer for the Cosmic Axion Spin Precession Experiment — •Marina Gil Sendra — Johannes Gutenberg Universität Mainz — Helmholtz Institute Mainz

In this poster we present a scheme for the atomic polarizer for the CASPEr collaboration.

CASPEr aims for the detection of possible candidates for dark matter, axions, via their interaction with atomic nuclei. The signals from these particles will be weak so all possibilities for signal enhancement need to be considered. The chosen nuclei for the experiment are ^{129}Xe that are hyperpolarized using the spin-exchange optical pumping technique, in which the polarizarion is transferred via Fermi Contact Interaction from an alkali metal, Rubidium. The hyperpolarized Xenon is to be placed in a magnetic field that will be swept from ultralow field up to 14 T.

A 27: Laser Applications: Optical Measurement Technology (with Q)

Time: Thursday 11:00–12:15 Location: P 5

Group Report A 27.1 Thu 11:00 P 5

Novel optical beams, from accelerating wavepackets to Janus waves — •Dimitrios Papazoglou[1,2] and Stelios Tzortzakis[1,2,3] — [1]Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, P.O. Box 1527, 71110, Heraklion, Greece — [2]Department of Material Science and Technology, University of Crete, P.O. Box 2208, 71003, Heraklion, Greece — [3]Science Program, Texas A&M University at Qatar, P.O. Box 23874, Doha, Qatar

Lately a plethora of optical beams with non-trivial amplitude and phase distributions like for example the accelerating Airy and ring-Airy beams have been introduced. These novel optical beams propagate in curved trajectories and resist to diffraction or dispersion. Therefore, they are able to self-heal and bypass obstacles, advantages that make them exiting for applications ranging from materials processing to telecommunications. Recently we have revealed that these waves are members of the broader family of Janus waves. Counterintuitively, when these Janus waves are focused, two focal regions, instead of one are formed. On the other hand, the generation and control of these wavepackets is not trivial. Their complexity challenges our current state of the art techniques for wavefront shaping, and has urged us to exploit, among others, unconventional approaches like the use of optical aberrations. The talk will focus on the exciting ongoing quest of materializing these novel optical wavepackets, and their usage to a broad range of applications ranging from tailored filaments, light bullets, multi-photon polymerization and THz generation.

A 27.2 Thu 11:30 P 5

"Single Pixel" Imaging and its application in beam profile analysis — •Daniel Laukhardt, Till Mohr, Sébastien Blumenstein, and Wolfgang Elsässer — Technische Universität Darmstadt, Darmstadt, Germany

Nowadays it is not implicitly necessary to make use of high resolution cameras in order to get spatial resolved images. With the progress of computational capacity the application of single pixel detectors appeared more frequently in the scope of imaging. To achieve spatial resolution in this single pixel detector concept, a set of particular masks is needed which is sequentially projected onto the object, providing the spatial information. This task can be fulfilled by digital micromirror devices (DMD) which have the advantage of a high reflectivity in a broad wavelength range. Recent applications of single pixel imaging range from real time 3D imaging in the visible spectrum [1] to imaging in the terahertz spectral region [2].

In this contribution, we perform beam profile analysis using the single pixel imaging concept for a large wavelength span using a DMD and three different single pixel detectors. Thereby we are able to measure the beam profile of different light sources covering the range from the blue visible to the mid infrared spectral region.

[1] B. Sun et al., Science, Vol. 340, Issue 6134, pp. 844-847 (2013)
[2] W. L. Chan et al., Appl. Phys. Lett., Vol. 93, 121105 (2008)

A 27.3 Thu 11:45 P 5

Miniature cavity-enhanced diamond magnetometer — •Georgios Chatzidrosos[1], Arne Wickenbrock[1], Lykourgos Bougas[1], Nathan Leefer[2], Teng Wu[1], Kasper Jensen[3], Yannick Dumeige[4], and Dmitry Budker[1,2,5,6] — [1]Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany — [2]Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, 2100 Copenhagen, Denmark — [3]CNRS, UMR 6082 FOTON, Enssat, 6 rue de Kerampont, CS 80518, 22305 Lannion cedex, France — [4]Helmholtz Institut Mainz, 55099 Mainz, Germany — [5]Department of Physics, University of California, Berkeley, CA 94720-7300, USA — [6]Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

We present a miniaturized cavity-enhanced room-temperature magnetic field sensor based on nitrogen vacancy (NV) centers in diamond. The magnetic resonance signal is detected by probing absorption on the 1042 nm spin-singlet transition. The enhanced absorption of the infrared light gives an improved signal contrast greater than 13% at room temperature. Based on this, we demonstrate a magnetic-field sensitivity of $120\,\mathrm{pT}/\sqrt{\mathrm{Hz}}$, and a projected a photon shot-noise-limited sensitivity of $12\,\mathrm{pT}/\sqrt{\mathrm{Hz}}$ for the amount of infrared light collected, while the quantum projection-noise-limited sensitivity for our sensing volume of $\sim 390\mu\mathrm{m} \times 1200\ \mu\mathrm{m}^2$ is estimated to be $0.7\,\mathrm{pT}/\sqrt{\mathrm{Hz}}$

A 27.4 Thu 12:00 P 5

Microwave-free magnetometry with nitrogen-vacancy centers in diamond — •Huijie Zheng[1,2], Arne Wickenbrock[1,2], Lykourgos Bougas[1,2], Nathan Leefer[1,2], Samer Afach[2], Andrey Jarmola[3], Victor. M Acosta[4], and Dmitry Budker[1,2,3,5] — [1]Johannes Gutenberg-Universitaet Mainz, 55128 Mainz, Germany — [2]Helmholtz Institut Mainz, 55128 Mainz, Germany — [3]University of California, Berkeley, CA 94720-7300, USA — [4]University of New Mexico, Center for High Technology Materials, Albuquerque, NM 87106, USA — [5]Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

We demonstrate a method of all-optical magnetometry by using magnetic-field-dependent features in the photoluminescence of negatively charged nitrogen-vacancy centers. In particular, our method relies on the level anti-crossing (LAC) in the triplet ground state at 102.4mT without the requirement of microwaves. Firstly, we present a magnetometer with a demonstrated noise floor of $6\,\mathrm{nT}/\sqrt{\mathrm{Hz}}$. Secondly, we show how the sensitivity is improved by implementing a more dilute diamond sample with a smaller linewidth of the LAC feature in a more homogeneous background field. The technique presented here removes the microwave requirements for magnetometry with NV centers which makes the scheme potentially useful in applications where the sensor is placed close to conductive materials.

A 28: Ultracold Plasmas, Rydberg Systems and Molecules (with Q)

Time: Thursday 11:00–13:15 Location: P 104

Group Report A 28.1 Thu 11:00 P 104

Coherent excitation of a single trapped Rydberg ion — •Fabian Pokorny[1], Gerard Higgins[1,2], Chi Zhang[1], Quentin Bodart[1], and Markus Hennrich[1] — [1]Department of Physics, Stockholm University, 10691 Stockholm, Sweden — [2]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria

Trapped Rydberg ions are a novel approach for quantum information processing [1]. By combining the high degree of control of trapped ion systems with the long-range dipolar interactions of Rydberg ions [2], fast entanglement gates may be realised in large ion crystals [3].

Quantum information processing in such a system links qubit rotations in the ions' ground states with entanglement operations via the Rydberg interaction. This combination of quantum operations requires that the Rydberg excitation can be controlled coherently.

In the experiments presented here a strontium ion confined in a linear Paul trap was excited to the Rydberg state via a two-photon excitation with 243nm and 307nm light [4]. We observed EIT in this system and mapped the population to the Rydberg state and back via STIRAP. This is the first observed coherently manipulated Rydberg excitation of an ion.

[1] M. Müller, et al., New J. Phys. **10**, 093009 (2008)
[2] D. Jaksch, et al., Phys. Rev. Lett. **85**, 2208 (2000)
[3] F. Schmidt-Kaler, et al, New J. Phys. **13**, 075014, (2011)
[4] G. Higgins, et al, arXiv:1611.02184v1, (2016)

A 28.2 Thu 11:30 P 104

Multicritical behavior in dissipative Ising models — •Vincent Overbeck[1], Mohammad Maghrebi[2], Alexey Gorshkov[2], and Hendrik Weimer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Joint Quantum Institute and Joint Center for Quantum Information and Computer Science, NIST/University of Maryland, College Park, Maryland 20742, USA

Physical phenomena of dissipative quantum many-body systems can be quite different from those of their equilibrium counterparts. We analyze a Z_2- preserving dissipative Ising model using a variational principle [1,2]. In the steady state phase diagram, we find in addition to a continuous transition, a first order transition between an ordered and an unordered phase and a tricritical point. We extend our analysis by a Ginzburg-Landau approach, verifying in detail the validity of our product state ansatz. We show that fluctuations due to spatial inhomogeneities are produced in the same way as in equilibrium, allowing us to determine an upper critical dimension, above which fluctuations in the multicritical regime vanish and the critical exponents of our product state theory become correct. Finally, we will present a renormalization group analysis of our functional, investigating how a one loop correction influences the position of the tricritical point.

[1] H. Weimer, Variational Principle for Steady States of Dissipative Quantum Many-Body Systems, Phys. Rev. Lett. 114, 040402 (2015).
[2] H. Weimer, Variational analysis of driven-dissipative Rydberg gases, Phys. Rev. A 91, 063401 (2015).

A 28.3 Thu 11:45 P 104

Critical properties of a one-dimensional adsorbing state model — •Maryam Roghani and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße

2, 30167 Hannover, Germany

We study a quantum version of a one-dimensional adsorbing state model [1]. We find evidence for a steady state phase transition between a phase with algebraic correlations (active) and a phase with exponential decay (inactive). Remarkly, this transition appears to be present despite the system being in a mixed state. In the active phase, we also look into the quantum mutual information of the steady state, comparing to scaling predictions from conformal field theory.

[1]. M. Marcuzzi, M. Buchhold, S. Diehl, and I. Lesanovsky, Phys. Rev. Lett. 116, 245701 (2016)

A 28.4 Thu 12:00 P 104

Structure Formation in a Correlated Rydberg Gas — •Andre Salzinger[1], Elena Kozlikin[2], Martin Pauly[2], Alexander Schuckert[3], Robert Lilow[2], Matthias Bartelmann[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Heidelberg — [2]Institut für Theoretische Astrophysik, Heidelberg — [3]Institut für Theoretische Physik, Heidelberg

Cosmic structure formation can be described by a classical path integral formalism. We apply such a theoretical framework to predict structure formation in an initially correlated ensemble of Rydberg atoms. The free Hamiltonian motion of particles and their initial correlation function are contained in a generating functional. We model the non-classical excitation process including blockade and anti-blockade effects to emulate realistic initial conditions. Interactions between the particles are introduced via an operator acting perturbatively on the free generating functional which is evolved in time. Collective properties, such as density correlations can be extracted by applying appropriate operators.

We will discuss different experimental implementations with the aim of directly or indirectly observing the impact of initial correlations on structure formation.

A 28.5 Thu 12:15 P 104

Many-body dynamics of driven-dissipative Rydberg cavity polaritons — •Tim Pistorius and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

The usage of photons as long-range information carriers has greatly increased the interest in systems with nonlinear optical properties in recent years. The nonlinearity is easily achievable in Rydberg mediums through the strong van der Waals interaction which makes them one of the best candidates for such a system. Here, we propose a way to analyze the steady state solutions of a Rydberg medium in a cavity through the combination of the variational principle for open quantum systems [1] and the P-distribution of the density matrix. To get a better understanding of the many-body-dynamics a transformation into the polariton picture is performed and investigated.

[1] H. Weimer, Variational Principle for Steady States of Dissipative Quantum Many-Body Systems, Phys. Rev. Lett.114, 040402 (2015).

A 28.6 Thu 12:30 P 104

Pulsed Rydberg four-wave mixing in a microcell — •Fabian Ripka, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart

Photonic quantum devices based on atomic vapors at room temperature combine the advantages of atomic vapors being intrinsically reproducable as well as semiconductor-based concepts being scalable and integrable. One key device in the field of quantum information are on-demand single-photon sources. A promising candidate for realization relies on the combination of two effects in atomic ensembles, namely four-wave mixing (FWM) and the Rydberg blockade effect.

Coherent dynamics to Rydberg states [1] and sufficient Rydberg interaction strengths [2] have already been demonstrated in thermal vapors. Also in a pulsed FWM scheme coherent phenomena could be observed [3,4]. Additionally, time-resolved probing of collective Rydberg excitation has been performed [5], revealing a lifetime long enough for effective Rydberg-Rydberg interactions.

We report on the latest results of Rydberg four-wave mixing in a volume size comparable to the Rydberg interaction range. This scheme promises to enable the creation of non-classical light states.

[1] Huber et al., PRL 107, 243001 (2011)
[2] Baluktsian et al., PRL 110, 123001 (2013)
[3] Huber et al., PRA 90, 053806 (2014)
[4] Chen et al., Appl. Phys. B, 122:18 (2016)
[5] Ripka et al., Phys. Rev. A, 053429 (2016)

A 28.7 Thu 12:45 P 104

Creating ^{23}Na^{40}K ground state molecules with detuned STIRAP — •Frauke Seeßelberg[1], Xin-Yu Luo[1], Nikolaus Buchheim[1], Zhenkai Lu[1], Immanuel Bloch[1,2], and Christoph Gohle[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Molecules in their absolute vibrational and rotational ground state promise exciting new possibilities for quantum simulation due to their large inducible dipole moments. It is however challenging to obtain molecules, which are sufficiently cold and dense enough for this purpose.

Starting from a near quantum degenerate Bose-Fermi mixture of sodium and potassium we employ stimulated Raman adiabatic passage (STIRAP). STIRAP is a two-photon process, with which we transfer weakly bound heteronuclear NaK Feshbach molecules via an intermediate, excited molecular state in the d/D potential manifold to the molecular ground state. To reduce excessive scattering from near resonant levels in the excited state, we go one-photon detuned with respect to this intermediate molecular level. We experimentally investigate the efficiency of the STIRAP process at various one-photon detunings and compare them with a theoretical model.

A 28.8 Thu 13:00 P 104

Precision two-color spectroscopy of ^{40}Ca for the determination of the s-wave scattering length — •Veit Dahlke[1], Evgenij Pachomow[1], Eberhard Tiemann[2], Fritz Riehle[1], and Uwe Sterr[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

By two-color photoassociation of ^{40}Ca four weakly bound vibrational levels in the Ca$_2$ $X^1\Sigma_g^+$ ground state potential were measured, using highly spin-forbidden transitions to intermediate states of the coupled system $^3\Pi_u$ and $^3\Sigma_u^+$ near the $^3P_1{+}^1S_0$ asymptote. We have interrogated cold ensembles of about 10^5 calcium atoms trapped in a crossed optical dipole trap at temperatures of approximately 1 μK. The unperturbed binding energies have been measured with kHz accuracy benefiting from few Hertz linewidth offset-locked tunable lasers and detailed lineshape analysis.
From the observed binding energies, including the least bound state, the long range dispersion coefficients $\mathrm{C}_6, \mathrm{C}_8, \mathrm{C}_{10}$ and a precise value for the s-wave scattering length were derived. The precise description of the asymptotic potential was also used to determine scattering lengths for all stable isotopes of calcium.

A 29: Ultrashort Laser Pulses: Generation and Applications (with Q)

Time: Thursday 14:30–16:45 Location: P 5

A 29.1 Thu 14:30 P 5

Frequency conversion from the near-infrared to the deep UV with an MgO crystal — •Dennis Mayer, Mario Niebuhr, Christian Matthaei, Axel Heuer, and Markus Gühr — Institut für Physik und Astronomie, Universität Potsdam

Femtosecond pulses in the deep and vacuum ultraviolet region are ideal probes for ultrafast molecular and solid state photoelectron spectroscopy. Due to the recent progress in amplified high repetition rate sources, the nonlinear conversion schemes established at kHz repetition rates need to be scaled to a regime of higher average flux and lower per pulse energy. Newly established solid state harmonic generation provides advantages over conventional gas phase harmonic generation in terms of the conversion efficiency [1]. However, this comes at the cost of higher absorption and shorter effective harmonic generation length.

We concentrate on the generation of harmonics in wide bandgap insulators and on the harmonics emitted below the bandgap. We utilize a 100 kHz amplified Yb:KGW system and present a systematic study of femtosecond nonlinear conversion in MgO.

[1] Y.S. You et al., Nature Physics (2016)

A 29.2 Thu 14:45 P 5

Development and characterization of a pulse preserving XUV multilayer monochromator — •Tanja Neumann[1], Yudong Yang[2], Roland Mainz[2], Franz Kärtner[2], and Thorsten Uphues[1] — [1]CFEL, Attosecond Research and Science Group, Hamburg University, Luruper Chaussee 149, 22761 Hamburg — [2]Center for Free-Electron Laser Science, DESY and Department of Physics, University of Hamburg, Hamburg, Germany

HHG based time-resolved experiments in the XUV are a key technologie to study atomic, surface and chemical processes in realtime. Some of these experiments require high energy resolution to distinguish between spin compenents or resolve chemical shifts in the corresponding energy spectra. In the frame work of a master thesis a narrow bandwidth multilayer mirror monochromator (MMM) was developed for separation and energy tunability of a well defined spectral bandwidth from a high order harmonic spectrum generated by 25 femtosecond laser pulses at 800 nm central wavelength. The MMM is tailored to the experimental requirements of a surface experiment and is able to select a defined bandwidth of less than 1 eV from the harmonic spectrum in the photon energy range between 90 and 98 eV. For time resolved experiments it designedto be used at the same time to recombine the laser pulse and the XUV pulse and focus them down to the experiment maintaining temoral and spectral overlap in the given energy range. A major advantage of the MMM is the preservation of the time structure of the XUV and laser pulse, thus addition dispersion correction is not needed.

A 29.3 Thu 15:00 P 5

Design and testing of a setup for sub two-cycle optical pulse compression from Ti:sapphire oscillators — •Philip Dienstbier[1], Takuya Higuchi[1], Francesco Tani[2], Michael Frosz[2], John Travers[3], Philip St. J. Russell[2], and Peter Hommelhoff[1] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstraße 1, 91058 Erlangen, Germany — [2]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [3]Heriot-Watt University, Edinburgh, EH14 4AS, United Kingdom

Ultrashort pulsed lasers with a duration of a single oscillation of the electric field are an ideal tool to investigate the sub-cycle dynamics of electrons under an intense field [1] as the temporal contrast is increased. Recent observation of rescattering physics at nanotips with the aid of optical field enhancement suggests that the strong-field regime can be reached with pulse energies even below 1 nJ [2]. Commercial laser systems in the nJ-regime such as Ti:sapphire oscillators however are limited to pulse durations around two optical cycles. Here we present a setup to spectrally broaden the output of a Ti:sapphire oscillator by a customized solid-core photonic crystal fiber and a prism based 4f-pulse compressor with expected compression down to 3 fs corresponding to a single optical cycle. A MIIPS pulse characterization scheme for various overlapping spectral ranges was realized and used to test the pulse compressor.

[1] M. T. Hassan et al., Rev. Sci. Instrum. **83**, 111301 (2012).

[2] M. Krüger, M. Schenk and P. Hommelhoff, Nature **475**, 78 (2011).

A 29.4 Thu 15:15 P 5

Design and simulation of a NOPA for the pulse diagnostics XUV PUMA at FLASH, DESY — •Niklas Borchers[1,2], Martin Büscher[1,2], Mark Prandolini[3], Sven Toleikis[3], Bert Struve[1], and Ulrich Teubner[1,2] — [1]Institut für Laser und Optik, Hochschule Emden/Leer, D-26723 Emden — [2]Institut für Physik, Universität Oldenburg, D-26129 Oldenburg — [3]Deutsches Elektronen-Synchrotron DESY, D-22607 Hamburg

To allow precise measurement of the jitter and pulse duration of free electron lasers such as FLASH on a shot to shot basis novel techniques are necessary. Of course, this is a difficult task in the extreme ultra violet spectral region (4.2 to 45nm; XUV), in particular in combination with the ultrashort time scales (<50fs). A corresponding diagnostic which is based on a plasma gate is XUV PUMA (Pulsdauermeßapparatur), which is currently under development. As the resolution is mainly limited by the probe pulse, ultrashort tunable sub- 30fs pulses in a range from 580nm to 680nm wavelength with a pulse energy >1μJ are required for the cross correlator as one key element of the diagnostics. The pulses will be generated with a NOPCPA (non-collinear optical parametric chirped pulse amplifier). Prior to set-up, the NOPCPA has been simulated in all major aspects (SHG, dispersion, efficiency, etc.) using a tailored MATLAB program. With the aid of the simulation, a compact system, as required by the FLASH beamline end station, has been designed to optimally match the parameters required by the XUV PUMA. This work is sponsored by BMBF 05K16ME1.

A 29.5 Thu 15:30 P 5

Non-Collinear Circular Polarized High Harmonic Generation — •Patrik Grychtol[1], Jennifer Ellis[1], Kevin Dorney[1], Carlos Hernández-García[2], Franklin Dollar[1], Christopher Mancuso[1], Tinting Fan[1], Dmitriy Zusin[1], Christian Gentry[1], Charles Durfee[3], Daniel Hickstein[1], Henry Kapteyn[1], and Margaret Murnane[1] — [1]JILA-NIST and Department of Physics, University of Colorado, Boulder, CO 80309, USA — [2]Grupo de Investigación en Aplicaciones del Láser y Fotónica, Departamento de Física Aplicada, University of Salamanca, Spain — [3]Department of Physics, Colorado School of Mines, Golden, CO 80401, USA

The process of high harmonic generation (HHG) allows for producing attosecond bursts of extreme ultraviolet and soft x-ray light on the tabletop. HHG sources are ideal tools for a variety of scientific and technologically important applications, such as imaging of nanoscale material properties, ultrafast spectroscopy of photoelectrons or element-specific characterization of spin dynamics. While the emission of bright HHG radiation had been limited to linear polarization for quiet a long time, recent exciting breakthroughs have demonstrated the production of high harmonic beams with controllable polarization using two counter-rotating circularly polarized driving laser beams in a collinear or non-collinear geometry. This contribution will focus on the non-collinear case, which offers several key benefits, such as the polarization selective angular separation of the harmonics without a spectrometer. Furthermore, it will be demonstrated how full phase-matching in a non-collinear geometry can be achieved.

A 29.6 Thu 15:45 P 5

Synchronous interaction of free electrons with optical evanescent wave excited by femtosecond laser pulses — •Martin Kozak, Paul Beck, Joshua McNeur, Norbert Schönenberger, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen

In recent years, the coherent interaction between optical near-fields and free-electrons became the basis for several experimental techniques focused on electron acceleration (dielectric laser accelerators, DLAs [1]) or energy-resolved electron imaging (photon-induced near-field electron microscopy, PINEM [2]). In classical DLA schemes, the synchronous near-field mode is excited by femtosecond laser pulse on top of a periodic dielectric element with period smaller than the laser wavelength [1]. Preparation of such a nanoscale phase-mask elements requires advanced nanofabrication. In this contribution we show the first demonstration of the synchronous interaction between free propagating electrons and an evanescent optical wave excited by total internal reflection on the flat surface of high-refractive index dielectrics. The maximum observed energy modulation is comparable to the grating-based DLA and is limited by the electron group velocity dephasing with respect to the phase velocity of the evanescent wave. Light coupling to the synchronous evanescent wave can be in future improved using the evanescent field of a transverse magnetic mode guided in an optical waveguide. [1] J. Breuer, and P. Hommelhoff, Phys. Rev. Lett. 111, 134803 (2013). [2] B. Barwick, D. J. Flannigan, and A. H. Zewail, Nature 462, 902-906 (2009).

A 29.7 Thu 16:00 P 5

Ultrashort pulsed compact 2050 nm fiber laser accelerating electrons at a dielectric structure — Heinar Hoogland[1,2], Joshua McNeur[2], Martin Kozák[2], •Peter Hommelhoff[2], and Ronald Holzwarth[1] — [1]Menlo Systems GmbH, Am Klopferspitz 19a, 82152 Martinsried, Germany — [2]Lehrstuhl für Laserphysik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 1, 91058 Erlangen, Germany

A robust all-polarization maintaining fiber laser system at 2050 nm emitting femtosecond pulses at 1-MW peak power level is studied for subsequent dielectric laser acceleration of non-relativistic electrons. The laser setup consists of a Thulium/Holmium codoped gain fiber based oscillator in figure-9 design and a pulse picked chirped pulse two-stage amplifier arrangement. Both temporal stretching as well as recompression of the 2050 nm pulses are achieved by exploiting a single chirped volume Bragg grating, circumventing a bulky diffraction grating based temporal pulse management solution that is highly prone to mechanical perturbations. The laser emits strictly linear polarized pulses at 370-fs pulse duration and 570 nJ pulse energy. By applying this compact fiber laser architecture to a table-top sized "teeny-tiny" accelerator device based on a single Silicon nanograting, 25-keV electrons are accelerated by gradients up to 53 MeV/m. The overall compactness of the entire experimental stage allows for drastically reduced electron accelerator dimensions over traditional large-scale radio-frequency linear accelerator arrangements.

A 29.8 Thu 16:15 P 5

Temporal characterization of femtosecond electron bunches in a laser-triggered scanning electron microscope — •Norbert Schönenberger, Martin Kozák, Joshua McNeur, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen

To study the dynamics in atomic and condensed matter systems, including phonon excitations and electron dynamics in atoms and molecules, sub-femtosecond timescales need to be resolved. The temporal resolution of these ultrafast experiments with electron beams is limited by both the electron dispersion in vacuum and the Coulomb repulsion between electrons. Here we present the temporal characterization of electron bunches emitted from a Schottky-type tip source inside a standard scanning electron microscope (SEM). Photoemission from the tip is induced by 100 fs ultraviolet pulses. The temporal profile of the bunch is obtained by energy- and time-resolved cross-correlation measurements between the electron bunch and the electromagnetic near-field mode of an infrared laser pulse traversing a periodic dielectric nanostructure. We study the influence of the bunch charge and the settings of the electron column on the longitudinal behaviour of the electron packets emitted from the tip to gain further insight into the behaviour of new electron sources, sub-femtosecond-resolved dielectric laser accelerator (DLA) diagnostics and electron diffraction and microscopy experiments [1].

[1] Martin Kozák, et al. Optical gating and streaking of free-electrons with attosecond precision, arXiv:1512.04394 (2015)

A 29.9 Thu 16:30 P 5

Ultrafast laser fabrication of biomimetic micro and nano structured surfaces — •Evangelos Skoulas — N.Plastira 100, Heraclion, Greece

We report on the fabrication of artificial biomimetic surfaces fabricated via femtosecond laser processing. Metallic, semiconductor and dielectric surfaces were irradiated and Laser Induced Surface Structures (LIPSS) were observed in each type of material surface. In particular femtosecond laser pulses with linear, circular, radial and azimuthal polarization states were utilized for structuring steel (metallic), silicon (semiconductor) and fused silica (dielectrics) surfaces. Experimental results showed that the direction of LIPSS in each case proved to be polarization dependent. A complete study was carried out for the investigation and understanding of LIPSS dependence on fluence value and the number of pulses per spot at two different wavelengths of irradiation enabling the creation of new and more complex surface structures. Furthermore, different LIPSS morphologies and geometries were observed. Additionally large area surfaces were fabricated, tailored with various micro and nano structures bearing great structural resemblance with surfaces found in nature such as lotus leaf, shark skin and butterfly Greta Oto wing. Those bioinspired surfaces were found to exhibit remarkable optical and wetting properties which were attributed to the specific laser induced surface morphology. Thus femtosecond laser processing can be a novel and one single-step method for the fabrication of functional surfaces on almost all classes of solid materials.

A 30: Ultracold Atoms I (with Q)

Time: Thursday 14:30–16:30 Location: P 104

Group Report A 30.1 Thu 14:30 P 104

Optical traps for single ions and Coulomb crystals — •Leon Karpa, Julian Schmidt, Alexander Lambrecht, Pascal Weckesser, Yannick Minet, Fabian Thielemann, Markus Debatin, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs Universität Freiburg, Germany

We demonstrate optical trapping of $^{138}Ba^{+}$ ions without residual rf-confinement for durations of up to 3 s, an improvement in lifetime by 3 orders of magnitude compared to recent experiments[1,2]. With the trapping probability approaching unity for durations of 100 ms combined with low heating and electronic decoherence rates our results establish optical ion trapping as a novel and robust tool for the manipulation of cold trapped ions, e.g. in atom-ion interaction experiments[3].

The presented approach can also be applied for all-optical trapping of Coulomb crystals which we demonstrate by spectroscopy of a crystal excited within the optical trap. We discuss possible applications of our results in the fields of ultracold chemistry and structural quantum phase transitions.

[1] C. Schneider, M. Enderlein, T. Huber and T. Schaetz, Nat. Photon. **4**, 772 (2010)
[2] Huber, A. Lambrecht, J. Schmidt, L. Karpa and T. Schaetz, Nat. Commun. **5**, 5587 (2014)
[3] see e.g.: A. Grier, M. Cetina, F. Orucevic, and V. Vuletic, PRL **102**, 223201 (2009)

A 30.2 Thu 15:00 P 104

Fictitious magnetic field gradients in optical microtraps as an experimental tool for interrogating and manipulating cold atoms — •Yijian Meng, Bernhard Albrecht, Christoph Clausen, Alexandre Dareau, Philipp Schneeweiss, and Arno Rauschenbeutel — TU Wien/Atominstitut, VCQ, Vienna, Austria

Optical microtraps provide a strong spatial confinement for laser-cooled atoms. They can, e.g., be realized with strongly focused trapping light beams or the optical near fields of nano-scale waveguides and photonic nanostructures. Atoms in such traps often experience strongly spatially varying AC Stark shifts which are proportional to the magnetic quantum number of the respective energy level. These inhomogeneous fictitious magnetic fields can cause a displacement of the trapping potential that depends on the Zeeman state. Hitherto, this effect was mainly perceived as detrimental. However, it also provides a means to probe and to manipulate the motional state of the atoms in the trap by driving transitions between Zeeman states. Furthermore, by applying additional real or fictitious magnetic fields, the state-dependence of the trapping potential can be controlled. Here, using laser-cooled atoms that are confined in a nanofiber-based optical dipole trap, we employ this control in order to tune the microwave coupling of motional quantum states. We record corresponding microwave spectra which allow us to infer the trap parameters as well as the temperature of the atoms. Finally, we reduce the mean number of motional quanta in one spatial dimension to 0.3(1) by microwave sideband cooling.

A 30.3 Thu 15:15 P 104

An atomic erbium Bose-Einstein condensate generated in a quasistatic optical dipole trap — •Daniel Babik, Jens Ulitzsch, Roberto Röll, and Martin Weitz — Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

We report on the generation of a Bose-Einstein condensate of erbium atoms in a quasistatic optical dipole trap in an experiment aimed at the study of physics of strong light-induced gauge fields. In alkali atoms with their S-ground state configuration in far detuned laser fields with detuning above the upper state fine structure splitting the trapping potential is determined by the scalar electronic polarizability. In contrast for an erbium quantum gas with its $L > 0$ electronic ground state, the trapping potential for inner-shell transitions also for far detuned dissipation-less trapping laser fields becomes dependent on the internal atomic state (i.e. spin). It is expected to reach much longer coherence times with erbium in spin-dependent optical lattice experiments and for far detuned Raman manipulation in comparison with alkali atoms.

In our experiment an erbium atomic beam is decelerated by a Zeeman slower using radiation tuned to the 400.91 nm transition of atomic erbium. Following work by the Innsbruck group, we trap erbium atoms in a narrow-line magneto-optical trap near 582.84 nm. Subsequently, we load erbium atoms into the quasistatic dipole potential generated by a focused beam near 10.6 μm wavelength provided by a CO2-laser and cool atoms evaporatively to quantum degeneracy. In the future, we plan to investigate topological states and strong synthetic magnetic fields with the rare earth atomic quantum gas.

A 30.4 Thu 15:30 P 104

State-dependent transport of neutral atoms in two dimensions — •Gautam Ramola, Stefan Brakhane, Geol Moon, Max Werninghaus, Carsten Robens, Richard Winkelmann, Alexander Knieps, Wolfgang Alt, Dieter Meschede, and Andrea Alberti — Institut für Angewandte Physik, Bonn, Germany

Discrete time quantum walks (DTQWs) offer a versatile platform for exploring quantum transport phenomena involving the delocalization of pseudo-spin-1/2 particles on a lattice. Our recently built 2D state-dependent optical lattice setup provides an ideal platform to simulate topologically protected edge state transport using DTQWs in two dimensions [1]. The 2D quantum simulator makes use of polarization-synthesized lattice beams to deterministically transport neutral Cs atoms based on their internal state [2]. Furthermore, a high numerical aperture (NA = 0.92) objective lens [3] is used for imaging and addressing atoms with single site resolution, enabling us to create sharp boundaries between different topological domains. I will report on the experimental realization of the polarization synthesized optical lattice in two dimensions and on the most recent results.

[1] T. Groh et al. Robustness of topologically protected edge states in quantum walk experiments with neutral atoms, Phys. Rev. A **94** (2016)

[2] C. Robens et al. Fast, high-precision optical polarization synthesizer for ultracold-atom experiments, arXiv:1611.07952 (2016)

[3] C. Robens et al. A high numerical aperture (NA = 0.92) objective lens for imaging and addressing of cold atoms, arXiv:1611.02159 (2016)

A 30.5 Thu 15:45 P 104

Robustness of Topologically Protected Edge States in Quantum Walk Experiments with Neutral Atoms — •Thorsten Groh[1], Stefan Brakhane[1], Wolfgang Alt[1], Dieter Meschede[1], Janos Karoly Asbóth[2], and Andrea Alberti[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, H-1525 Budapest, P.O. Box 49, Hungary

Discrete time quantum-walks (DTQWs) with trapped ultracold atoms offer a versatile platform for the experimental investigation of topological insulator materials. An experimental proposal based on neutral atoms in spin-dependent optical lattices to realize one- and two-dimensional discrete-time quantum walks (DTQWs) with spatial boundaries between distinct Floquet topological phases is presented.

The robustness of topologically protected edge states arising at the boundaries separating distinct topological domains is analyzed in the presence of experimentally induced decoherence. Under realistic decoherence conditions, the experimental feasibility to observe unidirectional, dissipationless transport of matter waves along topological boundaries is investigated. [1]

[1] T. Groh, S. Brakhane, W. Alt, D. Meschede, J. K. Asbóth, and A. Alberti, "Robustness of topologically protected edge states in quantum walk experiments with neutral atoms," Phys. Rev. A 94, 013620 (2016).

A 30.6 Thu 16:00 P 104

Implementing supersymmetric dynamics in ultracold atom systems — •Martin Lahrz, Christof Weitenberg, and Ludwig Mathey — Universität Hamburg, Hamburg, Germany

Supersymmetry plays an essential role in solvable quantum mechanical problems, ranging from the hydrogen atom to soliton physics. The solvability of these systems can be traced back to supersymmetric partner Hamiltonians and their isospectral features. In this talk, we propose a detailed experimental setup for ultracold atom systems to realize such a pair of supersymmetric Hamiltonians. To test their supersymmetric relation, we propose a Mach–Zehnder interference experiment that can be realized with current technology. It compares the dynamics of a coherently split wave packet under these Hamiltonians. The contrast of the resulting interference pattern gives a sharp signal if the Hamiltonians form a supersymmetric pair. This proposal establishes ultracold atom dynamics and matter–wave interferometry as a device to test sophisticated features of quantum mechanical systems with clarity.

A 30.7 Thu 16:15 P 104

The PRIMUS-Project; an optical dipole trap under microgravity — •Christian Vogt[1], Sascha Kulas[1,2], Andreas Resch[1], Sven Herrmann[1], Claus Lämmerzahl[1], and the PRIMUS-Team[1,3] — [1]ZARM, Universität Bremen — [2]JPL, Pasadena, USA — [3]Institut für Quantenoptik, LU Hannover

Matter wave interferometry in microgravity offers the potential of largely extended interferometry times and thus precision measurements with much increased sensitivity. Motivated by this prospect, a large effort is currently underway to advance the necessary technology and perform first such atom optical experiments on microgravity platforms such as drop towers, zero-g airplanes or sounding rockets. The QUANTUS collaboration has thereby established a magnetic chip trap as a compact and efficient source of matterwaves for such microgravity cold atom experiments. Within the PRIMUS experiment we pursue another approach and set up an optical dipole trap as an alternative source for matter wave interferometry in microgravity. While this comes with additional technical challenges, it also offers several benefits, such as the possible application of Feshbach resonances, improved harmonicity of the trap or the trapping of all mF states. To implement the dipole trap we use a high power laser at 1960nm wavelength and load atoms directly from a Rb magneto optical trap. Here we will report on the current status and first results from the project. The PRIMUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 1642.

A 31: Poster Session III

Time: Thursday 17:00–19:00 Location: P OGs

A 31.1 Thu 17:00 P OGs

A two-species quantum gas experiment for the preparation of ultracold polar NaK molecules — Matthias W. Gempel, Torsten Hartmann, Torben A. Schulze, •Kai K. Voges, Alessandro Zenesini, and Silke Ospelkaus — Institut für Quantenoptik, Universität Hannover

Ultracold atomic quantum gas mixtures provide the starting point for the preparation of ultracold polar ground state molecules, which are excellent candidates for the study of quantum chemistry and exotic dipolar quantum phases. Here, we present an experimental apparatus for the preparation of ultracold Na and K quantum gas mixtures.

Sodium and potassium are two favorable candidates for a mixture experiment due to the well-known cooling strategies for the individual atoms and due to the large dipole moment of NaK molecules in their electronic and vibrational ground state.

We describe our experimental setup including a high resolution objective providing an experimentally verified resolution of approx. 700nm and a versatile electrode configuration for the manipulation and control of molecules in external electric fields. We present our approach towards the preparation of quantum degenerate Na+K mixtures, our progress on the measurement of the up-to-now unknown scattering properties of the boson-boson mixture and our envisioned pathway for the efficient conversion of NaK Feshbach molecules into ground state molecules.

A 31.2 Thu 17:00 P OGs

Cavity Optomechanics and Spin-Optodynamics with Cold Atoms — •Nicolas Spethmann[1], Jonathan Kohler[2], Sydney Schreppler[2], Lukas Buchmann[2], and Dan Stamper-Kurn[2,3] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physics, University of California, Berkeley, CA 94720, USA — [3]Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

Cold atom experiments routinely deliver samples with excellent control over both external and internal degrees of freedom. We combine these quantum systems with quantum-limited sensing facilitated by a high-finesse optical cavity, opening the initially well isolated quantum system to the environment in a controlled manner.

We employ the sensitive detection of motion of the atomic ensemble to demonstrate force sensing near the standard quantum limit, achieving a sensitivity of $(42yN)^2/Hz$. We further demonstrate cavity-mediated coupling of two near-groundstate mechanical oscillators limited by quantum back-action. Employing the interaction of the atomic spin with the cavity light, we create a spin-analog of a harmonic oscillator, allowing for measurement and coherent control of collective atomic spin oscillators. This gives us access to unique features of spin-optodynamics, such as a negative temperature, high-energy 'ground state'. Our results point to the potential, and also the challenges, of detecting and coupling quantum objects with quantum light.

A 31.3 Thu 17:00 P OGs

Towards time-resolved, weakly-destructive measurements of strongly interacting Fermi gases. — •Kevin Roux, Barbara Cilenti, Oscar Bettermann, and Jean-Philippe Brantut — Ecole Polytechnique Federale de Lausanne (EPFL), Lausanne, Switzerland

We present the design of a new apparatus aimed at trapping an ultracold gas of fermionic lithium in a high-finesse optical resonator. The optical cavity will serve as a deep, far off resonant dipole trap, allowing for efficient capture and evaporative cooling, and as a measurement tool. With a high finesse for close to resonance light, the cavity will allow to perform weakly destructive measurements of slow transport processes, following the density evolution in real time, with a signal to noise ratio approaching the single atom sensitivity. We plan to apply this technique to measure low currents through mesoscopic channels (both 1D and 2D). The cavity could also be used to induce long range, photon mediated interactions leading to a rich phase diagram. We will present the general design of the system and the progresses of the experimental setup.

A 31.4 Thu 17:00 P OGs

Realization of uniform synthetic magnetic fields by periodically shaking an optical square lattice — Charles Creffield[1], •Gregor Pieplow[1], Fernando Sols[1], and Nathan Goldman[2] — [1]Departamento de Física de Materiales, Universidad Complutense de Madrid, E-28040 Madrid, Spain — [2]CENOLI, Faculté des Sciences, Université Libre de Bruxelles (U.L.B.), B-1050 Brussels, Belgium

A powerful method to create effective magnetic fields is to shake a lattice of cold gases trapped in an optical lattice. Typically such schemes produce space-dependent effective masses and non-uniform flux patterns. In this work we try to tackle this problem by proposing several lattice shaking protocols, theoretically investigating their associated effective Hamiltonians and their quasienergy spectra. This allows the identification of novel shaking schemes, which simultaneously provide uniform effective mass and magnetic flux, with direct implications for cold-atom experiments and photonics.

A 31.5 Thu 17:00 P OGs

Optical trapping of ion crystals — •Yannick Minet, Julian Schmidt, Alexander Lambrecht, Pascal Weckesser, Fabian Thielemann, Markus Debatin, Leon Karpa, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs Universitaet Freiburg, Germany

Trapped cold ion crystals provide a well suited platform for realising quantum simulations due to long-range Coulomb interactions, which allow coupling of electronic and motional states on the quantum level via the crystal phonons [1]. Controling quantum phenomena in Paul traps in higher dimensional crystals is severely affected by rf-driven micromotion. Optical trapping of ions has been proposed as a solution to this limitation while providing versatile trapping geometries, including lattices.

We now demonstrate trapping of ion crystals with up to six Barium ions by an optical dipole trap [2,3] without any rf-fields. We are able to directly observe their Coulomb interaction and resonantly measure the frequencies of normal modes. We discuss the influence of various trapping parameters, such as beam waist, Rayleigh length, laser power, axial confinement by dc electric fields and additional changes in the trapping potential due to interactions between the ions. Finally, we discuss prospects of 2D and 3D quantum simulations in optical lattices.

[1] D.J. Wineland, Rev. Mod. Phys. 85, 1103 (2013)
[2] T. Huber *et al.*, Nat. Comm. 5, 5587 (2014)
[3] A. Lambrecht *et al.*, arXiv preprint arXiv:1609.06429 (2016)

A 31.6 Thu 17:00 P OGs

Realization of a Quantum Galvanometer — •Malte Reinschmidt, Carola Rogulj, Peter Federsel, Lukas Gussmann, Andreas Günter, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

Developing new quantum sensors is the biggest challenge in today*s quantum technology. Thereby, quantum fluctuations play an important role as they provide direct access to the quantum information of a system. Our goal is to develop a quantum galvanometer, which allows for quantum transport phenomena to be measured in various solid state systems such as quantum dots or topological insulators. In a first attempt, we are planning to realize the quantum galvanometer by coupling a current driven nanomechanical oscillator to a Bose-Einstein condensate. The correlations in the electron current should then be transferred onto an atom laser, which we measure with single atom sensitivity.

We show the current status of the experiment, including the realization and characterization of the nanomechanical oscillator, and its implementation to a cold-atom apparatus. We also give insight into the ion-optical detection system and its sensitivity with respect to electro-magnetic field fluctuations. Using fluctuating microwave fields, we show that field correlations are coherently transferred onto the atom laser and can be reconstructed from the single atom detection signal.

A 31.7 Thu 17:00 P OGs

Microscale integrated atom-photon junction — •Elisa Da Ros, Jonathan Nute, Pierre Jouve, Vineetha Naniyil, Daniele Bandolini, Nathan Cooper, and Lucia Hackermüller — Nottingham University, United Kingdom

The goal of this project is to develop a highly integrated and scalable device for coherently interfacing light and matter with potential applications in quantum memory and quantum sensing. Our system relies on the interaction between photons guided through a single-mode optical fiber and an ensemble of cold Cs atoms tightly confined by an optical dipole trap, formed in a microscopic void that has been laser etched through the fibre itself. This device is a prototype for the insertion of cold atoms into otherwise purely photonic systems such as optical waveguide chips.

A 31.8 Thu 17:00 P OGs

Home-built second harmonic generation: from near infrared to visible — •Andreas Hasenfratz, Pascal Weckesser, Ulrich Warring, and Tobias Schätz — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Experiments in atomic physics, e.g. experiments with trapped atomic ions, often require custom-made laser sources in the VIS to near UV regime, where commercial laser systems are expensive or not available. In these cases frequency doubled solid state lasers represent a common solution. To achieve this frequency doubling, we use in our setups non-linear crystals for second harmonic generation that are placed within a ring-resonator cavity. Here, we present our latest home-built doubling setup converting light from NIR to VIS and discuss its characteristics.

A 31.9 Thu 17:00 P OGs

Interatomic interactions in ultracold mixtures — •Vineetha Naniyil, Pierre Jouve, Elisa Da Ros, Jonathan Nute, Daniele Bandolini, Nathan Cooper, and Lucia Hackermüller — Nottingham University, United Kingdom

Experimental studies on degenerate Bose-Fermi mixtures suggest that they are a promising candidate for use in quantum information technologies. Our experimental work aims to generate ultracold mixtures of 6Li and 133Cs that would allow us to study interspecies interactions like heteronuclear Efimov states and fermionic molecules. Here we present some initial results in which we use in situ optical density measurements of molecular 6Li Bose-Einstein condensates to compare different theoretical models for the atomic density distribution. We also describe the design and characterisation of a dual-species collimated oven source and Zeeman slower for 6Li and 133Cs.

A 31.10 Thu 17:00 P OGs

Interplay of excitation hopping and electron-spin dynamics in Rydberg aggregates with spin-orbit coupling — •Karsten Leonhardt[1], Sebastian Wüster[1,2], and Jan-Michael Rost[1] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Indian

Institute of Science Education and Research, Bhopal

Atoms became viable candidates of analog quantum simulators for condensed matter many-body Hamiltonians due to tremendous advances in cooling, trapping and selective manipulations. The key are (off)-resonant excitations to Rydberg states, which induce strong, long-range interactions whereby the atomic systems exhibit coherent dynamics between many-body states on mesoscopic time and length scales. So far the focus was on demonstrating implementations of Ising-type Hamiltonians [1,2] realized through van der Waals interactions of identical Rydberg (dressed) states, and, spin-exchange Hamiltonians realized through resonant dipole-dipole interactions between different Rydberg states [3,4]. Here we discuss implications arising from spin-orbit coupling, which enable the interplay of orbital angular momentum excitation hopping and electron-spin-flip dynamics. **References**

[1] P. Schauß et al. Science **347**, 1455 (2015).
[2] J. Zeiher et al. Nat. Phys. **12**, 1095 (2016).
[3] G. Günther et al. Science **342**, 954 (2013).
[4] D. Barredo et al. PRL **114**, 113002 (2015).

A 31.11 Thu 17:00 P OGs

Parallel preparation of few body systems with Spatial Light Modulators — •Marvin Holten, Puneet Murthy, Benjamin Classen, Mathias Neidig, Ralf Klemt, Philipp Preiss, Gerhard Zuern, and Selim Jochim — Physikalisches Institut, University of Heidelberg, Germany

One of the main challenges of quantum simulation with cold atoms is the initialization of the system in the desired state. The most common approach is to cool the atoms in a bulk gas and then transfer them into the desired potential (e.g. an optical lattice). Here, the temperature in the bulk systems sets a lower limit to the temperature in the potential. We want to address this issue with a novel bottom-approach, where a many-body state is assembled from small, individually prepared building blocks.

One of the main challenges of the parallel preparation of small blocks is the creation of tailor-made optical potentials. To this end, we introduced a Spatial Light Modulator (SLM) to our 2D lithium experiment. On this poster, we present first results of atoms trapped inside different potentials created by the SLM. We show how phase-modulation together with several aberration correction methods are used to achieve very accurate light intensity distributions.

Finally, we investigate the utilization of these capabilities for the parallel creation of many double wells, loaded with two fermions each. By adiabatically merging several of these double wells into a larger lattice, we wish to access the fermionic Hubbard model at very low temperature, in the near future.

A 31.12 Thu 17:00 P OGs

Detecting correlations in deterministically prepared quantum states with single-atom imaging — •Andrea Bergschneider, Vincent M. Klinkhamer, Jan Hendrik Becher, Philine L. Bommer, Justin F. Niedermayer, Gerhard Zürn, Philipp M. Preiss, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

We deterministically prepare quantum states consisting of few fermions in single- and double-well potentials. Here we report on a new imaging scheme for ^{6}Lithium with which we detect the correlations of the quantum state on a single-atom level and with spin resolution.

The detection method uses fluorescence imaging at high magnetic field where the optical transitions for the used hyperfine states are almost closed. With a high-resolution objective we image about 15 scattered photons per atom on an EMCCD camera. This is sufficient to identify and locate single atoms in our imaging plane. We can perform this scheme in-situ or after an expansion in time-of-flight and additionally resolve the spin by subsequently adressing the different hyperfine states.

By combining this scheme with our deterministic preparation, we measure the two-point momentum correlations to probe the spatial symmetry of the two-particle wavefunction. The high contrast and the scalability of the detection technique allows us to go beyond measuring two-point correlations and characterize many-body quantum states.

A 31.13 Thu 17:00 P OGs

Pairing in the normal phase of a quasi-2D Fermi gas — •Ralf Klemt[1], Marvin Holten[1], Mathias Neidig[1], Puneet Murthy[1], Philipp M. Preiss[1], Gerhard Zuern[1], Igor Boettcher[2], Tilman Enss[3], and Selim Jochim[1] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada — [3]Institute for Theoretical Physics, University of Heidelberg, Germany

Pairing is the crucial ingredient for fermionic superfluidity. For weakly interacting superfluids, Bardeen Cooper Schrieffer (BCS) theory successfully predicts important properties as for example the critical temperature T_C, the specific heat, the pairing gap and the second order nature of the phase transition. Here, pairing occurs at same temperature as the phase transition. However, the nature of pairing for strongly interacting systems is not yet well understood. In particular, strong interactions can drive pairing even above T_C. This is especially true for 2D systems, where the nature of pairing is still a matter of debate.

Here we report on our experimental results on pairing in the normal phase of a two component 2D Fermi gas. We use spatially resolved radio-frequency (RF) spectroscopy to probe the onset of pairing at different interaction strengths across the 2D BEC-BCS crossover. As we can probe our inhomogeneous system locally, also the density dependence is recorded. We map out a large pairing regime above the critical temperature, where we observe pairing to be influenced by many body effects in the strongly interacting regime.

A 31.14 Thu 17:00 P OGs

Atom Lithography with a high flux Atom Laser beam — •Amir Kordbacheh and Nick Robins — Research School of Physics and Engineering, The Australian National University, Canberra, ACT 0200 Australia

The focusing of neutral atoms by use of near-resonant light fields is the subject of intense interest in our project. This interest has been driven to a large extent by the possibility of generating focal spots on the nanometer scale by use of specially configured laser intensity profiles. The result is a technique for nanostructure fabrication with possibilities for both high resolution and massive parallelism [1]. In this configuration, each node of the standing wave acts as an individual lens, and the entire standing wave acts as a lens array. Because a standing-wave light field repeats with a periodicity of order $\lambda/2$, where λ is the wavelength of the light, a large array of structures can be fabricated in parallel. What we are aiming is to use a Rubidium, Bose Einstein Condensate (BEC) as a source of perfectly collimated Atom Laser beam in order to deposit the atoms on a given substrate. The most significant goal in this project is to reduce the resolution (FWHM) of the flux structure width as much as possible. Due to improving the resolution of the write beam, by some numerical simulations we are trying to optimize all the parameters regarding atoms and standing wave lens to find the best focal points and minimizing the effects of aberrations for our desired elements. Considering the s-wave interaction between atoms (the mean field potential) by the semi classical Gross- Piaevskii (GP) model, would be of a great importance which is taken into account.

A 31.15 Thu 17:00 P OGs

HILITE - High-Intensity Laser Ion-Trap Experiment — •Nils Stallkamp[1,2], Stefan Ringleb[2,3], Sugam Kumar[4], Tino Morgenroth[1,3], Gerhard Paulus[2,3], Wolfgang Quint[1,5], Thomas Stöhlker[1,2,3], and Manuel Vogel[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [2]Helmholtz-Institut Jena — [3]Institut für Optik und Quantenelektronik, Universität Jena — [4]Inter-University Accelerator Centre, New Delhi, India — [5]Physikalisches Institut, Universität Heidelberg

We are currently setting up a Penning-trap experiment to investigate laser-ion interaction in high-intensity photon fields and study non-linear processes like multi-photon and tunnel ionization of trapped ions. The setup is designed to be transported to different high-intensity laser facilities, like FLASH at DESY, or JETI/POLARIS in Jena. The trap is designed as an open-endcap Penning trap, which allows free access from both sides for particle loading and the laser beam. Beside the two endcap electrodes, it consists of a split-ring electrode for excitation and detection in the center and two conical-shaped capture electrodes for dynamic capture of ions from external sources. A non-destructive detection technique of the ion motion, as well as a selection of specific ion species of interest will be implemented. The complete setup is located at the center of a superconducting magnet with a field strength of up to 6 T. A pulse-tube cooler is used for cooling the trap and the electronics to 4 K. Initially, a Ti:sapphire laser system with 10 mJ pulse energy and a pulse duration of 30 fs will be used. We will present the current status as well as planned measurements.

A 31.16 Thu 17:00 P OGs

Performance tests of a new electron gun for electron-ion crossed-beams experiments — •Tobias Molkentin[1], Alexander Borovik Jr[1], B. Michel Döhring[1], Benjamin Ebinger[1], Alfred Müller[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom und Molekülphysik, Justus-Liebig-Universität Gießen

Reliable atomic input data are of crucial importance for the modeling of ionized-matter environments and other plasma related applications. Cross sections for electron impact ionization of atoms and ions are particularly important. The sensitivity of an electron-ion crossed-beams experiment is mainly determined by the densities of both beams in the interaction region. To achieve an extension of the available range of accessible electron energies and densities a new electron gun [1,2], which delivers a ribbon-shaped beam, has been integrated into the experimental crossed-beams setup in Giessen. Its designed range of electron energies reaches from 10 to 3500 eV with high electron currents at all energies. The gun consists of ten different electrodes allowing for a variety of operation modes. Here, we present the results of performance tests investigating the different operation modes of the new electron gun. Due to the high intensity of the electron beam we observed space charge related effects [3], which are currently being investigated in detail.

[1] Shi et al., Nucl. Instr. Meth. Phys. Res. B 205 (2003) 201-206
[2] Borovik et al., J. Phys.: Conf. Ser. 488 (2014) 142007
[3] A. Müller et al., Nucl. Instr. Meth. Phys. Res. B 24 (1987) 369

A 31.17 Thu 17:00 P OGs

Preparation of an EBIT ion source for HILITE — •Tino Morgenroth[1,2], Nils Stallkamp[1,3], Stefan Ringleb[2], Oliver Forstner[1,2,3], Manuel Vogel[1,3], and Thomas Stöhlker[1,2,3] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [2]Institute of Optics and Quantumelectronics, Friedrich Schiller Universität Jena — [3]Helmholtz Institut Jena

The HILITE experiment is an open-endcap Penning trap setup, which is currently under construction at the GSI facility in Darmstadt. It allows the study of laser-ion interaction with highly-charged ions at high-intensity laser-systems such as JETI and POLARIS in Jena or FLASH in Hamburg. The main topic of our studies will be the observation of non-linear laser-ionisation effects, for which a well-defined ion-target in a desired charge distribution is a basic requirement. The need of the production of well-prepared ions is covered by a commercial EBIT ion source from the Dreebit company. This device produces highly-charged ions by consecutive impact ionization by an electron beam. The EBIT is optimized with respect to the ionisation process, to get a specific charge state of a distinct ion species, as well as the extraction, to get an optimal capturing of highly charged ions in the HILTE Penning trap. The experimental setup as well as results of the measurements of properties of the extracted ions and capture efficiency with HILITE will be presented. An outlook on the planned experimental work will be given.

A 31.18 Thu 17:00 P OGs

Electron-impact ionisation of xenon ions — •B. Michel Döhring[1], Alexander Borovik Jr.[1], Benjamin Ebinger[1], Tobias Molkentin[1], Alfred Müller[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Gießen, Deutschland — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Giessen, Gießen, Deutschland

Reliable atomic data are important for modelling of ionised gases in many different areas of physics, like astrophysics, plasma physics/spectroscopy and in atomic fusion research. Especially, cross sections for electron-impact ionisation of atoms and ions are required in such applications. The electron-impact ionisation process is fundamental in atomic physics. There is a new upcoming interest in xenon because it is proposed as a cooling gas in Tokamaks and as a propellant for ion micro-thrusters. Additionally, the xenon plasma can emit light in the extreme ultraviolet range and therefore it is a possible source of radiation in next-generation lithography devices.

We will present measurements of electron-impact single-ionisation cross sections of xenon ions. These data were measured at the electron-ion crossed-beams setup at the University of Giessen employing the well-known animated-crossed-beams technique [1]. We can now measure cross sections at energies up to twice the maximum accessible with our previous electron gun. The results are in good agreement with literature data. In the future the measurements will be extended to higher ion charge states like Xe^{23+} which were out of reach before.

[1] Müller et al., J. Phys. B. 18 (1985) 2993-3009

A 31.19 Thu 17:00 P OGs

Spectroscopy of highly charged ions using a main magnetic focus ion trap — •Marc Keil[1], Alexander Borovik Jr.[1], Stefan Schippers[1], and Alfred Müller[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

The Main Magnetic Focus Ion Trap (MaMFIT [1]), a compact tool for spectroscopy of highly-charged ions, has been recently installed in Giessen and has already been employed for investigation of dielectronic recombination in highly-charged iridium ions [2]. The present construction, however, restricts the experimental access exclusively to ions of the cathode material, which, in the present case is iridium. We report on an effort to upgrade the presently available MaMFIT device to enhance its versatility thus enabling experimental access to ions of a wider spectrum of elements. This construction and the installation of a ballistic gas inlet system [3] should facilitate fine-dosed delivery of the desired working gas directly into the ion trap region. The development of a system for periodic ion-trap dumping should prevent the accumulation of iridium ions sputtered from the cathode thus enabling us to trap light ions. Test measurements involving Ar^{q+} ions are envisaged for the near future.

[1] V. P. Ovsyannikov, A.V. Nefiodov, Nucl. Instr. Meth. Phys. Res. B 370 (2016) 32-41.
[2] A. Borovik, Jr et al., to be published.
[3] K. Fahy, Phys. Rev A 75 (2007) 032520.

A 31.20 Thu 17:00 P OGs

Nuclear excitation by electron capture in astrophysical plasmas — •Hyoyin Gan and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfecheckweg 1, 69117 Heidelberg, Germany

The elements in the Universe are formed in the process of nucleosynthesis in hot and dense plasmas which contain a tremendous numbers of photons and electrons. Under these conditions, nuclear excitation and decay processes may occur differently than under laboratory conditions, influencing the nucleosynthesis paths. We investigate the effect of photoexcitation [1] and nuclear excitation by electron capture [2] in the hot dense stellar plasma. In particular we address specific cases of nuclear isotopes which have a sensitive level scheme with respect to excitation mechanisms, for instance because of the presence of a long-lived isomeric state. Possible effects for the nucleosynthesis process are discussed.

[1] J. Gunst *et al.*, Phys. Rev. Lett. **112**, 082501 (2014).
[2] A. Pálffy, W. Scheid and Z. Harman, Phys. Rev. A **73**, 012712 (2006).

A 31.21 Thu 17:00 P OGs

Strong higher-order resonant contribution to x-ray line polarization in hot anisotropic plasmas — •Chintan Shah[1], Pedro Amaro[2], René Steinbrügge[1], Sven Bernitt[1,3], Stephan Fritzsche[3], Andrey Surzhykov[4], José Ramón Crespo López-Urrutia[1], and Stanislav Tashenov[2] — [1]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisches Institut, Heidelberg, Germany — [3]Friedrich-Schiller-Universität Jena, Jena, Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

The angular distribution and polarization of x rays emitted due to resonant recombination were experimentally studied using an electron beam ion trap. The electron-ion collision energy was scanned over the *KLL* dielectronic, trielectronic and quadruelectronic recombination resonances of $Fe^{18+..24+}$ and $Kr^{28+..34+}$ with an excellent resolution of $\sim$ 6 eV. The angular distribution of x rays was measured along and perpendicular to the beam axis. Subsequently, polarization was measured using Compton polarimetry [1]. We observed that most of the x-ray transitions lead to polarization including higher-order trielectronic and quadruelectronic resonances. These channels dominate the polarization of the dominant K_α x-ray line emitted by hot plasmas [2]. We conclude that accurate plasma polarization diagnostics can only be obtained with the careful inclusion of relativistic Breit interaction [3] and hitherto neglected higher-order resonances [2].

[1] C. Shah et al., PRA 92, 042702 (2015)
[2] C. Shah et al., PRE 93, 061201(R) (2016)
[3] P. Amaro et al., submitted (2016).

A 31.22 Thu 17:00 P OGs

High-resolution studies of resonant photorecombination with

an electron beam ion trap — •Chintan Shah[1], Leticia Täubert[1], Julia Jäger[1], Sven Bernitt[1,2], and José Ramón Crespo López-Urrutia[1] — [1]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [2]Friedrich-Schiller-Universität Jena, Jena, Germany

Dielectronic recombination, the fundamental process where a free electron is captured by the highly charged ion and its kinetic energy is transferred to excite a bound electron, has been intensively investigated due to its interest for fundamental atomic physics and the diagnostic of astrophysical and laboratory plasmas. Besides DR, higher-order resonant photorecombination processes such as trielectronic or quadruelectronic recombination are also relevant, where two or three bound electrons can be simultaneously excited by the capture of a free electron. Significant contributions of trielectronic or quadruelectronic recombination to the total recombination rates make it necessary to consider these processes in the modeling of ionization balance and cooling rate of hot plasmas [1]. Here we present the measurements of these processes with K-shell excitation of iron ions, carried out in an electron beam ion trap.

[1] C. Shah et al., PRE 93, 061201(R) (2016)

A 31.23 Thu 17:00 P OGs

Optical spectroscopy of highly ionized ruthenium of astrophysical interest — •Hendrik Bekker[1], Paul Marie[1], Chintan Shah[1], Klaus Werner[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Eberhard Karls Universität, Tübingen

Observations of trans-iron elements in certain stars are a window into the slow neutron capture process (s-process) [1]. To interpret the spectra of these objects, atomic data of highly charged trans-iron ions are required. In this work several charge states of ruthenium (Z = 44) were investigated. The Heidelberg electron beam ion trap (HD-EBIT) was employed to charge-state selectively ionize and excite ruthenium ions through electron impact. The spectra of subsequent fluorescence light were recorded using a grating spectrometer. In total, 47 optical lines of the charge states Ru^{9+} to Ru^{18+} were measured. These were compared to predictions from atomic theory, resulting in tentative identifications of transitions and determination of ionization energies. Ruthenium ions are of interest here as their electronic structures are similar to those of technetium ions (Z = 43), the lightest unstable element. Due to the limited lifetime of Tc, its observation in stars gives insight into the stellar evolution and dredge-up processes [2].

[1] K. Werner et al., ApJL, 753, L7 (2012)
[2] P.W. Merrill, The Astrophysical Journal 116 21 (1952)

A 31.24 Thu 17:00 P OGs

Polar-maXs: Micro-calorimeter based X-ray polarimeters — •Christian Schötz[1], Daniel Hengstler[1], Jeschua Geist[1], Sebastian Kempf[1], Loredana Gastaldo[1], Andreas Fleischmann[1], Christian Enss[1], and Thomas Stöhlker[2,3,4] — [1]KIP, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Darmstadt — [4]IOQ, Jena University

We are presently developing the x-ray detector system Polar-maXs, which will combine for the first time the high energy resolution, large dynamic range and excellent linearity of magnetic micro-calorimeters with the sensitivity to polarization caused by polarization-dependent Compton or Rayleigh scattering in an array of scatterers.

Polar-maXs consists of two layers. The first layer comprises a 4 x 4 array of x-ray scatterers behind a corresponding array of collimator holes. Depending on the energy range of interest and whether Compton or Rayleigh scattering is to be used, these scatterers are fabricated from low-Z or high-Z material. The scattered x-rays are detected by an array of 576 x-ray absorbers read-out by paramagnetic temperature sensors as metallic magnetic micro-calorimeters (MMC). Each absorber covers an area of 0.5mm x 0.5mm and is made of 10 micrometer thick gold, to guarantee high stopping power for x-ray with energies up to 20 keV and an energy resolution of better than 20 eV (FWHM) in the complete energy range. We discuss general design considerations as well as the results of Monte-Carlo simulations for a variety of detector designs. We present the results of first measurements with the Hydra-principle.

A 31.25 Thu 17:00 P OGs

Rydberg Quantum Optics in Ultracold Gases — •Christoph Braun[1,2], Florian Christaller[1,2], Christoph Tresp[1,2], Ivan Mirgorodskiy[1], Asaf Paris-Mandoki[1], and Sebastian Hofferberth[1,2] — [1]5. Phys. Inst. and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Department of Physics, Chemistry and Pharmacy, University of Southern Denmark, 5230 Odense M, Denmark

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level of individual photons.

We present the use of an electrically tuned Förster-resonance to enhance the Rydberg-mediated interaction between single-photons. The strong interaction in the vicinity of a Förster-resonance allows performing fine-structure-resolving spectroscopy of the involved Rydberg pair-states.

We also show that an atomic medium smaller than the blockade radius can be utilized to substract exactly one photon from an input pulse over a wide range of input photon-numbers, thus the absorption of a single photon renders the medium from opaque to transperant. Reduced dephasing enables the observation of coherent Rabi-Oscillations of a single "super-atom" interacting with a light field close to the single-photon level.

A 31.26 Thu 17:00 P OGs

Towards a two-species Rydberg experiment for ion-atom scattering in the quantum regime — •Nicolas Zuber, Thomas Schmid, Christian Veit, Thomas Dieterle, Robert Löw, and Tilman Pfau — 5. Physikalische Institut & Center for Integrated Quantum Science and Technology, Universität Stuttgart, Stuttgart, Germany

We are building up an experiment for ultra cold mixtures of rubidium 87 and lithium 6 with the possibility for Rb Rydberg excitation. The setup will allow for the creation and study of heteronuclear Rb*-Li Rydberg molecules by photoassociation spectroscopy. This will enable us to study ion-atom scattering in the ultra cold quantum regime so far not reached by the hybrid ion-atom-trap experiments [1]. For this purpose the anisotropic F-state Rydberg molecules will be used for the alignment of the lithium atom with respect to the ionic Rb^+ core. A two-photon ionization process provides an option for very fast ionization of the Rydberg molecule and thus the precise timing of the Rb^+-Li scattering event. The detection of the scattered ion will be done with an ion microscope and a spatially and temporally resolving delay-line detector with a single particle rate up to several MHz.

[1] R. Saito et al, arXiv:1608.07043

A 31.27 Thu 17:00 P OGs

Detection of single Rydberg impurities coupled to a Bose-Einstein condensate — •Florian Meinert, Kathrin Kleinbach, Felix Engel, Woojin Kwon, Fabian Böttcher, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Atoms prepared in highly excited Rydberg states constitute remarkable quantum objects with extreme properties. Among others, the electronic wavefunction may extend over mesoscopic distances easily reaching the micrometer scale.

In our experiment, we explore single Rydberg impurities immersed in a Bose-Einstein condensate (BEC), for which thousands of ground-state atoms lie within the Rydberg wavefunction. Based on detailed spectroscopic studies of electron-neutral scattering in the ultracold, we report on the current status of our endeavor to employ the interaction of the Rydberg electron with the condensate atoms to imprint the Rydberg wavefunction onto the BEC density. In combination with high resolution optical addressing and readout, we aim for direct imaging of Rydberg orbitals.

A 31.28 Thu 17:00 P OGs

An optogalvanic flux sensor for trace gases based on Rydberg excitations — •Ralf Albrecht[1], Johannes Schmidt[1,2], Patrick Schalberger[2], Holger Baur[2], Robert Löw[1], Tilman Pfau[1], Norbert Frühauf[2], and Harald Kübler[1] — [1]5. Physikalisches institut, IQST, University of Stuttgart — [2]Institute for Large Area Microelectronics, IQST, University of Stuttgart

Rydberg atoms in thermal vapor are discussed as promising candidates for the realization of quantum devices such as single photon sources and sensors [1]. One example for a classical application could be a gas sensor. We want to exploit the low binding energy of Rydberg states in atoms or molecules which are easily ionized by collisions with other gases. This allows us to convert the optical excitation of the trace gas directly into charges and subsequently measure a current with low background signal [2]. This method of detecting a trace gas is very selective, due to the excitation into a bound state which gets ionized only afterwards. Furthermore, a sensitivity better than parts per million seems to be in reach. As we are able to include electronic devices ranging from simple electrode structures to complex circuits like operational amplifiers [3] into the cell, this sensitivity can be further improved.

[1] J. A. Sedlacek, et al., *Phys. Rev. Lett.* **111**, 063001 (2013)
[2] D. Barredo, et al., *Phys. Rev. Lett.* **110**, 123002 (2013)
[3] P. Schalberger, et al., *JSID* **19**, 496-502 (2011)

A 31.29 Thu 17:00 P OGs

Rydberg superatom dynamics in optical lattices — •Fabian Letscher[1,2], David Petrosyan[3], and Michael Fleischhauer[1] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany — [3]Institute of Electronic Structure and Laser, FORTH, GR-71110 Heraklion, Crete, Greece

The strong and long-range interactions between Rydberg atoms can suppress more than one optical excitation within a certain blockade volume. A mesoscopic ensemble of atoms then forms a so-called Rydberg superatom. In contrast to a two-level system, strong dephasing during laser excitation of the superatom can lead to its Rydberg excitation probability approaching unity. A lattice of such strongly driven superatoms allow for simulations and studies of various phases and phase transitions of open many-body systems.

Here, we discuss the excitation dynamics and steady-state phases of Rydberg superatom lattices in two regimes of laser excitation, namely: the resonant (blockade) regime and off-resonant (facilitation) regime. In the blockade regime, we show that the systems in the steady state can form a bistable, antiferromagnetically ordered phase with long-range spatial correlations. In the facilitation regime, an excitation cascade may occur leading to a fast growth of Rydberg excitation clusters. We simulate the excitation dynamics on a triangular lattice reminiscent of frustrated spin models in a strongly dissipative environment and study the cluster collisions and the role of resulting defects.

A 31.30 Thu 17:00 P OGs

Rydberg Dressed Quantum Many-Body Systems — Lorenzo Festa, •Nikolaus Lorenz, Marcel Duda, and Christian Gross — Max Planck Institute of Quantum Optics, Munich, Germany

We are setting up a novel experiment for the study of quantum many-body systems with engineered long-range interactions. These interactions are induced by off-resonant laser coupling to Rydberg states, so called Rydberg dressing. Our aim is to explore fundamentally new types of quantum matter based on these tailored long-range interactions. A first goal is to study tailored quantum magnets in microtrap arrays, where Potassium provides interesting prospects for deterministic array loading. Here we report on the status of the project and on the technological implementation of the experimental apparatus. This is designed in order to maximize coupling to Rydberg states via ultraviolett laser excitation and to minimize the experimental cycle time to allow for experiments that require high statistics.

A 31.31 Thu 17:00 P OGs

P-state Rydberg molecules — •Tanita Eichert[1], Thomas Niederprüm[1], Oliver Thomas[1,2], Carsten Lippe[1], Indujan Sivanesarajah[1], and Herwig Ott[1] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

Our poster addresses the experimental investigation of P-state Rydberg molecules. The scattering interaction of the highly excited electron of a Rydberg atom and a ground state atom causes an oscillatory potential that supports molecular bound states. In our experiment we use high resolution time-of-flight spectroscopy over a range of several 10 GHz to precisely determine the binding energies and lifetimes of molecular states in the vicinity of the 25P-state. We observe molecular states, which induce a spin-flip of the perturber atom due to the mixing of the atom's hyperfine states by the molecular interaction. We also resolve molecular states, which feature strong entanglement between the orbital angular momentum of the Rydberg electron and the nuclear spin of the ground state atom. The so called butterfly molecules arise in rubidium due to a shape resonance in the p-wave electron-atom scattering. We find states bound up to -50 GHz, corresponding to binding lengths of 100 to 350 Bohr radii and with permanent electric dipole moments of around 500 Debye.

A 31.32 Thu 17:00 P OGs

Electronic tubular image states around metallic nanorings — •Christian Fey[1], Henrik Jabusch[1], Johannes Knörzer[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We investigate theoretically the capability of metallic nanostructures to support so called electronic tubular image states (TIS). These are quantized states of a single electron bound to the nanostructure by the interplay of two different forces: Firstly an attractive image force resulting from the polarization of the neutral metal and secondly a repulsive centrifugal force due to a circular motion of the electron. These states were originally predicted for metallic carbon nanotubes and have many properties in common with atomic Rydberg systems [1]. Our work focuses on TIS around nanorings. We present their image potentials as well as the resulting TIS and elucidate the role of the objects geometry by comparing its image potential to potentials of other nanostructures like spheres and cylinders.

[1] B.E. Granger, P. Král, H.R. Sadeghpour, M. Shapiro; Phys. Rev. Lett. **89** 135506 (2002)

A 31.33 Thu 17:00 P OGs

Perturbation-induced quantum scars and Rydberg atoms in dense background gases — •Perttu Luukko and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany

Quantum scarring is the tendency of high-energy quantum eigenstates to condense around moderately unstable classical periodic orbits in a chaotic system. Recently we have shown (Luukko et al., Sci. Rep. **6** 37656, 2016) that a similar phenomenon occurs in separable systems with local perturbations in the potential landscape. In this case strong and numerous scars form around periodic orbits of the corresponding unperturbed system even if the perturbations are randomly placed. The scarring can be explained by considering the effect of classical periodic orbits to the level structure of the unperturbed system in a semiclassical theory.

A Rydberg atom interacts with nearby ground-state atoms mainly through a short-range polarization potential, while the unperturbed Coulomb potential is separable. This creates the necessary setting for perturbation-induced scarring. Indeed, our simulations for Rb predict that in the presence of a high number of randomly placed perturbers a significant fraction of lowest-energy electronic states that split from a constant n manifold are scarred. The scarring comes with a shift in energy, which might be relevant for experiments probing Rydberg spectra in cold and dense atom clouds. Ultra-long range bound molecular states in these systems might also be connected to the formation of scars.

A 31.34 Thu 17:00 P OGs

Ion microscopy of ultracold ground state and Rydberg atoms — •Markus Stecker, Jens Grimmel, Raphael Nold, Andreas Günther, and József Fortágh — Center for Quantum Science, Physikalisches Institut, Eberhard-Karls-Universität Tübingen, Germany

We developed a novel quantum gas microscope based on ionization of atoms and high resolution ion optics. The system achieves a magnification up to 1000 and a theoretical resolution limit below 100nm. The microscope consists of four electrostatic lenses and a microchannel plate in conjunction with a delay line detector. This allows the observation of ultracold ground state as well as Rydberg atoms with single atom sensitivity and high temporal and spatial resolution.

We show the ion-optical setup and its experimental implementation to an ultra-cold atom setup. We investigated its performance by spatially patterned ionization of ground state atoms out of a magneto-optical trap. Furthermore, we present excitation and detection of Rydberg atoms. We studied the Stark effect on Rydberg atoms in different electric field ranges. At high fields, we measured the spectra of highly Stark-shifted Rydberg resonances and compared these findings to a newly developed numerical calculation including ionization rates. In the low field region, we investigated Förster resonances and their influence on the excitation statistics.

A 31.35 Thu 17:00 P OGs

Rydberg atoms of ^{87}Rb in crossed electric and magnetic fields — •Manuel Kaiser, Jens Grimmel, Peter Zwissler, Lara Torralbo-Kampo, and József Fortágh — Center for Quantum Science, Physikalisches Institut, Universität Tübingen, Germany

External fields change the energy structure of Rydberg atoms drastically and can therefore be used to measure the fields or to manipulate the atoms but also disturb measurements if stray fields can not be compensated. Therefore precise knowledge of the Stark and Zeeman spectrum is of great interest.

We present measurements and numerical calculations of Stark and Zeeman shifts for Rydberg states of ^{87}Rb. We have extended our previous calculations [1] to a crossed electric and magnetic field situation taking into account the Stark and Zeeman structure as well as the transitions strength between all states in the EIT ladder scheme. We have performed high resolution measurements in various heated vapour cells being able to resolve the Motional Stark Effect in weak magnetic fields.

[1] J. Grimmel, M. Mack, F. Karlewski, F. Jessen, M. Reinschmidt, N. Sándor and J. Fortágh, N. J. Phys. 17, 053005 (2015).

A 31.36 Thu 17:00 P OGs

Towards a hybrid quantum system of Rydberg atoms and superconducting coplanar waveguide resonators — •Li Yuan Ley, Helge Hattermann, Conny Glaser, Daniel Bothner, Benedikt Ferdinand, Lörinc Sárkány, Reinhold Kleiner, Dieter Koelle, and József Fortágh — CQ Center for Collective Quantum Phenomena and their Applications, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

Coupling Rydberg atoms to coplanar superconducting resonators has been proposed to enable efficient state transfer between solid state systems and ultracold atoms. This coupling could be used for the generation of an atomic quantum memory or the implementation of new quantum gates [1,2].

After the successful demonstration of magnetic coupling between ultracold ground state atoms and a coplanar waveguide resonator, we progress towards coupling Rydberg atoms to the electric field of the cavity. Due to the large dipole moment of Rydberg atoms, the coupling strength to the cavity is expected to be much larger than in the case of ground state atoms. At the same time, Rydberg states are strongly affected by any detrimental fields, such as the electric field of adsorbates on the chip, leading to spatially inhomogeneous energy shifts. We report on the characterization of these fields, state selective detection of Rydberg atoms and on the progress towards strong coupling.

[1] L. Sárkány et al., Phys. Rev. A 92, 030303 (2015).
[2] J. D. Pritchard et al., Phys. Rev. A 89, 010301 (2014).

A 31.37 Thu 17:00 P OGs

Long-range quantum gate via Rydberg states of atoms in a thermal microwave cavity — •Lorinc Sárkány[1], József Fortágh[1], and David Petrosyan[2,3] — [1]Eberhard Karls Universität Tübingen, Physikalisches Institut, Auf der Morgenstelle 14, D-72076 Tübingen, Germany — [2]Institute of Electronic Structure and Laser, FORTH, GR-71110 Heraklion, Crete, Greece — [3]Aarhus Institute of Advanced Studies, Aarhus University, DK-8000 Aarhus C, Denmark

We propose a universal quantum gate based on two spatially separated Rydberg atoms coupled through a non-resonant microwave cavity, which may be in any superposition or mixture of photon number states. Quantum interference of different transition paths from the two-atom ground to the double-excited Rydberg states involving a single microwave photon exchange through the cavity makes both the transition amplitude and resonance largely insensitive to cavity excitations. Our scheme for attaining ultra-long-range interactions and entanglement also applies to mesoscopic atomic ensembles in the Rydberg blockade regime and is scalable to many ensembles trapped within a centimeter-sized microwave resonator.

A 31.38 Thu 17:00 P OGs

Evidence for direct observation of radiative charge transfer photons in noble gas clusters — •Andreas Hans, Xaver Holzapfel, Philipp Schmidt, Christian Ozga, Sascha Apazeller, Catmarna Küstner-Wetekam, Arno Ehresmann, and André Knie — Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

The environment of an atom is essential for the decay possibilities of excited states. If an atom is bound in a cluster, possible intra-atomic relaxation processes must be extended by several non-local processes like Interatomic Coulombic Decay (ICD) and Electron Transfer Mediated Decay (ETMD). However, fast processes like Auger decay can still happen locally and create doubly charged sites within a cluster. Because a one-site doubly-charged state possesses a much higher potential energy than a two-site singly-charged state, the system can relax by the transfer of an electron from a neutral atom to the doubly charged site. In this Radiative Charge Transfer (RCT), the excess energy is emitted as a photon. The process has been observed several times in the form of lacking energy in electron-ion-coincidence experiments. Here, we present evidence for the direct measurement of the emitted photons from noble gas clusters.

A 31.39 Thu 17:00 P OGs

Ultra-fast interatomic processes investigated by electron impact induced fluorescence spectroscopy — •Catmarna Küstner-Wetekam, Andreas Hans, Philipp Schmidt, Christian Ozga, Xaver Holzapfel, Arno Ehresmann, and André Knie — Institut für Physik and CINSaT, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

In weakly bound systems like clusters novel relaxation pathways emerge for electronically excited states via different interparticle reactions such as Interatomic Coulombic Decay (ICD [1]) and Radiative Charge Transfer (RCT [2]). Both are of general interest due to their possible role in radiation damage in biological systems [1,2]. Here, we introduce an experiment using electron impact induced fluorescence spectroscopy (EIFS [3]) for ionization of noble gas clusters and examination of ICD and RCT fluorescence lines [4,5]. The excitation energy can be varied between 5 eV and 3 keV to observe different relaxation mechanisms in clusters by detection of emitted photons in a wavelength range from 40 nm to 650 nm.

[1] F. Trinter et al., Nature, 505, 664 (2014)
[2] X. Ren et al., Nat. Commun., 7, 11093 (2016)
[3] A. Knie et al., J. Elec. Spec., 185, 492-497 (2012)
[4] A. Knie et al., New J. Phys., 16, 102002 (2014)
[5] A. Hans et al., Chem. Phys., In Press (2016)

A 31.40 Thu 17:00 P OGs

Population inversion in atomic clusters — •Andreas Rubisch, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

High harmonic generation in intense laser pulses is a valuable tool to obtain radiation in the UV and x-ray regime. In order to overcome the typically low conversion efficiency, it was proposed to assist the emission of high harmonics in single atoms or molecules by an intense near-infrared (NIR) driving pulse [1].

Such a mechanism could be powerful in atomic clusters as well. There the NIR pulse generates a nano-plasma, which, however, is highly unstable upon evaporation. Here we study helium droplets doped with a handful of xenon atoms, where by means of dopant-induced ignition a lower-temperature nano-plasma is formed [2,3].

We perform classical molecular-dynamics calculations in order to quantify the competition between population inversion and subsequent recombination on one hand and evaporation through electron-electron collisions on the other hand.

[1] T. Bredtmann et al., PRA 93, 021402(R) (2016)
[2] A. Mikaberidze et al., PRL 102, 128102 (2009)
[3] S.R. Krishnan et al. PRL 107, 173402 (2011)

A 31.41 Thu 17:00 P OGs

Multicoincidence studies of Interatomic Coulombic Decay in neon dimers — •Derya Aslitürk, Till Jahnke, Jonas Rist, Markus Schöffler, Florian Trinter, Markus Weitz, Daniel Trapert, Sebastian Eckart, Pia Huber, Christian Janke, Sven Grundmann, Miriam Weller, Darja Trojanowskaja, Kevin Henrichs, Gregor Kastírke, Maurice Tia, Christoph Goihl, Max Kircher, Nikolai Schlott, Hendrik San, and Reinhard Dörner — Institut für Kernphysik, Goethe Universität Frankfurt, Max von Laue-Str. 1, 60439 Frankfurt am Main

A measurement of resonant ICD [1] has been performed that at the BESSY synchrotron source using Cold Target Recoil Ion Momentum Spectroscopy. The main goal of this measurement was to perform a quantum state resolved investigation by resolving: 1) The initial electronic state which will undergo ICD 2) The Initial vibrational state 3) The ICD lifetime 4) The ICD electron energy 5) The ICD electron angle in the body fixed frame 6) The final electronic state of the fragment 7) The fragment kinetic energy or vibrational state. First experimental results will be presented.

References: [1] S. Barth, S. Joshi, S. Marburger, (2005) "Observation of resonant Interatomic Coulombic Decay in Ne clusters". The Journal of Chemical Physics 122 (24)

A 31.42 Thu 17:00 P OGs

Investigation of metal clusters by multi-reflection time-of-flight mass spectrometry — •Paul Fischer[1], Gerrit Marx[1], Madlen Müller[1], Birgit Schabinger[1], Lutz Schweikhard[1], Florian Simke[1], and Robert Wolf[2] — [1]Institut für Physik, Universität Greifswald — [2]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney

Multi-reflection time-of-flight mass spectrometers (MR-ToF MS) are successfully employed for ion investigation and separation, offering advantages e.g. in the study of short-lived radionuclides due to their high mass resolving power and comparatively short measurement time [1,2].

A MR-ToF analyzer recently built at Greifswald has been combined with a laser-ablation/ionization source. Different types of metal clusters - compositions of multiple atoms of the ablated material - have been studied by use of conventional ToF and MR-ToF operation. The experimental results illustrate the possibilities of cluster production and investigation with the new system.

[1] R.N. Wolf et. al, Int. J. Mass spectrom. 349-350 (2013) 123

[2] F. Wienholtz et. al, Nature 498 (2013) 346

A 31.43 Thu 17:00 P OGs

Charging Dynamics of Dopants in Helium Nanoplasmas — •Dominik Schomas[1], Andreas Heidenreich[2,3], Barbara Grüner[1], Frank Stienkemeier[1], Siva Rama Krishnan[4], and Marcel Mudrich[1] — [1]Albert-Ludwigs Universität Freiburg — [2]Kimika Fakultatea, Euskal Herriko Unibertsitatea (UPV/EHU) and Donostia International Physics Center (DIPC), Donostia — [3]IKERBASQUE, Basque Foundation for Science, Bilbao — [4]Indian Institute of Technology - Madras, Chennai

Helium nanodroplets irradiated by intense near-infrared (NIR) laser pulses ignite and form highly ionized nanoplasmas even at laser intensities where helium is not directly ionized by the optical field, provided the droplets contain a few dopant atoms. We present a combined theoretical and experimental study of the helium nanoplasma ignition dynamics for various dopant species. In particular, we elucidate the interplay of dopant ionization inducing the ignition of a helium nanoplasma, and the charging of the dopant atoms driven by the ionized helium host. Most efficient nanoplasma ignition and charging is found when doping helium droplets with xenon atoms, in which case high charge states both of helium (He^{2+}) and of xenon (Xe^{21+}) are detected.

A 31.44 Thu 17:00 P OGs

Correlated electron dynamics in expanding nanoplasmas — •Tim Oelze[1], Bernd Schütte[2], Jan Lahl[1,6], Jan P. Müller[1], Maria Müller[1], Arnaud Rouzée[2], Marc J. J. Vrakking[2], Marek Wieland[3,4], Ulrike Frühling[3,4], Markus Drescher[3], Alaa Al-Shemmary[5], Torsten Golz[5], Nikola Stojanovic[5], and Maria Krikunova[1] — [1]TU Berlin — [2]MBI Berlin — [3]Uni Hamburg — [4]CUI Hamburg — [5]DESY Hamburg — [6]Lund University

When clusters get hit by intense laser pulses a nanoplasma is created within the clusters. Finally the clusters disintegrate while emitting electrons and photons.We investigate the complex nanoplasma dynamics of clusters that are irradiated with intense laser pulses by analysing their electron kinetic energy spectra. In distinct studies we examined those spectra of atomic and molecular clusters of oxygen, carbon dioxide, xenon and krypton as well as xenon-argon mixed clusters upon irradiation of intense near-infrared laser pulses or extreme ultraviolet pulses from the free electron laser FLASH. Pump-probe measurements and terahertz streaking were employed to observe autoionization and correlated electronic decay processes from previously unknown bound states in the samples. Terahertz streaking shows that these states are depopulated at least picoseconds to nanoseconds after the interaction of the respective laser pulses with the samples. The occurence of those late decay processes in a variety of excited cluster samples and by different sources of excitation suggests that those mechanisms are of general relevance for the relaxation of laser induced nanoplasmas.

A 31.45 Thu 17:00 P OGs

Three-dimensional characterization of free nanostructures via two-color coherent diffractive imaging — •Katharina Sander[1], Maxim A. Yurkin[2,3], and Thomas Fennel[1] — [1]Institute of Physics, University of Rostock, Germany — [2]Voevodsky Institute of Chemical Kinetics and Combustion, Novosibirsk, Russia — [3]Novosibirsk State University, Russia

Coherent x-ray diffraction promises high-resolution structural characterization of single free nanoparticles such as biological specimens, aerosols and atomic clusters. Hard x-ray diffraction patterns contain small angle scattering data and allow for efficient reconstruction of the 2D projected target density with well-established phase retrieval algorithms [Fienup, Appl. Opt., 1982]. A 3D reconstruction is feasible by combining multiple scattering patterns for randomly oriented reproducible targets [Ekeberg, Phys. Rev. Lett., 2015] if the particle orientation problem can be solved - typically a highly complex task involving statistical analysis. Here, we propose a 3D phase retrieval scheme based on the simultaneous measurement of hard and soft x-ray diffraction images to mitigate this difficulty. In the wide angle soft x-ray scattering, important additional information about the target orientation is contained in the diffraction images [Barke, Nat. Comm., 2015]. In this theoretical study, we explore routes to assign the target orientation to the respective hard x-ray scattering images using a pre-calculated dataset of the soft x-ray scattering patterns and test retrieval of the 3D target shape including its inner structure.

A 31.46 Thu 17:00 P OGs

A VMI spectrometer for nanoplasma experiments — •Nicolas Rendler[1], Dominik Schomas[1], Robert Moshammer[2], Thomas Pfeifer[2], and Marcel Mudrich[1] — [1]Albert-Ludwigs-Universität Freiburg — [2]Max-Planck-Institut für Kernphysik

We present a new apparatus to explore the dynamics of helium nanoplasmas via NIR and XUV femtosecond pump-probe experiments. Doped helium nanodroplets feature complex plasma ignition dynamics strongly depending on the dopant properties. The newly designed velocity map imaging (VMI) spectrometer is capable of mapping high energy electrons and ions (<250 eV) occurring in Coulomb exploding nanoplasmas. Fragment ions formed in the nanoplasma expansion will be analyzed simultaneously using a high-voltage time-of-flight (TOF) mass spectrometer mounted in the same setup.

A 31.47 Thu 17:00 P OGs

Characterization of the time structure of a pulsed helium nanodroplet source via single-particle diffractive imaging — •Pablo Nuñez von Voigt[1], N. Monserud[2], B. Langbehn[1], T. Möller[1], M. Sauppe[1], A. Spanier[1], K. Sander[3], C. Peltz[3], T. Fennel[3], B. Schütte[2], M. Vrakking[2], A. Rouzée[2], F. Frassetto[4], L. Poletto[4], A. Trabattoni[5], F. Calegari[6], C. Nisoli[5,6], and D. Rupp[1] — [1]IOAP TU Berlin, Germany — [2]MBI, Germany — [3]Universität Rostock, Germany — [4]CNR Padova, Italy — [5]Politecnico di Milano, Italy — [6]CNR Milano, Italy

Single-shot experiments with coherent diffraction imaging enable the structure determination of individual nanoparticles. We used intense high-harmonic XUV-pulses to study the time structure of our pulsed source for helium nanodroplets (Even-Lavie valve, 5K, 80bar). The single-droplet images reveal a varying cluster size along the cluster pulse and an optimal opening time of the valve of 24 μs.

A 31.48 Thu 17:00 P OGs

Time-Resolved Ionization Dynamics of Xenon Clusters — •Katharina Kolatzki[1], M. Sauppe[1], T. Bischoff[1], B. Langbehn[1], M. Müller[1], B. Senfftleben[1], A. Ulmer[1], J. Zimbalski[1], J. Zimmermann[1], L. Flückiger[1,6], T. Gorkhover[5], C. Bostedt[3,7], C. Bomme[2], S. Düsterer[2], B. Erk[2], M. Kuhlmann[2], D. Rolles[2], D. Rompotis[2], R. Treusch[2], T. Feigl[4], T. Möller[1], and D. Rupp[1] — [1]IOAP, Technische Universität Berlin, Germany — [2]FLASH, Deutsches Elektronen-Synchrotron, Germany — [3]DoP, Northwestern University, USA — [4]optiX fav GmbH, Germany — [5]LCLS, Stanford Linear Accelerator Center, USA — [6]ARC CoAMI, LaTrobe University, Australia — [7]Argonne National Lab, USA

We studied the ultrafast dynamics in single large rare gas clusters in an XUV/XUV pump-probe diffraction experiment at the FLASH free-electron laser. The spatial overlap of both microfoci at all time delays could be optimized using the delay-dependent features in the ion spectra of small clusters. Increasing charge states and decreasing ion kinetic energies show the suppressed recombination towards longer time delays.

A 32: Rydberg gasses I

Time: Friday 11:00–13:00 Location: HS 20

A 32.1 Fri 11:00 HS 20

Rydberg blockade of excitons in Cu_2O — •Julian Heckötter[1], Marcel Freitag[1], Marc Assmann[1], Tomasz Kazimierczuk[2], Dietmar Fröhlich[1], and Manfred Bayer[1] — [1]Experimentelle Physik 2, TU Dortmund, Dortmund, Germany — [2]Institute of Experimental Physics, University of Warsaw, Warsaw, Poland

In this work we report on absorption measurements on Rydberg-Excitons [1] in Cu_2O with quantum numbers up to $n = 25$. In Cu_2O, excitonic states with an odd angular momentum quantum number, such as P- and F-excitons, are dipole allowed. We study the interaction between P-envelope states of high principal quantum numbers. For non-degenerate states the concept of the Rydberg blockade mechanism [2] is introduced to explain the decrease in absorption for increasing laser powers. We find a scaling of the blockade efficiency as n^{10} in accordance with theory [1].

In recent two-color pump-probe experiments we used two narrow bandwidth dye lasers to investigate the interaction between degenerate states. For high pump powers, we find a decrease in absorption at the resonances of high n but also an enhancement in between. Here, the blockade efficiency shows a n^8 scaling behaviour. In addition, for lower n states, the reduction of absorption is overlayed by an initial increase of the oscillator strengths.

[1] T. Kazimierczuk et al., Nature **514**, (2014), p. 343
[2] E. Urban et. al, Nature Physics **5**, (2009)

A 32.2 Fri 11:15 HS 20

Collective holonomic phase gate by Rydberg-dressed photon blockade — •Felix Motzoi and Klaus Molmer — Aarhus University

We present a scheme for applying a phase gate on an array of neutral atoms, conditioned on all of them being in the same ground state. The gate consist of a geometric phase using the ancillary degrees of freedom given by a cavity and second ensemble of neutral atoms of a different species, via an EIT mechanism to blockade or allow photons to enter the system. All operations are dark with respect to the atoms, of both the quantum register and ancillary species, with far-detuned Rydberg dressing avoiding almost any Rydberg population. This allows for a gate error that scales nearly independently of the total number of quantum registers.

A 32.3 Fri 11:30 HS 20

High-fidelity Rydberg-blockade entangling gate using shaped, analytic pulses — •Lukas Theis[1], Felix Motzoi[1], Frank Wilhelm[1], and Mark Saffman[2] — [1]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Department of Physics, University of Wisconsin-Madison, Wisconsin, USA

We show that the use of shaped pulses improves the fidelity of a Rydberg-blockade two-qubit entangling gate by several orders of magnitude compared to previous protocols based on square pulses or optimal control pulses. Using analytical derivative removal by adiabatic gate (DRAG) pulses that reduce excitation of primary leakage states and an analytical method of finding the optimal Rydberg blockade, we generate Bell states with a fidelity of $F > 0.9999$ in a 300 K environment for a gate time of only 50 ns, which is an order of magnitude faster than previous protocols. These results establish the potential of neutral atom qubits with Rydberg-blockade gates for scalable quantum computation.

A 32.4 Fri 11:45 HS 20

Topological ordering and entanglement of Rydberg atoms in the presence of decoherence — •Durga Bhaktavatsala Rao Dasari[1] and Klaus Moelmer[2] — [1]3. Physikalisches Institut, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany. — [2]Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, DK-8000, Aarhus C, Denmark.

We investigate the role of topology and decoherence for generating robust many body entanglement in a Rydberg atomic system. Such decoherence assisted entanglement results only when the atoms are arranged on graph like structures with a preferred connectivity. Further, lattice structures that have maximum nearest neighbors of 2 in 1D, 4 in 2D and 6 in 3D always lead to such entanglement. Any defect arrangement that does not satisfy these geometrical constraints can destroy both entanglement and purity in the entire network. We further show how the topologically ordered state of Rydberg atoms can lead to deterministic single photon emission without the requirement for the global Rydberg blockade.

A 32.5 Fri 12:00 HS 20

Stability and instabilities of bosonic crystalline quantum phases of Rydberg dressed lattice gases — •Andreas Geissler[1], Mathieu Barbier[1], Ulf Bissbort[2], Yongqiang Li[3], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe Universität Frankfurt am Main, Germany — [2]Engineering Product Development, SUTD, Singapore — [3]Department of Physics, NUDT, China

Recent experiments have shown the feasibility of Rydberg dressing [1], even in a lattice system [2], thus paving the way towards realizing exotic states of matter in ultracold gases. While our latest results have shown a rich diversity of crystalline and supersolid quantum phases in bosonic lattice systems [3], induced by the strong correlations due to Rydberg dressing, a better understanding of crystallisation is still required. We therefore analyse the instabilities due to quasiparticle excitations, which we determine from linearised Gutzwiller equations. Furthermore, we simulate the dissipative dynamics induced by the finite lifetime of Rydberg states and decoherence effects inherent to these driven systems. The Lindblad master equation is solved within a Gutzwiller mean-field description, which also allows for itinerant dynamics. We thus show the existence of exotic ordered steady states after various parameter sweeps, as well as the stability of these states.

[1] Y.-Y. Jau et al., Nat. Phys. 12, 71-74 (2016)
[2] J. Zeiher et al., arXiv:1602.06313
[3] A. Geißler et al., arXiv:1509.06292

A 32.6 Fri 12:15 HS 20

Reservoir engineering using Rydberg atoms — David W. Schönleber, Christopher D. B. Bentley, and •Alexander Eisfeld — Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden

We apply reservoir engineering to construct a thermal environment with controllable temperature in an ultracold atomic Rydberg system [1]. A Boltzmann distribution of the system's eigenstates is produced by optically driving a small environment of ultracold atoms, which is coupled to a photonic continuum through spontaneous emission. This technique provides a useful tool for quantum simulation of both equilibrium dynamics and dynamics coupled to a thermal environment. Additionally, we demonstrate that pure eigenstates, such as Bell states, can be prepared in the Rydberg atomic system using this method.

[1] D. W. Schönleber et al., arXiv:1611.02914 (2016)

A 32.7 Fri 12:30 HS 20

Bistability vs. Metastability in Driven Dissipative Rydberg Gases — •Oliver Thomas[1,2], Fabian Letscher[1,2], Thomas Niederprüm[1], Michael Fleischhauer[1], and Herwig Ott[1] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

We investigate the possibility of a bistable phase in an open many-body system. To this end we discuss the microscopic dynamics of a continuously off-resonantly driven Rydberg lattice gas in the regime of strong decoherence. Our experimental results reveal a prolongation of the temporal correlations exceeding the lifetime of a single Rydberg excitation and show strong evidence for the formation of finite-sized Rydberg excitation clusters in the steady state. We simulate the dynamics of the system using a simplified and a full many-body rate-equation model. The results are compatible with the formation of metastable states associated with a bimodal counting distribution as well as dynamic hysteresis. Yet, a scaling analysis reveals, that the correlation times remain finite for all relevant system parameters, which suggests a formation of many small Rydberg clusters and finite correlation lengths of Rydberg excitations. These results constitute strong evidence against the presence of a global bistable phase previously suggested to exist in this system.

A 32.8 Fri 12:45 HS 20

Coherent many-body dynamics in Rydberg-dressed spin chains — •Simon Hollerith[1], Johannes Zeiher[1], Antonio Rubio-Abadal[1], Jae-yooni Choi[1], Rick van Bijnen[3], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, — [3]Institut für Quantenoptik und Quanteninformation, Technikerstr. 21a, 6020 Innsbruck, Austria

Off-resonant optical coupling of a ground state atom to a Rydberg state, so called "Rydberg-dressing", has been proposed as a versatile method to implement various long-range interacting spin models with ultracold atoms. In our experiment, we realize Rydberg-dressing to implement an Ising spin system, starting with an atomic Mott insulator of Rubidium-87 in an optical lattice with a single atom per site. Using a single photon uv-transition, we couple off-resonantly to a Rydberg p-state. First interferometric experiments in a two-dimensional sample showed the versatility of Rydberg dressing for control of the interactions, however collective loss processes reduced the lifetime of the system. Here, we present results of Rydberg-dressing in a 1d spin chain with long-range Ising interactions. Contrary to the 2d case, the collective loss can be avoided and lifetimes get close to the values expected in an ideal two-level system. We substantiate the improved lifetimes by showing coherent collapse and revival dynamics in the 1d chain. Our results pave the way to study novel symmetry protected topological phases in periodically driven 1d spin chains.

A 33: Ultracold atoms and BEC - V (with Q)

Time: Friday 11:00–13:00 Location: N 1

A 33.1 Fri 11:00 N 1

Quantum Galvanometer with ultracold atoms — •Carola Rogulj, Peter Federsel, Malte Reinschmidt, Lukas Gussmann, Andreas Günther, and József Fortágh — Physikalisches Institut, Auf der Morgenstelle 14, D-72076 Tübingen

Hybrid quantum systems are engineered to combine properties and advantages of two quantum systems. Heading for novel quantum technologies, ultracold atoms and nanomechanical resonators are promising candidates for quantum information processing. Ultracold atoms and degenerate quantum gases can be very precisely manipulated and provide long coherence times, which makes them for example well suited quantum memories. Nanomechanical oscillators can not only be functionalized to allow for sensitive force detection, but can also be cooled down to their quantummechanical ground state. In my talk, I will show a Quantum Galvanometer scheme and its experimental realisation, where an oscillating nanomechanical resonator carrying electrical current is brought to interaction with a Bose Einstein condensate of ^{87}Rb atoms. This is achieved by means of an atomchip with magnetic conveyor belt. In our case, the resonator consists of a gold coated silicon nitride beam. It creates a fluctuating electromagnetical field which serves as output coupler for an atom laser. We have developed a state and energy selective single atom detection scheme that allows to observe temporal correlations of this atom laser. The magnetomechanically coupled hybrid system will thus enable us to measure the statistics of current fluctuations in a setup that is capable of resolving quantum properties of electrical current.

A 33.2 Fri 11:15 N 1

A deterministic ion source based on ultracold atoms — •Cihan Sahin, Jens Benary, Philipp Geppert, Andreas Müllers, and Herwig Ott — Technische Universität Kaiserslautern

An ion source with minimal energy spread and deterministic emission has many applications in basic research and technical applications including surface spectroscopy, ion implantation or ion interferometry.

We have developed an ion source based on ^{87}Rb atoms confined in a magneto-optical trap. The atoms are ionized with a three photon scheme, built-up of infrared lasers. This results in a minimal energy transfer to the ionization fragments and reduces the electron background from the photoelectric effect.

To detect the electrons and ions, we currently use channel electron multipliers (CEM). The electron, registered within a few ns after ionization, is utilized for the deterministic operation of the ion source. The much slower ions are controlled by a gate electrode, which is by default blocking them. If an electron is registered, the gate is opened for a short time to let the corresponding ion pass.

Currently, we are able to operate the source with an ion rate from a few to 10^4 s^{-1} in gated mode, and 10^6 s^{-1} without gate operation. We discuss the results obtained so far including the statistical properties of our source.

In a next step, the ion CEM will be replaced with a position sensitive detector for ion momentum spectrocopy. Additionally, an adaptive ion optics upgrade may be used to manipulate ion trajectories in real time and allow for aberation corrections.

A 33.3 Fri 11:30 N 1

Ultracold electron source from a MOT studied by ToF-microscopy — •Olena Fedchenko[1], Sergey Chernov[1], Melissa Vielle-Grosjean[2], Gerd Schönhense[1], and Daniel Comparat[2] — [1]Institut für Physik, JGU Mainz, Germany — [2]University Paris-Sud, Orsay, France

We report on the first results of the application of cold Cs atoms as a monochromatic (photo-) electron source obtained with time-of-flight momentum microscopy. Such sources provide an electron beam for high energy resolution (meV-range) spectroscopic electron microscopy [1]. The experimental set-up consists of a magneto-optical trap with Cs atoms, ionization lasers, lens system of the ToF-microscope and delay-line detector [2]. Last two allow mapping of 3D spectral function I(k$_x$, k$_y$, t). The ToF study of photoelectron dynamics was performed using pulsed pico- and femtosecond lasers for ionization above or just at the ionization threshold. In the first case a picosecond pulsed LD @ 375 nm was used for the direct ionization from 6p$_{3/2}$. In the second case a LD @ 1470 nm (excitation $6p_{3/2} \rightarrow 7s_{1/2}$) was used in combination with a Ti-sapphire laser @ 750-800 nm (ionization from the 7s$_{1/2}$). Consequently, varying the initial photoelectron energy in the range from 5 meV up to 860 meV above the ionization limit gives the opportunity to find optimal conditions to get the best electron beam parameters - time and energy spread, emittance, brightness and focusing.

Funded by ANR/DFG HREELM

[1] M. Kitajima et al., Europ. Phys. J. D 66, 130 (2012). [2] A. Oelsner et al., J. Electron Spectrosc. 178-179, 317 (2010).

A 33.4 Fri 11:45 N 1

Realization of uniform synthetic magnetic fields by periodically shaking an optical square lattice — Charles Creffield[1], •Gregor Pieplow[1], Fernando Sols[1], and Nathan Goldman[2] — [1]Departamento de Física de Materiales, Universidad Complutense de Madrid, E-28040 Madrid, Spain — [2]CENOLI, Faculté des Sciences, Université Libre de Bruxelles (U.L.B.), B-1050 Brussels, Belgium

A powerful method to create effective magnetic fields is to shake a lattice of cold gases trapped in an optical lattice. Typically such schemes produce space-dependent effective masses and non-uniform flux patterns. In this work we try to tackle this problem by proposing several lattice shaking protocols, theoretically investigating their associated effective Hamiltonians and their quasienergy spectra. This allows the identification of novel shaking schemes, which simultaneously provide uniform effective mass and magnetic flux, with direct implications for cold-atom experiments and photonics.

A 33.5 Fri 12:00 N 1

Cavity-assisted measurement and coherent control of collective atomic spin oscillators — •Nicolas Spethmann[1,2], Jonathan Kohler[2], Sydney Schreppler[2], and Dan Stamper-Kurn[2,3] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physics, University of California, Berkeley, CA 94720, USA — [3]Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

I will present experiments of continuous measurement and coherent control of the collective spin of an atomic ensemble trapped and evolving in a high-finesse cavity. We employ autonomous optical feedback onto the atomic spin dynamics, conditioned by the cavity spectrum, as a feedback mechanism to stabilize the spin in either its high- or low-energy state. We measure the effective spin temperature from the asymmetry between the Stokes and anti-Stokes sidebands. We demonstrate that such a feedback-stabilized spin ensemble remains in a nearly pure quantum state, in spite of measurement back-action due to the continuous interaction with the probe field. Here, the high-energy spin state corresponds to a state with negative effective temperature. The system realized in our work paves the way for applications in the quantum regime, as for example quantum-limited, phase-preserving spin amplifiers or coherent quantum noise cancellation techniques.

A 33.6 Fri 12:15 N 1

Sudden and Slow Quenches into the Antiferromagnetic Phase of Ultracold Fermions — Monika Ojekhile[1], •Robert Höppner[1], Henning Moritz[2], and Ludwig Mathey[1] — [1]Zentrum für Optische Quantentechnologien and Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany

We propose a method to reach the antiferromagnetic state of two-dimensional Fermi gases trapped in optical lattices: Independent subsystems are prepared in suitable initial states and then connected by a sudden or slow quench of the tunneling between the subsystems, while subjecting the system to a time-dependent staggered magnetic field. Examples of suitable low-entropy subsystems are double wells or plaquettes, which can be experimentally realised in Mott insulating shells using optical super-lattices. Expanding on previous work reported in Ref. [1], we now investigate the effect of finite quench times and different quench protocols on the final state energy using a the quantum Heisenberg model of a finite system.

[1] Zeitschrift für Naturforschung A., Vol. 71, Issue 12, Pages 1143-1150

A 33.7 Fri 12:30 N 1

Measuring Correlations in a Double Well with Single-Atom Imaging — •Vincent M. Klinkhamer, Andrea Bergschneider, Jan Hendrik Becher, Philine L. Bommer, Justin F. Niedermeyer, Gerhard Zürn, Philipp M. Preiss, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

We deterministically prepare quantum states of two interacting Lithium atoms in an optical double-well potential. To recover the occupation number on the sites, we detect individual atoms with our new spin-resolved fluorescence imaging. However, interesting properties such as the symmetry between particles cannot be measured in this way. Therefore we measure the momenta of the individual atoms after time-of-flight expansion. This allows us to determine the correlations between two atoms with high contrast.

A 33.8 Fri 12:45 N 1

Scaling of a long-range interacting quantum spin system driven out of equilibrium — •Stephan Helmrich, Alda Arias, and Shannon Whitlock — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

Complex systems are often found to exhibit unexpectedly simple scaling laws that can signal new physical regimes or universal relations between otherwise very different systems. Although this provides a powerful tool for characterising systems close to equilibrium, there are only few known examples where scaling behavior can be found in dynamical settings. Here we demonstrate power-law scaling in a well-controlled quantum spin system driven out of equilibrium [1]. This enables us to reconstruct the non-equilibrium phase diagram of the system and to identify dissipation-dominated, driving-dominated and interaction-dominated regimes. Comparing the measured scaling laws with kinetic Monte Carlo simulations we uncover the microscopic origin of the observed scalings. This opens up a new means to study and classify quantum systems out of equilibrium and extends the domain where scale-invariant behavior can be found.

[1] S. Helmrich, A. Arias, and S. Whitlock. arXiv:1605.08609, 2016

A 34: Atoms in Strong Fields I

Time: Friday 11:00–13:00 Location: N 2

Invited Talk A 34.1 Fri 11:00 N 2

3d-Photoelectron Momentum Distributions from Multi-Photon Ionization with Ultra Short Polarization-Shaped Laser Pulses — •Matthias Wollenhaupt — Carl von Ossietzky Universität, 26129 Oldenburg, Germany

We present our experiments on multi-photon ionization of atoms with polarization-shaped femtosecond light pulses. In the first part, we demonstrate the generation of vortex-shaped photoelectron wave packets from resonance enhanced multi photon ionization (REMPI) of atoms with sequences of two time-delayed, counterrotating circularly polarized pulses from a supercontinuum femtosecond laser source. The electron vortices are measured by velocity map imaging (VMI) and reconstructed using tomographic techniques. In the second part, bichromatic polarization-shaped femtosecond laser pulses [1] are employed to manipulate photoelectron momentum distributions. We study REMPI by counterrotating circularly polarized and orthogonally linearly polarized bichromatic scenarios. The reconstructed 3d-photoelectron momentum distributions show different uncommon angular superposition states at different photoelectron energies. The analysis of the photoionization pathways reveals that REMPI by bichromatic polarization-shaped fields relies on the interplay of selection rules and intrapulse frequency mixing of spectral bands with different ellipticity. Finally, we use a bichromatic pump-probe scheme to follow the time evolution of an atomic spin-orbit wave packet observed in the 3d-photoelectron momentum distribution. [1] S. Kerbstadt, L. Englert, T. Bayer and M. Wollenhaupt, J. Mod. Opt., accepted (2016)

A 34.2 Fri 11:30 N 2

Single-beam bichromatic control of resonance-enhanced multi-photon ionization — •Tim Bayer, Stefanie Kerbstadt, Daniela Johannmeyer, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Straße 9-11, 26129 Oldenburg

Coherent control of quantum phenomena is based on the interference of multiple quantum pathways connecting the initial system state with a preselected target channel. Recently, ultrashort bichromatic laser fields have emerged as an efficient tool to steer coherent electron dynamics in, e.g., strong-field ionization of atoms and high harmonic generation. The beauty of bichromatic fields lies in the capability to disentangle different quantum pathways via frequency mixing and selection rules. Here we employ polarization-tailored bichromatic fields from a $4f$ polarization pulse shaper [1] to study resonance-enhanced multi-photon ionization of atoms as a prototype scenario for multi-pathway coherent control. Three-dimensional detection of the photoelectron momentum distribution by photoelectron imaging tomography provides detailed insights into the excitation and ionization dynamics. We present first results of current experiments on potassium atoms using orthogonal linearly and counter-rotating circularly polarized bichromatic fields.

[1] S. Kerbstadt, L. Englert, T. Bayer, M. Wollenhaupt, J. Mod. Opt., accepted (2016)

A 34.3 Fri 11:45 N 2

Velocity Map Imaging and Semi-classical analysis of Scattering Dynamics in Orthogonal Two-color Fields — •Daniel Würzler[1,2], Max Möller[1,2], Nicolas Eicke[3], Daniel Seipt[1,2], Max Sayler[1,2], Stephan Fritzsche[1,2], Manfred Lein[3], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantum-Electronics, Max-Wien-Platz 1, D-07743 Jena, Germany — [2]Helmholtz-Institute Jena, Froebelstieg 3, D-07743 Jena, Germany — [3]Institute for Theoretical Physics, Appelstraße 2, D-30167 Hannover, Germany

Tuning the relative phase of orthogonal two-color laser fields has become an important technique to get insight/control into sub-cycle electron dynamics of strong-field ionization processes. Here this technique is applied to velocity map imaging spectroscopy using an unconventional orientation with the polarization of the ionizing laser field perpendicular to and the steering field parallel to the detector surface. We measure the phase-dependent photoelectron momentum distribution of Neon and Xenon and analyse them by using semi-classical calculations in three dimensions including elastic scattering at different orders of return. The results are confirmed with the solution of three-dimensional time-dependent Schrödinger equation (3D TDSE) calculations. Thereby control over direct and rescattered electrons is demonstrated.

A 34.4 Fri 12:00 N 2

Single-shot characterization of few-cycle pulses based on stereographic above-threshold ionization at 1.8μm — •Philipp Kellner[1], Daniel Adolph[1,2], Danilo Zille[1], Yinyu Zhang[1,2], Philipp Wustelt[1], Daniel Wuerzler[1], Max Moeller[1], A.M. Sayler[1,2], and G.G. Paulus[1,2] — [1]Institute of Optics and Quantum Electronics, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Helmholtz Institute Jena, Froebelstieg 3, 07743 Jena, Germany

The investigation of carrier-envelope (CE-)phase-dependent effects in strong-field laser-matter interaction calls for the precise measurement and control of the time-dependent electric field of few-cycle pulses. For 800 nm center wavelength, stereographic above-threshold ionization (stereo-ATI) in Xenon, i.e., the so-called carrier-envelope phasemeter (CE-phasemeter) is an established technique for a simultaneous, single-shot, real-time measurement of both the CEP and the pulse duration. Here we demonstrate single-shot CEP and pulse length characterisation at 1.8μm with intense few-cycle pulses using stereo-ATI in Xenon and compare it to the results obtained at 800 nm. The demonstrated results open new opportunities in the investigation of CE-phase-dependent processes at shortwave infrared wavelengths.

A 34.5 Fri 12:15 N 2

Laser-subcycle control of sequential double-ionization dynamics of Helium — •Philipp Wustelt[1,2], Max Möller[1,2], Markus S. Schöffler[3], Xinhua Xie[3], Vaclav Hanus[3], A. Max Sayler[1,2], Andrius Baltuska[3], Gerhard G. Paulus[1,2], and Markus Kitzler[3] — [1]Institute of Optics and Quantum Electronics, Friedrich-Schiller-University Jena, D-07743 Jena, Germany — [2]Helmholtz Institute Jena, D-07743 Jena, Germany — [3]Photonics Institute, Technische Universität Wien, Vienna, Austria

We investigate sequential double-ionization of helium by intense close-to-circularly polarized few-cycle laser pulses using a classical trajectory-based model with two independent electrons. Simulated He^{2+} ion momentum distributions are compared to those obtained in recent benchmark experiments [1]. The influence of a number of pulse parameters such as peak intensity, carrier-envelope phase, pulse duration and second- and third-order spectral phase on the shape of the ion momentum distributions is studied. To explain certain fine-scale features observed in the measurement, it becomes important to consider subtle timing-variations in the two-electron emissions introduced by small values of chirp. This result demonstrates the possibility of controlling multi-electron dynamics on the attosecond time-scale by tuning the field-evolution of intense few-cycle laser pulses.

[1] Schöffler et al., Phys. Rev. A **93**, 063421 (2016)

A 34.6 Fri 12:30 N 2

Laser-driven recollisions under the Coulomb barrier — •Thomas Keil[1], Sergey Popruzhenko[2], and Dieter Bauer[1] — [1]Institut für Physik, Universität Rostock, 18051 Rostock, Germany — [2]National Research Nuclear University MEPhI, Kashirskoe shosse 31, 115409, Moscow, Russia

Photoelectron spectra obtained from the *ab initio* solution of the time-dependent Schrödinger equation can be in striking disagreement with predictions by the strong-field approximation (SFA) not only at low energy but also around twice the ponderomotive energy where the transition from the direct to the rescattered electrons is expected. In fact, the relative enhancement of the ionization probability compared to the SFA in this regime can be several orders of magnitude. We show for which laser and target parameters such an enhancement occurs and for which the SFA prediction is qualitatively good. The enhancement is analyzed in terms of the Coulomb-corrected action along analytic quantum orbits in the complex-time plane, taking soft recollisions under the Coulomb barrier into account. These recollisions in complex time and space prevent a separation into sub-barrier motion up to the "tunnel exit" and subsequent classical dynamics. Instead, the entire quantum path up to the detector determines the ionization probability [1].

[1] Th. Keil, S.V. Popruzhenko, D. Bauer, Phys. Rev. Lett. (accepted), preprint arXiv:1608.03844

A 34.7 Fri 12:45 N 2

Intense-field S-Matrix formalism with coulomb interaction applied to ATI — •Willi Paufler[1], Birger Böning[1], and Stephan Fritzsche[1,2] — [1]Friedrich-Schiller-Universität, Jena, Germany — [2]Helmholtz-Institut Jena, Germany

The commonly used Strong-Field Approximation is a powerful tool to study the interaction of few cycle laser pulses with atoms. SFA provides a good insight in many strong-field effects like Above-Threshold Ionization (ATI), Higher Harmonics Generation and Non Sequential Double Ionization. If the SFA is applied to ATI processes, we neglect the influence of the parent ion on the photoelectron and describe it as a free electron in presence of just the laser field. This simplification causes heavy problems in the Low-Energy Structures (LES) and the Keldysh approximation fails to describe this part of the spectrum. We investigate the Strong-field S-Matrix formalism using the continuum Coulomb waves augmented with the time-dependent Volkov phase [1] and compare the calculations with the results of the SFA and TDSE calculations.

[1] Faisal, F. H. M., Phys. Rev. A**94**, 031401 (2016)

A 35: Clusters II (with MO)

Time: Friday 11:00–13:00 Location: N 3

Invited Talk A 35.1 Fri 11:00 N 3

The Nanoplasma Oscilloscope — •Christian Peltz[1], A. LaForge[2], B. Langbehn[3], R. Michiels[2], C. Callegari[4], M. Di Fraia[4], P. Finetti[4], R. Squibb[5], C. Svetina[4], L. Raimondi[4], M. Manfredda[4], N. Mahne[4], P. Piseri[6], M. Zangrando[4], L. Giannessi[4], T. Möller[3], R. Feifel[5], K. C. Prince[4], M. Mudrich[2], D. Rupp[3], F. Stienkemeier[2], and T. Fennel[1] — [1]Uni Rostock, Germany — [2]Uni Freiburg, Germany — [3]TU Berlin, Germany — [4]ELETTRA-Sincrotrone Trieste, Italy — [5]Uni Gothenburg, Sweden — [6]Uni Milan, Italy

Atomic clusters enable the well-controlled generation of nanoscale plasmas allowing for the study of their ultrafast light-induced correlated and collective dynamics. In particular, short-wavelength FELs can probe these dynamics in a regime that is fundamentally different from the well-known near-infrared domain. Plasma processes like collisional plasma heating, collective resonance excitation, and ionization avalanching that are generic in the NIR are strongly suppressed in the XUV and soft X-ray domain. Instead, sequential direct photo- or Auger emission dominates the plasma generation and heating dynamics. Signatures of this multistep ionization are characteristic plateau-like electron spectra and frustration of direct photo-emission by the cluster potential. Here we report the first direct time-resolved measurement of the underlying cluster potential evolution using the nanoplasma oscilloscope method, implemented in a recent two-color XUV pump-probe experiment at the seeded, high gain harmonic generation FEL FERMI FEL-2 operating in double stage mode.

A 35.2 Fri 11:30 N 3

NIR-induced Auger decay in clusters — •Bernd Schütte, Marc Vrakking, and Arnaud Rouzée — Max-Born-Institut, Berlin

In nanoplasmas, which are formed by the interaction of clusters with intense laser pulses, Rydberg states are efficiently populated. While it is well known that some of the excited atoms and ions relax via the emission of photons [1], nonradiative relaxation mechanisms have only recently been discovered at moderate cluster ionization [2,3]. Here we show that nonradiative decay remains important at high ionization degrees, as is demonstrated for CH_4 clusters that interact with 400-fs NIR pulses ($I = 1 \times 10^{14}$ W/cm^2). We observe a clear peak in the electron spectrum at 7 eV that is assigned to Auger decay, and that is explained by a 3-step process: (i) Our calculations show that the laser pulse removes almost all electrons from the outer shells of C, resulting in a dominant C^{4+} ion contribution at the end of the laser pulse. (ii) Rydberg and outer-vacancy shell levels are populated by recombination, and (iii) relax via Auger decay. This picture is consistent with a dominant C^{3+} ion contribution observed in the experiment, whereas, surprisingly, C^{+} and C^{4+} ion contributions are negligible.

Our results could explain the high average ion charge states that have been observed in clusters in spite of highly efficient recombination processes. Furthermore, the observed population inversion may be exploited for the development of an XUV or X-ray laser.

[1] A. McPherson *et al.*, Nature **370**, 631 (1994).
[2] B. Schütte *et al.*, Phys. Rev. Lett. **114**, 123002 (2015).
[3] B. Schütte *et al.*, Nat. Commun. **6**, 8596 (2015).

A 35.3 Fri 11:45 N 3

The 3D shapes of spinning helium nanodroplets — •B. Langbehn[1], Y. Ovcharenko[1,2], D. Rupp[1], K. Sander[3], C. Peltz[3], A. Clark[4], R. Cucini[5], P. Finetti[5], M. Di Fraia[5], D. Iablonskyi[6], A. C. LaForge[7], V. Oliver Álvarez de Lara[4], O. Plekan[5], P. Piseri[8], T. Nishiyama[9], C. Callegari[5], K. C. Prince[5], K. Ueda[6], F. Stienkemeier[7], T. Fennel[3], and T. Möller[1] — [1]TU Berlin — [2]European XFEL — [3]Univ. Rostock — [4]EPFL, Lausanne — [5]Elettra-Sincrotrone Trieste — [6]Tohoku Univ. Sendai — [7]Univ. Freiburg — [8]Univ. di Milano — [9]Kyoto Univ.

Scattering techniques using intense femtosecond short-wavelength pulses from free-electron lasers (FEL) have been developed to gain an insight into the structure of nanoparticles such as viruses or clusters. Recent pioneering experiments in the hard X-ray range revealed that superfluid helium nanodroplets can gain high angular momentum resulting in large centrifugal deformation [1]. While hard X-ray experiments push towards atomic resolution, full 3D information on the particle shape (and orientation) from a single scattering pattern requires access to the wide-angle scattering signal available only at longer wavelength [2]. We have used intense XUV pulses from the FERMI-FEL to retrieve the 3D shapes of single helium nanodroplets. We follow the evolution from axisymmetric oblate over triaxial prolate to two-lobed droplets with increasing angular momentum, as predicted by the theoretical model of a classical spinning drop.

[1] Gomez et al., *Science* **345** (2014)
[2] Barke et al., *Nat. Comm.* **6** (2015)

A 35.4 Fri 12:00 N 3

Machine-learning assisted classification of diffraction images — •J. Zimmermann[1], M. Sauppe[1], A. Ulmer[1], B. Langbehn[1], S. Dold[2], B. v. Issendorff[2], I. Barke[3], H. Hartmann[3], K. Oldenburg[3], F. Martinez[3], K.H. Meiwes-Broer[3], B. Erk[4], C. Bomme[4], B. Manschwetus[4], J. Correa[4], S. Düsterer[4], R. Treusch[4], T. Möller[1], and D. Rupp[1] — [1]IOAP, TU Berlin — [2]Univ. Freiburg — [3]Univ. Rostock — [4]FLASH@DESY

Short wavelength Free-Electron-Lasers (FEL) enable diffractive imaging of individual nanosized objects with a single x-ray laser shot. Due to the high repetition rate, large data sets with up to several million diffraction pattern are typically obtained in FEL particle diffraction experiments, representing a severe problem for the data analysis. We here propose a workflow scheme to drastically reduce the amount of work needed for the categorization of large data-sets of diffraction patterns, with the ultimate goal of developing an unsupervised training procedure. With a first supervised approach a classification and viewer tool is used for classifying manually selected high quality diffraction pattern. These patterns are then used as training data for a Residual Convolutional Neural Network (RCNN). The RCNN is designed for the classification of data for efficient indexing and subsequent analysis. The residual learning framework is a new type of network structure that drastically increases the depth of neural networks [He, et al. Deep Residual Learning, 2015]. First performance evaluations are done using data from a single-shot wide-angle scattering CDI experiment on silver clusters conducted in 2015 at the FLASH facility in Hamburg.

A 35.5 Fri 12:15 N 3

The X-Ray Movie Camera: Time-Resolved Diffractive Imaging Of Individual Clusters — •M. Sauppe[1], T. Bischoff[1], K. Kolatzki[1], B. Langbehn[1], M. Müller[1], B. Senfftleben[1], A. Ulmer[1], J. Zimbalski[1], J. Zimmermann[1], L. Flückiger[2], T. Gorkhover[1,3], C. Bostedt[4,5], C. Bomme[6], S. Düsterer[6], B. Erk[6], M. Kuhlmann[6], D. Rolles[6], D. Rompotis[6], R. Treusch[6], T. Feigl[7], T. Möller[1], and D. Rupp[1] — [1]IOAP, Technische Universität Berlin, Germany — [2]ARC CoAMI, LaTrobe University, Australia — [3]LCLS, Stanford Linear Accelerator Center, USA — [4]Argonne National Laboratory, USA — [5]DoP, Northwestern University, USA — [6]FLASH, Deutsches Elektronen-Synchrotron — [7]optiX fab, Germany

Coherent diffractive imaging has been developed as a powerful technique for uncovering the structure of nano-sized particles like virues, aerosols and clusters, as well as laser-induced nanoparticle dynamics. So far in time-resolved imaging experiments either optical pump lasers have been used or pump- and probe-images were superimposed. Here we present a new experimental setup, were the image of the inital particle and the image of final state are spatially separated and recorded by a two detector system. From the pump-image we can extract informations like size, shape and exposed intensity, from the probe-image we gain insight into light-induced dynamics. Probe pulses can be delayed up to 650 ps, realized by the new split-and-delay unit DESC, which has been permantly installed at the CAMP end-station at the FLASH FEL. First results will be discussed.

A 35.6 Fri 12:30 N 3

Determination of average cluster sizes by fluorescence: proof of principle on Ne, Ar, and Kr clusters — •Xaver Holzapfel[1], Andreas Hans[1], Philipp Schmidt[1], Ltaief Ben Ltaief[1], Philipp Reiss[1], Reinhard Dörner[2], Arno Ehresmann[1], and André Knie[1] — [1]University of Kassel, Institute of Physics and Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), D-34132 Kassel, Germany — [2]Institute of Nuclear Physics, J. W. Goethe University, D-60438 Frankfurt, Germany

Finite aggregates like clusters cover the range between molecular and condensed matter physics and are used to study microscopic phenomena. The most important quantity for fundamental investigations of clusters is their average size. For clusters produced by a supersonic expansion, however, the average cluster size is usually estimated by an empirical law involving the stagnation pressure of the expansion, a law whos validity is under debate since its introduction. Here we present an alternative method for determination of the mean cluster size by resonant excitation of outer valence electrons and the subsequent emission of fluorescence photons in Ne, Ar and Kr. This method has been compared to average cluster size determination by the empirical law essentially corroborating the latter and can be used in the future for independent average cluster size determination.

A 35.7 Fri 12:45 N 3

Signatures of Rabi cycling and excited state population in single-shot coherent diffractive imaging — •Björn Thorben Kruse, Christian Peltz, and Thomas Fennel — Institute of Physics, University of Rostock, Germany

Single-shot coherent diffractive imaging (CDI) of individual free nanoparticles enables the study of their three-dimensional shape and orientation [1] as well as their optical and electronic properties [2]. Recently, even signatures of quantum-mechanical vortices have been observed in scattering images of superfluid helium droplets [3], demonstrating that CDI provides access to the observation of rotational excitation in quantum liquids. Whereas the imaging of these vortices is an indirect detection of quantum effects, it remains an open question to what extent quantum effects can be observed directly and how their signatures would look like. Here we study the possibility to directly image the nonlinear quantum-mechanical few-level dynamics in laser-excited nanoparticles. For our theoretical analysis, we employ a Maxwell-Bloch type description of the scattering problem, where the polarization dynamics is described in local few-level approximation and field propagation is treated with the finite-difference time-domain method (FDTD). The origin of non-linear effects in resonant XUV scattering from droplets and possible routes to the spatiotemporal imaging of population dynamics will be discussed.

[1] I. Barke et al., Nat. Comm. **6**, 6187 (2015)
[2] C. Bostedt et al., Phys. Rev. Lett. **108**, 093401 (2012)
[3] L. F. Gomez et al., Science **345**, 6199:906-909 (2014)

A 36: Rydberg gasses II

Time: Friday 14:30–16:15 Location: HS 20

A 36.1 Fri 14:30 HS 20

Facilitation dynamics and localization phenomena in Rydberg lattice gases with position disorder — Matteo Marcuzzi[1,2], •Jiří Minář[1,2], Daniel Barredo[3], Sylvain de Léséleuc[3], Henning Labuhn[3], Thierry Lahaye[3], Antoine Browaeys[3], Emanuele Levi[1,2], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy, University of Nottingham, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Non-equilibrium Quantum Systems, University of Nottingham, United Kingdom — [3]Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Université Paris-Saclay, France

We explore the dynamics of Rydberg excitations in an optical tweezer array under facilitation condition. Due to the finite temperature the atomic positions are randomly spread, an effect that leads to quenched correlated disorder in the interatomic interaction strengths. This drastically affects the facilitation dynamics as we demonstrate experimentally. To shed light on the role of disorder we show that the dynamics is governed by an Anderson-Fock model, i.e. an Anderson model formulated on a lattice with sites corresponding to many-body Fock states. We consider a one-dimensional atom chain and illustrate the effect of disorder experimentally in a situation in which the system maps on a two-dimensional Anderson-Fock model on a trimmed square lattice. We observe a clear suppression of excitation propagation which we ascribe to the localization of the many-body wavefunctions in Hilbert space. [arXiv:1607.06295]

A 36.2 Fri 14:45 HS 20

Calculation of Rydberg interaction potentials — •Sebastian Weber[1], Christoph Tresp[2], Henri Menke[3], Alban Urvoy[4], Ofer Firstenberg[5], Hans Peter Büchler[1], and Sebastian Hofferberth[2] — [1]ITP3, Universität Stuttgart, Germany — [2]PI5, Universität Stuttgart, Germany — [3]FKF, Max-Planck-Institut Stuttgart, Germany — [4]RLE, Massachusetts Institute of Technology, USA — [5]Weizmann Institute of Science, Israel

The long-range interaction between individual Rydberg atoms provides a powerful tool exploited in an ever-growing range of applications in quantum information science, quantum simulation, and ultracold chemistry. One hallmark of the Rydberg interaction is that both its strength and angular dependence can be finetuned with great flexibility by choosing appropriate Rydberg states and applying external electric and magnetic fields. More and more experiments are probing this interaction at short atomic distances or with such high precision that perturbative calculations as well as restrictions to the leading dipole-dipole interaction term are no longer sufficient. We discuss the full calculation of Rydberg interaction potentials including electromagnetic fields with arbitrary direction. Symmetry arguments and selection rules greatly reduce the size of the Hamiltonian matrix, enabling the direct diagonalization of the Hamiltonian up to higher multipole orders on a desktop computer. Finally, we present example calculations showing the relevance of the full interaction calculation to current experiments. Our software for calculating Rydberg potentials is made available as open-source (https://pairinteraction.github.io/).

A 36.3 Fri 15:00 HS 20

Charge-induced optical bistability in thermal Rydberg vapor — •Daniel Weller, Alban Urvoy, Andy Rico, Robert Löw, and Harald Kübler — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart

In this talk, we discuss the phenomenon of optical bistability in a driven ensemble of Rydberg atoms. By performing two experiments with thermal vapors of rubidium and cesium, we are able to shed light onto the underlying interaction mechanisms causing such a non-linear behavior [1]. Due to the different properties of these two atomic species, we conclude that the large polarizability of Rydberg states in combination with electric fields of spontaneously ionized Rydberg atoms is the relevant interaction mechanism. In the case of rubidium, we directly measure the electric field in a bistable situation via two-species spectroscopy. In cesium, we make use of the different sign of the polarizability for different l-states and the possibility of applying electric fields. In contrast to previous interpretations [2, 3], both these experiments allow us to rule out dipole-dipole interactions in our realization, and support our hypothesis of a charge-induced bistability.

[1] Phys. Rev. A 94, 063820
[2] Phys. Rev. Lett. 111 113901
[3] Phys. Rev. A 93, 063863

A 36.4 Fri 15:15 HS 20

Quantum optics with a single Rydberg superatom — •Asaf Paris-Mandoki[1], Christoph Braun[1,2], Florian Christaller[1,2], Ivan Mirgorodskiy[1], Christoph Tresp[1,2], and Sebastian Hofferberth[1,2] — [1]5. Phys. Inst. and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Department of Physics, Chemistry and Pharmacy, University of Southern Denmark, 5230 Odense M, Denmark

We discuss our recent experiments coupling an optical medium smaller than a single Rydberg blockade volume to a few-photon probe field. Due to the large number of atoms in the blockaded volume and the efficient coupling to the probe light mode, we achieve coherent coupling between the probe field and the effective Rydberg "superatom" even if the probe pulse contains only a few photons.

Fast dephasing between the internal degrees of freedom of the superatom allows us to realize a free-space single-photon absorber, which deterministically absorbs exactly one photon from an input pulse. We show that this system can be used for the subtraction of one photon from the input pulse over a wide range of input photon numbers. On the other hand, in the absence of dephasing, the fully blockaded ensemble undergoes collective Rabi oscillations. This enables us to study the dynamics of a single two-level system strongly coupled to a quantized light field in free space.

A 36.5 Fri 15:30 HS 20

A versatile, high-power laser system around 460nm for Rydberg excitation of ultracold potassium — •Alda Arias, Stephan Helmrich, Christoph Schweiger, Lynton Ardizzone, Graham Lochead, and Shannon Whitlock — Physikalisches Institut, Universität Heildeberg, Im Neuenheimer Feld 226, 69120 Heidelberg

The development of precise laser sources over the past few decades has enabled almost full control over the ground state properties of ultracold atoms, as well as single-atom electronic properties including Rydberg states. In this talk I will present a versatile laser source emitting more than 1.5W of single frequency light around 460nm. The system consists of a commercial Titanium-Sapphire laser with resonant cavity frequency doubling, stabilized to an external reference cavity and a saturated absorption spectroscopy reference. This laser system is ideally suited for atomic physics experiments such as two-photon excitation of Rydberg states of potassium with principal quantum numbers $n > 18$. We perform two-photon spectroscopy of the Rydberg states of ultracold potassium in a magneto-optical trap, observing strong loss features that corresponds to the excitation of s and d states, as well as transitions to dipole forbidden p and higher-l states caused by mixing from a small electric field.

A 36.6 Fri 15:45 HS 20

Monte-Carlo approach to calculate ionization dynamics of dense plasmas within particle-in-cell simulations — •Dong Wu and Stephan Fritzsche — Helmholtz Institut Jena

A physical model based on a Monte-Carlo approach is proposed to calculate the ionization dynamics of dense plasmas within particle-in-cell simulations, and where the impact (collision) ionization (CI), electron-ion recombination (RE) and ionization potential depression (IPD) by surrounding plasmas are taken into consideration self-consistently. When compared with other models, which are applied in the literature for plasmas near thermal equilibrium, the temporal relaxation of ionization dynamics can also be simulated by the proposed model. Besides, this model is general and can be applied for both single elements and alloys with quite different compositions. The proposed model is implemented into a particle-in-cell (PIC) code, with (final) ionization equilibriums sustained by competitions between CI and its inverse process (i.e., RE). Comparisons between the full model and model without IPD or RE are performed. Our results indicate that for bulk aluminium at temperature of 1 to 1000 eV, i) the averaged ionization degree increases by including IPD; while ii) the averaged ionization degree is significantly over estimated when the RE is neglected. A direct comparison from the PIC code is made with the existing models for the dependence of averaged ionization degree on thermal equilibrium temperatures, and shows good agreements with that generated from Saha-Boltzmann model or/and FLYCHK code.

A 36.7 Fri 16:00 HS 20

Long-range quantum gate via Rydberg states of atoms in a thermal microwave cavity — •Lorinc Sárkány[1], József Fortágh[1], and David Petrosyan[2,3] — [1]Eberhard Karls Universität Tübingen, Physikalisches Institut, Auf der Morgenstelle 14, D-72076 Tübingen, Germany — [2]Institute of Electronic Structure and Laser, FORTH, GR-71110 Heraklion, Crete, Greece — [3]Aarhus Institute of Advanced Studies, Aarhus University, DK-8000 Aarhus C, Denmark

We propose a universal quantum gate based on two spatially separated Rydberg atoms coupled through a non-resonant microwave cavity, which may be in any superposition or mixture of photon number states. Quantum interference of different transition paths from the two-atom ground to the double-excited Rydberg states involving a single microwave photon exchange through the cavity makes both the transition amplitude and resonance largely insensitive to cavity excitations. Our scheme for attaining ultra-long-range interactions and entanglement also applies to mesoscopic atomic ensembles in the Rydberg blockade regime and is scalable to many ensembles trapped within a centimeter-sized microwave resonator.

A 37: Ultracold atoms and BEC - VI (with Q)

Time: Friday 14:30–16:00 Location: N 1

Invited Talk A 37.1 Fri 14:30 N 1

Sympathetic cooling of OH- by means of a heavy buffer gas — •Henry Lopez[1], Bastian Höltkemeier[1], Jonas Tauch[1], Tobias Heldt[1], Eric Endres[2], Roland Wester[2], and Matthias Weidemüller[1] — [1]INF 226, 69120 Heidelberg — [2]Technikerstraße 25/3, 6020, Innsbruck

Sympathetic cooling is a versatile tool that is used when other standard cooling methods like laser cooling are not applicable. In the last few years there has been a big debate about its limitations under certain circumstances: is it possible to cool down trapped ions in a system where the coolant is heavier than the cooled particle? By using a spatially confined buffer gas * e.g. a magneto optical trap - for atoms and a high-order radio frequency trap for ions, we have theoretically shown that sympathetic cooling of ions in such hybrid systems becomes feasible. In order to proof this experimentally we are developing a novel hybrid atom-ion trap. As buffer gas we use an ultracold cloud of Rb atoms confined in a dark spontaneous-force optical trap loaded from a 2D-MOT. The ions, in particular OH-, are stored in an 8-pole rf trap made of thin wires, guaranteeing optical access into the trapping region. For probing the temperature of the ions we apply electron-photodetachment tomography of the negative ions. In this talk I report on the latest experimental results, the status of our experiment, its limitations and possible applications.

A 37.2 Fri 15:00 N 1

In-situ charge control of a silica optical nanofiber in an ion trap — •Benjamin Ames[1], Johannes Ghetta[1], Jan Petersen[2], Philip Holtz[1], Kirill Lakhmanskiy[1], Michael Brownnutt[3], Florian Ong[1], Arno Rauschenbeutel[2], Yves Colombe[1], and Rainer Blatt[1,4] — [1]Institut für Experimentalphysik, University of Innsbruck, Innsbruck, Austria — [2]TU Wien, Wien, Austria — [3]University of Hong Kong, Pokfulam, Hong Kong — [4]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

A trapped ion confined within the evanescent field of an optical nanofiber could be a novel ion-photon interface for networking quantum information between registers. However, achieving the sub-micron ion-fiber distance required to observe coupling to the evanescent field remains problematic due to charges on the nanofiber surface. We report on in-situ techniques developed to mitigate the charge of the nanofiber. Using photoemission and anomalous field emission we are able to charge the fiber positively, while both positive and negative states can be obtained by means of electron flooding at different energies. These results can be applied to a variety of AMO experiments where charge control of dielectrics is desired.

A 37.3 Fri 15:15 N 1

Commensurate-incommensurate transition with ions — •Andreas Alexander Buchheit[1], Haggai Landa[2], Cecilia Cormick[3], Thomas Fogarty[4], Vladimir Stojanovic[5], Eugene Demler[5], and Giovanna Morigi[1] — [1]Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]LPTMS, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay, France — [3]IFEG, CONICET and Universidad Nacional de Cordoba — [4]Okinawa Institute of Science and Technology, Japan, — [5]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We show that the commensurate-incommensurate transition can be simulated with a trapped linear chain of ions which are additionally confined by an optical lattice. The ratio between the ion interparticle distance in the absence of the lattice and the lattice wavelength can be adjusted by modifying the ion trapping potential, and we focus on the regime when these two lengths are nearly commensurate. We show that in this system one can observe the onset of the incommensurate phase through the creation of solitons at the chain edges followed by the formation of a soliton chain, and we further identify the range of ion temperatures and chain sizes which allows these dynamics to be realised. We finally discuss the observables which signal the inception of this phase and the regime of experimental parameters for which these dynamics can be observed.

A 37.4 Fri 15:30 N 1

Excitation and Transport of Discrete Solitons in Coulomb Crystals — •Jonathan Brox[1], Philip Kiefer[1], Miriam Bujak[1], Haggai Landa[2], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]LPTMS, Université Paris Sud, Orsay, France

We study structural defects (kinks), which are formed in 2D Coulomb crystal [1].

Ion crystals with such structural defects feature localized modes in the vibrational spectrum[2]. We show that resonant excitation of kinks leads to a directed transport conditional on the conformation of the topological protected defect inside the ion crystal [3].

[1] M. Mielenz et al., Phys. Rev. Lett. **110**, 133004 (2013)
[2] H. Landa et al., New J. Phys. **15**, 093003 (2013)
[3] J. Brox et al., publication in preparation

A 37.5 Fri 15:45 N 1

Strong Backscatterer at the Edge of a Two-dimensional Topological Insulator — •Junhui Zheng[1,2] and Miguel A. Cazalilla[2] — [1]Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt/Main, Germany — [2]Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan

We study the problem of a backscattering impurity coupled to the edge states of a two-dimensional topological insulator. In the regime where the backscattering potential is larger than the band gap and accounting for electron-electron interactions, it is shown that the system can be described as a resonant level coupled to the one-dimensional (1D) channel of interacting edge electrons. We discuss the relationship of this system to the model of a (structureless) impurity in a 1D interacting electron liquid. Different from the latter model, in the resonant regime transmission is suppressed also for weak to moderately attractive interactions.

A 38: Atoms in Strong Fields II

Time: Friday 14:30–16:30 Location: N 2

A 38.1 Fri 14:30 N 2

Experimental evidence for Wigner's tunneling time — •Nicolas Camus[1], Enderalp Yakaboylu[1,2], Lutz Fechner[1], Michael Klaiber[1], Martin Laux[1], Yonghao Mi[1], Karen Z. Hatsagortsyan[1], Thomas Pfeifer[1], Christoph H. Keitel[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]IST Austria, Am Campus 1, 3400 Klosterneuburg, Austria

Using a reaction microscope the ionization of atoms in elliptically polarized laser pulses at intensities in the tunneling regime and near-IR wavelength of 1300 nm has been investigated. Applying coincident electron-ion detection in combination with a gas-target that contains a mixture of two species (Argon and Krypton) we succeeded in measuring the 3D electron-momentum distributions for both targets under otherwise exactly identical conditions (same spectrometer settings and pulse parameters). A detailed analysis of even faint differences in the electron spectra for Ar and Kr allow a detailed test of theoretical models and, with the help of theory, a sensitive check of the commonly applied separation of the ionization process (tunneling) and the subsequent electron motion in the laser field (electron streaking). The experimental results will be presented and compared to state-of-the-art calculations for strong-field ionization, including additional effects like e.g. focal volume averaging, target depletion, and others. Finally, consequences in view of the ongoing controversial discussion of tunneling times in strong-field ionization will be highlighted [1]. [1] arXiv preprint arXiv:1611.03701 (2016)

A 38.2 Fri 14:45 N 2

Sequential and Non-Sequential Pathways in the Coulomb Explosion of CH_2IBr — •Katrin Reininger, Felix Schell, Friedrich Freyse, Marc Vrakking, Claus Peter Schulz, and Jochen Mikosch — Max-Born-Institut Berlin

Coulomb explosion induced by a strong laser field has the potential to uncover the positions of nuclei within a molecular system. We studied experimentally the three-body fragmentation dynamics of triply charged CH_2IBr produced by strong-field ionization with intense femtosecond laser pulses. The correlated fragments CH_2^+, Br^+, and I^+ were measured in coincidence in a reaction microscope which allows to obtain their momentum vectors. The dominant pathway observed is Coulomb explosion, where the C-I and the C-Br bonds break simultaneously. A Monte-Carlo reconstruction method is used to derive the geometry of the neutral molecule, which is compared with literature values. Additionally, we observe two weak sequential dissociation pathways: (i) cleavage of the C-I bond followed by fragmentation of CH_2Br^{2+} and (ii) cleavage of the C-Br bond followed by fragmentation of CH_2I^{2+}. Our study encourages the use of Coulomb explosion imaging as a time-resolved probe of molecular dynamics, while cautioning that it is important to understand the details of the fragmentation process.

A 38.3 Fri 15:00 N 2

Photoelectron holography and effects of the core potential — •Nikolay Shvetsov-Shilovski and Manfred Lein — Leibniz Universität Hannover, Hannover, Germany

Strong-field photoelectron holography (SFPH) is a new technique for time-resolved molecular imaging based on the interference of two types of outgoing electron trajectories in strong-field ionization [1]. Different subcycle interference structures were predicted within the semiclassical model accounting for the laser field only [2]. Although this model has provided valuable insight into the SFPH, neglecting the long-range Coulomb potential may be severe.

Using the two-step semiclassical model with interference [3] we investigate the modification of the interference structures due to the Coulomb potential and due to the choice of the initial state. Bearing in mind possible application of the SFPH to negative ions, we study holographic patterns in a short-range potential.

[1] Y. Huismans et al., Science 331, 61 (2011).
[2] X.-B. Bian et al., Phys Rev A 84, 043420 (2011).
[3] N. I. Shvetsov-Shilovski et al., Phys. Rev. A 94, 013415 (2016).

A 38.4 Fri 15:15 N 2

Tunneling exit characteristics from classical backpropagation of an ionized wavepacket — •Hongcheng Ni, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

We study the tunneling exit parameters of single active electron in the helium atom with the recently proposed backpropagation method [Phys. Rev. Lett. **117**, 023002 (2016)] upon different criteria towards defining tunneling ionization. We find, if tunneling ionization is characterized by the emergence of electrons at certain predefined distances from the ion, the tunneling exit parameters extracted have a number of inconsistencies; while if tunneling ionization is defined by a vanishing momentum in the instantaneous field direction, which captures both adiabatic and nonadiabatic tunneling dynamics, the tunneling exit parameters retrieved are intuitive and easy to understand. This analysis has important implications towards future numerical simulations of the attoclock experiments that commonly used trajectory-based methods starting from assumed exit time and position are imprecise. Thereby, we provide a mapping technique that links attoclock experimental observable to the intrinsic tunneling exit time.

A 38.5 Fri 15:30 N 2

Fast Photoelectrons from clusters in Intense IR lasers — •Abraham Camacho Garibay, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS, Dresden

Unlike single atoms where energy absorption occurs either directly through drift momentum (with the characteristic $2U_p$ cutoff) or by single binary collisions ($10U_p$ cutoff), many-particle systems exhibit additional absorption mechanisms. Either by multiple scattering events from different ions or by slingshot effects by the cluster potential, electrons can be emitted above the mentioned cutoffs. Here we simulate the dynamics of Ar clusters in intense IR laser fields, combining Classical Molecular Dynamics simulations with binary Coulombic collisions. Through this scheme, we have been able to observe photoelectrons with surprisingly high energies, in accordance with recent experimental results.

A 38.6 Fri 15:45 N 2

Electron spin filter and polarizer in a standing light wave — •Sven Ahrens — Beijing Computational Science Research Center, Building 9, East Zone, ZPark II, No.10 East Xibeiwang Road, Haidian District, Beijing 100193, China

Electrons can be diffracted in a standing wave of intense light, which has been first discussed by Kapitza and Dirac [1]. Theoretical evidence for electron spin effects has been given for this type of diffraction [2]. In the underlying quantum dynamics one can associate a rotation of the electron spin [3], but nevertheless the final diffraction pattern of such a process is insensitive to the initial spin configuration. Based on a numerical simulation we demonstrate that also spin-dependent diffraction as well as the generation of electron polarization is possible in two-photon Kapitza-Dirac scattering [4]. Furthermore, a refined description of spin-dependent electron diffraction can be deduced from an analytic approximation of the electron quantum state propagation matrix of the process.

[1] P. L. Kapitza and P. A. M. Dirac, Math. Proc. Cambridge Philos. Soc. 29, 297 (1933).
[2] S. Ahrens, H. Bauke, C. H. Keitel and C. Müller, Phys. Rev. Lett. 109, 043601 (2012).
[3] S. Ahrens, H. Bauke, C. H. Keitel and C. Müller, Phys. Rev. A 88, 012115 (2013).
[4] S. Ahrens, arXiv:1604.06201.

A 38.7 Fri 16:00 N 2

Virtual-detector approach to tunneling times in strong-field ionization — •Heiko Bauke, Nicolas Teeny, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Employing a virtual detector [1, 2], a hypothetical device that allows one to monitor the wave function's density with spatial and temporal resolution during the ionization process, it becomes possible to determine probability distributions for the moments when the electron enters and leaves the classically forbidden region from first principles. In this way, a tunneling time in strong-field ionization can be specified. It is shown that neither the moment when the electron most likely enters the tunneling barrier nor when it leaves the tunneling barrier coincides with the moment when the external electric field reaches its maximum. Under the tunneling barrier as well as at the exit the electron has a nonzero velocity in the electric field direction. These results are substantiated by an independent determination of the tunneling time via a quantum clock approach [3], which yields very similar results.

[1] N. Teeny, E. Yakaboylu, H. Bauke, C. H. Keitel, *Phys. Rev. Lett.* **116**, 063003 (2016)

[2] N. Teeny, C. H. Keitel, H. Bauke, *Phys. Rev. A* **94**, 022104 (2016)

[3] N. Teeny, C. H. Keitel, H. Bauke, arXiv:1608.02854 (2016)

A 38.8 Fri 16:15 N 2

Electron vortices in femtosecond multi-photon ionization — •Dominik Pengel, Stefanie Kerbstadt, Daniela Johannmeyer, Lars Englert, Tim Bayer, and Matthias Wollenhaupt — Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Straße 9-11, 26129 Oldenburg

We demonstrate the generation of vortex-shaped photoelectron wave packets from multi-photon ionization of potassium atoms with sequences of two time-delayed, counterrotating circularly polarized femtosecond laser pulses. The electron vortices are measured by velocity map imaging spectroscopy and reconstructed using tomographic techniques. Weak-field excitation produces 6-arm Archimedean spirals. A change from c6 to c4 rotational symmetry of the vortices is observed for non-perturbative laser atom interaction. In addition, the influence of the time-delay on the vortex shape is discussed and an outlook towards ultra-broadband excitation using few-cycle pulses is given.

A 39: Clusters III (with MO)

Time: Friday 14:30–16:30 Location: N 3

Invited Talk A 39.1 Fri 14:30 N 3

Experimental studies of Interatomic Coulombic Decay — •Till Jahnke — Goethe Universität Frankfurt, Institut für Kernphysik, Max-von-Laue-Str. 1, 60438 Frankfurt

Interatomic (or intermolecular) Coulombic Decay (ICD) has become an extensively studied electronic decay process during the last 15 years. Originally proposed by Cederbaum et al. [1] it was experimentally identified by means of different techniques [2,3,4] in the early 2000s. In ICD an excited atom or molecule deexcites by transferring its excitation energy to a loosely bound atomic neighbor and leads to the emission of an electron at that neighbor. Since that time a wealth of experimental and theoretical studies have shown that ICD is a rather common decay path in nature, as it occurs "almost everywhere" in loosely bound matter.

The talk will give a short introduction on ICD and report on recent experimental advances in the field covering time-resolved studies on the cluster size dependence of the efficiency of the decay and more detailed studies of different decaying systems.

[1] Cederbaum, L. S., Zobeley, J., and Tarantelli, F., Phys. Rev. Lett., 79, 4778 (1997). [2] Marburger, S., Kugeler, O., Hergenhahn, U., and Möller, T., Phys. Rev. Lett., 93, 203401 (2003). [3] Jahnke, T., Czasch, A., Schöffler, M. S., Schössler, S., Knapp, A. Käsz, M., Titze, J., Wimmer, C., Kreidi, K., Grisenti, R. E., Staudte, A., Jagutzki, O., Hergenhahn, U., Schmidt-Böcking, H., and Dörner, R., Phys. Rev. Lett., 93, 163401 (2004). [4] G. Öhrwall et al., PRL 93 173401 (2004)

A 39.2 Fri 15:00 N 3

Correlated decay processes in helium nanodroplets — •Marcel Mudrich[1], Nikolay Shcherbinin[1], Aaron LaForge[1], and Robert Richter[2] — [1]Physikalisches Institut, Uni Freiburg — [2]Elettra Synchrotrone Trieste

Helium nanodroplets are commonly used as inert nanometer-sized cryo-matrices for spectroscopy of embedded atoms, molecules, and clusters. Upon irradiation with extreme-ultraviolet synchrotron radiation, though, ultrafast energy and charge exchange processes between embedded species and helium atoms or even among the helium atoms can occur. In this talk we give examples of such correlated decay processes: Interatomic Coulombic decay of pure helium droplets and Auger decay of embedded rare gas atoms.

A 39.3 Fri 15:15 N 3

Laser initiation of the interatomic Coulombic decay process in quantum dots — •Anika Haller[1], Ying-Chih Chiang[2], Maximilian Menger[3], Emad F. Aziz[1,4], and Annika Bande[1] — [1]Helmholtz-Zentrum Berlin, Germany — [2]The Chinese University of Hong Kong, Hong Kong — [3]University of Pisa, Italy — [4]Freie Universität Berlin, Germany

The interatomic Coulombic decay (ICD) has originally been predicted as ultrafast energy transfer process between atoms and molecules. Recent studies show laser-induced ICD in paired quantum dots (QD) to be possible. We investigate a system of two GaAs QDs with two same-spin electrons each bound to one of the confining potentials. After resonant excitation of one electron by a time-dependent laser the system decays via ICD - interelectron energy transfer causes excitation of the other electron into the continuum. We show the field strength dependence of ICD from weak to strong-field intensities. The Fano peak profile shapes of the photoelectron spectra give a hint on the relative importance of ICD compared to the competing direct ionization. In addition, we study the impact of the laser focus. The electron dynamics is theoretically investigated by means of the space-resolved antisymmetrized multiconfiguration time-dependent Hartree method (MCTDH). As complementary approach we developed a state-resolved representation. We find multi-photon processes to be unimportant. Further, weak pulses display the highest ICD efficiency while direct ionization becomes less dominant. Focusing the laser on the light-absorbing QD further minimizes the probability for direct ionization.

A 39.4 Fri 15:30 N 3

Time-resolved photoelectron spectroscopy on resonantly excited He nanodroplets — •A. C. LaForge[1], Y. Ovcharenko[2], B. Langbehn[2], O. Plekan[3], R. Cucini[3], P. Finetti[3], D. Iablonskyi[4], A. Clark[5], V. Oliver Álvarez de Lara[5], P. Piseri[6], T. Nishiyama[7], M. Di Fraia[3], C. Callegari[3], K. C. Prince[3], K. Ueda[4], F. Stienkemeier[1], M. Mudrich[1], and T. Möller[1] — [1]Universität Freiburg — [2]TU Berlin — [3]Elettra-Sincrotrone Trieste — [4]Tohoku University, Sendai — [5]EPFL, Lausanne — [6]Università di Milano — [7]Kyoto University

The ionization dynamics of helium droplets resonantly excited by intense, XUV radiation has been investigated. Depending on the intensity, the excited atoms can decay by interatomic Coulombic decay (ICD) or form a network of excited atoms which then collectively autoionize leading to nanoplasma formation [1,2]. Recently, we have extended our studies to time resolve the processes using a pump-probe technique. Using a UV laser to deplete the excited states, we observe a signal loss in the ICD signal in the photoelectron spectrum for short time delays followed by its reappearance at longer time delays ($>$ 1 ps).

[1] Y. Ovcharenko et al., Phys. Rev. Lett. 112, 073401 (2014)

[2] A. LaForge et al., Sci. Rep. 4, 3621 (2014)

A 39.5 Fri 15:45 N 3

Photoelectron elastic scattering probed by angle resolved X-ray photoemission from free SiO_2 nanoparticles — •Burkhard Langer, Egill Antonsson, Ina Halfpap, Jaqueline Gottwald, and Eckart Rühl — Physikatische Chemie, Freie Universität Berlin

We report on measurements of the angular distributions of photoelectrons emitted from SiO_2 nanoparticles. A beam of free nanoparticles is crossed with a beam of X-rays from the BESSY II synchrotron facility. The studies were carried out over a wide energy range above the Si $2p$ and O $1s$ absorption edges, respectively. The photoelectron angular anisotropy is found to be lower for photoemission from SiO_2 nanoparticles than the theoretical values for isolated Si and O atoms. This can be explained by elastic scattering of the outgoing electrons at neighboring atoms. We will discuss a simple model that allows us to determine the number of elastic scattering events. In addition, a Monte Carlo calculation using literature values for scattering cross sections can be applied to quantitatively describe the measured angular distributions.

A 39.6 Fri 16:00 N 3

Tracing strong-field processes in nanoparticles in real time — •Bernd Schütte[1], Björn Thorben Kruse[2], Christian Peltz[2], Marc J. J. Vrakking[1], Arnaud Rouzée[1], and Thomas Fennel[1,2] — [1]Max-Born-Institut, Berlin — [2]Universität Rostock

Strong-field ionization of solid-density targets is fundamentally different from strong-field ionization of atoms, and can result in highly efficient absorption of laser energy. In order to understand fundamental strong-field phenomena, the investigation of isolated nanoparticles is advantageous, as energy is not dissipated into the environment, allowing one to focus on the primary laser-matter coupling mechanisms.

Here we trace the charging of Ar and Xe nanoparticles directly in the time domain by applying the recently developed ionization ignition method [1]. Seed electron generation by an intense XUV pulse allows us to temporally control the heating and ionization induced by a 1.5-ps NIR pulse, whose intensity ($I = 1.5 \times 10^{13}$ W/cm^2) is not sufficient to ionize neutral clusters. Surprisingly, we find that highly charged ions up to Xe^{15+} are produced. The average ion charge state increases exponentially during the rising edge of the NIR pulse, which is the first real-time observation of ionization avalanching. The experimental results will be compared with molecular dynamics calculations.

Our method provides new perspectives for the time-resolved investigation of strong-field phenomena in nanostructures, liquids and solids. It could e.g. be used to record the ablation of material in real time, which is relevant for practical applications such as laser machining.

[1] B. Schütte *et al.*, Phys. Rev. Lett. **116**, 033001 (2016).

A 39.7 Fri 16:15 N 3

Photo excitation of size selected lead clusters — •Markus Wolfram[1], Stephan König[1], Franklin Martinez[2], Gerrit Marx[1], and Lutz Schweikhard[1] — [1]Ernst-Moritz-Arndt Universität, Greifswald, Deutschland — [2]Universität Rostock, Rostock, Deutschland

At ClusterTrap [1] the photodissociation of positively and negatively charged lead clusters has been investigated. In addition to monomer evaporation we observe a further decay mode: At intermediate sizes (Pbn+, n=19-25, Pbn-, n=16-31) the main fragmentation pathway is the breaking off of a neutral heptamer, Pb*7. After preliminary experiments with a Nd:YAG laser (532nm), we plan to extend the available photon energies by use of an OPO laser system. Furthermore, by electron impact ionization of stored metal cluster cations [2] and simultaneous storage of cluster anions and electrons in the Penning Trap [3] the production of cluster cations and anions, respectively, of higher charge states has been achieved. Thus, it will be possible to extend the current studies to multiply charged lead clusters where further decay pathways are expected. In this contribution, recent modifications of the experimental setup and first results on the photo-excitation of size selected mono-anionic and cationic lead clusters will be presented.

The project is funded by the Collaborative Research Center (SFB) 652.

[1] F. Martinez et al., Int. J. Mass Spectrom. 365-366 (2014) 266 [2] L. Schweikhard et al., Hyp. Int. 99 (1996) 97 [3] A. Herlert et al., Phys. Scripta T80 (1999) 200

A 40: Ultracold Atoms II (with Q)

Time: Friday 14:30–16:30 Location: P 104

A 40.1 Fri 14:30 P 104

Realization of a dual-species MOT for dysprosium and potassium — •C. Ravensbergen[1,2], S. Tzanova[1,2], M. Kreyer[2], E. Soave[2], A. Werlberger[2], V. Corre[1,2], E. Kirilov[2], and R. Grimm[1,2] — [1]IQOQI, Austrian Academy of Sciences, Innsbruck, Austria — [2]Insitute for Experimental Physics, University of Innsbruck, Innsbruck, Austria

We report on the first realization of a dual-species magneto-optical trap that combines strongly magnetic lanthanide atoms (Dy) with an alkali species (K). Advanced cooling techniques in the form of narrow-line laser cooling and grey-molasses cooling give us favorable starting conditions to reach quantum degeneracy. With fermionic and bosonic isotopes of both species, our system offers a great wealth of isotopic mixtures. We are particularly interested in new Fermi-Fermi mixtures. These are expected to exhibit exotic quantum phases and novel pairing mechanisms, including for example mass-imbalanced pairing or a fermionic superfluid with a Fermi surface modified by the dipolar interactions.

A 40.2 Fri 14:45 P 104

Towards a Perpetual Bose-Einstein Condensate — •Shayne Bennetts, Chun-Chia Chen, Benjamin Pasquiou, and Florian Schreck — Institute of Physics, University of Amsterdam, Amsterdam, The Netherlands

Production of Bose-Einstein condensates (BECs) has always been a two stage process, first laser cooling a gas sample, then cooling evaporatively until degeneracy is reached. As a result, BECs and devices based on BEC such as atom lasers are pulsed. Applications like atom interferometers would benefit greatly from a perpetual source of condensate. We are developing such a perpetual source in which we separate the cooling stages in space rather than time and protect the condensate from scattered photons using distance, baffles and a "transparency" beam. We have now demonstrated a perpetual MOT of 2×10^9 ^{88}Sr atoms with temperatures as low as 20μK on a 7.4-kHz wide laser cooling transition with a continuous loading rate of 7×10^8 atoms/s. Using a different set of parameters and location we have also demonstrated a perpetual MOT of 2×10^8 ^{88}Sr at 2μK with a loading rate of 9×10^7 atoms/s which we have successfully loaded into a dipole trap. By switching to the 0.5% abundance ^{84}Sr isotope we are able to evaporate to BECs of 3×10^5 ^{84}Sr atoms. Critically, for the second location we have validated the effectiveness of our architecture in protecting a BEC from scattered broad-linewidth laser cooling light, which is used in the first cooling stages. These are crucial steps towards demonstrating a perpetual BEC and atom laser.

A 40.3 Fri 15:00 P 104

Optimization of modulation transfer spectroscopy on the rubidium D2 line — •Tilman Preuschoff, Patrick van Beek, Florian Ehmann, Malte Schlosser, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Highly stable laser sources with narrow linewidths are of great importance for experiments in the field of atom physics. Frequency-stabilized external-cavity diode lasers are a cost efficient and compact realization of suitable sources. Sub-Doppler spectroscopy techniques provide high resolution atomic references. Among them, the modulation transfer spectroscopy (MTS) scheme is significant due to the non-linear four-wave-mixing transfer process which offers a particularly high accuracy and signal bandwidth.

We present recent experimental and theoretical investigations of the MTS technique on the ^{85}Rb D2 line in an AOM-based setup. The obtained line shape is in good agreement with the theoretical description. Numerical simulations show that an optimal combination of signal amplitude and slope at the reference frequency is achieved in the regime of high modulation indices and frequencies. Within the experimentally available parameter regime this optimum is accessible. We demonstrate a frequency stabilization providing an effective linewidth below 200 kHz and a long-term stability better than 100 kHz in 15 h. The MTS scheme is compared to the frequency modulation spectroscopy scheme implemented in a similar optical setup based on inexpensive DDS signal generation and standard lock-in techniques.

A 40.4 Fri 15:15 P 104

Nonergodic diffusion of single atoms in a periodic potential — •Daniel Adam[1], Farina Kindermann[1], Andreas Dechant[2], Tobias Lausch[1], Daniel Mayer[1], Felix Schmidt[1], Steve Haupt[1], Michael Hohmann[1], Nicolas Spethmann[1], Eric Lutz[2], and Artur Widera[1] — [1]TU Kaiserslautern, Department of Physics, Kaiserslautern, Germany — [2]Friedrich-Alexander-Universität, Department of Theoretical Physics, Erlangen, Germany

Diffusion is ubiquitous in nature, and related models are essential to many fields in science, technology and society, including life sciences, traffic or financial market theory. The most prominent model for diffusion is Brownian motion. The hallmarks of this are a linearly increasing mean squared displacement (MSD); a Gaussian distributed step distance distribution; a stationary value for the autocorrelation function of single particle trajectories; and established ergodicity. Here, we engineer a system of a single atom in a periodic potential, which is coupled to a photon bath. We observe diffusion of the atom in the lattice, driven by random photon scattering events. While the dynamics exhibits a linear increase of the MSD for all times, we find that ergodicity is not established even for long timescales. Moreover, we observe a different timescale on which the step distribution approaches Gaussianity. Our experimental results for equilibrium systems are in excellent agreement with analytical predictions of a continuous time random walk model with exponential distance and waiting time distribution. Our results may be helpful for the interpretation of related observations in biological systems.

A 40.5 Fri 15:30 P 104

Measuring correlations of cold-atom systems using multiple quantum probes — •Michael Streif[1,2], Andreas Buchleitner[2], Dieter Jaksch[1,3], and Jordi Mur-Petit[1] — [1]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, United Kingdom — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [3]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, 117543 Singapore

The remarkable advances in experiments with ultracold bosonic atoms in optical lattices have triggered several possibilities to study the physics of many-body quantum systems. A common issue in most experiments is the destructive nature of the measurement method. For this reason, in recent times, ancillary quantum systems have been used as quantum probes. We here present a non-destructive method to probe a complex quantum system using multiple impurity atoms as quantum probes. It is demonstrated that non-local two-point correlation functions can be determined by accessing a coherence element of the density matrix of the impurities. In particular, for contact interactions between probes and system, our protocol yields the many-body density-density correlation function.

A 40.6 Fri 15:45 P 104

Cavity-induced quantum phases of ultracold atoms in commensurate potentials — •Benjamin Bogner, Giovanna Morigi, and Heiko Rieger — Theoretical Physics Saarland University, 66123 Saarbrücken, Germany

We analyse the quantum phases of bosonic atoms, which are tightly confined by a one-dimensional optical lattice and interact with the long-range potential induced by the coupling with an optical resonator. Their dynamics is described by an extended Bose-Hubbard model, where the cavity field induces long-range density-density interactions in the form of the square of the even-odd site occupation balance. The interplay of this potential with nearest neighbor hopping and onsite repulsion is analyzed by means of quantum Monte-Carlo simulations. The phase diagram is determined as a function of the hopping amplitude, the chemical potential, and the strength of the long-range cavity interaction, rescaled by the onsite potential strength, displaying superfluid, supersolid, Mott insulator, and density-wave regions phases. A comparison is drawn with the phase diagram of the extended one-dimensional Bose-Hubbard-model with only nearest-neighbour interactions.

A 40.7 Fri 16:00 P 104

Semiclassical theory of synchronization-induced cooling — •Simon B. Jäger[1], Stefan Schütz[1,2], Minghui Xu[3,4], Jinx Cooper[3,4], Murray J. Holland[3,4], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]icFRC, IPCMS (UMR 7504), ISIS (UMR 7006), Université de Strasbourg and CNRS, 67000 Strasbourg, France — [3]JILA, National Institute of Standards and Technology and Department of Physics, University of Colorado, Boulder, Colorado 80309-0440, USA — [4]Center for Theory of Quantum Matter, University of Colorado, Boulder, Colorado 80309, USA

We analyse the cooling dynamics of the motion of atoms confined inside an optical cavity, in the regime in which the atoms are incoherently pumped and the dipoles can synchronize. Our study is performed in the semiclassical regime and assuming that cavity decay is the largest rate characterizing the dynamics. We show that the cooling dynamics consists of three regimes. First hot atoms are individually cooled by the cavity friction forces. After this stage, motion and internal degrees of freedom evolve and the motion is further cooled until the dipoles synchronize. In this latest stage, when the dipoles are sychronized dipole-dipole correlations are stationary and the motion is further cooled to temperatures which are limited by the pump rate. In this regime spin and atomic position are correlated, such that the internal excitations oscillate spatially with the cavity standing wave forming an effective antiferromagnetic order. We discuss the limits of the semiclassical treatment and its extension to a full quantum mechanical model.

A 40.8 Fri 16:15 P 104

Sympathetic cooling of quantum simulators — •Meghana Raghunandan and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover

We discuss the possibility of maximizing the cooling of a quantum simulator by controlling the system-environment coupling such that the system is driven into the ground state. We make use of various analytical tools such as effective operator formalism [1] and the quantum master equations to exactly solve the model of an Ising spin chain consisting of N particles coupled to a radiation field. We maximize the cooling by finding the dependence of the effective rate of transitions of the various excited states into the ground state. We show that by adding a single dissipative qubit, we already get quite substantial cooling rates.

[1] Effective operator formalism for open quantum systems. Phys. Rev. A 85, 032111