Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture halls a320, f107, f303; Poster Empore Lichthof)

Invited Talks

A 1.1	Mon	11:00–11:30	a320	**Unraveling the mechanisms of single- and multiple-electron removal in energetic electron-ion collisions: from few-electron ions to extreme atomic systems.** — •Alexander Borovik Jr
A 2.1	Mon	11:00–11:30	f107	**Highly nonlinear ionization of atoms induced by intense HHG pulses** — Björn Senfftleben, Martin Kretschmar, Andreas Hoffmann, Mario Sauppe, Johannes Tümmler, Ingo Will, Tamás Nagy, Marc J. J. Vrakking, Daniela Rupp, •Bernd Schütte
A 3.1	Mon	11:00–11:30	f303	**Creation of ultracold bosonic ^{23}Na^{39}K ground state molecules** — •Kai Konrad Voges, Philipp Gersema, Torsten Hartmann, Mara Meyer zum Alten Borgloh, Torben Alexander Schulze, Alessandro Zenesini, Silke Ospelkaus
A 6.1	Mon	14:00–14:30	a320	**Time-resolved X-ray Imaging of Anisotropic Nanoplasma Expansion** — •Christian Peltz, Christoph Bostedt, Mathias Kling, Thomas Brabec, Eckart Ruehl, Artem Rudenko, Tais Gorkhover, Thomas Fennel
A 6.2	Mon	14:30–15:00	a320	**Imaging anisotropic dynamics in superfluid helium nanodroplets** — •B. Langbehn, K. Sander, Y. Ovcharenko, C. Peltz, A. Clark, M. Coreno, R. Cucini, A. Demidovich, M. Drabbels, P. Finetti, M. Di Fraia, L. Giannessi, C. Grazioli, D. Iablonskyi, A. C. LaForge, T. Nishiyama, V. Oliver Álvarez de Lara, P. Piseri, O. Plekan, K. Ueda, J. Zimmermann, K. C. Prince, F. Stienkemeier, C. Callegari, T. Fennel, D. Rupp, T. Möller
A 7.1	Mon	14:00–14:30	f107	**Laser spectroscopy of the heaviest actinides** — •Premaditya Chhetri, Dieter Ackermann, Hartmut Backe, Michael Block, Bradley Cheal, Christoph Emanuel Düllmann, Julia Even, Rafael Ferrer, Francesca Giacoppo, Stefan Götz, Fritz Peter Hessberger, Mark Huyse, Oliver Kaleja, Jadambaa Khuyagbaatar, Peter Kunz, Mustapha Laatiaoui, Werner Lauth, Lotte Lens, Enrique Minaya Ramirez, Andrew Mistry, Tobias Murböck, Sebastian Raeder, Fabian Schnieder, Piet Van Duppen, Thomas Walther, Alexander Yakushev
A 8.1	Mon	14:00–14:30	f303	**Reducing their complexity and miniaturise BEC interferometers** — •Waldemar Herr, Hendrik Heine, Alexander Kassner, Christoph Künzler, Marc C. Wurz, Ernst M. Rasel
A 10.1	Tue	14:00–14:30	a320	**Scattering of twisted x-rays from a crystal** — •Anton Peshkov, Stephan Fritzsche, Andrey Surzhykov
A 11.1	Tue	14:00–14:30	f107	**Probing electronic wavefunctions and chiral structure using all-optical attosecond interferometry** — •Michael Krüger, Doron Azoury, Omer Kneller, Shaked Rozen, Barry D. Bruner, Alex Clergerie, Bernard Pons, Baptiste Fabre, Yann Mairesse, Oren Cohen, Olga Smirnova, Nirit Dudovich
A 12.1	Tue	14:00–14:30	f303	**BECCAL - Quantum Gases on the ISS** — •Lisa Wörner, Christian Schubert, Jens Grosse, Claus Braxmaier, Ernst Rasel, Wolfgang Schleich, the BECCAL collaboration

A 15.1	Wed	11:00–11:30	f107	**The ALPHATRAP g-factor experiment** — •TIM SAILER, IOANNA ARAPOGLOU, ALEXANDER EGL, FELIX HAHNE, MARTIN HÖCKER, PETER MICKE, BINGSHENG TU, ANDREAS WEIGEL, JOSÉ R. CRESPO LÓPEZ-URRUTIA, SVEN STURM, KLAUS BLAUM
A 16.1	Wed	11:00–11:30	a320	**Photoionization dynamics of many-electron atoms: an accelerated Green functions approach** — •MICHAEL BONITZ, NICLAS SCHLÜNZEN, JAN-PHILIP JOOST, MAXIMILIAN RODRIGUEZ RASMUSSEN
A 17.1	Wed	11:00–11:30	f303	**Fate of the Amplitude Mode in a Trapped Supersolid** — •JENS HERTKORN, FABIAN BÖTTCHER, MINGYANG GUO, JAN-NIKLAS SCHMIDT, TIM LANGEN, HANS PETER BÜCHLER, TILMAN PFAU
A 19.1	Wed	14:00–14:30	f107	**Fragmentation of HeH^+ in strong laser fields** — •FLORIAN OPPERMANN, PHILIPP WUSTELT, SAURABH MHATRE, STEFANIE GRÄFE, GERHARD G. PAULUS, MANFRED LEIN
A 20.1	Wed	14:00–14:30	f303	**Coherent laser spectroscopy of highly charged ions using quantum logic** — •PETER MICKE, TOBIAS LEOPOLD, STEVEN A. KING, ERIK BENKLER, LUKAS J. SPIESS, LISA SCHMÖGER, MARIA SCHWARZ, JOSÉ R. CRESPO LÓPEZ-URRUTIA, PIET O. SCHMIDT
A 23.1	Thu	11:00–11:30	f107	**Manipulating dissipative channels of highly excited systems** — •STEFAN YOSHI BUHMANN
A 24.1	Thu	11:00–11:30	f303	**Status update of the muonic hydrogen ground-state hyperfine splitting experiment** — •A. OUF, R. POHL ON BEHALF OF THE CREMA COLLABORATION
A 25.1	Thu	14:00–14:30	a320	**Anderson localization in a Rydberg composite** — •MATTHEW EILES, ALEXANDER EISFELD, JAN-MICHAEL ROST
A 26.1	Thu	14:00–14:30	f107	**Towards fast adaptive resonant x-ray optics** — MIRIAM GERHARZ, •JÖRG EVERS
A 26.2	Thu	14:30–15:00	f107	**Control of complex Fano resonances by shaped laser pulses** — CAMILO GRANADOS, NICOLA MAYER, EVGENII IKONNIKOV, MISHA IVANOV, •OLEG KORNILOV
A 27.1	Thu	14:00–14:30	f303	**Dynamics of a mobile hole in a Hubbard antiferromagnet** — •MARTIN LEBRAT, GEOFFREY JI, MUQING XU, CHRISTIE CHIU, MARKUS GREINER
A 29.1	Fri	11:00–11:30	b305	**Coherent facilitation dynamics in Rydberg atomic lattice quantum simulators** — •PAOLO PIETRO MAZZA, RICHARD SCHMIDT, IGOR LESANOVSKY
A 30.1	Fri	11:00–11:30	f303	**Interaction-induced lattices for bound states: Designing flat bands, quantized pumps and higher-order topological insulators for doublons** — •GRAZIA SALERNO, GIANDOMENICO PALUMBO, NATHAN GOLDMAN, MARCO DI LIBERTO

Invited talks of the joint symposium SYCU

See SYCU for the full program of the symposium.

SYCU 1.1	Mon	11:00–11:30	e415	**Photoelectron circular dichroism in the light of resonance enhanced multi-photon ionization** — •THOMAS BAUMERT
SYCU 1.2	Mon	11:30–12:00	e415	**New strategies for controlled chirality from the rovibrational dynamics of molecules** — •ANDREY YACHMENEV
SYCU 1.3	Mon	12:00–12:30	e415	**Time-dependency in Photoelectron Circular Dichroism: from femtosecond scale to attosecond** — •VALERIE BLANCHET
SYCU 1.4	Mon	12:30–13:00	e415	**Synthetic chiral light for efficient control of chiral light-matter interaction** — •DAVID AYUSO, OFER NEUFELD, ANDRES F. ORDONEZ, PIERO DECLEVA, GAVRIEL LERNER, OREN COHEN, MISHA IVANOV, OLGA SMIRNOVA

Invited talks of the joint symposium SYAI

See SYAI for the full program of the symposium.

SYAI 1.1	Mon	14:00–14:30	e415	**Atom interferometry and its applications for gravity sensing** — •Franck Pereira dos Santos, Luc Absil, Romain Caldani, Xiaobing Deng, Romain Karcher, Sébastien Merlet, Raphaël Piccon, Sumit Sarkar
SYAI 1.2	Mon	14:30–15:00	e415	**Atom interferometry for advanced geodesy and gravitational wave observation** — •Philippe Bouyer
SYAI 1.3	Mon	15:00–15:30	e415	**Fundamental physics with atom interferometry** — •Paul Hamilton
SYAI 1.4	Mon	15:30–16:00	e415	**Atoms and molecules interacting with light** — •Lucia Hackermüller

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	11:00–11:30	e415	**Electron Pulse Control with Terahertz Fields** — •Dominik Ehberger
SYAD 1.2	Tue	11:30–12:00	e415	**Laser-Based High-Voltage Metrology with ppm Accuracy** — •Kristian König, Christopher Geppert, Phillip Imgram, Jörg Krämer, Bernhard Maass, Johann Meisner, Ernst Otten, Stephan Passon, Tim Ratajczyk, Johannes Ullmann, Wilfried Nörtershäuser
SYAD 1.3	Tue	12:00–12:30	e415	**Structured singular light fields** — •Eileen Otte
SYAD 1.4	Tue	12:30–13:00	e415	**Coherent Coupling of a Single Molecule to a Fabry-Perot Microcavity** — •Daqing Wang

Invited talks of the joint symposium SYQL

See SYQL for the full program of the symposium.

SYQL 1.1	Thu	11:00–11:30	e415	**The unity of physics: the beauty and power of spectroscopy** — •Paul Julienne
SYQL 1.2	Thu	11:30–12:00	e415	**Using spectroscopy to explore the Rb_2 molecule and its formation** — •Johannes Hecker Denschlag
SYQL 1.3	Thu	12:00–12:30	e415	**Cold molecules: a chemistry kitchen for physicists** — •Olivier Dulieu
SYQL 1.4	Thu	12:30–13:00	e415	**The birth of a degenerate Fermi gas of molecules** — •Jun Ye

Invited talks of the joint symposium SYCM

See SYCM for the full program of the symposium.

SYCM 1.1	Fri	11:00–11:30	e415	**Trapped Laser-cooled Molecules for Quantum Simulation, Particle Physics, and Collisions** — •John Doyle
SYCM 1.2	Fri	11:30–12:00	e415	**Cold polyatomic molecules** — •Gerhard Rempe
SYCM 1.3	Fri	12:00–12:30	e415	**Collisions between laser-cooled molecules and atoms** — •Michael Tarbutt
SYCM 1.4	Fri	12:30–13:00	e415	**Collisions between cold molecules in a superconducting magnetic trap** — •Edvardas Narevicius

Sessions

A 1.1–1.5	Mon	11:00–12:30	a320	**Highly charged ions and their applications**
A 2.1–2.8	Mon	11:00–13:15	f107	**Attosecond physics I**
A 3.1–3.7	Mon	11:00–13:00	f303	**Ultracold atoms, ions, and BEC I (joint session A/Q)**
A 4.1–4.8	Mon	11:00–13:15	f102	**Clusters I (joint session MO/A)**
A 5	Mon	13:15–13:45	f107	**Annual general meeting**
A 6.1–6.7	Mon	14:00–16:15	a320	**Atomic clusters (joint session A/MO)**
A 7.1–7.7	Mon	14:00–16:00	f107	**Precision spectroscopy of atoms and ions I**
A 8.1–8.7	Mon	14:00–16:00	f303	**Ultra-cold atoms, ions, and BEC II (joint session A/Q)**
A 9.1–9.23	Mon	16:00–18:00	Empore Lichthof	**Poster Session - Atomic Physics I**
A 10.1–10.8	Tue	14:00–16:15	a320	**Collisions, scattering and correlation phenomena**

A 11.1–11.7	Tue	14:00–16:00	f107	**Attosecond physics II**
A 12.1–12.7	Tue	14:00–16:00	f303	**Ultracold atoms, ions, and BEC III (joint session A/Q)**
A 13.1–13.7	Tue	14:00–15:45	f142	**Clusters II (joint session MO/A)**
A 14.1–14.30	Tue	16:00–18:00	Empore Lichthof	**Poster Session - Atomic Physics II**
A 15.1–15.8	Wed	11:00–13:15	f107	**Precision spectroscopy of atoms and ions II**
A 16.1–16.8	Wed	11:00–13:15	a320	**Interaction with strong or short laser pulses I**
A 17.1–17.7	Wed	11:00–13:00	f303	**Ultracold atoms, ions, and BEC IV (joint session A/Q)**
A 18.1–18.1	Wed	13:10–13:55	f303	**Lunch talk: German Research Foundation (DFG) (joint session A/K/P/MO/MS/Q)**
A 19.1–19.8	Wed	14:00–16:15	f107	**Interaction with strong or short laser pulses II**
A 20.1–20.7	Wed	14:00–16:00	f303	**Precision spectroscopy of atoms and ions III**
A 21.1–21.8	Wed	14:00–16:00	f342	**Ultracold plasmas and Rydberg systems I (joint session Q/A)**
A 22.1–22.28	Wed	16:00–18:00	Empore Lichthof	**Poster Session - Atomic Physics III**
A 23.1–23.7	Thu	11:00–13:00	f107	**Interaction with VUV and X-ray light I**
A 24.1–24.7	Thu	11:00–13:00	f303	**Ultracold atoms, ions, and BEC V (joint session A/Q)**
A 25.1–25.6	Thu	14:00–15:45	a320	**Ultra-cold plasmas and Rydberg systems II (joint session A/Q)**
A 26.1–26.6	Thu	14:00–16:00	f107	**Interaction with VUV and X-ray light II**
A 27.1–27.6	Thu	14:00–15:45	f303	**Ultra-cold atoms, ions, and BEC VI (joint session A/Q)**
A 28.1–28.33	Thu	16:00–18:00	Empore Lichthof	**Poster Session - Atomic Physics IV**
A 29.1–29.7	Fri	11:00–13:00	b305	**Ultra-cold plasmas and Rydberg systems III (joint session A/Q)**
A 30.1–30.7	Fri	11:00–13:00	f303	**Ultra-cold atoms, ions, and BEC VII (joint session A/Q)**

Annual General Meeting of the Atomic Physics Division

Monday 13:15–13:45 f107

- Bericht
- Wahl
- Verschiedenes

A 1: Highly charged ions and their applications

Time: Monday 11:00–12:30 Location: a320

Invited Talk A 1.1 Mon 11:00 a320

Unraveling the mechanisms of single- and multiple-electron removal in energetic electron-ion collisions: from few-electron ions to extreme atomic systems. — •Alexander Borovik Jr — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany

For over a half century, electron-impact ionization of ions remains an open topic in atomic physics [1]. While single-electron removal processes in light few-electron systems are currently understood and can be reliably described by theoretical approaches, ionization of many-electron ions, especially multiple ionization, are still not understood completely. In this situation, experiment, where available, is the only reliable source of information [2]. However, as we move to ions in high charge states, requirements on the experimental conditions rise, making new approaches and instrumentation necessary. In the present overview, we describe the current status in the field and report on recent activities that aim at expanding the experimental capabilities by the development of electron guns beyond the state-of-the-art and by employing large heavy-ion accelerator facilities such as FAIR [3].

[1] A. Müller, Adv. At. Mol. Phys. 55, 293 (2008). [2] D. Schury et al. J. Phys. B 53, 015201 (2019). [3] M. Lestinsky et al., Eur. Phys. J. ST 225, 797882 (2016).

A 1.2 Mon 11:30 a320

Electron-impact single ionization of W^{q+} ions: Experiment and theory for $11 \leq q \leq 18$ — •Daniel Schury[1,2], Alexander Borovik Jr[3], Benjamin Ebinger[3,4], Fengtao Jin[3,5], Kaija Spruck[1], Alfred Müller[1], and Stefan Schippers[3] — [1]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany — [2]Institut des Nanosciences de Paris, Sorbonne Université, 75252 Paris, France — [3]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [5]Department of Physics, National University of Defense Technology, 410022 Changsha, People's Republic of China

Cross sections for electron-impact single ionization (EISI) of multiply charged tungsten ions (W^{q+}) with charge states in the range $11 \leq q \leq 18$ in the electron-ion collision energy ranges from below the respective ionization thresholds up to 1000 eV were measured using the crossed-beams method and extrapolated up to 150 keV using subconfiguration-averaged distorted-wave (SCADW) theory [1]. Ionization rate coefficients were derived from the combined experimental and scaled theoretical cross sections and compared to the data contained in the ADAS database. Significant discrepancies were found in the temperature range where the ions investigated here are expected to form in collisionally ionised plasmas. [1] D Schury *et al* 2020 *J. Phys. B: At. Mol. Opt. Phys.* **53** 015201

A 1.3 Mon 11:45 a320

Polarization effects in bound-free pair production — •Jonas Sommerfeldt[1,2], Robert Müller[1,2], Anton Artemyev[3], and Andrey Surzhykov[1,2] — [1]Technische Universität Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Germany — [3]Universität Kassel, Germany

The study of electron-positron pair production in ion-ion and ion-photon collisions has a long history in accelerator physics. The bound-free e^-e^+ process is of special interest since it leads to the loss of ions from the beam. During the last decades, a large number of works has been performed to investigate the total and differential cross section of this process. In contrast, its polarization properties are way less known.

In this contribution, we present a theoretical study of bound-free e^-e^+ pair production in the interaction of γ rays with bare ions. A particular emphasis is placed on the longitudinal polarization of the produced positrons and final hydrogen-like ions. To evaluate this polarization we employed exact solutions of the relativistic Dirac equation and used first-order perturbation theory to treat the electron-photon coupling. Our results suggest that bound-free pair production can be a source of strongly polarized positrons and ions [1].

[1] J. Sommerfeldt *et al.*, Physical Review A **100**, 042511 (2019)

A 1.4 Mon 12:00 a320

FISIC - The Fast-Ion Slow-Ion Collision Experiment — •Daniel Schury[1,3], Emily Lamour[1], Stéphane Macé[1], Christophe Prigent[1], Sébastien Steydli[1], Dominique Vernhet[1], Alain Méry[2], Jean-Marc Ramillon[2], Jimmy Rangama[2], Jean-Yves Chesnel[2], Patrick Rousseau[2], Angela Bräuning-Demian[3], Alexandre Gumberidze[3], Uwe Spillmann[3], and Thomas Stöhlker[3,4,5] — [1]INSP/Sorbonne Université/CNRS UMR 7588, 75005 Paris, France — [2]CIMAP/CNRS/Université de Caen Normandie, 14032 Caen, France — [3]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [4]Friedrich-Schiller-Universität Jena, 07743 Jena, Germany — [5]Helmholtz Institute Jena, 07743 Jena, Germany

Ion-ion collisions in atomic physics were performed mainly in the context of magnetically confined plasmas or fast-ion/plasma-discharge experiments. Still no reliable experimental data exists for fast (MeV/u) and slow (keV/u) ion collisions in the regime where the ion stopping power is maximum and all the primary electronic processes reach their maximum, making the role of the individual processes on the collision almost impossible to disentangle, while being of high importance in ion-matter interaction. Therefore we designed a new ion-ion collision experiment, the **F**ast **I**on **S**low **I**on **C**ollisions project, a mobile experimental set-up, being able to conduct crossed beam ion-ion collisions at different high energy ion beam facilities. Today we present the current status of the set-up and performance of the low-energy branch of FISIC and present first planned experiments.

A 1.5 Mon 12:15 a320

Electron-impact single and double ionization of multiply charged xenon ions — •B. Michel Döhring[1,2], Benjamin Ebinger[1,2], Alexander Borovik Jr[1], Kurt Huber[1], Fengtao Jin[3], Alfred Müller[1], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt (Germany) — [3]Department of Physics, National University of Defense Technology, Changsha (China)

Electron-impact ionization cross sections are important for plasma physics applications, ranging from fusion research through ion thrusters. During recent years a new high-current electron gun [1] has been put into operation at the Giessen electron-ion crossed-beams experiment that extends the range of available electron-ion collision energies from previously 1 keV to now 3.5 keV. Thus, investigations of ions in charge states with ionization thresholds close to or beyond 1 keV are now possible. The present study comprises cross sections for single and double ionization of Xe^{q+} ions with $q = 12 - 14$. In addition, we have performed quantum calculations of these cross sections. Our experimental and theoretical results agree well with one another.

[1] B. Ebinger et al., 2017 Nucl. Instrum. Meth. B **408** 317.

A 2: Attosecond physics I

Time: Monday 11:00–13:15 Location: f107

Invited Talk A 2.1 Mon 11:00 f107

Highly nonlinear ionization of atoms induced by intense HHG pulses — Björn Senfftleben[1], Martin Kretschmar[1], Andreas Hoffmann[1], Mario Sauppe[1,2], Johannes Tümmler[1], Ingo Will[1], Tamás Nagy[1], Marc J. J. Vrakking[1], Daniela Rupp[1,2], and •Bernd Schütte[1] — [1]Max-Born-Institut Berlin — [2]ETH Zürich

High-harmonic generation (HHG) is typically considered to be a weak source of extreme-ultraviolet (XUV) photons. Here we demonstrate a very intense source of few-femtosecond XUV pulses based on HHG, reaching intensities up to 7×10^{14} W/cm^2 [1]. These pulses enable us to ionize Ar atoms up to Ar^{5+}, requiring the absorption of at least 10 XUV photons. This number can be appreciated by considering that it

is similar to the number of near-infrared (NIR) photons absorbed in a typical strong-field ionization experiment.

Our results are the consequence of a novel scaling scheme, showing that the optimization of the XUV intensity requires conditions that are distinctly different from the conditions that are required to optimize the HHG pulse energy. An important advantage of our approach is that we use a moderate NIR pulse driving energy (≈ 10 mJ). Therefore, our results make it possible to perform experiments requiring intense XUV pulses in a much larger number of laboratories than is currently the case. This substantially improves the prospects for nonlinear XUV optics experiments, single-shot coherent diffractive imaging of isolated nanotargets as well as attosecond-pump attosecond-probe experiments.

[1] B. Senfftleben *et al.*, arXiv:1911.01375

A 2.2 Mon 11:30 f107

Generation of elliptically polarized high-harmonics: towards chiral isolated attosecond pulses — •Ulrich Bengs and Nickolai Zhavoronkov — Max-Born Institut Berlin

High harmonic generation (HHG) is the fundamental process underlying the generation of attosecond pulses, which allow to study the electronic structure of matter on its natural timescale. However, until recently, HHG was limited to linear polarization. A promising way to overcome this limitation is offered by bicircular HHG [1] which is known to produce circularly polarized pairs of harmonics with opposite helicity. We demonstrate an implementation of bicircular HHG with few-cycle driving fields consisting of a 5 fs, circularly polarized pulse centered around 800 nm and its counter-rotating second harmonic with 8 fs duration. Utilizing the propensity rules that govern the contrast between harmonics of opposite helicity [2, 3] we are able to shape the harmonic spectrum to be dominated by harmonics of only one helicity over a broad spectral range and measure the ellipticity by means of XUV-polarimetry showing, that the harmonics are indeed elliptically polarized. Additionaly, we report the generation of a continuous spectrum spanning 32-55 eV, which lays the foundation for isolated attosecond pulses with elliptical polarization, making the technique a powerful tool in the development of a lightsource for ultrafast chiral-sensitive studies.

[1] D.B. Milosevic et al, Phys. Rev. A 61, 063403 (2000)
[2] A. Jimenez-Galan et al, Phys. Rev. A 97, 023409 (2018)
[3] N. Zhavoronkov and M. Ivanov, Opt. Lett. 42, 4720-4723 (2017)

A 2.3 Mon 11:45 f107

Attosecond XUV Fourier transform spectroscopy — •Laura Maikowski, Lorenz Drescher, Oleg Kornilov, Marc Vrakking, and Tobias Witting — Max-Born-Institut, Max-Born-Strasse 2A, 12489 Berlin

We aim to extend the methods of Fourier transform spectroscopy into the XUV domain. Our goal is to create a phase-locked pair of isolated attosecond XUV pulses, in combination with a strong NIR few-cycle pulse. As pulse splitting in the XUV is difficult, we create a pulse pair in the NIR range and then generate the XUV pulse pair via high harmonic generation [1,2,3]. As we want to create isolated attosecond pulses we have to create a pair of few-cycle pulses. To achieve this we constructed a few-cycle compatible Mach-Zehnder interferometer, which is actively phase-stabilized to a residual delay jitter of 5 as rms. A pair of 4 fs, 800nm few-cycle pulses from this interferometer is used to produce a pair of attosecond XUV pulses in the 15 to 50 eV energy range.

[1] Austin et al. Lateral Shearing Interferometry of High-Harmonic Wavefronts. Opt. Lett 36, 1746-48 (2011)

[2] Meng et al. Octave-Spanning Hyperspectral Coherent Diffractive Imaging in the Extreme Ultraviolet Range. Opt. Expr. 23, 28960-69 (2015)

[3] Jansen et al. Spatially Resolved Fourier Transform Spectroscopy in the Extreme Ultraviolet. Optica 3, 1122-25 (2016)

A 2.4 Mon 12:00 f107

Perspectives of high harmonics generation with tailored femtosecond driving pulses — •Lars Englert, Marcel Behrens, Felix Otten, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg

In the recent years, we presented work on the coherent control of ultrafast quantum dynamics in tailored femtosecond laser fields, including the generation of polarization-shaped femtosecond laser pulses [1], the tomographic reconstruction of sculpted photoelectron wave packets [2] and the photoelectron circular dichroism (PECD) of chiral molecules [3]. Currently, we combine a commercial table top high harmonics generation (HHG) source, providing XUV radiation up to 100 eV, with polarization shaping of the femtosecond IR driving field to extend our expertise in coherent control from the IR/VIS to the XUV regime. In this talk, we present an overview of the attosecond beamline and discuss perspectives for the oncoming experiments on the control of the HHG process, in terms of gating mechanisms for the generation isolated attosecond pulses and polarization control for the generation of circularly polarized XUV pulses, as well as single-photon PECD and chiral HHG in the XUV regime.

[1] S. Kerbstadt *et al.*: Opt. Express **25**, 12518 (2017)
[2] D. Pengel *et al.*: Phys. Rev. Lett. **118**, 053003 (2017)
[3] C. Lux *et al.*: Chem. Phys. Chem. **16**, 115 (2015)

A 2.5 Mon 12:15 f107

Strong-field coherent control of photoemission from tungsten needle tips with a two-color laser field — •Philip Dienstbier[1], Timo Paschen[1], Lennart Seiffert[2], Thomas Fennel[2], and Peter Hommelhoff[1] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]Institut für Physik, Universität Rostock, 18059 Rostock

Ionization by two-color laser fields with well-defined relative phase allows tuning and controlling electronic dynamics on the sub-femtosecond time scale. In the perturbative photoemission regime we have demonstrated electron emission induced by a fundamental that can be modulated with a contrast of up to 97.5% when superimposing a weak second harmonic field due to interference between two different quantum channels in photoemission from a nanometer sharp metallic needle tip [1,2].

We extend this coherent control scheme to the strong-field photoemission regime by using a two-color field synthesized with few-cycle pulses. In the strong-field regime, not only the ionization but also electron trajectories can be manipulated during the rescattering process by varying the relative phase of the second harmonic field [3]. In this talk we show experimental findings for field-driven dynamics and confirm the results by time-dependent Schrödinger equation and simple-man's model simulations.

[1] M. Förster et al. , Phys. Rev. Lett. **117**, 217601 (2016).
[2] T. Paschen et al., J. Mod. Opt. **64**, 10-11, 1054-1060 (2017).
[3] L. Seiffert et al., J. Phys. B. **51**, 134001 (2018).

A 2.6 Mon 12:30 f107

Two-Color time resolved photoionization experiments with a high-repetition rate laser — •Hemkumar Srinivas, Farshad Shobeiry, Divya Bharti, Anne Harth, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, Heidelberg 69117

Photoionization in atoms and molecules have long been used to study the atomic/ molecular structure. With the advent of ultrashort laser pulses in the femtosecond and attosecond time-scale, it has been possible to observe dynamics at the atomic level in real time.

This is done with the help of a pump-probe scheme wherein the initial laser pulse excites or ionizes the system and this is followed by another pulse with a precise time delay that helps mapping the phase of the emitted electron wavepacket.

In this work, we implement an XUV-IR pump-probe technique called RABBIT[1] to understand and observe electron dynamics in Noble gases and simple molecular systems such as diatomic molecules. Of particular interest is to investigate the effects of the intensity of the probing infrared field on the electron in the continuum and how it affects the angular distribution for the electron emission. The usage of a high-repetition rate laser reduces the acquisition time significantly, thereby making it easier to investigate processes with a relatively low ionization cross-section in a shorter timeframe.

Reference : [1] PM Paul et. al, Science(292) 5522

A 2.7 Mon 12:45 f107

Time operator, real tunneling time in strong field interaction and the attoclock — •Ossama Kullie — Institute of Physics, Department of Mathematics and Natural Science, University of Kassel.

In the present work, we show that our real tunneling time relation derived in earlier works [1] can be derived from an observable or a time operator, which obeys an ordinary commutation relation. Moreover, we show that our real tunneling time has a close relation or actually is equivalent to the Eisenbud-Wigner delay time. Furthermore it can also be constructed from the well-known Aharonov-Bohm time operator. This shows that the specific form of the time operator is not

decisive, and dynamical time operators relate identically to the intrinsic time of the system. It contrasts the famous Pauli theorem, and confirms the fact that time is an observable, i.e. the existence of time operator and that the time is not a parameter in quantum mechanics. We discuss the relations with different types of tunneling times such as Eisenbud-Wigner time, dwell time and the statistically or probabilistic defined tunneling time. [1] O. Kullie, Phys. Rev. A. **92**, 052118 (2015), Ann. of Phys. **389**, 333 (2018), Mathematics **6**, 192 (2018)

A 2.8 Mon 13:00 f107

Ionization time in the nonadiabatic attoclock, *Multiphoton process versus tunneling in strong field interaction* — •Ossama Kullie — Institute of Physics, Department of Mathematics and Natural Science, University of Kassel.

The measurement of the tunneling time in attosecond experiments, termed attoclock, triggered a hot debate about the tunneling time and the separation into two regimes of ionization, the multiphoton and the tunneling. In the adiabatic field calibration, we showed in earlier works [1] that our real tunneling time fits well in the experimental data of the attoclock. However, Hofmann et al (J. of Mod. Opt. **66**, 1052, 2019), presented a new experimental data of the attoclock with a nonadiabtic calibration of the field strength. In the present work we show that our model is capable to account for the nonadiabaticity and we find an excellent agreement with the nonadiabatic experimental attoclock result of Hofmann et al. Interestingly, we show that our model offers a clear picture for the multiphoton and tunneling parts, and the well known regime separation is now resolved. In particular the the tunneling part is equalized by the nonadiabaticity, the absorption of $n(F)$ photons (where F is the peak of field strength, and the time delay is ionization time delay with respect to the atomic field strength, where the Barrier suppression ionization sets up. [1] O. Kullie, Phys. Rev. A. 92, 052118 (2015), J. Phys. B **49**, 095601 (2016), J. Phys. Commun. **2**, 065001 (2018)

A 3: Ultracold atoms, ions, and BEC I (joint session A/Q)

Time: Monday 11:00–13:00 Location: f303

Invited Talk A 3.1 Mon 11:00 f303

Creation of ultracold bosonic ^{23}Na^{39}K ground state molecules — •Kai Konrad Voges, Philipp Gersema, Torsten Hartmann, Mara Meyer zum Alten Borgloh, Torben Alexander Schulze, Alessandro Zenesini, and Silke Ospelkaus — Universität Hannover, Institut für Quantenoptik

Heteronuclear ground state molecules, with their large electric dipole moments, are an excellent platform for the investigation of fascinating dipolar quantum phenomena.
Bialkali ground state molecules are assembled from an ultracold atomic quantum gas mixture by utilizing Feshbach molecule association and subsequent stimulated Raman adiabatic passage (STIRAP) to the ground state.
In this talk we present the coherent creation of bosonic ^{23}Na^{39}K rovibrational ground state molecules following this pathway. We perform radio frequency pulses to populate a weakly bound molecular state close to a broad Feshbach resonance. We analyze the molecule creation efficiency with respect to the atom number ratio and radio frequency pulse duration. After that, we transfer the Feshbach molecules to a single spin-polarized hyperfine ground state using STIRAP through strongly coupled $c^3\Sigma(v = 30)$ and $B^1\Pi(v = 8)$ states, which we investigated spectroscopically beforehand. In this way we reach efficiencies of up to 70 %. We model the transfer process by incorporating multiple states from the excited state manifold and find a good agreement with our experimental results.

A 3.2 Mon 11:30 f303

Spin-rotation coupling in p-wave Feshbach resonances — •Manuel Gerken[1], Binh Tran[1], Eleonora Lippi[1], Bing Zhu[1,2], Stefan Häfner[1], Juris Ulmanis[1], Eberhard Tiemann[3], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

We report on the observation of spin-rotation coupling in p-wave Feshbach resonances in an ultracold mixture of fermionic ^{6}Li and bosonic ^{133}Cs. In addition to the doublet structure in the Feshbach spectrum due to spin-spin interaction, we observe a triplet structure of different m_ℓ states by magnetic field dependent atom-loss spectroscopy. Here, the m_ℓ states are projections of the pair-rotation angular momentum ℓ on the external magnetic field. Through comparison with coupled-channel calculations, we attribute the observed splitting of the $m_\ell = \pm 1$ components to electron spin-rotation coupling. Comparison with an oversimplified model, estimating the spin-rotation coupling by describing the weakly bound close-channel molecular state with the perturbative multipole expansion, reveals the significant contribution of the molecular wavefunction at short internuclear distances. Our findings highlight the potential of Feshbach resonances in providing precise information on short- and intermediate-range molecular couplings and wavefunctions. We also present measurements of spin-spin coupling in p-wave Feshbach resonances in a Li^6 mixture.

A 3.3 Mon 11:45 f303

Tune-out and magic wavelengths for the ^{23}Na^{40}K molecule — •Roman Bause[1], Xing-Yan Chen[1], Andreas Schindewolf[1], Ming Li[2], Marcel Duda[1], Svetlana Kotochigova[2], Immanuel Bloch[1,3], and Xin-Yu Luo[1] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Department of Physics, Temple University, Philadelphia, Pennsylvania 19122, USA — [3]Ludwig-Maximilians-Universität, 80799 München

State-dependent optical dipole traps for ultracold atoms or molecules have wide application in quantum engineering and precision measurements. One extreme case is the tune-out condition, where the light shift of one state vanishes while the other one remains finite. Another extreme case is the magic condition, where the light shifts of both states are identical. We demonstrate a versatile, rotational-state dependent optical dipole trap for the ground-state ^{23}Na^{40}K molecule and its first rotationally excited state. Close to a low-lying, narrow molecular transition, we experimentally determined a tune-out and a magic frequency. Because these frequencies are less than 10 GHz apart, it is possible to create both types of trap as well as any intermediate trap configuration with the same laser system and switch between them during an experimental cycle. We propose that the rotational-state dependent trap can be used for evaporative cooling of polar molecules or investigation of their collisional properties.

A 3.4 Mon 12:00 f303

Efimov physics in strongly mass-imbalanced atom-dimer gases — •Panagiotis Giannakeas[1] and Chris H. Greene[2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Department of Physics and Astronomy, Purdue University, Indiana, USA

Three-body collisions in a two-species ultracold gases possess unique Efimovian idiosyncrasies. Indeed, for this particular colliding complex the magnitude and the sign intra- and inter-species scattering lengths can render an inherently different Efimovian landscape where the corresponding recombination spectra exhibit Efimov resonances intertwined with Stueckelberg suppression effects. Our current studies exploit these unique attributes of Efimov physics in mass-imbalanced systems by investigating the relevant scattering processes in atom-dimer gases. In particular, our analysis shows that the corresponding atom-dimer collisions are strongly enhanced when an Efimov bound state from the energetically closed three-body channel lies in the atom-dimer continuum, i.e. energetically open channel. Namely, our study demonstrates that in mass-imbalanced atom-dimer gases exists a series of atom-dimer resonances which fulfill a Fano-Feshbach scenario. In addition, we highlight the pivotal role of Stueckelberg physics on the width of the atom-dimer resonances where by adjusting the intra-species scattering length the atom-dimer continuum fully decouples from the Efimov states. Finally, our analysis addresses the universal aspects of this type of atom-dimer resonances, as well as, the importance of the Van der Waals physics.

A 3.5 Mon 12:15 f303

Autodetachment reaction dynamics in anion-atom reac-

tions. — •Saba Zia Hassan[1,2], Jonas Tauch[1], Milaim Kas[4,5], Markus Nötzold[3], Henry Lopez[1], Eric Endres[1], Roland Wester[3], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut Heidelberg, INF 226, 69120 Heidelberg — [2]International Max Planck Research School for Quantum Dynamics, Max Planck Institute for Nuclear Physics, 69117 Heidelberg — [3]Institut für Ionenphysik und Angewandte Physik, Technikerstraße 25/3, 6020 Innsbruck — [4]Département de Chimie, Faculté des Sciences, Université Libre de Bruxelles (ULB), 1050 Brusseles — [5]Deutsches Elektronen-Synchrotron (DESY), 22607 Hamburg

Associative detachment (AD) reactions play a key role in the destruction of anions to form neutral molecules in chemical networks, like interstellar medium, Earth's ionosphere and biochemistry. Here, we investigate AD reactions involving a closed-shell anion OH^- and rubidium atoms in a hybrid atom-ion trap. The overlap of atoms and anions leads to elastic and inelastic collisions, cooling the external and internal degrees of freedom respectively. Ab-initio calculations also predict the occurrence of AD reaction, i.e. $Rb+OH^- \rightarrow RbOH$. A detailed experimental investigation of AD reactions can serve as a stringent test on the effective core potentials used in theoretical studies. Furthermore, with a precise control on the fraction of electronically excited rubidium in the ensemble, the dynamics of quantum state dependent reactive collisions can be studied. In this contribution the latest results will be presented.

A 3.6 Mon 12:30 f303

A new ultracold atomic mixture experiment : SoPa — •Rohit Prasad Bhatt, Lilo Höcker, Jan Kilinc, and Fred Jendrzejewski — Kirchhoff-Institute for Physics, Im Neuenheimer Feld 227, D-69120 Heidelberg

Ultracold atomic gases present a high control over experimental parameters which makes them an ideal candidate to simulate a wide variety of physical systems. Ultracold atomic mixtures expand these horizons by covering an even greater range of quantum many body phenomena like dynamical gauge fields, quantum thermodynamic cycles etc. In this talk, I present the new Na-K experiment at Heidelberg, which we are setting up as a platform to study some of those problems.

A 3.7 Mon 12:45 f303

Squeezed-field path-integral description of a BEC — •Ilias Mir Heliassudin Seifie[1,2], Vijay Pal Singh[1,2,3], and Ludwig Mathey[1,2,3] — [1]Center for Optical Quantum Technologies, University of Hamburg, Germany — [2]The Hamburg Center for Ultrafast Imaging, Germany — [3]Institute of Laser Physics, University of Hamburg, Germany

We propose a generalization of the Feynman path integral using squeezed coherent states. In fact, the introduction of the squeezing parameter into the path integral enhances the adaptability of the theoretical model to the physical system. Therefore, our method can be applied to any analytical and numerical approach that is based on the path-integral representation. We apply this approach to the dynamics of Bose-Einstein condensates. In the low energy regime of a BEC, we obtain a generalization of the linearized Gross Pitaevskii equation, containing coherent and squeezing fields, and a description of second sound in weakly interacting condensates as a squeezing oscillation of the order parameter. In the higher energy and finite temperature regime, we analyze the coupling between the two fields and develope corresponding numerical and analytical methods.

A 4: Clusters I (joint session MO/A)

Time: Monday 11:00–13:15 Location: f102

Invited Talk A 4.1 Mon 11:00 f102

Infrared Spectroscopy of HHe_n^+ and DHe_n^+ Complexes — •Oskar Asvany and Stephan Schlemmer — I. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, Köln

The combination of a cryogenic ion-trap machine, operated at 4.7 K, with the free-electron-laser FELIX allowed the first experimental characterization of the antisymmetric stretch (ν_3) and bending (ν_2) fundamentals of the linear He–X^+–He (X = H, D) cores of the in situ prepared HHe_n^+ and DHe_n^+ complexes for $n = 3-6$. The found band origins, at around 1290 cm^{-1} for ν_3 and around 850 cm^{-1} for ν_2 (for HHe_n^+), are fully supported by first-principles quantum-chemical computations. These results are consistent with structures for the species with $n = 3$ and 6 being of T-shaped C_{2v} and of D_{4h} symmetry, respectively, while the species with $n = 4$ are suggested to exhibit interesting dynamical phenomena related to large-amplitude motions. Future high-resolution measurements will give detailed insight into the structure of these fundamental complexes.

A 4.2 Mon 11:30 f102

Photon-energy dependent ionisation of isolated Xenon atoms — Thomas Baumann[1], Rebecca Boll[1], Markus Ilchen[1], Joakim Laksman[1], Tommaso Mazza[1], Michael Meyer[1], Valeria Musić[1], Daniel Rivas[1], •Aljoscha Rörig[1], Svitozar Serkez[1], Philipp Schmidt[1], Sergey Usenko[1], Julia Schäfer[2], Robin Santra[2], Sang-Kil Son[2], Shashank Pathak[3], Daniel Rolles[3], and Benjamin Erk[4] — [1]European XFEL GmbH, Schenefeld, Germany — [2]Center for Free-Electron Laser Science (CFEL), Hamburg, Germany — [3]Kansas State University, Manhattan, USA — [4]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

In October 2019 we investigated the photon-energy-dependence of the ionisation process of isolated Xenon atoms exposed to extremely intense soft X-ray radiation at the European XFEL free-electron laser in Schenefeld, Germany. We were able to tune the photon energy over a wide range (700 eV - 3000 eV) while maintaining constant high pulse energy of several millijoule. As a function of photon energy, we detected distinct variations of the ion yield in certain charge state regions due to non-linear effects, and extreme-charge states up to +42 of Xenon. These variations are the result of transient resonances that increase the photoionisation cross section at certain charge states and photon energies, as the binding energies in the atomic orbitals shift as a result of increasing charge state during a single FEL pulse. The experimentally obtained data is in good accordance with the calculated charge state distributions, thus allowing us a detailed insight into the transient electronic structure of highly excited atoms.

A 4.3 Mon 11:45 f102

Oscillations in immiscible liquids due to persistent currents — •Frederic Folz, Ayoub Elyaagoubi, Albrecht Ott, and Giovanna Morigi — Universität des Saarlandes

Absorption spectroscopy exhibits a noisy absorption pattern in samples of colloidal gold at marginal stability [1]. This might be the signature of an oscillatory behavior. Here, we discuss a theoretical model that traces these oscillations back to agglomeration and sedimentation processes, given a persistent influx of molecules. We analyse the results in relation to the experimental findings.

[1] Experiments carried out by Ayoub Elyaagoubi in the group of Prof. Ott at Saarland University, unpublished

A 4.4 Mon 12:00 f102

Geometry and Stability of Small Cationic Silicon Carbide Clusters — •Robert Radloff, Lars Dahllöf, Kai Pollow, Karim Ahmed Saroukh, Marko Förstel, and Otto Dopfer — Technische Universität Berlin, Institut für Optik und Atomare Physik, Germany

Ejecta of carbon-rich stars contribute significantly to interstellar dust. The emitted particles are generally hot and consist of single atoms or ions. With increasing distance from the star, this matter cools down and starts to condense, eventually forming first molecules and creating a rich chemistry. Observations suggest not only small molecules like SiC [1], Si_2C [2], SiC_2 [3], etc. to be present in the circumstellar environment of carbon-rich stars but also solid silicon carbide grains [4]. Up to now, it has remained unclear how these dust grains are created. It seems likely that they form from small SiC molecules via condensation but no intermediates have been detected so far.

In this contribution we present the energetic, geometric, and optical properties of small cationic silicon carbide clusters obtained via photodissociation spectroscopy, mass spectrometry, and quantum chemical calculations. We show the first optical spectrum of a silicon carbide cation and present hitherto unreported fragmentation channels and ground state geometries of several cationic silicon carbide clusters.

[1] J. Cernicharo et. al., Astrophys. J. Lett. **341**, L25 (1989)
[2] J. Cernicharo et. al., Astrophys. J. Lett. **806**, L3 (2015)
[3] P. Thaddeus et. al., Astrophys. J. Lett. **283**, L45-48 (1984)
[4] R. Treffers and M. Cohen, Astrophys. J. **188**, 545-552 (1974)

A 4.5 Mon 12:15 f102

N2 activation on size selected Tantalum clusters investigated by cryo kinetics and IR spectroscopy — •Matthias P. Klein[1], Daniela V. Fries[1], Annika Steiner[1], Helmut Schwarz[2], and Gereon Niedner-Schatteburg[1] — [1]Fachbereich Chemie and Forschungszentrum OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Straße 52, 67663 Kaiserslautern — [2]Institut für Chemie, Technische Universität Berlin, 10623 Berlin

Catalytic N_2 activation by active transition metal surfaces is one of the most important industrial processes. For a thorough understanding of the activation steps, we need suitable model systems. By means of cryo IR-PD spectroscopy and cryo adsorption kinetics supported by DFT modelling, we are able to investigate the vibrational and kinetic behavior of various transition-metal-cluster-N_2/H_2 complexes (Fe, Co, Ni, Rh, Ru) and gain information about reaction precursors and intermediates. Small tantalum clusters have shown to activate N_2 dissociatively and even support the formation of ammonia. We chose to examine the Ta_4^+ and Ta_5^+ clusters in more detail. We observe a rearrangement of the adsorbate shell and activated N_2 upon stepweise N_2 adsorption. In the Ta_4^+ case, the adsorption kinetics suggest a complex dynamics for large adsorption shells. A pseudo-first-order kinetic fit fails in this case. In contrast, the adsorption kinetics of the Ta_5 cluster are reproducible by such a fit. IR bands represent a range from weakly bound N_2 to actual N_2 activation precursors.

A 4.6 Mon 12:30 f102

Optimizing Aerodynamic Lens Geometries for Gold Nanoparticle Beams — •Lena Worbs[1,2], Jannik Lübke[1,2,3], Armando Estillore[1], Amit K. Samanta[1], Lourdu Xavier Paulraj[1], Kartik Ayyer[1,4], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]Fachbereich Physik, Universität Hamburg — [3]Center for Ultrafast Imaging, Hamburg — [4]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg

Coherent diffractive imaging at free-electron lasers promises to allow the reconstruction of the three-dimensional molecular structures of isolated particles at atomic resolution [1]. However, because of the typically low signal to noice ratio, this requires the collection of a large amount of diffraction patterns. Since every intercepted particle is destroyed by the intense x-ray pulse, a new and preferably identical sample particle has to be delivered into every pulse. One delivery technique is an aerodynamic lens stack (ALS), providing collimated or focused beams of nanoparticles. With the aid of numerical simulations we optimized the geometry of an ALS to produce high-density beams of nanoparticles, e.g., gold nanoparticles. Here, we present the simulation result for an optimized ALS and its experimental characterization using novel laser-based particle detection techniques [2]. We also show an application of ALS for XFEL experiments on gold nanoparticles.

[1] M. M. Seibert, et al., *Nature* **470**, 78 (2011).
[2] L. Worbs, et al., *Opt. Expr.*, arXiv:1909.08922 [physics.optics]

A 4.7 Mon 12:45 f102

Chemical dynamics in Argon clusters induced by intense x-rays — •Zoltan Jurek[1,2], Yoshiaki Kumagai[3], Hironobu Fukuzawa[3,4], Sang-Kil Son[1,2], Beata Ziaja[1,2,5], Robin Santra[1,2,6], and Kiyoshi Ueda[3,4] — [1]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron, Notkestrasse 85, 22607 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22671 Hamburg, Germany — [3]Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai 980-8577, Japan — [4]RIKEN SPring-8 Center, Sayo, Hyogo 679-5148, Japan — [5]Institute of Nuclear Physics, PAS, Radzikowskiego 152, 31-342, Krakow, Poland — [6]Department of Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany

In this talk, we focus on the dynamics of rare gas clusters exposed to ultrashort X-ray Free Electron Lasers (XFELs) pulses of intermediate x-ray fluence. In this fluence regime the system is only partially ionized. Therefore, chemical properties of the sample may still play an important role in shaping the ionization dynamics beside the emerging Coulomb forces. As a result, complex fragmentation of the cluster can occur. We show signatures of chemical effects in spectroscopy observables, and present our theoretical simulations, unraveling the time evolution of irradiated Ar clusters in detail [1].This study addresses a regime that is a very common scenario at current XFEL experiments.

[1] Y. Kumagai et al, Phys. Rev. Lett. 120, 223201 (2018)

A 4.8 Mon 13:00 f102

The role of water in the photophysics of indole — •Lanhai He[1], Melby Johny[1,2], Thomas Kierspel[1,2], Jolijn Onvlee[1,2], Bernd Winter[4], Sebastian Trippel[1,2], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]Center for Ultrafast Imaging, Universität Hamburg — [3]Department of Physics, Universität Hamburg — [4]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin

Hydrogen bonds play an important role in biological processes and proteins, e.g., protein folding and molecular recognition. The influence of water in complex systems, such as a protein, can only be explained if the cluster formation and the breaking of the micro-solvated molecular clusters itself is understood. We studied the photo-fragmentation of indole and indole-water$_1$ upon x-ray absorption, which triggers inner-shell ionization from nitrogen and carbon ($1s$) orbitals. The generated ions and electrons were measured with an angle-resolved coincidence detection scheme, and the results revealed fragmentation-pathway-dependent electron spectra, linking the structural fragmentation dynamics to different electronic excitations. On the other hand, the photoelectron spectrum of an aqueous indole-water solution has been measured through x-ray ionization of indole in a liquid microjet. Analyzing the chemical shifts for the characteristic photoelectron spectra, the hydration of indole in water solutions is about to be identified.

A 5: Annual general meeting

Time: Monday 13:15–13:45 Location: f107

Duration: 30 min.

A 6: Atomic clusters (joint session A/MO)

Time: Monday 14:00–16:15 Location: a320

Invited Talk A 6.1 Mon 14:00 a320

Time-resolved X-ray Imaging of Anisotropic Nanoplasma Expansion — •Christian Peltz[1], Christoph Bostedt[2], Mathias Kling[3], Thomas Brabec[4], Eckart Ruehl[5], Artem Rudenko[6], Tais Gorkhover[7], and Thomas Fennel[1] — [1]Institute of Physics, University of Rostock, Germany — [2]Paul Scherrer Institute, Villigen, Switzerland — [3]Faculty of Physics, LMU Munich, Germany — [4]Department of Physics and Centre for Photonics Research, University of Ottawa, Canada — [5]Physical Chemistry, FU Berlin, Germany — [6]Department of Physics, Kansas-State University, USA — [7]LCLS, SLAC National Accelerator Laboratory, Menlo Park, USA

We investigate the time-dependent evolution of laser-heated solid-density nanoparticles via coherent diffractive x-ray imaging, theoretically and experimentally. Our microscopic particle-in-cell calculations for R = 25 nm hydrogen clusters reveal that infrared laser excitation induces continuous ion ablation on the cluster surface. This process generates an anisotropic nanoplasma expansion that can be accurately described by a simple self-similar radial density profile. It's time evolution can be reconstructed precisely by fitting the time-resolved scattering images using a simplified scattering model in Born approximation [1]. Here we present the first successful high resolution reconstruction of corresponding experimental results, obtained at the LCLS

facility with SiO2 nanoparticles (D=120 nm), giving unprecedented insight into the spatio-temporal evolution of the nanoplasma expansion.

[1] C. Peltz, C. Varin, T. Brabec and T. Fennel , Phys. Rev. Lett. **113**, 133401 (2014)

Invited Talk A 6.2 Mon 14:30 a320

Imaging anisotropic dynamics in superfluid helium nanodroplets — •B. Langbehn[1], K. Sander[2], Y. Ovcharenko[1,3], C. Peltz[2], A. Clark[4], M. Coreno[5], R. Cucini[6], A. Demidovich[6], M. Drabbels[4], P. Finetti[6], M. Di Fraia[6,5], L. Giannessi[6], C. Grazioli[5], D. Iablonskyi[7], A. C. LaForge[8], T. Nishiyama[9], V. Oliver Álvarez de Lara[4], P. Piseri[10], O. Plekan[6], K. Ueda[7], J. Zimmermann[1,11], K. C. Prince[6,12], F. Stienkemeier[8], C. Callegari[6,5], T. Fennel[2,11], D. Rupp[1,11,13], and T. Möller[1] — [1]TU Berlin — [2]Univ. Rostock — [3]European XFEL — [4]EPFL Lausanne — [5]ISM-CNR Trieste — [6]Elettra-Sincrotrone Trieste — [7]Tohoku Univ. Sendai — [8]Univ. Freiburg — [9]Kyoto Univ. — [10]Univ. di Milano — [11]MBI Berlin — [12]Swinburne Univ. of Tech. — [13]ETH Zürich

Intense short-wavelength light pulses from free-electron lasers (FELs) enable the study of the structure and dynamics of nanometer-sized particles in the gas phase using coherent diffraction imaging methods. In our experiment, we explored the light induced dynamics of xenon doped helium nanodroplets. We used intense near-infrared pulses to ignite a nanoplasma inside the droplets. After a variable time delay of up to 800 ps, we imaged the dynamics triggered by the nanoplasma using extreme ultraviolet pulses from the FERMI FEL. The recorded scattering patterns exhibit pronounced directionalities that can be attributed to anisotropic changes of the droplet surface. A possible connection of these directed dynamics to the droplet's vortex structure will be discussed.

A 6.3 Mon 15:00 a320

Setup and characterization of a helium liquid jet for diffraction experiments — •K. Kolatzki[1,2], R. M. P. Tanyag[2], G. Noffz[2], A. Ulmer[2], T. Möller[2], and D. Rupp[1,3] — [1]LFKP, ETH Zurich, Switzerland — [2]IOAP, TU Berlin — [3]Max-Born-Institut Berlin

When conducting coherent diffractive imaging experiments at XUV and X-ray facilities with atomic clusters as targets, it is desirable that these targets are constant in size and spacing. Large helium droplets produced via Rayleigh-type breakup of a liquid jet meet these requirements: Compared to other types of clusters or droplets, they can exhibit very narrow size distributions and even spacing. Helium droplets also have a simple electronic structure, show interesting properties like superfluidity and can be used as a cooling matrix for embedded atoms and molecules.

Recently, we have constructed and characterized a source for a helium liquid jet and subsequent droplets, which is available for user experiments at the European XFEL's SQS endstation. Via shadowgraphy methods, we have analyzed the jet's shape and the droplet size distributions. Results from these measurements and an improved setup will be presented.

A 6.4 Mon 15:15 a320

Solvation and desorption dynamics of Cs atoms attached to He nanodroplets — •Nicolas Rendler, Audrey Scognamiglio, Lukas Bruder, Katrin Dulitz, and Frank Stienkemeier — University of Freiburg, Freiburg, Germany

Despite the low perturbative environment provided by the superfluidity of helium nanodroplets, excited or charged dopants can be strongly affected by the surrounding helium atoms. Numerous processes can be triggered by the electronic excitation and ionization of the dopant. For example, the repulsive electron-He interaction can result in the ejection of electronically excited dopants [1] which can be accompanied by electronic relaxation induced by the He environment [2]. In some cases, pairwise He-dopant interaction can also lead to the formation of He-dopant exciplexes [2,3]. Desorption dynamics, electronic relaxation as well as exciplex formation, strongly depend on the dopant species and still lack a complete understanding. We present an experimental study of the desorption dynamics of photo-excited Cs atoms attached to He nanodroplets using femtosecond pump-probe spectroscopy in combination with velocity-map imaging detection.

[1] M. Mudrich, F. Stienkemeier, Int. Rev. Phys. Chem. 33, 301-339, (2014).

[2] E. Loginov, M. Drabbels, J. Phys. Chem. A 111, 7504-7515, (2007).

[3] J. von Vangerow et al., J. Phys. Chem. Lett. 8 (1), 307-312, (2017).

A 6.5 Mon 15:30 a320

Coherent diffractive imaging of excited state population dynamics in a helium droplet — •Björn Kruse[1], Benjamin Liewehr[1], Christian Peltz[1], and Thomas Fennel[1,2] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, D-18059 Rostock — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2A, D-12489 Berlin

Coherent diffractive imaging (CDI) of isolated helium nanodroplets has been successfully demonstrated with a lab-based HHG source [1] operating in the vicinity of the 1s - 2p transition of helium. To reconstruct the shape and orientation of nanoparticles, CDI experiments have so far been analyzed in terms of a classical linear response description [2]. However, for high intensities and especially for resonant excitation, population dynamics of bound electrons and stimulated emissions may become important, violating the assumptions underlying a linear description. To what extend and how nonlinear processes influence CDI scattering images is currently largely unknown. In our theoretical analysis, we describe the quantum-mechanical few-level bound state dynamics using a density matrix formalism and incorporate this into a 3D Maxwell solver based on the finite-difference time-domain method (FDTD). We discuss the spatio-temporal population dynamics and its impact on scattering images.

[1] D. Rupp et al., Nat. Commun. **8**, 493 (2017)

[2] I. Barke et al., Nat. Commun. **6**, 6187 (2015)

A 6.6 Mon 15:45 a320

Development of core-level binding energies of mass-selected lead clusters — •Klara Raspe[1], Norman Iwe[1], Fabian Bär[2], Kariman Elshimi[2], Simon Dold[2], Franklin Martinez[1], Steffen Palutke[3], Marion Kuhlmann[3], Sven Toleikis[3], Josef Tiggesbäumker[1], Bernd von Issendorff[2], and Karl-Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18059 Rostock, Germany — [2]Fakultät für Physik, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [3]Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany

The high photon flux and the photon energies of several tens of eV as delivered by FLASH allow to conduct core-level photoemission studies on size-selected metal clusters in the gas phase. Interesting aspects are phenomena like core-hole screening and the subsequent dynamics triggered by the core electron emission. However, probing these nanometer-sized targets requires the preparation of a sufficiently high target density in the FEL interaction region. This condition is met by an experimental setup, which includes a high-current cluster source, a quadrupole mass filter and a radio-frequency ion trap. Photoelectron spectra of lead cluster anions have been recorded in the size range of N = 3 up to 50 atoms. The spectra show a size-dependent shift of the binding energies of the 5d electrons towards the bulk work function, which is compared to the metallic sphere model.

A 6.7 Mon 16:00 a320

Coulomb interaction in the photoemission of polyanionic silver clusters — •Norman Iwe[1], Franklin Martinez[1], Madlen Müller[2], Klara Raspe[1], Lutz Schweikhard[2], Josef Tiggesbäumker[1], and Karl-Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock, Rostock, Deutschland — [2]Institut für Physik, Universität Greifswald, Greifswald, Deutschland

Multiply negatively charged, nano-sized particles are characterized by a barrier potential, given by the Coulomb interaction between the excess electrons. In order to extract details of this barrier with unprecedented quality, photoelectron spectroscopy is combined with tunable laser pulse excitation. The emitted photoelectron interacts with the remaining negatively charged system, which leads to a specific Coulomb cut-off in the photoelectron spectra, as known from molecular polyanions.

In this contribution, we present experimental spectra of mass- and charge-selected silver clusters, Ag_{800}^{z-} (z=2-6), which show a characteristic dependence on the laser wavelength. The photoelectron spectra are qualitatively described by electrons coming from a Fermi distribution in a jellium-like potential, while direct emission as well as tunneling through the Coulomb barrier are taken into account.

A 7: Precision spectroscopy of atoms and ions I

Time: Monday 14:00–16:00 Location: f107

Invited Talk A 7.1 Mon 14:00 f107

Laser spectroscopy of the heaviest actinides — •Premaditya Chhetri[1,2], Dieter Ackermann[3], Hartmut Backe[4], Michael Block[1,2,4], Bradley Cheal[5], Christoph Emanuel Düllmann[1,2,4], Julia Even[6], Rafael Ferrer[7], Francesca Giacoppo[1,2], Stefan Götz[1,2,4], Fritz Peter Hessberger[1,2], Mark Huyse[7], Oliver Kaleja[1,4], Jadambaa Khuyagbaatar[1,2], Peter Kunz[8], Mustapha Laatiaoui[1,2,4], Werner Lauth[4], Lotte Lens[1], Enrique Minaya Ramirez[9], Andrew Mistry[1,2], Tobias Murböck[1], Sebastian Raeder[1,2], Fabian Schnieder[2], Piet Van Duppen[7], Thomas Walther[10], and Alexander Yakushev[1,2] — [1]GSI, Darmstadt, Germany — [2]HI Mainz, Mainz, Germany — [3]GANIL, Cean, France — [4]JGU, Mainz, Germany — [5]Liverpool University, Liverpool, UK — [6]University of Groningen, KVI-CART, Groningen, Netherlands — [7]KU Leuven, Leuven, Belgium — [8]TRIUMF, Vancouver, Canada — [9]IPN, Orsay, France — [10]TU Darmstadt, Darmstadt, Germany

Precision measurements of optical transitions of the heaviest elements are a versatile tool to probe the electronic shell structure which is strongly influenced by electron-electron correlations, relativity and QED effects. Optical studies of transfermium elements with Z>100 is hampered by low production rates and the fact that any atomic information is initially available only from theoretical predictions. Using the sensitive RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) technique coupled to the SHIP separator at GSI, a strong optical $^1S_0 \rightarrow {}^1P_1$ ground-state transition in the element nobelium (Z=102) was identified and characterized [1]. The isotopes of ^{252,253,254}No were measured [2]. Production of ^{255}No via the electron capture of ^{255}Lr, at very low rate, made the measurements of hyperfine structure of ^{255}No possible. From these measurements, nuclear information on the shapes and sizes were inferred. In addition, several high-lying Rydberg levels were observed, which enabled the extraction of the first ionization potential with high precision [3].

These results as well as the prospects for future exploration of the atomic structure of the next heavier element, lawrencium (Z=103) will be discussed.

[1] M. Laatiaoui et al., Nature **538**, 495 (2016).
[2] S. Raeder et al., PRL **120**, 232503 (2018).
[3] P. Chhetri et al., PRL **120**, 263003 (2018).

A 7.2 Mon 14:30 f107

Resonance ionization mass spectrometry on $^{243-248}$Cm — •Nina Kneip[1], Christoph E. Düllmann[2,3,4], Christian M. Marquardt[5], Christoph Mokry[2,4], Petra J. Panak[5,6], Sebastian Raeder[3], Jörg Runke[2,3], Petra Thörle-Pospiech[2,4], Felix Weber[1], Klaus Wendt[1], and Norbert Trautmann[2] — [1]Institute of Physics, Johannes Gutenberg University Mainz — [2]Institute of Nuclear Chemistry, Johannes Gutenberg University Mainz — [3]GSI Helmholtz Centre for Heavy Ion Research mbH, Darmstadt — [4]Helmholtz Institute Mainz — [5]Institute for Nuclear Waste Disposal, Karlsruhe Institute of Technology, Karlsruhe — [6]Institute of Physical Chemistry, Heidelberg University

In numerous applications resonance ionization mass spectroscopy has demonstrated its versatility as a highly efficient and selective method for the ultra-trace determination of actinides. The RISIKO facility involves a 30 kV magnetic sector field mass separator in combination with a laser ion source and a high repetition rate pulsed Ti:sapphire laser system. Optical spectroscopy on a number of curium isotopes was performed using sample sizes of typically 10^9 atoms. The individual tunable lasers involve automated grating-tuning and Intra-Cavity Second Harmonic Generation. Efficient two-step ionization schemes for Cm were identified and scans across Rydberg series were performed using two different first excitation steps. With a Cm sample containing the isotopes 243 to 248 isotope shifts were measured for the first time of all these isotopes and the ionization potential was deduced with significantly enhanced precision using the Rydberg Ritz formula.

A 7.3 Mon 14:45 f107

Two-Photon Shelving spectroscopy on a UV-transition in atomic Dysprosium — •Jan-Niklas Schmidt, Viraatt Anasuri, Fabian Böttcher, Kevin Ng, Mingyang Guo, Tim Langen, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Dysprosium features one of the largest magnetic moment in the periodic table. The non-negligible dipole-dipole interaction has therefore a strong influence on the properties of an ultracold atomic cloud and can even yield to new phases of matter [1]. To further increase the dipolar interaction between individual atoms in a lattice the lattice spacing has to be reduced, e.g. by means of a lattice in the UV region.

In order to find a magic wavelength we perform precise measurements on a UV transition at 359 nm with an expected linewidth of 52 kHz in an atomic beam of dysprosium. We use a electron shelving technique to amplify the spectroscopic signal on the weak transition. This enables us to map out the isotope shifts for the most abundant isotopes. In the case of fermionic Dysprosium we determine the hyperfine structure splitting and calculate the values for the hyperfine coefficients. In addition to this we give an upper bound to the lifetime of the excited state.

[1] M. Guo et al., Nature **574**, 386-289 (2019)

A 7.4 Mon 15:00 f107

Prospects for laser spectroscopy beyond nobelium (Z>102) — •Mustapha Laatiaoui[1,2,3], Alexei Buchachenko[4,5], and Larry Viehland[6] — [1]Johannes Gutenberg-Universität, Fritz-Strassmann Weg 2, 55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, Staudingerweg 18, 55128 Mainz, Germany — [3]KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium — [4]Skolkovo Institute of Science and Technology, Skolkovo Innovation Center, Nobel str. 3, Moscow 121205, Russia — [5]Institute of Problems of Chemical Physics RAS, Chernogolovka, Moscow District 142432, Russia — [6]Chatham University, Pittsburgh, Pennsylvania 15232, USA

Optical spectroscopy constitutes the historical path to accumulate basic knowledge on the atom and its structure. Former work based on fluorescence and resonance ionization spectroscopy enabled identifying optical spectral lines up to element 102, nobelium [Nature (2016) 538:495]. The new challenges faced in this research field are the refractory nature of the heavier elements and the decreasing production yields. In this contribution, a new concept of ion mobility-assisted laser spectroscopy will be presented, which will enable to overcome the sensitivity limits of atomic structure investigations persisting in the region of the superheavy elements. The concept offers capabilities of both broadband level searches and high-resolution hyperfine spectroscopy of synthetic elements beyond nobelium.

This work is supported by the European Union's Horizon 2020 research and innovation programme (grant agreement No. 819957) & the Russian Foundation for Basic Research (project No. 19-03-00144).

A 7.5 Mon 15:15 f107

hyperfine splitting in Li- and B-like multi-charged ions — •Valeriia Kosheleva[1,2,3], Andrey Volotka[1,2], Dmitry Glazov[3], and Stephan Fritzsche[1,2] — [1]Helmholtz Institute Jena, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]Department of Physics, St. Petersburg State University, 199034 St. Petersburg, Russia

We report a complete evaluation of the two-photon exchange corrections to the hyperfine structure (hfs) in Li-like ions for a wide range of nuclear charge Z within the framework of rigorous QED approach [1]. In comparison to the previous theoretical calculations, we substantially improved the accuracy of the interelectronic-interaction corrections to the ground-state hfs in Li-like ions by applying the extended Furry picture framework.Furthermore, we perform comprehensive relativistic calculations of the interelectronic- interaction and QED contributions to the ground-state hfs for selected B-like ions in the range Z = 49-83 [2]. As the result, we tabulated the most accurate theoretical hfs values in B-like ions. It is worth noting that the uncertainty of final values almost equally originates from the Bohr-Weisskopf correction and from the higher-order interelectronic-interaction contribution. The Bohr-Weisskopf uncertainty, however, can be canceled in specific differences of the hfs values. While the second uncertainty strongly motivates the rigorous evaluation of the two-photon exchange diagrams, which has been performed so far only for lithiumlike ions.

[1] V. P. Koshelva, A. V. Volotka, D. A. Glazov, S. Fritzsche, to be published. [2] D. A. Glazov, et al., Phys. Rev. A 99, 062503 (2019).

A 7.6 Mon 15:30 f107

maXs: micro-calorimeter arrays for high-resolution X-ray spectroscopy — •S. Allgeier[1], M. Arndt[1], M. Friedrich[1], J. Geist[1], C. Schötz[1], D. Hengstler[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], R. Märtin[2], G. Weber[2], S. Trotsenko[3], T. Morgenroth[3], M.O. Herdrich[2], P. Pfäfflein[2], Th. Stöhlker[2,3,4], T. Schumm[5], and S.P. Stellmer[6] — [1]KIP, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Helmholtzzentrum für Schwerionenforschung — [4]IOQ, Jena University — [5]Vienna University of Technology — [6]PI, Bonn University

Metallic magnetic calorimeters (MMCs) are energy dispersive particle detectors which provide an excelent energy resolution over a large energy range combined with a very good linearity. MMCs are operated at millikelvin temperatures and convert the energy of an incoming X-ray photon into a temperature pulse which is measured by a paramagnetic temperature sensor. The resulting change of sensor magnetization is read out by a highly sensitive SQUID magnetometer. We developed several two-dimensional detector arrays optimized for X-ray energies up to 20, 30, 100 and 200 keV respectivly. The micro-fabricated detectors are operated in a mobile dilution refrigerator. We discuss the performance of our detectors including a record breaking energy resolution of 9.8 eV @ 60 keV. With their performance MMCs have been used in various applications, including the measurement of the ^{229}Th isomer energy and are an ideal tool for upcoming precision QED tests at CRYRING@GSI/FAIR.

A 7.7 Mon 15:45 f107

In Search for the Unobserved Low Lying Atomic Energy Levels of Actinium — •Ke Zhang[1,2], Dominik Studer[2], Vadim Gadelshin[2], Felix Weber[2], Nina Kneip[2], Tom Kieck[1,2], Sebastian Raeder[1,2], Dmitry Budker[1,2], and Klaus Wendt[2] — [1]Helmholtz Institute Mainz, 55099 Mainz, Germany — [2]Johannes Gutenberg-University Mainz, 55099 Mainz, Germany

Actinium (Z = 89) is the name giver and the first member of the series of actinides. Based upon its ground state configuration $7s^2 6d\ ^2D_{3/2}$, the element exhibits a highly complex atomic structure. Recently 86 energy levels in the energy range between 0 cm^{-1} and 36 218 cm^{-1} have been predicted by theory, from which so far only 28 level energies have been confirmed experimentally. In particular the lowest lying missing odd levels $7s^2 7p\ ^2P^o_{1/2}$ and $7s^2 7p\ ^2P^o_{3/2}$, predicted at 7565 cm^{-1} and 12 345 cm^{-1}, which are accessible by direct laser excitation from the atomic ground state, are of high relevance to test the theoretical description of the Ac spectrum. We utilize two-step resonance ionization spectroscopy with high repetition rate pulsed Titanium: sapphire lasers operating on about 10^{10} atoms in a hot cavity ion source at the Mainz university atomic beam apparatus MABU. The study of these optical transitions involves direct non-resonant ionization into the continuum beyond 43 394.45 cm^{-1}. For the first infrared transition to excite the $^2P^o_{1/2}$ level, predicted at 1321.8 nm, difference frequency generation is needed, while the ionization step employs 279 nm light generated by frequency tripling.

A 8: Ultra-cold atoms, ions, and BEC II (joint session A/Q)

Time: Monday 14:00–16:00 Location: f303

Invited Talk A 8.1 Mon 14:00 f303

Reducing their complexity and miniaturise BEC interferometers — •Waldemar Herr[1], Hendrik Heine[1], Alexander Kassner[2], Christoph Künzler[2], Marc C. Wurz[2], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität, Hannover, Germany — [2]Institut für Mikroproduktionstechnik, Leibniz Universität, Hannover

Matterwave interferometry with Bose Einstein Condensates (BEC) promises exciting prospects in inertial sensing and research on fundamental physics both on ground and in space. By now, we can create BECs very efficiently by using atom chips and compact realisations have already been shown, e.g. by creating the first BEC in space on a sounding rocket mission. However, for in-field or satellite-borne applications, it is vital to further reduce the complexity in order to lower size, weight and power demands and to transform BEC interferometers to easy-to-use devices.

In this talk, different aspects ranging from interferometry schemes, sensor fusion concepts and results on a magneto optical trap and sub-Doppler cooling using only a single beam of light in combination with an optical grating on an atom chip will be discussed.

A 8.2 Mon 14:30 f303

Quantum fluctuations and uncertainty relations in NLS solitons and breathers — •Oleksandr Marchukov[1,2], Boris Malomed[2], Maxim Olshanii[3], Vanja Dunjko[3], Randall Hulet[4], and Vladimir Yurovsky[2] — [1]Technische Universität Darmstadt, Darmstadt, Germany — [2]Tel Aviv University, Tel Aviv-Yaffo, Israel — [3]University of Massachusetts Boston, Boston, MA, USA — [4]Rice University, Houston, TX, USA

We consider the quantum fluctuations of the macroscopic variables associated with a breather, a second-order soliton solution of nonlinear Schrödinger equation. Linearizing the evolution of the bosonic quantum field around the Bose condensate in a breather state, we express the quantum fluctuations of the macroscopic variables through the fluctuations of the full quantum field. We compare two models for the state of the quantum field of fluctuations surrounding the classical field of the Bose-Einstein condensate: a conventionally used, computationally convenient "white noise", and a correlated noise which assumes that the breather has been created from a fundamental soliton, by means of the application of the factor-of-four quench of the nonlinearity strength. We evaluate the initial quantum uncertainties of the macroscopic parameters and their time evolution. This approach is well suited for the description of Bose gas with large number of atoms and suggests the possibility for experimental observation of macroscopic quantum fluctuations.

A 8.3 Mon 14:45 f303

Rogue waves in a selfgravitating BEC — •Sandro Gödtel[1], Claus Lämmerzahl[1], and Domenico Giulini[1,2] — [1]ZARM, University of Bremen, Germany — [2]ITP, Leibniz University Hannover, Germany

The coupling between gravity and quantum mechanics is still an open question in physics. For this, we investigate an approach to increase possible gravitational effects within a quantum system such as a Bose-Einstein condensate. We show that the theoretical description by the well-known Gross-Pitaevskii equation leads to an interesting nonlinear phenomenon, namely rogue waves. Originally observed in ocean waves these waves locally increase the density and are often modeled by the Peregrine soliton or the so called multi-rogue wave solutions. By including a gravitational self-interaction we estimate the impact on the condensate with typical experimental values and specify the regime where it may become significant and observable.

A 8.4 Mon 15:00 f303

Guided Atom Interferometry with Bose-Einstein Condensates in Painted Optical Potentials — •Sebastian Bode, Knut Stolzenberg, Alexander Herbst, Henning Albers, Ernst M. Rasel, and Dennis Schlippert — Institute of Quantum Optics - Leibniz University Hannover

Inertial navigation allows for the positioning in space diminishing the dependency on global navigation satellite systems. Guided atom interferometers are a candidate for compact inertial measurement units with outstanding accuracy and stability in harsh environments.
We utilize a 2D-acousto-optic deflector (AOD) in the beam path of an optical dipole trap in combination with a software defined radio (SDR) RF-source for the creation of time-dependent arbitrary potentials. The experimental setup facilitates the creation of ^{87}Rb BECs with large atom numbers and subsequent guided atom interferometry. For the splitting, holding, and recombination of the atom cloud during the interferometric sequence the confining potential is modified resulting in multiple distinct potential minima with well defined atom populations. We report on first results in absolute and differential measurements and discuss various future configurations.

This work is funded by the Federal Ministry of Education and Research (BMBF) through the funding program Photonics Research Germany (contract number 13N14875), and the DFG under Germany*s Excel-

lence Strategy (EXC 2123) "QuantumFrontiers".

A 8.5 Mon 15:15 f303

Josephson effects in coupled anisotropic Bose-Einstein condensates — •Marc Momme, Yuriy Bidasyuk, and Michael Weyrauch — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Josephson effects can manifest in a bose-condensed atomic gas with two components, if the phase of both components remains (mostly) coherent. That way, many experimental and theoretical studies of bosonic Josephson effects have been conducted to gain insight about the nature of macroscopic quantum coherence. The common theoretical description for such systems is the two-mode model, which relies on the assumption that the coupling between two components is much weaker then the energy required to create excitations inside each condensate. However if the Josephson oscillations couple with the longitudinal modes of the trap, the two-mode approximation is no longer valid.

The present study focuses on one system where such a coupling can occur: the bosonic equivalent of a long Josephson junction. Thereby a BEC is put in a cigar-shaped trap with the barrier parallel to the long axis of the trap. Effectively, two coupled quasi one-dimensional condensates are formed. We compare the results of mean-field numerical simulations with predictions of simplified effective models. We show how collective excitations influence the population dynamics of the condensates.

A 8.6 Mon 15:30 f303

Josephson junction dynamics in an ultracold two-dimensional Bose gas — •Vijay Singh and Ludwig Mathey — Zentrum für Optische Quantentechnologien and Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany

We investigate the Berezinskii-Kosterlitz-Thouless (BKT) scaling of the critical current of Josephson junction dynamics across a barrier potential in a two-dimensional (2D) Bose gas, motivated by recent experiments by Luick *et al.* arXiv:1908.09776. Using classical-field dynamics, we determine the dynamical regimes of this system, as a function of temperature and barrier height. As a central observable we determine the current-phase relation, as a defining property of these regimes. In addition to the ideal junction regime, we find a multimode regime, a second-harmonic regime, and an overdamped regime. For the ideal junction regime, we derive an analytical estimate for the critical current, which predicts the BKT scaling. We demonstrate this scaling behavior numerically for varying system sizes. The estimates of the critical current show excellent agreement to the numerical simulations and the experiments. Furthermore, we show the damping of the supercurrent due to phonon excitations in the bulk, and the nucleation of vortex-antivortex pairs in the junction.

A 8.7 Mon 15:45 f303

Dynamical control of conductivity in a bosonic Josephson junction — •Beilei Zhu[1], Vijay Pal Singh[1], Junichi Okamoto[2], and Ludwig Mathey[1,3] — [1]Zentrum für Optische Quantentechnologien and Institut für Laserphysik, Universität Hamburg, Hamburg, Germany — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

We propose to demonstrate dynamical enhancement of conductivity in a bosonic Josephson junction composed of two weakly coupled one dimensional condensates. A current is induced by a periodically modulated potential difference between the condensates, giving access to conductivity of the junction. We propose to control the conductivity via parametric driving of the tunneling energy. We demonstrate that the low frequency conductivity of the junction can be enhanced or suppressed, depending on the choice of the driving frequency. The experimental realization of this proposal constitutes a quantum simulation of recently proposed mechanism for optically induced superconductivity in pump-probe experiments.

A 9: Poster Session - Atomic Physics I

Time: Monday 16:00–18:00 Location: Empore Lichthof

A 9.1 Mon 16:00 Empore Lichthof

Two-center dielectronic recombination and interatomic coulombic electron capture in slow atomic collisions — •Andreas Jacob, Carsten Müller, and Alexander B. Voitkiv — Institute for Theoretical Physics I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

We study recombination of a free electron with an atomic species A, which move in a gas of another species B [1,2]. Recombination proceeds via resonant transfer of energy excess to B which either becomes excited and then stabilizes via spontaneous radiative decay [1] (two-center dielectronic recombination; 2CDR) or becomes ionized [2] (interatomic coulombic electron capture; ICEC). We compare these processes with each other and with the well-known single-center process of radiative recombination and discuss under which conditions they can outperform the latter.

[1] A. Jacob, C. Müller, and A. B. Voitkiv, Phys. Rev. A 100, 012706 (2019).

[2] A. Jacob, C. Müller, and A. B. Voitkiv, J. Phys. B 52, 225201 (2019).

A 9.2 Mon 16:00 Empore Lichthof

Formation of the positive ion of antihydrogen via radiative attachment of a positron to antihydrogen — •Andreas Jacob[1], Carsten Müller[1], Alexander B. Voitkiv[1], Shaofeng Zhang[2], and Xinwen Ma[2] — [1]Institute for Theoretical Physics I, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [2]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China

The formation of positive ions of antihydrogen ($\bar{H}^+$) via radiative attachment of free positrons (e^+) to antihydrogen ($\bar{H}$) is studied [1]. The attachment mechanisms considered include: (i) spontaneous radiative attachment in which an incident e^+ is captured into the ground state of $\bar{H}^+$ via photo emission; (ii) induced radiative attachment in which $\bar{H}^+$ is formed due to photo emission induced by a laser field; (iii) two-center dileptonic attachment where an incident e^+ is captured by $\bar{H}$ moving in a gas of matter atoms B and capture proceeds via resonant transfer of energy excess to B which becomes excited and then stabilizes via spontaneous radiative decay [2]. We compare these mechanisms with each other and show that (ii) and (iii) can strongly dominate over (i).

[1] A. Jacob, C. Müller, A. B. Voitkiv, S. F. Zhang and X. Ma (2019), submitted to Phys. Rev. Research.

[2] A. Jacob, C. Müller, and A. B. Voitkiv, Phys. Rev. A 100, 012706 (2019).

A 9.3 Mon 16:00 Empore Lichthof

Mass defect of electronic transitions, in atoms, ions and atomic clocks — •Víctor José Martínez Lahuerta[1], Simon Eilers[1], Marius Schulte[1], Jan Kiethe[2], Tanja Mehlstäubler[2], Piet Oliver Schmidt[2,3], and Klemens Hammerer[1] — [1]Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute), Leibniz University Hannover, Appelstrasse 2, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [3]Institute for Quantum optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany

In this work we present a low-order relativistic correction to the multipolar atom-light Hamiltonian for two bound particles corresponding to a simple model for Hydrogen like atoms and ions. From this result, we can systematically predict frequency shifts in atomic clocks based on trapped ions due to the mass defect. We also take into account non perfect traps, finding accordance with previous results and new corrections.

A 9.4 Mon 16:00 Empore Lichthof

Continuum-Continuum Recombination in High-Order Harmonic Generation — •Fermin Rodriguez Hernandez[1], Frank Grossmann[2], and Jan Michael Rost[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, Dresden, Germany

The generation of high-order harmonics (HHG) in a model atomic sys-

tem is investigated using both: the traditional ground state scheme and the laser-assisted collision scenario. We find strong signatures of continuum-continuum transitions in the HHG spectra when the laser intensity is sufficiently high, i.e., in the over-the-barrier ionization regime. They consist in a double plateau structure with a characteristic first cutoff frequency $\omega_{CC} = 1.85U_p$ in the ground state scheme and $\omega_{CC} = 1.67U_p$ in the laser-assisted collision scenario. We demonstrate analytically that $\omega_{CC} = 1.85U_p$ originates by the coherent interference of the second and first collision of electronic wavepackets generated every half of the laser period, respectively. In the laser-assisted collision scenario, $\omega_{CC} = 1.67U_p$ rises after the interference of two components of the continuum wavepacket, which can be associated with two classes of recolliding trajectories known as free and stranded trajectories, respectively. Differences between 1D and 3D realizations will be discussed.

A 9.5 Mon 16:00 Empore Lichthof

Supersonic Molecular Beam for Velocity Map Imaging Experiments: Model Simulations and Design Concept — •Philipp Thurau, Kevin Eickhoff, Lars Englert, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg

The spatial phase shift in a focused laser beam, known as the Gouy phase, is a limiting factor for carrier envelope phase (CEP) sensitive experiments using velocity map imaging (VMI) techniques due to the large acceptance volume of VMI spectrometers. In order to minimize focal CEP averaging, we plan to utilize a skimmed supersonic molecular beam to confine the interaction region of our VMI spectrometer. Employing a well-established Monte Carlo method (see G. A. Bird & J. M. Brady, *Molecular gas dynamics and the direct simulation of gas flows*, Clarendon Press, Oxford (1994)), we simulate flow trajectories of a supersonic beam through different instrumental geometries, including a differentially pumped multi-chamber configuration and a VMI design where the nozzle is integrated in the repeller electrode (Ghafur *et al.*: Rev. Sci. Instrum., **80**, 033110 (2009)). In view of future studies of the photoelectron circular dichroism of chiral molecules, we optimize the system parameters for particle density and beam temperatures. Initial simulation results and design concepts are presented.

A 9.6 Mon 16:00 Empore Lichthof

Control of free electron wave packets by polarization-tailored ultrashort bichromatic laser fields — Stefanie Kerbstadt[1,2], Kevin Eickhoff[1], •Lea-Christin Feld[1], Tim Bayer[1], and Matthias Wollenhaupt[1] — [1]Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg — [2]Center for Free-Electron Laser Science (CFEL), Deutsches Elektronen-Synchrotron DESY, Hamburg

We use polarization-shaped bichromatic laser pulses to control three-dimensional photoelectron momentum distributions from atomic multiphoton ionization. To analyze the underlying physical mechanisms, we consider two bichromatic control schemes based on intra-pulse frequency mixing and inter-band N- vs. M-photon interference, respectively. In the first scheme, interferometric ($\omega : 2\omega$) fields are used to select or suppress specific ionization channels in the resonance-enhanced two-photon ionization of potassium atoms by second-order intra-pulse frequency mixing. In the second scheme, we utilize a white light polarization pulse shaper to generate carrier-envelope phase-stable ($3\omega : 4\omega$) fields in order to manipulate the symmetry properties of photoelectron wave packets from 3- vs. 4-photon ionization of sodium atoms. In both cases, bichromatic polarization control of free electron wave packets is based on the creation of a superposition of multiple angular momentum states with different kinetic energy spectra. We show that the latter are determined by the bichromatic multiphoton spectra, emphasizing the close relationship between bichromatic multiphoton ionization and nonlinear optical spectroscopy.

A 9.7 Mon 16:00 Empore Lichthof

Spatial phase modulation of electron beams meets spectral interference of electron wave packets — •Darius Köhnke[1], Christopher Rathje[1], Kevin Eickhoff[1], Stefanie Kerbstadt[1,2], Tim Bayer[1], Sascha Schäfer[1], and Matthias Wollenhaupt[1] — [1]Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg — [2]Center for Free-Electron Laser Science (CFEL), Deutsches Elektronen-Synchrotron DESY, Hamburg

Recently, vortex beams have attracted significant attention. We compare the generation and manipulation of tailored free electron vortices via atomic multiphoton ionization (MPI) by polarization-shaped ultrashort laser pulses on the one and transmission electron microscopy (TEM) with customized diffraction masks (Verbeeck *et al.*, Nature **467**, 301-304 (2010)) on the other hand, focussing here on the creation of free electron vortices with c_7 rotational symmetry (Kerbstadt *et al.* Nat. Comm. **10**, 658 (2019)). Photoelectron vortices are generated by MPI of Na atoms using counterrotating bichromatic ($3\omega : 4\omega$) laser pulses created by a white light polarization shaper. The electron vortex beams are generated in a TEM using Au masks on a SiN substrate. Although ultrafast polarization shaping is performed in frequency domain while electron beam shaping operates in momentum space, the two techniques are strongly related. Important analogies and differences are discussed. In addition, we analyze the topological charge of the tailored free electron vortices and investigate the respective capabilities of the different technical approaches.

A 9.8 Mon 16:00 Empore Lichthof

Solving the semiclassical propagator via Bayesian quadrature — •Benjamin Rabe and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Semiclassical approximations to the quantum mechanical propagator have shown to give intuitive insight of the dynamics of atomic and molecular systems. One formulation of the semiclassical propagator is the initial value representation (IVR) first derived by Herman and Kluk. [1] This IVR makes use of an expression of the initial state in terms of fixed width coherent states, which form N-dimensional fixed width Gaussian wavepackets in position space. Each wavepacket starting from (q_i, p_i) represents a classical trajectory.

The integration over initial conditions (q_i, p_i) of classical trajectories is commonly done via Monte-Carlo integration, which requires the inclusion of a tremendous amount of trajectories. As an alternative approach, we propose the integration of an approximation to the Herman-Kluk propagator done by complex valued Gaussian process regression, which can be done analytically for certain choices of covariance functions. This procedure is referred to as Bayesian quadrature. [2] This approach should reduce the number of trajectories needed significantly and therefore allow for a better solution especially for evolution to larger times.

[1] Michael F Herman and Edward Kluk. Chemical Physics, 91(1):27-34, 1984.

[2] Anthony O'Hagan. Journal of statistical planning and inference, 29(3):245-260, 1991.

A 9.9 Mon 16:00 Empore Lichthof

Generation of Entanglement in Spin Chains through the Presence of External Fields — •Darvin Wanisch — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Fröbelstieg 1, 07743 Jena

Systems of interacting spins are potential candidates for quantum information processing tasks, such as the transfer and distribution of entanglement. Here, we investigate how – static or dynamic – external fields can enhance the end-to-end entanglement in interacting Heisenberg spin chains and how they may affect the reliability and efficiency of this process considering potential practical implementations.

A 9.10 Mon 16:00 Empore Lichthof

Competition of photon and electron emission in interatomic decay of heterogeneous noble gas clusters — •Lutz Marder[1], André Knie[1], Christian Ozga[1], Christina Zindel[1], Clemens Richter[2], Uwe Hergenhahn[2,3], Arno Ehresmann[1], and Andreas Hans[1] — [1]Institute of Physics, University of Kassel, Kassel, Germany — [2]Leibniz Institute of Surface Modification, Leipzig, Germany — [3]Max Planck Institute for Plasma Physics, Greifswald, Germany

Noble gas clusters represent prototype systems for the investigation of fundamental atomic and molecular processes. Van-der-Waals bonds enable new relaxation pathways not available in isolated systems. In recent years many of these have been studied, often using coincidence measurement techniques.

Here, we present our state-of-the-art experiment where both electrons and photons were detected in coincidence, which allows for investigation of multi-particle decay pathways after excitation with synchrotron radiation. The results show that the addition of krypton to pure neon clusters strongly alters the emission by the opening of a faster ionizing decay channel compared to the radiative decay.

A 9.11 Mon 16:00 Empore Lichthof

The influence of nitrogen on interatomic processes in argon clusters: quenching of radiative decay — •Catmarna Küstner-Wetekam[1], Philipp Schmidt[1], Christian Ozga[1], Arno Ehresmann[1], Uwe Hergenhahn[2,3], André Knie[1], and Andreas Hans[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Max Planck Institute for Plasma Physics Wendelsteinstr. 1, 17491 Greifswald, Germany — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

To understand fundamental processes of radiation chemistry in realistic samples it is necessary to study prototypical systems, where a molecule or atom is surrounded by neighbours.

Weakly bound van-der-Waals clusters are one possible system, in which novel relaxation pathways occur. In contrast to isolated atoms electronically excited states may now decay via different interparticle processes such as radiative charge transfer (RCT) and interatomic Coulombic decay (ICD). Here we investigate these processes in different environments by gradually increasing the amount of nitrogen in argon clusters.

A 9.12 Mon 16:00 Empore Lichthof

Simulation of wide-angle single-shot x-ray scattering via the propagation multislice method — •Paul Tuemmler, Björn Kruse, Christian Peltz, and Thomas Fennel — Institut für Physik, Universität Rostock

Single-shot wide-angle x-ray scattering has enabled the three-dimensional characterization of free nanoparticles from a single scattering image [1,2]. Key to this method is the fact, that the scattering patterns contain information of density projections on differently oriented projection planes. Wide-angle scattering typically requires XUV photon energies where absorption and attenuation cannot be neglected in the description of the scattering process [3,4]. The multislice Fourier transform (MSFT) method, which provides a fast scattering simulation within the Born approximation, can be extended to also include these propagation effects. In this presentation the performance of conventional MSFT and propagation MSFT will be discussed and compared to full simulations using FDTD for typical scenarios relevant for wide-angle x-ray scattering [1,5].

[1] I. Barke *et al.*, Nat. Commun. **6**, 6187 (2015).
[2] K. Sander *et al.*, J. Phys. B **48**, 204004 (2015).
[3] D. Rupp *et al.*, Nat. Commun. **8**, 493 (2017).
[4] B. Langbehn *et al.*, Phys. Rev. Lett. **121**, 255301 (2018).
[5] C. Peltz *et al.*, Phys. Rev. Lett. **113**, 133401 (2014).

A 9.13 Mon 16:00 Empore Lichthof

Investigation of Frenkel excitons located in the valence shell of homogeneous and heterogeneous noble gas clusters — •Xaver Holzapfel, Andreas Hans, Gregor Hartmann, Christian Ozga, Philipp Schmidt, Arno Ehresmann, and André Knie — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Electronic excitations in the valence shell of homogeneous and heterogeneous clusters were studied by fluorescence spectroscopy. Information about excitonic states as well as the mean cluster size of the cluster distribution created by supersonic expansion were obtained by measuring the fluorescence excitation yield in the UV and VUV spectral range. Using a multidimensional fitting algorithm, the mean cluster size was determined from the surface and bulk contributions of all measured fluorescence spectra. Furthermore, differently shaped cluster distributions were included in the analysis of the mean cluster sizes. The comparison of measured mean cluster sizes to the scaling laws and to investigations on heterogeneous systems indicated excitonic states which are different from the commonly used assignment of solid state experiments.

A 9.14 Mon 16:00 Empore Lichthof

Time-resolved rescattering of slow photoelectrons by single-cycle terahertz radiation — Martin Ranke[1,2], Sophie Walther[1,2], Anastasios Dimitriou[1,2], Markus Pfau[1,2], •Mark J. Prandolini[1], Thomas Gebert[3], Andrey Kazansky[4], Nikolay Kabachnik[4], Marek Wieland[1,2], Markus Drescher[1,2], and Ulrike Frühling[1,2] — [1]Institut für Experimentalphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging (CUI), 22761 Hamburg, Germany — [3]Max-Planck-Institut für Struktur und Dynamik der Materie, 22761 Hamburg, Germany — [4]Ikerbasque - Basque Foundation for Science, Spain

Dynamics of low-energy photoelectrons, generated by multiphoton ionization from near-infrared (NIR) laser pulses, in the presence of intense near single-cycle carrier-envelope phase stable terahertz (THz) pulses, were experimentally investigated, using a velocity-map imaging spectrometer (VMIS). For certain time delays between the NIR and THz pulses, a strong modulation of the photoelectron momentum distribution was observed and attributed to rescattering from the ionic core. During the rescattering process, an additional momentum was transferred to the photoelectrons leading to a higher kinetic energy in the continuum in contrast to directly emitted photoelectrons that are not rescattered. A classical two-step (CTS) model, based on solving classical photoelectron trajectories, indicates that a few photoelectrons reach a distance on the order of 20 nm before they are retracted and rescattered from the ionic core.

A 9.15 Mon 16:00 Empore Lichthof

Influence of prepulses on pair production in strong oscillating electric fields — •Oliver Mathiak, Selym Villalba-Chavez, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Production of electron-positron pairs from vacuum in strong electric fields oscillating in time is studied. The fields are assumed to consist of a main pulse of high intensity, which is preceded by a prepulse of much lower intensity. Pair production probabilities in this field configuration are obtained by solving the time-dependent Dirac equation numerically. We show that a range of field parameters exists where the prepulse, despite its relative weakness, can leave visible traces in the momentum spectra of created particles [1].

[1] L. F. Granz, O. Mathiak, S. Villalba-Chavez and C. Müller, Phys. Lett. B 793, 85 (2019)

A 9.16 Mon 16:00 Empore Lichthof

Numerical simulations of high-order harmonic generation: from atomic to extended systems — •Chuan Yu, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

In recent years, research on high-order harmonic generation (HHG) has been extended from gas-phase atoms to bulk solids. Compared with the well-established three-step model for atoms, the HHG processes in extended systems are more complicated and still less understood. To further explore the connection between atomic and solid-state HHG, we perform time-dependent density functional theory (TDDFT) simulations for both finite and extended model systems. The TDDFT approach, accounting for many-electron effects in a self-consistent manner, has turned out to be flexible and useful in studying the effects of finite size, impurity and disorder. On the basis of numerical simulations within the TDDFT framework, we may better elucidate the transition from atomic to solid-state HHG.

A 9.17 Mon 16:00 Empore Lichthof

Controlling non-adiabatic ionization with ultra-short pulses — •Sajjad Azizi, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany

Non-adiabatic ionization, a new channel in the photo-ionization with high-frequency lasers, occurs for strong and short pulses due to large gradients of the *pulse envelope*. This unusual dependence on the envelope derivative can be explored by manipulating the time profile of the pulse envelope. It is shown that the non-adiabatic ionization yield can be enhanced with particular shaped pulses in comparison to the yield of the corresponding Fourier-limited pulse (FLP). This is surprising since the FLP is the strongest and shortest pulses for a given spectral representation.

A 9.18 Mon 16:00 Empore Lichthof

Fast Nonequilibrium Green functions calculations for atomic systems — •Maximilian Rodriguez Rasmussen, Niclas Schlünzen, Jan-Philip Joost, and Michael Bonitz — Christian-Albrechts-Universität zu Kiel, Kiel, Germany

The Nonequilibrium Green Functions formalism (NEGF) [1] is well suited to accurately describe the dynamics of correlated quantum systems. A main cause of practical limitation is the high computational effort, manifest in a T^3 scaling with propagation time T. The scaling can be improved to T^2 by introducing the Generalized-Kadanoff–Baym Ansatz (GKBA) [2]. Its application to the description of atoms, where precise theoretical results on fast dynamical processes, such as laser ex-

citations, are needed, is of particular interest [3,4]. Recently the G1-G2 formalism [5] based on the GKBA was developed. With this method a dramatically improved scaling proportional to T can be achieved. Here first results for atomic systems are presented.

[1] L. P. Kadanoff, G. Baym, *Quantum Statistical Mechanics* (1962)
[2] P. Lipavský et al., *Phys. Rev. B 34, 6933* (1986)
[3] E. Perfetto et al., *Phys. Rev. A 92, 3* (2015)
[4] R. Tuovinen et al., *The J. of Chem. Phys., 51, 17* (2019)
[5] N. Schlünzenet al., *submitted*, arXiv:1909.11489 [cond-mat.str-el]

A 9.19 Mon 16:00 Empore Lichthof

Phase-of-the-phase spectroscopy as a tool to calibrate a laser — •Felix Trepkau, Vasily Tulsky, and Dieter Bauer — University of Rostock, 18051 Rostock, Germany

We present a way to accurately calibrate a two-color bi-circular laser field. Such laser configurations have recently attracted special attention due to well-defined angular properties of photoelectrons that they create while interacting with matter. The calibration technique we propose is based on the phase-of-the-phase spectroscopy and relies on sharp intensity-sensitive features in the photoelectron signal [1-2].

[1] V. A. Tulsky, M. A. Almajid, and D. Bauer, Two-color phase-of-the-phase spectroscopy with circularly polarized laser pulses, Phys. Rev. A 98, 053433 (2018)

[2] V. A. Tulsky, B. Krebs, J. Tiggesbäumker, D. Bauer, Revealing laser-coherent electron features using phase-of-the-phase spectroscopy, arXiv:1911.0047 (2019) (submitted to J. Phys. B)

A 9.20 Mon 16:00 Empore Lichthof

Strong-field ionization driven by spatially structured laser fields — •Birger Böning[1], Willi Paufler[1], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Germany

We theoretically investigate nondipole effects in the above-threshold ionization (ATI) of atoms using the strong-field approximation (SFA). To this end, we construct Volkov-like continuum wavefunctions of the photoelectron in laser fields with an arbitrary spatial dependence. We show how to find these solutions to the Schrödinger equation for an electron in a laser field that can be written as a continuous superposition of plane waves. This approach includes, for example, Gaussian or twisted laser fields and is therefore not limited to plane waves. As a first application, we compute peak offsets along the laser propagation direction in the ATI with mid-infrared plane-wave laser fields. As a second application, we consider the ATI driven by standing light waves, which gives rise to the so-called high-intensity Kapitza-Dirac effect.

A 9.21 Mon 16:00 Empore Lichthof

Measuring the Zak phase of the SSH chain by HHG — •Daniel Moos, Christoph Jürss, and Dieter Bauer — University of Rostock, Rostock, Germany

In recent work [1,2], a many-order-of-magnitude enhancement in the high-harmonic generation (HHG) efficiency has been shown between different topological phases of a 1D chain with a time-dependent density functional theory calculation. Shortly thereafter [3] the same effect was observed using a much simpler model and the tight-binding approximation. The discovery that the simplest model known to exhibit topological effects, the Su-Schrieffer-Heeger (SSH) model, shows this feature raises the question which other effects this model might also contain. In this work we measure the Berry phase of the SSH model using the expression given by Zak, thereby showing that topological phases may be distinguished by all-optical means.

[1] Dieter Bauer, Kenneth K. Hansen, Phys. Rev. Lett. 120, 177401 (2018).
[2] Helena Drüeke, Dieter Bauer, Phys. Rev. A 99, 053402 (2019).
[3] Christoph Jürß, Dieter Bauer, Phys. Rev. B 99, 195428 (2019).

A 9.22 Mon 16:00 Empore Lichthof

ATAS of neon with tunable few-cycle SWIR pulses — •Patrick Rupprecht, Lennart Aufleger, Alexander Magunia, Thomas Ding, Marc Rebholz, Stefano Amberg, Nikola Mollov, Felix Henrich, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Attosecond transient absorption spectroscopy (ATAS) has developed into an essential method to study excited-state coupling dynamics in atomic and molecular systems. So far, most ATAS experiments have been carried out with femtosecond laser pulses of one specific central wavelength. In this poster contribution, we present first results of ATAS measurements on neon with few-cycle, approximately 15 fs FWHM, pulses centered around 1300 nm, 1400 nm and 1550 nm. These short-wave infrared (SWIR) pulses were used for high harmonic generation as well as for a time-delayed strong-field perturbation pulse altering the neon absorption lines using a passively stable split and delay line. The influence of the different central wavelengths on the neon resonances in the extreme ultraviolet (XUV) 40 eV to 60 eV photon-energy regime is shown by varying the intensity of the SWIR in time overlap as well as recording XUV–SWIR time-delay traces at different SWIR intensities. Implications for resonance lineshape changes as well as light-induced state observations are discussed.

A 9.23 Mon 16:00 Empore Lichthof

The laser-driven Kitaev chain — •Alexander Luther and Dieter Bauer — Institute of Physics, University of Rostock, 18051 Rostock, Germany

During the recent years, research on high-harmonic generation (HHG) in solid state systems experienced an increasing interest. Most of the often used tight-binding models to describe the interaction of laser fields with solid-state systems conserve the number of electrons. The Kitaev chain, a model for a one-dimensional p-wave superconductor, contains a pairing term that does not conserve the number of electrons and thus is usually treated in Bogolyubov-de-Gennes (BdG) representation. In our work, we study the role of electrons and holes on finite Kitaev chains in the HHG process using a time-dependent tight-binding approach in which the BdG Hamiltonian contains the coupling to the external driver in length gauge. Further, we investigate the laser-driven dynamics of the Majorana edge states, which appear at the ends of of the chain in the topological non-trivial phase of a Kitaev chain.

A 10: Collisions, scattering and correlation phenomena

Time: Tuesday 14:00–16:15 Location: a320

Invited Talk A 10.1 Tue 14:00 a320

Scattering of twisted x-rays from a crystal — •Anton Peshkov[1,2], Stephan Fritzsche[3,4], and Andrey Surzhykov[1,2] — [1]Technische Universität Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Helmholtz-Institut Jena, Germany — [4]Friedrich-Schiller-Universität Jena, Germany

The elastic scattering of x-rays by bound atomic electrons is known to be an excellent probe of the structure of matter. One of the most intriguing example here is x-ray crystallography used to determine the arrangement of atoms in a crystal. The essential physics of this process has been known and understood for many years for the incident plane-wave radiation. However, this is not the case for twisted light beams that carry a nonzero projection of the orbital angular momentum (OAM) onto their propagation direction and whose intensity pattern has an annular character. In order to understand how the scattering from crystals depends on the "twistedness" of incident x-rays, we present here a theoretical analysis of the elastic scattering of Bessel beams from a single crystal of lithium. Our numerical calculations show that the scattering cross section is sensitive to the OAM projection of twisted beams and differs from the standard plane-wave case when the size of the crystal is reduced to the nanometer scale.

[1] A. A. Peshkov *et al.*, Phys. Scr. 94, 105402 (2019).

A 10.2 Tue 14:30 a320

Two-center electron-impact ionization via collisional excitation-autoionization — •Fiona Grüll, Alexander B. Voitkiv, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Electron-impact ionization of an atom can be strongly influenced by

the presence of a neighbour atom. We study electron-impact ionization via excitation-autoionization in a two-center atomic system consisting of atoms A and B. First, collisional excitation of the neighbouring atom B occurs by high-energy electron impact. Afterwards, the excitation energy is transferred radiationlessly via a two-center Auger process to the other atom or ion, leading to its ionization, whereas atom B returns into its initial state. In contrast to other processes creating an autoionizing two-center state by electron impact [1,2], the incident electron in resonant two-center electron-impact ionization 2C(e,2e) leads to excitation – rather than ionization – of atom B. We show that, due to resonant 2C(e,2e), electron-impact ionization can be qualitatively modified and strongly enhanced by several orders of magnitude in a narrow range of emitted electron energies. As a consequence, resonant 2C(e,2e) can provide a substantial contribution to the total electron-impact ionization cross section of atom A and can also lead to changes in the angular distribution of ejected electrons [3].

[1] S. Yan et al., Phys. Rev. A 97, 010701(R) (2018).
[2] X. Ren et al., Nature Commun. 7, 11093 (2016).
[3] F. Grüll, A. B. Voitkiv and C. Müller, Phys. Rev. A 100, 032702 (2019)

A 10.3 Tue 14:45 a320

Calculation of Rayleigh scattering by highly charged heavy ions — •Dmitrii Samoilenko[1], Andrey Volotka[2,3], and Stefan Fritzsche[2,3,4] — [1]Friedrich-Schiller-Universität Jena, Jena, Germany — [2]Helmholtz-Institut Jena, Jena, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [4]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Jena, Germany

Rayleigh scattering for photon energies close to core-core transitions resonances in highly charged lead ions is investigated theoretically. Angular distribution of cross section and polarization of the scattered light is obtained using rigorous quantum electrodynamics approach. The results are compared to those given by often used simple dipole approximation. It is shown that for certain scenarios a significant effect of higher multipoles on both angle-differential cross section and linear polarization of the scattered light can be indicated.

A 10.4 Tue 15:00 a320

Polarization transfer in Rayleigh scattering — •Sophia Strnat[1], Vladimir A. Yerokhin[2], and Andrey Surzhykov[1,3] — [1]Technische Universität Braunschweig, Germany — [2]Peter the Great St. Petersburg Polytechnic University, Russia — [3]Physikalisch Technische Bundesanstalt, Germany

In this work we present a theoretical study of Rayleigh scattering of hard x-rays by closed-shell atoms. In order to investigate this process we employed relativistic Dirac theory and second order perturbation approach. Special attention was paid to the polarization transfer between incident and outgoing light. In particular, we applied density matrix formalism to describe the polarization of the outgoing photons for arbitrary linear and/or circular polarization of the incident photons. We derived the Stokes parameters of the scattered light in terms of their counter-partners for incident light and of the transition amplitudes. Our study generalizes the previous work (reported in Ref [1]) which was restricted to only linear polarization. Detailed calculations were performed for helium-, neon-, argon- and krypton-like lead. Based on these calculations we show that Rayleigh scattering can be used not only to probe the polarization purity of synchrotron radiation but also as an alternative tool for measuring circular polarization in the x-ray domain.

[1] A. Surzhykov *et al.*, Physical Review A **98**, 053403 (2018)

A 10.5 Tue 15:15 a320

A New Super Current — •Hubert Klar — Universität Freiburg, Germany

We treat slow electron scsttering from a highly excited Rydberg atom. The electron-target interaction i nolonger controled by single particle Coulomb forces but by by a potential ridge between Coulomb valleys in the potential surface. We show that the diffraction fromthe ridge leads to adichromatic splitting of that surface. In the incoming channel the ridge becomes flat and allows to the electrons to jump onto the top of the ridge. That motion is unstable, but shows an electron-electron attraction. The pair moves towards the nucleus, and is reflected due to a new fictitious force relected. The outgoing wave on the ridge top is unstable. the pair decays into a bound Rydberg state of the target and one escaping electron. The latter is attracted by a neighbor atom, and the above described process may be repeated many times. In this way one electron is transported without any ineleastic collision through a multiatom material. In contrast to a Couper pair our pair formation works independent of the temperatur, and explains the high temperatur super conductivity.

A 10.6 Tue 15:30 a320

Stable longitudinal spin domains in a one-dimensional nondegenerate gas — •Sean D. Graham[1], Dorna Niroomand[1], Robert J. Ragan[2], and Jeffrey M. McGuirk[1] — [1]Simon Fraser University, Burnaby, Canada — [2]University of Wisconsin - La Crosse, La Crosse, USA

We demonstrate that linear spin-dependent potentials can stabilize longitudinal spin domains in a weakly-interacting gas of ^{87}Rb atoms above quantum degeneracy. Coherent spin-rotating interactions are modified by a small spin-dependent potential that varies the local Larmor precession. Stable domains are observed when the gradient of the linear spin-dependent potential opposes the initial spin gradient within the domain wall. Experimental results over a range of cloud temperatures, densities, and linear spin-dependent potentials are compared to solutions of the quantum Boltzmann equation in the hydrodynamic and collisionless regimes. In the hydrodynamic regime, the measured stabilizing gradients agree well with the quantum Boltzmann theory. However, the stabilizing gradients in the collisionless regime deviate from the quantum Boltzmann theory as the mean free path becomes comparable to the domain-wall width. We extend this domain stabilization technique by stabilizing one-dimensional dipolar, quadrupolar, and hexapolar spatial spin modes using spin-dependent potentials that are linear within every domain wall.

A 10.7 Tue 15:45 a320

From polarons to bipolarons in Bose-Einstein condensates. — •Luis Ardila — Institut für Theoretische Physik-Hannover Universität

Mobile impurities in a Bose-Einstein condensate can form quasiparticles termed Bose polarons. Here I show how these quasi-particles are originated when a single impurity is dressed by the excitations of the quantum bosonic bath. The most striking advantage of these polarons is the huge degree of controllability of the coupling strength between the impurity and the bosonic bath. Thus, one can realize polarons from weak all the way up to the strong interacting regime. For strong interactions two polaron can bind together forming bound bipolarons states. They emerge due to the induced nonlocal interaction mediated by density oscillations of the bath. It turns out that exploring low-dimensions, polarons can form many-body bound states even at intermediate coupling. Here, we use exact QMC to study an impurity immersed in a 2D superfluid and to compute the polaron energy, the effective mass and the quasiparticle residue for arbitrary coupling strength. We find important deviations of the quasiparticle properties from perturbation theory even at very weak coupling strengths. In the strongly interacting regime, the ground-state polaron loses the quasiparticle nature characteristic of weak interactions and forms a many-body bound state featuring a large effective mass, a vanishing wavefunction residue and a size that extends over many healing lengths of the bath .

A 10.8 Tue 16:00 a320

Efficient double ionization by interatomic Coulombic decay — •Jacqueline Fedyk, Kirill Gokhberg, and Lorenz S. Cederbaum — Theoretical Chemistry, Heidelberg University, Heidelberg, Germany

Several processes, such as single-photon double-ionization and double Auger decay, are known, which result in correlated emissions of two electrons. The ratios of double to single-ionization in these processes usually amount only to a few percent. Recently, a new decay mechanism has been reported, which leads to double ionization of alkali dimers attached to helium droplets [1]. This double ionization proceeds via interatomic Coulombic decay and occurs with an efficiency comparable to single-ionization. Motivated by these experimental results, we investigated this new decay mechanism, which is called double interatomic Coulombic decay (dICD). In particular, we asked ourselves, if the observed efficiency of dICD was its general characteristic, or if these results were due to the specific choice of the experimental system. To answer this question, we analytically derived the decay width of dICD. First, we developed an asymptotic formula, based on the assumption that the two centers are spatially well-separated. Second, we derived a general analytical expression by using many-body per-

turbation theory. Finally, we investigated the efficiency of dICD for experimentally realizable small atomic and molecular clusters.

[1] A. C. LaForge, M. Shcherbinin, F. Stienkemeier,R. Richter, R. Moshammer, T. Pfeifer, and M. Mudrich, Nature Physics 15, 247 (2019)

A 11: Attosecond physics II

Time: Tuesday 14:00–16:00 Location: f107

Invited Talk A 11.1 Tue 14:00 f107

Probing electronic wavefunctions and chiral structure using all-optical attosecond interferometry — •Michael Krüger[1,2], Doron Azoury[1], Omer Kneller[1], Shaked Rozen[1], Barry D. Bruner[1], Alex Clergerie[3], Bernard Pons[3], Baptiste Fabre[3], Yann Mairesse[3], Oren Cohen[2], Olga Smirnova[4], and Nirit Dudovich[1] — [1]Department of Physics of Complex Systems, Weizmann Institute of Science, 76100 Rehovot, Israel — [2]Department of Physics and Solid State Institute, Technion, 32000 Haifa, Israel — [3]Université de Bordeaux, CNRS - CEA, CELIA, Talence, France — [4]Max-Born-Institut, 12489 Berlin, Germany

Phase retrieval of electronic wavefunctions generated by photoionization has been a longstanding challenge. Here we measure the time-reversed process of photoionization – photorecombination – in attosecond pulse generation. We demonstrate all-optical interferometry of two independent phase-locked attosecond light sources [1]. Our measurement enables us to directly determine the phase shift associated with electron scattering and with structural minima in atomic systems.

In a second study, we superimpose two attosecond light sources with perpendicular polarization, achieving direct time-domain polarization control [2]. We establish an extreme-ultraviolet lock-in detection scheme, allowing the isolation and amplification of weak chiral signals. We demonstrate our scheme by a phase-resolved measurement of magnetic circular dichroism.

[1] D. Azoury et al., Nature Photonics 13, 54 (2019).
[2] D. Azoury et al., Nature Photonics 13, 198 (2019).

A 11.2 Tue 14:30 f107

Attosecond pump-probe coincidence spectroscopy at 100 kHz — •Mikhail Osolodkov[1], Tobias Witting[1], Federico Furch[1], Felix Schell[1], Fabio Cavalcante[2], Carmen Menoni[2], Claus Peter Schulz[1], and Marc J.J. Vrakking[1] — [1]Max Born Institute, Berlin, Germany — [2]Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, USA

Photoinduced coupled electron-nuclear dynamics in molecules typically proceeds on a femtosecond timescale which can be studied by attosecond pump-probe spectroscopy. Here we report on the setup of an extreme ultraviolet - near infrared (XUV-NIR) pump probe beamline operating at 100 kHz, which is combined with a reaction microscope, designed for high repetition rate operation [1]. The latter allows to measure the 3D momentum distributions of electrons and ions in coincidence and, thus, will enable detailed insights into photoinduced molecular processes. The beamline utilizes a high power noncollinear optical parametric chirped pulse amplification system (NOPCPA) operating at 100 kHz [2]. Both, XUV attosecond pulse trains (APTs), as well as isolated attosecond pulses (IAPs) can be generated through the high-order harmonic generation process (HHG) and delivered to the experiment together with synchronized NIR pulses. We present first results of pump-probe coincidence spectroscopy measurements, performed utilizing argon and molecular nitrogen as a target with XUV APTs and approximately 7 fs FWHM NIR pulses.

[1] Sascha Birkner, PhD thesis, Freien Universitat Berlin (2015)
[2] Federico J. Furch et al., Optics Letters 42, 2495-2498 (2017)

A 11.3 Tue 14:45 f107

Molecular Frame Studies of Channel-Resolved Laser-Driven Electron Recollision — Federico Branchi[1], Horst Rottke[1], Mark Mero[1], Marc J.J. Vrakking[1], Varun Makhija[2], and •Jochen Mikosch[1] — [1]Max-Born-Institut, Berlin, Germany — [2]University of Mary Washington, Fredericksburg, USA

When a molecule interacts with a strong, infrared laser field, a number of phase-locked attosecond processes can be initiated. From the perspective of transient probing of molecular structure, Laser-Induced Electron Diffraction (LIED) is of particular recent interest. In LIED, the tunnel-ionized electron wavepacket is accelerated and driven back to the parent molecule, where it rescatters elastically. With mid-infrared driving laser fields, where the achieved electron kinetic energies are high, bond lengths and angles of molecules can be extracted from the electron scattering images, by fitting the measured differential cross section with an independent atom model.

We are particularly interested in ionization channel-resolved studies, since LIED can be performed independently with two different continuum wavepackets, on the same molecule, at the same time. Such experiments are hence very powerful in testing the way in which structural information is retrieved from the data. Current measurements on 1,3-butadiene molecules are performed in a reaction microscope, which is coupled to a 100kHz repetition rate, mid-infrared OPCPA laser system. We will report on differences we found between the rescattering associated with ground and excited state ionization continuum and on extracting three-dimensional molecular frame information.

A 11.4 Tue 15:00 f107

Study of multiphoton transition in the continuum using RABBITT — •Divya Bharti, Farshad Shobeiry, Hemkumar Srinivas, Robert Moshammer, Thomas Pfeifer, and Anne Harth — Max Planck institut für Kernphysik, Heidelberg, Germany

Rapid advancement in the laser technology has made it possible to generate high power few-cycle Infrared (IR) pulses suitable for the generation of tabletop XUV radiation. These developments have made the study of attosecond physics accessible. Photoionization is a fundamental process in light-matter interaction. The photoelectrons released in this process carry information about the detection method as well as the electronic structure of the original atom.

We study single-photon ionization followed by multiphoton continuum-continuum (CC)-transitions in a RABBITT [1] like setup. RABBITT(Reconstruction of Attosecond beating by Interference of Two-Photon Transitions) is a widely used XUV-NIR pump-probe technique to study photoionization time delays. The presence of an IR (probe) field leads to the appearance of sidebands in the photoelectron spectra. These sidebands oscillate as the delay between XUV (pump) and IR field varies. We analyze the variation in the modulation of the sidebands with respect to e.g. the IR (probe) intensity or the probe frequency to analyze and study the effect of multiphoton transition. This technique will allow us to access the phases of CC-transition matrix elements [2].

[1] Muller, H. Appl Phys B (2002) 74
[2] Harth et al., Phys. Rev. A 99, 023410

A 11.5 Tue 15:15 f107

Static Coherent State Method: High-order Harmonic Generation in atomic and molecular systems in different gauges — •Mohammadreza Eidi and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems - Dresden

We apply the static coherent states (SCS) method [1] to investigate high-order harmonic generation (HHG) in atomic and molecular systems, comparing results for different gauges. We present a case study of the Hydrogen molecular ion H2+ interacting with a few-cycle linearly polarized optical laser in full three-dimensional space. In the original implementation, coherent states are chosen randomly which requires a large number of them. Here, we employ a Gaussian optimization process technique to reduce the number of coherent states without sacrificing accuracy.

[1] Eidi, et.al. Applied Sciences, 8(8):1252, jul 2018.

A 11.6 Tue 15:30 f107

Imprinting orbital angular momentum onto a propagating matter wave — •Jonas Wätzel and Jamal Berakdar — Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Halle (Saale)

Recently, the transfer of orbital angular momentum (OAM) to a bound electron by absorbing photons of an optical vortex was proven experimentally [1]. In contrast, the vortex-matter interaction in the case of a propagating photoelectrons is debatable. Indeed, this amounts to transferring the phase information of a classical electromagnetic wave,

defined within several hundreds of nanometers, to an ensemble of quantum particles with an extent of few angstroms. In this talk, I present experimental and numerical results of the two-color photoionization of an extended sample of He atoms. Surprisingly, we found that the carried OAM of the IR probe field can be transferred coherently to a photoelectron liberated by an XUV FEL laser pulse. Remarkably, the imprinted phase information survives the averaging over the ensemble of He atoms out to macroscopic distances, where the signal is observed. Our results point to the occurrence of non-dipolar transitions initiated by the IR vortex field, which are inaccessible by one-photon processes driven by conventional unstructured light waves. Based on our predictions, new electron spectroscopy methods and qualitatively new analytical tools can be constructed.

[1] Schmiegelow, C. T. et al. "Transfer of optical orbital angular momentum to a bound electron" Nat. Commun. 7, 12998 (2016).

A 11.7 Tue 15:45 f107

Angular resolved photoemission of metal atoms embedded in helium nanodroplets in the MPI regime — •Bennet Krebs, Michael Zabel, Lev Kazak, and Josef Tiggesbäumker — Institut für Physik, Universität Rostock, Germany

Angular resolved photoelectron emission spectra of single metal atoms embedded in helium nanodroplets are measured, analyzed and compared to free atoms. A femtosecond laser system provides 110 fs, linear polarised laser pulses, which are used to ionize the atomic targets in the multiphoton regime (I$\approx 10^{13\ldots14}$W/cm^2) without ionizing the helium nanodroplet itself. Furthermore a time delay controlled two color setup with overlapping $2\omega/\omega$ (400 nm/800 nm) fields is used to probe the attosecond dynamics. For this we apply the highly sensitive Phase-of-the-Phase (PoP) method, which has been previously used to extract information about photoelectron trajectories. Compared to the anisotropic above-threshold-ionization (ATI) signals from free atoms a near isotropic emission is obtained for the embedded species. Furthermore, an enhancement of ATI signals and additional ATI orders can be observed. In the same vein we see a reduction of relative phase contrast. The impact of elastic scattering of the electrons with the surrounding helium environment will be discussed.

A 12: Ultracold atoms, ions, and BEC III (joint session A/Q)

Time: Tuesday 14:00–16:00 Location: f303

Invited Talk A 12.1 Tue 14:00 f303

BECCAL - Quantum Gases on the ISS — •Lisa Wörner[1,2], Christian Schubert[1,3], Jens Grosse[1,2], Claus Braxmaier[1,2], Ernst Rasel[1,2], Wolfgang Schleich[1,4], and the BECCAL collaboration[1,2,3,4,5,6,7] — [1]German Aerospace Center, DLR — [2]University of Bremen — [3]Leibniz University Hanover — [4]University Ulm — [5]Humboldt University Berlin — [6]Johannes Gutenberg University — [7]Ferdinand Braun Institute

BECCAL (Bose-Einstein Condensate and Cold Atom Laboratory) is a bilateral NASA-DLR mission dedicated to execute experiments with ultra-cold and condensed atoms in the microgravity environment of the international space station. It builds on the heritage of NASA's CAL and the DLR founded QUANTUS and MAIUS missions. BECCAL aims to enable a broad range of experiments, covering atom interferometry, coherent atom optics, scalar Bose-Einstein gases, spinor Bose-Einstein gases and gas mixtures, strongly interaction gases and molecules, and quantum information. This contribution gives an overview over the current status of BECCAL and its anticipated capabilities for scientific investigations.

BECCAL is supported by DLR with funds provided by BMWi under Grants Nos. 50WP1700-1706.

A 12.2 Tue 14:30 f303

Cavity-Enhanced Microscope for Cold Atoms — •Tigrane Cantat-Moltrecht, Nick Sauerwein, and Jean-Philippe Brantut — LQG EPFL, Lausanne, Switzerland

We are setting up a novel type of microscope consisting of an ultra-cold Fermi gas of Lithium 6 atoms in a high-finesse cavity, combined with high-numerical-aperture optics (0.38).

Atoms in the cavity can be detected through their dispersive interaction with light. A second laser beam, focused tightly onto the lithium cloud, locally enhances the coupling of the atoms to the cavity, allowing for non-destructive measurements with sub-micron resolution. Controlling this coupling will also allow to tune the cavity-mediated interactions temporally and spatially, paving the way for novel schemes of quantum simulation of random all-to-all interactions between fermions.

Currently, the core of the optical system has been fully characterized and the vacuum and laser system are operational. I will summarize the important ideas and technical developments behind the design, present the current status of our setup and the next steps towards a working "cavity-microscope".

A 12.3 Tue 14:45 f303

Delta-kick collimation in dynamic time averaged optical potentials — •Henning Albers[1], Alexander Herbst[1], Ashwin Rajagopalan[1], Wolfgang Ertmer[1], Ernst M. Rasel[1], Dennis Schlippert[1], and The PRIMUS-Team[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]ZARM, Universität Bremen

The precision of atom interferometers highly depends on the center-of-mass motion and the expansion rate of the atomic ensemble. By reducing the latter, systematic effects, e.g. through wavefront aberration, can be reduced. In our setup we perform evaporative cooling in a dynamic time averaged optical dipole trap, generated by spatial modulation of the trapping beams in the horizontal plane, yielding 2×10^5 condensed atoms after 3 s of evaporation. Subsequently we carry out delta-kick collimation (DKC). Beyond pulsed DKC, we use a trapped scheme keeping the atoms captured the entire time. DKC can be performed at any stage of evaporative cooling, thus short-cutting the generation of ultra-cold effective temperatures. In this talk we will show the results of fast BEC production and discuss the DKC results as well as limitations and the perspective of generating up to 10^6 delta-kicked condensed atoms within 1 s.

This work is funded by the DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 1641 (PRIMUS), the Federal Ministry of Education and Research (BMBF) through the funding program Photonics Research Germany (contract number 13N14875), and the DFG under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".

A 12.4 Tue 15:00 f303

In-medium bound states of two bosonic impurities in a one-dimensional Fermi gas — David Huber[1], Hans-Werner Hammer[1,2], and •Artem Volosniev[3] — [1]TU Darmstadt, Darmstadt, Germany — [2]ExtreMe Matter Institute EMMI, Darmstadt, Germany — [3]IST Austria, Klosterneuburg, Austria

We investigate the ground-state energy of a one-dimensional Fermi gas with two bosonic impurities. We study the case where impurity and fermions have equal masses, and the impurity-impurity two-body interaction is identical to the fermion-impurity interaction, such that the system is solvable with the Bethe ansatz. For attractive interactions, we find that the energy of the impurity-impurity subsystem is below the energy of the bound state that exists without the Fermi gas. We interpret this as a manifestation of attractive boson-boson interactions induced by the fermionic medium, and refer to the impurity- impurity subsystem as an in-medium bound state. For repulsive interactions, we find no in-medium bound states.

A 12.5 Tue 15:15 f303

QUANTUS-2 - Towards double Bragg interferometry in microgravity with a collimated BEC — •Merle Cornelius[1], Peter Stromberger[2], Julia Pahl[3], Christian Deppner[4], Sven Herrmann[1], Claus Lämmerzahl[1], and The QUANTUS-Team[1,2,3,4,5,6] — [1]ZARM, Universität Bremen — [2]JGU Mainz — [3]HU Berlin — [4]LU Hannover — [5]Universität Ulm — [6]TU Darmstadt

Quantum sensors based on matter wave interferometry have a wide range of applications for geodesy or tests of fundamental physics. The sensitivity of such precision measurements increase with the interrogation time, thus operating on a microgravity platform is highly beneficial. As a pathfinder for future space missions, the QUANTUS-2 experiment was designed to perform atom interferometry during the free fall time at the ZARM drop tower in Bremen. Our atom chip setup

enables rapid BEC production of Rb-87 atoms and utilization of delta-kick collimation to reduce the residual expansion below 100 μm/s. The collimated ensemble, observable after 2 s with a high signal to noise ratio, provides an excellent input source for atom interferometry on long time scales. Here we present first results on ground based interferometric measurements with single Bragg diffraction and a prospect to double Bragg interferometry with a collimated BEC in microgravity with long interferometer times in the range of seconds.

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 50WM1952.

A 12.6 Tue 15:30 f303

Observation of First and Second Sound in a Homogeneous Bose Gas — •Timon Hilker[1], Lena Dogra[1], Jake Glidden[1], Christoph Eigen[1], Robert Smith[1,2] und Zoran Hadzibabic[1] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]Clarendon Laboratory, University of Oxford, UK

The existence of two distinct sound velocities is one of the hallmarks of superfluids. In a compressible quantum gas both modes couple to density, which allows us to observe, for the first time, both sound velocities in a moderately interacting ultracold Bose gas. Using a magnetic field gradient, we excite centre-of-mass oscillations of a homogeneous K-39 Bose gas in a three-dimensional box trap, revealing two distinct resonant oscillations. In a microscopic analysis of the mode structure, we find quantitative agreement for the first (and second) sound with the hydrodynamic description of Landau's two-fluid model in terms of in-phase (out-of-phase) oscillations dominated by the thermal (BEC) atoms. We study the speed and the damping of both modes for various interaction strengths and temperatures and investigate in particular the crossover from collisionless to hydrodynamic behaviour above T_C.

A 12.7 Tue 15:45 f303

Continuous phase transitions in spinor Bose-Einstein condensates with spin-orbital angular momentum coupling — •Yuxiong Duan[1,2], Yuriy Bidasyuk[1], and Andrey Surzhykov[1,2] — [1]Physikalisch–Technische Bundesanstalt, D–38116 Braunschweig, Germany — [2]Technische Universität Braunschweig, D–38106 Braunschweig, Germany

Spin-orbital angular momentum (S-OAM) coupling in Bose-Einstein condensates has been recently realized using Raman coupling with Laguerre-Gaussian beams. A rich phase diagram even at zero temperature is predicted as a result of interplay between spin-orbit coupling, collisional interactions and quantization of angular momentum. In present work we focus on some key features introduced to the phase portrait by quantized angular momentum as this is the main difference of our system from more thoroughly studied linear momentum spin-orbit coupling. We demonstrate how appearance of quantized vortices in the S-OAM coupled system significantly alters the mechanism of phase transitions. In particular we find that the transition between the stripe phase and polarized (or unpolarized) phase is a continuous phase transition. During this process, a vortex molecule appears and contracts towards its center. This unique behavior is absent in the case of linear momentum spin-orbit coupling.

A 13: Clusters II (joint session MO/A)

Time: Tuesday 14:00–15:45 Location: f142

A 13.1 Tue 14:00 f142

Molecular Rotation in floppy Molecules: He-H_3^+ — Thomas Salomon[1], Igor Savic[2], Oskar Asvany[1], Dieter Gerlich[3], Ad van der Avoird[4], Michael E. Harding[5], Jürgen Gauss[6], Filippo Lipparini[7], and •Stephan Schlemmer[1] — [1]I. Physikalisches Institut, Universität zu Köln — [2]Department of Physics, University of Novi Sad, Serbia — [3]Institut für Physik, Technische Universität Chemnitz — [4]Theoretical Chemistry, Radboud University Nijmegen, The Netherlands — [5]Fakultät für Chemie und Biowissenschaften Karlsruher Institut für Technologie (KIT) — [6]Department Chemie, Johannes Gutenberg-Universität Mainz — [7]Dipartimento di Chimica e Chimica Industriale, Universita di Pisa, Italy

The ro-vibrational predissociation spectrum of He-H_3^+ has been recorded via the ν_2 vibrational mode in a cold 22-pole ion trap. The spectrum for the bare H_3^+ consists of only a few ro-vibrational lines. Instead, the spectrum of the complex is very rich ($\sim$ 465 lines) even at the low temperature (4 K) of the experiment. Part of this complexity is associated with the (almost) free internal rotation of H_3^+. The experimental results are compared to theoretical predictions of ro-vibrational spectra on the basis of ab initio calculations of the He-H_3^+ potential energy surface. The energy levels result in transitions which agree in many cases with experimental results within a few wavenumbers. In addition, an experimental energy term diagram is reconstructed from the observed transitions. The influence of the Coriolis interaction resulting from the H_3^+ internal rotation in a rotating He-H_3^+ frame will be discussed.

A 13.2 Tue 14:15 f142

Competition between inter- and intra-atomic ionization phenomena: Observation of Electron-Transfer-Mediated decay and Auger decay in Xenon-doped water clusters — •Aaron Ngai[1], Rupert Michiels[1], Nora Berrah[2], Carlo Callegari[3], Edwin Chapman[1], Raimund Feifel[4], Michele Di Fraia[3], Jakob Krull[1], Aaron C. LaForge[2], Paolo Piseri[5], Oksana Plekan[3], Kevin Prince[3], Richard J. Squibb[4], Vit Svoboda[6], Daniel Uhl[1], Hans-Jakob Wörner[6], Andreas Wituschek[1], and Frank Stienkemeier[1] — [1]Insititute of Physics, University of Freiburg — [2]Department of Physics, University of Connecticut — [3]Elettra-Sincrotrone Trieste — [4]Department of Physics, University of Gothenburg — [5]Dipartimento di Fisica and CIMaINa — [6]Laboratorium für Physikaliche Chemie, ETH Zürich

Electron-transfer-mediated decay (ETMD) is a subset of the more general inter-coulombic decay (ICD). In condensed-matter or cluster systems, ETMD competes with other ionization processes such as autoionization (e.g. Auger decay). Using XUV-XUV pump-probe spectroscopy, we observe the competition between ETMD and Auger decay of Xe^+ ($4d_{3/2}$ and $4d_{5/2}$) embedded in water clusters. In particular, we can distinguish between these two similar processes by observing the resulting Xe^{N+} ions in addition to time-resolving their femtosecond dynamics. In our experiment using the FERMI FEL at Elettra, two main features differentiating these decays are expected: the charges of the final Xe^{N+} ions, and kinetic energy broadening of Auger electrons through post-collision interactions (PCI).

A 13.3 Tue 14:30 f142

Cryogenically Cooled Beams of Bio-Nanoparticles — •Lena Worbs[1,2], Jannik Lübke[1,2,3], Armando Estillore[1], Amit K. Samanta[1], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, Deutsches-Elektronen Synchrotron DESY, Hamburg — [2]Fachbereich Physik, Universität Hamburg — [3]Center for Ultrafast Imaging, Hamburg

Coherent diffractive imaging at free-electron lasers promises to allow the reconstruction of the three-dimensional molecular structures of isolated particles at atomic resolution [1]. However, because of the typically low signal to noice ratio, this requires the collection of a large amount of diffraction patterns. Since every intercepted particle is destroyed by the intense x-ray pulse, a new and preferably identical sample particle has to be delivered into every pulse.

We present novel approaches for the production of high density particle beams of shock-frozen bio-nanoparticles using a cryogenic buffer-gas cooling technique [2]. We have also developed a numerical simulation infrastructure that allows quantitative simulation of isolated particle trajectories inside the buffer-gas cell. The cryogenically-cooled nanoparticle beams are characterized using laboratory-based light-scattering [3]. To further improve the resulting particle beam, an aerodynamic lens is implemented to increase its density.

[1] M. M. Seibert, et al., *Nature* **470**, 78 (2011).
[2] A. K. Samanta, et al., arXiv:1910.12606 [physics.bio-ph]
[3] L. Worbs, et al., *Opt. Expr.*, arXiv:1909.08922 [physics.optics]

A 13.4 Tue 14:45 f142

Ultrafast Spectroscopy of Perylene Derivative Nanoparticles — •Chris Rehhagen[1,2], Shahnawaz Rafiq[2], Stefan Lochbrunner[1], and Gregory Scholes[2] — [1]Institute for Physics and Department of Life, Light and Matter, University of Rostock,

18051 Rostock, Germany — [2]Frick Laboratory, Princeton University, 08540 Princeton, USA

Organic dye nanoparticles and nanostructures are of increasing interest in opto-electronic applications due to their potentially large exciton mobilities. While as inorganic nanoparticles are already applied in many scenarios, the properties of organic nanostructures are yet to be explored. Among a breadth of organic systems available, Perylene derivatives especially attract much interest as they provide a high oscillator strength, photostability, and a tuneability of the transition energy and supramolecular structure by changing the bay-substitutes.

We use flash precipitation to prepare nanoparticles of the Perylene Red (PR) and Perylene Orange (PO) dyes and correlate their optical spectra, quantum yields, emission lifetimes and their size. Ultrafast pump-probe spectroscopy is then performed on samples of different size classes to characterize their excited state dynamics. In PR nanoparticles, a new electronic state, formed after photoexcitation, was observed. Remarkably, no such intermediate state was observed in the PR monomer. In PO nanoparticles, we observe an ultrafast excimer formation. In both systems and for different size classes, we characterize the exciton diffusion in the nanoparticles by analyzing signatures in the transient dynamics resulting from exciton-exciton annihilation.

A 13.5 Tue 15:00 f142

Spectroscopic investigation of gas-phase silvercluster-porphyrin hybrides — •Carl Frederic Ussling[1], Tobias Bischoff[1], Andre Knecht[1], Andrea Merli[1], Merle I. S. Röhr[2], Polina G. Lisinetskaya[2], Roland Mitrić[2], and Thomas Möller[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin — [2]Institut für Physikalische und Theoretische Chemie, Universität Würzburg

In the last decades the size and structure-dependent optical properties of noble metal clusters have been widely investigated [1][2].
In the smallest size regime, both the cluster geometry and optical properties turned out to be particularly effected by the number of constituents [3]. Due to their strong UV and Vis absorption it has been predicted, that small silver clusters could be useful to develop new biomolecular sensors [4]. Hybrid systems consisting of small metal clusters and small molecular units have been developed and their optical behavior experimentally explored [5]. We investigated the possibility to combine small cationic silver clusters with single porphyrins in a collision cell and studied first the optical properties of $Ag_3[Ag(OEP)]^+$ in the UV range.

[1] E. M. Fernández et al., *Phys. Rev. B* **70**, 165403 (2004)
[2] C. Sönnichsen et al., *New J. Phys.* **4**, 93 (2002)
[3] K. L. Kelly et al., *J. Phys. Chem. B* **107**, 668 (2003)
[4] T. Tabarin et al., *J. Chem. Phys.* **127**, 134301 (2007)
[5] V. Bonačić-Koutecký et al., *Phys. Chem. Chem.* **14**, 9282 (2012)

A 13.6 Tue 15:15 f142

Investigation of isolated aggregates of coumarin derivatives in the gas phase by applying combined IR/UV spectroscopy — •Pol Boden, Anke Stamm, Michael Borchers, Dominic Bernhard, Dominique Maué, and Markus Gerhards — TU Kaiserslautern and State Research Center OPTIMAS, Germany

Coumarin and its derivatives are well known for their photo-induced reactivity leading to their importance as photobiological and photochemical substances. Here we report on 7-Hydroxy-4-methylcoumarin (7-H4MC) and its amino analogue 7-amino-4-methylcoumarin (7-A4MC). The examination of 7-A4MC is of great interest because aminocoumarins show an intramolecular charge-transfer (ICT) between the amino group and the benzopyrone unit in solvents of moderate to high polarity. In order to investigate intrinsic effects with respect to ICT and structure of the 7-A4MC dimer in the neutral and cationic ground states as well as in the S_1 state, combined IR/UV spectroscopy is applied in molecular beam experiments. A comparison of the measured IR transitions with calculated frequencies and optimized structures allows clear structural assignments. Furthermore the 7H4MC dimer and its mono- and dihydrate are investigated both in their neutral and cationic ground state with regard to structural changes occuring upon UV photoionization. The tendencies of coumarins for self-aggregation observed in aqueous solution are investigated in detail on isolated species giving (in combination with hydration) a closer look on structure and function of coumarins.

A 13.7 Tue 15:30 f142

Rayleigh scattering of a pulsed supersonic jet of Ar and CO_2 at high particle densities — •Sara Fazli and Wolfgang Christen — Humboldt-Universität zu Berlin, Institut für Chemie, Brook-Taylor-Straße 2, 12489 Berlin

We present an experimental setup for the investigation of Rayleigh scattering of a pulsed supersonic jet and present first results for the scattered light intensity as a function of cluster source conditions. A jet of pure Ar or CO_2, respectively, is expanded through a parabolic nozzle at source temperatures between 230 K and 410 K and source pressures between 2 MPa and 10 MPa. The change of the Rayleigh scattering signal with source pressure and temperature is compared with the prediction of Hagena's scaling law (J. Chem. Phys. 56, 1793, 1972). Results show a pronounced dependence of the scaling parameters on the aggregation state (gas versus liquid) of the expanding fluid.

A 14: Poster Session - Atomic Physics II

Time: Tuesday 16:00–18:00 Location: Empore Lichthof

A 14.1 Tue 16:00 Empore Lichthof

The attoclock and its interpretations, theoretically and experimentally — •Ossama Kullie — Institute of Physics, Department of Mathematics and Natural Science, University of Kassel.

The measurement of the tunneling time in experiments with intense short laser pulse, termed attoclock, triggered a hot debate about the tunneling time and the separation into two regimes of ionization, the multiphoton and the tunneling. Theoretically, a crucial issue is the tunneling time, whether it is a real or an imaginary quantity. A related issue, whether time is an observable or a parameter in quantum mechanics. Another point is the statistical interpretation of the tunneling time, nevertheless we show that our real tunneling time is conform with the statistical point of view. Experimentally the issue is crucial since the result depends on the field strength calibration, and its consequence for the tunneling or multiphoton ionization regimes and hence the interpretation of the theoretical result. We give a detailed picture concerning these issues, and discuss some features for future works on both sides, experiment and theory. [1] O. Kullie, Ann. of Phys. **389**, 333 (2018), (open access) Mathematics **6**, 192 (2018).

A 14.2 Tue 16:00 Empore Lichthof

Impact of electron transport on attosecond streaking in dielectrics — •L. Seiffert[1], E. A. Herzig[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]CFEL, DESY — [6]National Research Council of Italy — [7]FU Berlin — [8]MBI Berlin — [9]Universität 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 low-energy electron transport involving elastic and inelastic collisions. Here, we demonstrate real-time access to electron scattering in dielectric nanoparticles via attosecond streaking. Utilizing semi-classical transport simulations [1] 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 [2,3].

[1] F. Süßmann et al., Nat. Commun. **6**, 7944 (2015)
[2] L. Seiffert et al., Nat. Phys. **13**, 766-770 (2017)
[3] Q. Liu et al., J. Opt. **20**, 024002 (2018)

A 14.3 Tue 16:00 Empore Lichthof

Overview of a tabletop setup for the generation of ultrashort XUV laser pulses for attosecond physics — •Felix Otten, Lars

Englert, Marcel Behrens, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg

Until recently, coherent X-ray sources such as free electron lasers or synchrotrons were available only for large research facilities. Due to new techniques in pulse generation, compression and amplification, ultrashort XUV light sources are now also available for small-scale laboratories. We present an overview of a tabletop setup for the generation of coherent XUV radiation in the attosecond regime based on high harmonic generation. The beamline consists of a commercial carrier-envelope-phase-stabilized IR femtosecond laser source with a hollow fiber compressor to provide few cycle driver pulses for the XUV pulse generation. We present initial results of the measured XUV spectra and give an outlook for future experiments on attosecond physics.

A 14.4 Tue 16:00 Empore Lichthof

Collisional effects in the extreme nonlinear response of dielectrics — •Benjamin Liewehr[1], Björn T. Kruse[1], Christian Peltz[1], Peter Jürgens[2], Anton Husakou[2], Tobias Witting[2], Marc J. J. Vrakking[2], Alexandre Mermillod-Blondin[2], and Thomas Fennel[1,2] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, D-18059 Rostock — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2A, D-12489 Berlin

The understanding of nonlinear optical phenomena in dielectric solids has been recently complemented by the physics of Bloch oscillations and interband recombination in the high frequency domain (HHG) [1,2] while low order harmonics have been linked to the strong field excitation dynamics that drive Brunel- and injection currents [3,4]. To which extent the excitation dynamics can be reconstructed from time resolved low order harmonic emission remains an open question, in particular regarding electron impact ionization and elastic collisions. Here we investigate the nonlinear electronic response using a rate-equation-based ionization-radiation model and study the effect of collisions on low-order wave-mixing. Possible routes to separate contributions from laser-driven strong-field ionization and electron-impact ionization avalanching are discussed.

[1] H. Liu et al., Nature Phys. **13**, 262 (2017)
[2] G. Vampa, et al., Nature **522**, 462 (2015)
[3] F. Brunel, J. Opt. Soc. Am. B **4**, 521 (1990)
[4] P. Jürgens et al., arXiv:1905.05126 (2019)

A 14.5 Tue 16:00 Empore Lichthof

Electron correlation induced hole dynamics in high harmonic generation by bicircular laser fields — •Nicola Mayer, Álvaro Jiménez-Galán, Serguei Patchkovskii, and Misha Ivanov — Max Born Institute, Max-Born-Straβe 2A, 12489 Berlin, Germany

The use of bicircular laser fields to drive the high-harmonic generation (HHG) process allows for the generation of circularly polarized extreme-ultraviolet (XUV) light, hence paving the way for the study of chiral phenomena on the attosecond timescale. In the case where the frequency ratio between the two counter-rotating drivers is 2:1, the 3N+1 and 3N+2 harmonic orders are allowed, while 3N harmonics are nominally forbidden by symmetry. In Ref. [1] strong forbidden 3N lines were nonetheless observed in Helium; their appearance was attributed to the excitation of Rydberg states via the Frustrated Tunneling Ionization (FTI) mechanism [2]. In this contribution, we investigate the role of the Rydberg states in the electron-correlation-induced dynamics in the bicircular scheme of HHG. In particular, we show how the long-range Coulomb interaction between the tunneled electron and the parent ion together with the spin-orbit interaction in the core can lead to rich dynamics in the ion of a noble gas with np valence shell such as Argon or Neon. We investigate the role of the hole dynamics in the Ar and Ne ions in the high-harmonic generation process and address the possibility of observing the hole dynamics via the background-free measurement of forbidden 3N harmonic lines.

[1] A.Jiménez-Galán et al., Optics Express, Vol. 25, No. 19, (2017).
[2] T. Nubbemeyer, Phys. Rev. Lett., Vol. 101, No. 233001, (2008).

A 14.6 Tue 16:00 Empore Lichthof

Simulation of high-order harmonic generation in ZnO — •Christian Hünecke, Ivan Gonoskov, Martin Richter, and Stefanie Gräfe — Institute for Physical Chemistry, Friedrich-Schiller University Jena, Germany

Pump-probe experiments shed some light on the involvement of optical phonons in the generation of high-harmonic radiation in zinc oxide [1]. Two approaches for the theoretical description of the HHG spectra are employed. At first the time-dependent Schroedinger equation is solved numerically using a Coulomb-type potential with periodic boundary conditions. The calculated harmonic spectra are compared with the results based on the real-time real-space time-dependent density functional theory (TDDFT) obtained using the software-package "Octopus" [2]. In the TDDFT scheme the influence of a phonon is analyzed by parametrically shifting the position of the nuclei in the lattice structure of ZnO.

[1]: R. Hollinger, V. Shumakova, A. Pugžlys, S. Khujanov, A. Baltuška, C. Spielmann, D. Kartashov, "High-order harmonic generation traces ultrafast coherent phonon dynamics in ZnO", Ultrafast Phenomena 2018, to be published in Eur. Phys. J. - Web of Conferences
[2]: Xavier Andrade et al., "Real-space grids and the Octopus code as tools for the development of new simulation approaches for electronic systems", Physical Chemistry Chemical Physics 17, 31371-31396 (2015)

A 14.7 Tue 16:00 Empore Lichthof

First results of the Alphatrap *g*-factor experiment — •Fabian Heisse[1], Ioanna Arapoglou[1], Alexander Egl[1], Felix Hahne[1,2], Martin Höcker[1], Peter Micke[1,3], Tim Sailer[1], Bingsheng Tu[1], Andreas Weigel[1], José R. 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 — [3]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig

Quantum electrodynamics (QED) is considered to be the most successful quantum field theory in the Standard Model. Its most precise test is conducted via the comparison of QED calculations with the measurement of the free electron *g*-factor. However, this test is restricted to low electrical field strengths. Consequently, it is of utmost importance to perform similar tests at high field strengths.

The Alphatrap experiment is a dedicated cryogenic Penning-trap setup to measure the *g*-factor of bound electrons in highly charged ions up to hydrogen-like lead. There, an electrical field strength on the order of 10^{16} V/cm acts on the electron, allowing to test bound-state QED with highest precision.

Our first measurement results of the *g*-factor of a single boron-like $^{40}Ar^{13+}$ ion as well as the laser spectroscopy of its $2p^2P_{1/2} - {}^2P_{3/2}$ fine-structure transition will be presented [1–2]. Furthermore, an outlook on upcoming studies and prospects will be given.

[1] I. Arapoglou *et al.* Phys. Rev. Lett. **122**, 253001 (2019)
[2] A. Egl *et al.* Phys. Rev. Lett. **123**, 123001 (2019)

A 14.8 Tue 16:00 Empore Lichthof

Towards Quantum Logic Spectroscopy of Molecular Oxygen Ions — •Maximilian J. Zawierucha[1], Jan C. Heip[1], Fabian Wolf[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38159 Braunschweig — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Precision spectroscopy of vibrational overtones in oxygen molecular ions is a promising route for an improved upper bound on a possible variation of the proton-to-electron mass ratio. Here, we present the status of our experiment, aiming at high precision quantum logic spectroscopy of molecular oxygen ions. In the past, we have demonstrated a non-destructive internal state detection scheme for $^{24}MgH^+$ ions, that relies on the detection of state dependent forces with a co-trapped $^{25}Mg^+$ ion. We have theoretically developed a variant of this scheme for the investigation of O_2^+. Further, we will present recent experimental results on rotational state-resolved ionization from a new molecular beam setup that will be used to load single oxygen molecules into a linear Paul trap for future quantum logic spectroscopy experiments.

A 14.9 Tue 16:00 Empore Lichthof

Two-photon spectroscopy of Rubidium atoms in the vicinity of Silicon Nano-photonic Waveguides — •Artur Skljarow[1], Wolfram H.P. Pernice[2], Harald Kübler[1], Hadiseh Alaeian[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Germany — [2]Institute of Physics, University of Münster, Heisenbergstr. 11, D-48149 Münster, Germany

The marriage of photonic structures and thermal atomic vapors on a chip provides efficient atom-light coupling on a miniaturized scale well beyond the diffraction limit. We study an integrated silicon photonic chip, composed of several sub-wavelength ridge waveguides, immersed

in a micro-cell with rubidium vapor. Employing two-photon excitation, including a telecom wavelength, we observe that the waveguide transmission spectrum gets modified when the photonic mode is coupled to rubidium atoms through its evanescent tail. The measured spectra corroborate pretty well with a generalized effective susceptibility model that includes the Casimir-Polder potentials, due to the silicon surface, and the transient interaction between the evanescent field and the moving atoms. This work paves the way towards a miniaturized and integrated hybrid atomic-photonic system compatible with CMOS technologies.

[1] R. Ritter et al., Appl. Phys. Lett. 107, 041101 (2015)
[2] R. Ritter et al., New Journal of Physics 18, 103031 (2016)
[3] R. Ritter et at., Phys. Rev. X 8, 021032 (2018)

A 14.10 Tue 16:00 Empore Lichthof

Resonance ionization spectroscopy on picogram amounts of $^{249-252}$Cf — •Felix Weber[1], Nina Kneip[1], Christoph E. Düllmann[2,3,4], Vadim Gadelshin[1], Christoph Mokry[2,4], Sebastian Raeder[3], Jörg Runke[2,3], Petra Thörle-Pospiech[2,4], Norbert Trautmann[2], and Klaus Wendt[1] — [1]Insitute of Physics, JGU Mainz — [2]Institute of Nuclear Chemistry, JGU Mainz — [3]GSI Helmholtzzentrum, Darmstadt — [4]Helmholtz Institute Mainz

Californium is an artificial actinide element. The isotopes $^{249-252}$Cf have half-lives $\gtrsim 1$ a; among these, the four heaviest ones can be produced by neutron-capture in high-flux reactors. Still only few optical spectroscopic studies have been performed on californium. Resonant laser ionization spectroscopy is an efficient technique to study atomic level schemes, and can be applied on samples containing 10^9 atoms or even less, and is also a powerful technique for ultra-trace determination. A sample containing about $5 \cdot 10^9$ atoms of $^{249-252}$Cf were prepared on a zirconium backing. Widely tunable frequency doubled Ti:Sapphire lasers (350-490 nm) with an output power of up to $1\,W$ were used to identify atomic levels applying efficient two step ionization schemes. For five different first excitation steps, autoionizing states were measured. Additionally, Rydberg series of californium were identified for the first time, converging to the ground and first excited state of the ion. Also the isotopic shift for one ground state transition was determined. In a next step high resolution spectroscopy to resolve the hyperfine splitting in odd Cf-isotopes will be addressed, e.g. to determine the so far unknown nuclear moment of ^{251}Cf.

A 14.11 Tue 16:00 Empore Lichthof

Catching and trapping thorium ions from external laser-ablation ion source in a linear Paul trap and sympathetic cooling with a large calcium ion crystal — •Sebastian Wolf[1], Wenbing Li[1], Tom Kieck[1,2], Raphael Haas[1,2], Christoph E. Düllmann[1,2,3,4], Dmitry Budker[1,2,3], and Ferdinand Schmidt-Kaler[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Helmholtz-Institut Mainz — [3]PRISMA, Cluster of Excellence, Mainz — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

Isotopes of thorium, including ^{229}Th with its isomeric state provide for interesting spectroscopic tests of fundamental symmetries of nature. Trapping and sympathetically cooling thorium ions into a Paul trap is a precondition for such studies. For the production of ^{232}Th$^+$ we have demonstrated laser-ablation, electron impact ionization and injection from this external source, followed by trapping and sympathetic cooling [1] and ion mass identification [2]. A new ion trap setup is now optimized to capture ^{229}Th produced from a recoil source from α-decay of ^{233}U [3]. Due to the spontaneous nature of radioactive decay, no timing information is available concerning the production of ^{229}Th. Therefore, we employ polarization gradient cooling of a large calcium ion crystal. Incoming injected thorium ions will heat the ion crystal to reveal a signature which allows for time-dependent switching of trap potentials for rapid identification of successful capture.

[1] K. Groot-Berning *et al.*, Phys. Rev. A **99**, 023420 (2019).
[2] F. Stopp *et al.*, Hyperfine Interact 240:33 (2019).
[3] R. Haas *et al.*, arXiv: 1911.11674 (2019).

A 14.12 Tue 16:00 Empore Lichthof

Lineare Paulfalle mit transparenten Elektroden — •Alexander Wilzewski[1,2], Sebastian Wolf[1,2], Kai Krimmel[1,2], Johannes Heinrich[3], Mark Keil[4], Ron Folman[4], Dmitry Budker[1,2,5] und Ferdinand Schmidt-Kaler[1,2] — [1]Helmholtz-Institut Mainz, Mainz 55218, Germany — [2]QUANTUM, Institut für Physik, JGU Mainz, Mainz 55128, Germany — [3]Laboratoire Kastler Brossel, UPMC-Sorbonne Universites, CNRS, ENS-PSL Research University, College de France — [4]Department of Physics, Ben-Gurion University of the Negev, Be'er Sheva 84105 Israel — [5]Department of Physics, University of California at Berkeley, Berkeley, CA 94720, USA

Wir stellen erste Messungen zur Charakterisierung einer linearen segmentierten Ionenfalle aus transparenten Chips vor. Diese sind aus Quartzglas-Substrat hergestellt und mit leitendem ITO sowie Goldelektroden beschichtet, was es erlaubt das Fluoreszenzlicht großer Be^+ Wolken und Kristalle durch die Falle selbst zu beobachten. Die Kristalle aus Be^+ sollen zum sympathetischen Kühlen anderer Ionenspezies genutzt werden und Anwendung beim Kühlen von Antiwasserstoffionen [1] oder der Speicherung und Kühlung von geladenen Teilchen sehr unterschiedlicher Ladungs-zu-Masse-Verhältnissen [2] finden.

[1] P. Pérez et al., "The GBAR antimatter gravity experiment", Hyperfine Interactions 233, 21-27 (2015)
[2] N. Leefer et al., "Investigation of two-frequency Paul traps for antihydrogen production", Hyperfine Interactions 238:12 (2017)

A 14.13 Tue 16:00 Empore Lichthof

Towards a planar, single-beam MOT for strontium atoms — •Saskia Bondza[1,2], Tobias Leopold[1,2], Stefanie Kroker[1,3], and Christian Lisdat[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]DLR-Institut für Satellitengeodäsie und Inertialsensoren, c/o Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [3]TU Braunschweig, LENA Laboratory for Emerging Nanometrology Universitätsplatz 2, 38106 Braunschweig

With recent advances of lab-scale optical atomic clocks, a demand for the development of transportable and miniaturized quantum-optical technology has emerged. For neutral-atom-based optical clocks, atoms from the alkaline-earth group, e.g. strontium, feature a particularly useful level structure with a strong and a narrow cooling transition and an ultra-narrow clock transition, all in the visible wavelength regime. We aim to extend the successful approach of miniaturization for alkali atom magneto-optical traps (MOT), where single-beam trapping geometries are routinely employed, to the case of strontium. Here, the challenge is to build a planar beam-shaping geometry with achromatic properties with respect to the two cooling wavelengths. Different approaches to solve this problem are presented and evaluated alongside accompanying work on laser-controlled strontium atom sources.

A 14.14 Tue 16:00 Empore Lichthof

Towards sympathetic cooling of single (anti-)protons — •Teresa Meiners[1], Johannes Mielke[1], Matthias Borchert[1,3], Frederik Jacobs[1], Julian Pick[1], Amado Bautista-Salvador[2], Juan Manuel Cornejo[1], Ralf Lehnert[1,4], Malte Niemann[1], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [3]Ulmer Fundamental Symmetries Laboratiory, RIKEN, Wako, Saitama 351-0198, Japan — [4]Indiana University Center for Spacetime Symmetries, Bloomington, IN 47405, USA

The aim of the BASE collaboration is to test fundamental physics by performing precision measurements on single (anti-)protons, such as g-factor comparisons, for a stringent test of CPT invariance with baryons. The state-of-the-art measurements are performed in cylindrical Penning traps using resistive cooling and image current detection. Sympathetically cooling the (anti-)proton using a co-trapped atomic ion would significantly decrease preparation times and therefore considerably increase the sampling rate of the experiment (which would allow measurements at considerably improved precision).

We develop concepts for sympathetic cooling of single protons using a laser cooled $^9Be^+$ ion within the BASE collaboration. We present our recently upgraded apparatus including Penning traps for production, cooling, transport, and detection of $^9Be^+$ ions and protons as well as a trap for motional coupling of these two ion species.

A 14.15 Tue 16:00 Empore Lichthof

Search for electronic bridge excitation of the nuclear clock isomer ^{229m}Th — •David-Marcel Meier, Johannes Thielking, Gregor Zitzer, Maxim V. Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

The transition between the nuclear ground state and the low-energy isomer of ^{229}Th has been proposed as a frequency reference for an op-

tical clock of high accuracy, but its optical excitation is still pending.

We are investigating the excitation of the nucleus via electronic bridge/NEET processes, using two-photon laser excitation to access high-lying electronic levels in Th^+ and in Th^{2+} [1]. About 100 excited electronic states of Th^+ with energies ranging from 7.4 to 9.6 eV have been investigated for their fluorescence decay signals, without observing an indication of nuclear excitation. Experiments with selected levels of Th^{2+} have been performed using resolved hyperfine spectra [2] for a detection of the isomer. It is planned to revisit with improved statistics the narrower range of excitation energy 8.28(17) eV that has recently been obtained at LMU [3].

[1] D.-M. Meier et al., Phys. Rev. A 99, 052514 (2019).
[2] J. Thielking et al., Nature 556, 321-325 (2018).
[3] B. Seiferle et al., Nature 573, 243-246 (2019).

A 14.16 Tue 16:00 Empore Lichthof

Ion trap system for sympathetic cooling of $^{229}Th^{3+}$ ions — •Gregor Zitzer, Johannes Thielking, David-Marcel Meier, Maksim Okhapkin, and Ekkehard Peik — Physikalisch-Technsiche Bundesanstalt, 38116 Braunschweig, Germany

The energy determination of the low-energy ^{229}Th nuclear isomer is progressing and the latest results indicate an energy value of 8.3 eV [1]. The corresponding VUV transition wavelength is accessible for direct laser excitation of the nucleus. This is of special interest for a novel type of optical clocks, providing an elevated accuracy and a unique sensitivity for tests of fundamental physics in the hadron sector.

The charge state 3+ for ^{229}Th is preferred for a potential clock system with laser-cooled ions where one can benefit from the relatively simple and convenient electronic level structure.

We have set up an ion trap system for Th^{3+} ions sympathetically cooled with $^{88}Sr^+$ for experiments with large Coulomb crystals, precision hyperfine spectroscopy and future clock operation. The trap system consists of a multi-segmented linear radiofrequency ion trap in which we are able to load, cool and store the Sr^+ crystals. In these crystals, $^{229}Th^{3+}$ will be localized close to the trap axis, inside a tubular shell of Sr^+ ions. The $^{229}Th^{3+}$ ions will be generated by a ^{233}U source via α-decay [2] and guided towards the Paul trap. The current status of the Th loading and trapping system will be presented.

[1] B. Seiferle et al., Nature, 573, 243-246 (2019) [2] L. v. d. Wense et al., Nature, 533, 47-51 (2016)

A 14.17 Tue 16:00 Empore Lichthof

Current status of the Al^+ ion clock at PTB — •Fabian Dawel[1,2], Johannes Kramer[1,2], Nils Scharnhorst[1,2], Ludwig Krinner[1,2], Lennart Pelzer[1,2], Stephan Hannig[1,2], Kai Dietze[1,2], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, D — [2]Leibnitz-Universtität-Hannover, 30167 Hannover, D

Here we present the status of the $^{27}Al^+$ clock at PTB. The Al^+ ion optical clock has one of the lowest systematic uncertainties [1]. This is due to its very low sensitivity to external fields. Al^+ exhibits only nuclear linear Zeeman shifts and a very small black body radiation shift which is estimated to be less than 10^{-19} in our trap setup. The Al^+ is co-trapped with $^{40}Ca^+$ in a linear Paul trap. The Ca^+ ion is used for cooling and quantum logic spectroscopy (QLS) of the Al. For QLS groundstate cooling is needed and achived by DEIT which results in a fractional second order Doppler shift from residual motion of the Al^+/Ca^+ crystal of well below 10^{-18} [2]. We present coherent excitation of the $^1S_0$ to $^3P_1$ transition of Al^+ with a contrast of around 90%. We also present a scheme for phase-stabilising the clock laser light paths from the IR-laser to the ion to achieve long probe times on the clock transition $^1S_0$ to $^3P_0$ at 267 nm.

[1]*Brewer et al. Phys. Rev. Lett. **123**, 033201 (2019)
[2]*Scharnhorst et al., Phys. Rev. A **98**, 023424 (2018)

A 14.18 Tue 16:00 Empore Lichthof

Towards high-precision spectroscopy of the 1S–2S transition in He^+ — •Fabian Schmid[1], Akira Ozawa[1], Johannes Weitenberg[1,2], Theodor W. Hänsch[1,3], and Thomas Udem[1,3] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fraunhofer-Institut für Lasertechnik ILT, Aachen — [3]Ludwig-Maximilians-Universität München

Accurate tests of a physical theory require a system whose properties can be both measured and calculated with very high precision. One famous example is the hydrogen atom which can be precisely described by bound-state quantum electrodynamics (QED) and whose transition energies can be accurately measured by laser spectroscopy.

We are currently setting up an experiment to perform spectroscopy on the narrow 1S–2S transition in hydrogen-like He^+ ions. Due to their charge, He^+ ions can be held near-motionless in the field-free environment of a Paul trap, providing ideal conditions for a high precision measurement. Furthermore, interesting higher-order QED corrections scale with large exponents of the nuclear charge, making this measurement much more sensitive to these corrections compared to the hydrogen case.

Driving the transition requires narrow-band extreme-ultraviolet (XUV) radiation at 61 nm. Our approach is to apply direct frequency comb spectroscopy with an XUV frequency comb which is generated from an infrared source using intracavity high harmonic generation. The target He^+ ions will be trapped in a linear Paul trap and sympathetically cooled by co-trapped Be^+ ions.

A 14.19 Tue 16:00 Empore Lichthof

The ARTEMIS Experiment For Precision Measurements Of The Electron g-Factor In Highly Charged Ions — Patrick Baus[1], Gerhard Birkl[1], Zhexi Guo[2,3,4], •Kanika Kanika[2,3], Jeffrey Klimes[2,3,4], Wolfgang Quint[2,3], and Manuel Vogel[3] — [1]Institute of Applied Physics, Technical University Darmstadt, 64289 Darmstadt, Germany — [2]Department of Physics and Astronomy, University of Heidelberg, 69120 Heidelberg, Germany — [3]GSI Helmholtz Centre for Heavy Ion Research, 64291 Darmstadt, Germany — [4]Max Planck Institute for Nuclear Physics, 69120 Heidelberg, Germany

The ARTEMIS experiment at the HITRAP facility at GSI, Darmstadt aims at high precision g-factor measurements of electrons bound to highly charged ions (HCIs) using the Laser-Microwave double-resonance spectroscopy. The highly charged ions are stored in a small volume in a half-open Penning trap in a homogeneous magnetic field of 7 T and can be resistively cooled through their image currents. The long storage times of weeks indicate a residual gas pressure inside the trap chamber of less than 10^{-15} mbar. The Creation Trap allows for the in-situ production of ions, acting as a mini-EBIT and also to have the in-flight capture of the ions from the HITRAP beamline. The Spectroscopy Trap has an Indium Tin Oxide (ITO) window, which also acts as an endcap electrode and provides for large optical access for the Laser-Microwave spectroscopy technique. After connection to the HITRAP beamline, the method will be applied to H-like heavy ions such as Bi^{82+}, U^{91+} to probe the hyperfine structure transitions and measure the nuclear and electron magnetic moments.

A 14.20 Tue 16:00 Empore Lichthof

A new value for the isomer energy of ^{229}Th, determined by high-resolution γ-spectroscopy with metallic magnetic micro-calorimeters — •D. Hengstler[1], J. Geist[1], S. Allgeier[1], M. Arndt[1], M. Friedrich[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], S. Stellmer[2], T. Schumm[3], and C. Düllmann[4] — [1]Heidelberg University — [2]University of Bonn — [3]Vienna University of Technology — [4]Mainz University

The isotope ^{229}Th has the nuclear isomer state with the lowest presently known excitation energy, which possibly allows to connect the fields of nuclear and atomic physics with a potential application in a nuclear clock. However, in order to excite this very narrow transition from the ground state to the isomer state with a laser a precise knowledge of the transition energy is needed. A detector with good energy resolution allows to deduce this transition energy from a high-statistic γ-spectrum of ^{229}Th originating from the α-decay of ^{233}U.

To improve the accuracy of the currently most accepted value of (7.8 ± 0.5) eV, we developed and fabricated the detector array maXs-30 consisting of 8×8 metallic magnetic calorimeters. The detector features a large active detection area of 4 mm × 4 mm to face the low rate of the relevant γ-transitions, a world-record energy resolution $\Delta E_{\mathrm{FWHM}} < 10$ eV up to 60 keV as well as a very small non-linearity and reliable energy calibration.

We present our latest ^{229}Th spectrum measured with a purified ^{233}U source and derive a trustful value for the isomer energy on different ways, leading to a result of $E_{\mathrm{iso}} = (8.09 \pm 0.13(\mathrm{stat})^{+0.05}_{-0.14}(\mathrm{syst}))$ eV.

A 14.21 Tue 16:00 Empore Lichthof

Metallic Magnetic Calorimeters for High Precision X-Ray Spectroscopy on Highly Charged Ions — •M. Friedrich[1], S. Allgeier[1], M. Arndt[1], J. Geist[1], D. Hengstler[1], C. Schötz[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], Ph. Pfäfflein[2], S. Trotsenko[2,3], T. Morgenroth[3], M.O. Herdrich[2], G. Weber[2], R. Märtin[2], and Th. Stöhlker[2,3,4] — [1]KIP, Heidelberg University — [2]HI Jena — [3]GSI Darmstadt — [4]IOQ,

Jena University

Heavy Highly Charged Ions (HCIs) are promising candidates to test QED in extreme electromagnetic fields. Due to the high nuclear charge of such ions the electronic transitions are shifted to the X-ray regime, while the Lamb-Shift amounts to more than 0.1 % of the transition energies. Metallic magnetic calorimeters are energy dispersive X-ray detectors, which provide an extremely high energy resolution over a wide energy range as well as an excellent energy calibration. Thus, they are perfectly suited for high precision X-ray spectroscopy on HCIs in ion storage rings where photon flux is small and beam time is limited.
For an upcoming measurement on H-like U^{91+} at CRYRING@ESR we report on our newly developed, fabricated and characterised two-dimensional detector array maXs100 consisting of 64 pixels with a total detection area of 10x10 mm^2. An absorber thickness of 100 μm (50 μm) results in an expected energy resolution of $\Delta E_{\mathrm{FWHM}} \sim 38\,\mathrm{eV}(27\,\mathrm{eV})$. This detector is mounted on a side arm of a dilution refrigerator and will enable the determination of the 1s Lamb-Shift with sub-eV precision.

A 14.22 Tue 16:00 Empore Lichthof

Active Control of a Femtosecond Enhancement Cavity for XUV Spectroscopy — •Patrick Knauer, Janko Nauta, Jan-Hendrik Oelmann, Alexander Ackermann, Ronja Pappenberger, Nick Lackmann, Steffen Kühn, Julian Stark, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Driving narrow transitions of highly charged ions in the extreme ultraviolet (XUV) regime requires a coherent XUV source. A femtosecond enhancement cavity can provide this by transferring an infrared frequency comb with a peak intensity of up to $\approx 3 \cdot 10^{14}\,\mathrm{W/cm^2}$ at a repetition rate of 100 MHz to the XUV through high-harmonic generation [1,2]. The enhancement cavity is mounted on a rigid titanium structure for stable long-term operation, and vibrations from the vacuum pumps are isolated from the optical setup by air-lifted feet [3]. To achieve a high enhancement of the driving infrared frequency comb, the cavity has to be precisely stabilised at high intra-cavity powers of several kW. Noise caused by thermal expansion, residual vibrations or other sources has to be cancelled. For this, we present an active stabilisation control consisting of a short and long term feedback loop, which is implemented using a field programmable gate array equipped micro controller.

[1] C. Gohle et al., Nature 436, 234-237 (2005).
[2] G. Porat et al., Nat. Photon, 12, 387 - 391 (2018).
[3] J. Nauta et al., Nucl. Instrum. Meth. B 408, 285 (2017).

A 14.23 Tue 16:00 Empore Lichthof

Designed quantum states for $^{40}Ca^+$ clock interrogation — •Lennart Pelzer[1], Kai Dietze[1], Ludwig Krinner[1,2], Stephan Hannig[1,3], Nicolas Spethmann[1], Nati Aharon[4], Alex Retzker[4], Tanja E. Mehlstäubler[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, 30167 Hannover, Germany — [3]DLR-Si, 30167 Hannover, Germany — [4]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

Single ion optical clocks are limited in their statistical uncertainty by quantum projection noise. Stabilizing the interrogation laser to a transition in a multi-ion crystal would allow longer probe times and thus improve statistical uncertainty, but increasing the number of ions while maintaining low systematic uncertainties is demanding.

Using engineered quantum states by employing a continuous dynamical decoupling scheme, all relevant frequency shifts in a $^{40}Ca^+$ ion-crystal get suppressed. Furthermore, entangling atoms on an optical transition can improve the statistical uncertainty as well as the systematic uncertainty by engineering entangled states that are e.g. free of the linear Zeeman shift.

We present progress on tailoring a robust clock transition by dressing both Zeeman manifolds of the $S_{1/2}$ to $D_{5/2}$ transition with four driving RF-fields as well as first results on entangling two Ca^+ ions using a Mølmer-Sørensen gate.

A 14.24 Tue 16:00 Empore Lichthof

A recoil ion source providing slow $^{229(m)}$Th ions in a broad charge state distribution — •Tom Kieck[1,2], Dmitry Budker[1,2,3,4], Christoph E. Düllmann[1,2,4,5], Raphael Haas[1,2], Dennis Renisch[1,2], and Ferdinand Schmidt-Kaler[1] — [1]Johannes Gutenberg-Universität Mainz, Germany — [2]Helmholtz-Institut Mainz, Germany — [3]University of California, Berkeley, CA, USA — [4]PRISMA Cluster of Excellence, Mainz, Germany — [5]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

^{229m}Th is a nuclide of high interest in fundamental and applied physics. Currently, ^{229m}Th is best obtained from the alpha decay of ^{233}U. The TACTICa (Trapping And Cooling of Thorium Ions with Calcium) collaboration aims at capturing Th ions inside a $^{40}Ca^+$ Coulomb crystal. They will be sympathetically cooled in a Paul trap and available for precision spectroscopy. For ^{229}Th, the alpha decay imparts 84 keV kinetic energy. The recoil ions are electrostatically decelerated to facilitate trapping. This mechanism retains the original charge state distribution up to high charge states. Complementary, a laser-ablation ion source is installed, providing Th^{1+} ions of isotopes available in macroscopic quantities. This combination of ion sources allows the investigation of a large number of Th isotopes in different charge states. Simulation results of the ion beam, alpha spectra of the ^{233}U source and a first design of the setup will be presented.

R. Haas et al., arXiv:1911.11674

A 14.25 Tue 16:00 Empore Lichthof

A free-electron target for the ion-storage rings at FAIR: current status — Carsten Brandau[1,2], Alexander Borovik Jr[1], •B. Michel Döhring[1,2], Benjamin Ebinger[1,2], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt (Germany)

The Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany, is presently under construction and will provide worldwide unique possibilities for heavy-ion research. For the investigation of electron-ion collisions, a free-electron target is presently built [1]. It will be installed initially at the low-energy ring CRYRING@ESR but can also easily be adapted to the other heavy-ion storage rings of FAIR. The electron target will operate in 90 degrees geometry between ion and a ribbon-shaped electron beam. The electrode geometry has been designed such that a large part of the well localized electron-ion interaction region can be easily accessed by x-ray and electron spectrometers under large solid angles. We will summarize the physics, the concept and the present status of the project.

[1] M. Lestinsky et al., 2016 Eur. Phys. J. ST 225 797.

A 14.26 Tue 16:00 Empore Lichthof

Study of astrophysical plasmas in a compact EBIT — •Moto Togawa, Steffen Kühn, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik

The Heidelberg compact electron beam ion traps (HC-EBIT) use permanent magnets instead of superconducting coils, operate at room temperature, and are easily transportable. They reliably produce highly charged ions (HCI) at electron-beam energies up to 10 keV. Combining them with a high brilliance synchrotron-radiation source enables resonant fluorescence spectroscopy in the X-ray region, and precision measurements stringently benchmarking atomic structure calculations and models of astrophysical plasmas. We show how, using narrow bandwidth X-ray sources and a HC-EBIT with an off-axis electron gun (Polar-X-EBIT) specific electronic processes present in astrophysical plasmas can be separately studied.

A 14.27 Tue 16:00 Empore Lichthof

ECR ion source for the local injector of CRYRING at GSI/FAIR — •Sebastian Fuchs[1,2], Paul Willamowski[1], Alexander Borovik Jr[1], Svetlana Fedotova[2], Gleb Vorobjev[2], Frank Herfurth[2], Michael Lestinsky[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany

We report on the adaptation of an all-permanent-magnet 10-GHz electron-cyclotron-resonance (ECR) ion source for the local injector of the low-energy heavy-ion storage ring CRYRING at the international Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. CRYRING which is currently being commissioned offers world-unique possibilities for atomic physics experiments [1]. The here featured activity aims at providing a reliable and powerful ECR ion source of the 'multi-mode' type [2] for the local injector, that can be used without the GSI accelerator chain for first in-ring experiments. The ion source was optimized at the Giessen ion-source test bench,

e. g. for intense C^+ ion beam production using different source gases reaching a C^+ current of up to 15.5 μA. The employment of the present ion source at CRYRING required several adjustments, among others, an adaptation of the ion-beam forming optics onto the acceleration voltage of 40 kV.

[1] M. Lestinsky *et al.*, Eur. Phys. J. ST **225**, 797 (2016).
[2] F. Broetz *et al.*, Phys. Scr. **T92**, 278 (2001).

A 14.28 Tue 16:00 Empore Lichthof

BMBF-Verbundforschung im Rahmen von APPA@FAIR — •Stefan Schippers[1] und Thomas Stöhlker[2,3] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt — [3]Helmholtzinstitut Jena, 07743 Jena

APPA (Atomic and Plasma Physics and Applications) ist eine der vier Forschungssäulen von FAIR. Die unter dem gemeinsamen Dach von APPA agierenden internationalen Forschungskollaborationen BIOMAT (Biophysik und Materialwissenschaften), HED@FAIR (Plasmaphysik) und SPARC (Atomphysik), konzentrieren sich auf die Erforschung der Bausteine und Phänomene der Materie unter extremen Bedingungen (hohe Felder, Dichten, Drücke und Temperaturen). Gegenstand der APPA-Verbundforschung sind thematisch abgestimmte Forschungsprojekte im Bereich beschleunigergestützter Experimente mit schweren Ionen an der zukünftigen FAIR-Anlage. Zentrale Punkte dabei sind: 1) Fortentwicklung der Großgeräteinfrastruktur, vor allem Forschung und Entwicklung zur Steigerung der wissenschaftlichen Leistungsfähigkeit vorhandener Anlagen sowie zukünftiger Beschleuniger- und Detektorsysteme einschließlich der entsprechenden Basistechnologien, 2) Aufbau der APPA-Experimente bei FAIR und 3) Durchführung des Forschungsprogramms der derzeit laufenden FAIR-Phase 0.

A 14.29 Tue 16:00 Empore Lichthof

Towards the Development of the Compact Setup for Ion-Production and Spectroscopy — •Alexander Borovik Jr. — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany

A compact setup based on the MaMFIS [1] technology, capable of production and trapping of highly charged ions under room temperatures is under operation in Giessen since several years. It constantly undergoes uprades aimed at its development into a versatile setup for spectroscopy of highly charged ions with a possibility of their extraction for further utilization. In the present contribution, we report on the development of a new compact electron gun, which, under high spatial constraints, is capable of delivering electron beams with energies at least up to 15keV and can be moved along the X,Y and Z axes during operation. The latter feature allows for the optimization of the electron-beam transmission, which, as a result, can now be as high as 99,999%. The progress in the development of the compact power-efficient electron collector will also be addressed. [1] V.P. Ovsyannikov A.V. Nefiodov 2016 *Nucl. Instrum. Meth. B* **370** 32-41

A 14.30 Tue 16:00 Empore Lichthof

Relativistic calculation of one Photoionization of neutral atom — •Jiahao Fan[1], Jiri Hofbrucker[1,2], Andrey Volotka[2,3], and Stephan Fritzsche[1,2] — [1]Friedrich-Schiller-Universität Jena,Gemany — [2]Helmholtz-Institut Jenam, Gemany — [3]St. Petersburg State University, Russia

Photoionzation is one of the most fundamental atomic process which occurs in the light-matter interaction, and the most extensively studied. The neutral atom obtains the energy carried by a photon, and then the electron can be excited which has the corresponded Binding energy, and the electron is excited into continuum state and leaves a ion. Only photons that posses an energy corresponding to an ionization the electron transition of the system are absorbed, with a certain probability. This makes Photoionization very wavelength sensitive. My work is to verify and simulate the total cross section of this process within the framework of relativistic second-order Pertubation theory and independent particle approximation on Mathmatica, compare the different results in F, Ne and Na elements. Indeed I checked the different differential cross section distribution with different incoming photon energy.

A 15: Precision spectroscopy of atoms and ions II

Time: Wednesday 11:00–13:15 Location: f107

Invited Talk A 15.1 Wed 11:00 f107

The Alphatrap *g*-factor experiment — •Tim Sailer[1], Ioanna Arapoglou[1], Alexander Egl[1], Felix Hahne[1,2], Martin Höcker[1], Peter Micke[1,3], Bingsheng Tu[1], Andreas Weigel[1], José R. 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 — [3]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig

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 (HCI) up to hydrogen-like $^{208}Pb^{81+}$. In the electrical field of the nucleus with a strength of the order of 10^{16} V/cm, bound-state quantum electrodynamics can be tested with highest precision in extreme conditions.

We recently performed the first measurements at the Alphatrap setup, measuring the g-factor of boron-like $^{40}Ar^{13+}$. Additionally, a novel measurement technique that enables laser spectroscopy on single ions has been developed and was used to measure the $2p^2P_{1/2} - {}^2P_{3/2}$ fine-structure transition on the same ion. Furthermore, the Alphatrap setup has recently been connected via a UHV beamline to the Heidelberg electron-beam-ion-trap (HD-EBIT), which gives access to heavy highly-charged ions. First ions produced in that EBIT have been successfully loaded and stored in Alphatrap with corresponding measurements being set up. The results of these measurements and prospects of upcoming studies will be discussed.

A 15.2 Wed 11:30 f107

A New Experiment for the Measurements of the Nuclear Magnetic Moment of $^3He^{2+}$ and the Ground-State Hyperfine Splitting of $^3He^+$ — •Marius Müller[1,2], Stefan Dickopf[1,2], Andreas Mooser[1], Antonia Schneider[1], Tom Segal[1], Stefan Ulmer[3], Jochen Walz[4,5], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Ruprecht-Karls-Universität, Heidelberg, Germany — [3]RIKEN, Ulmer Fundamental Symmetries Laboratory, Wako, Japan — [4]Johannes Gutenberg-Universität, Mainz, Germany — [5]Helmholtz-Institut Mainz, Germany

The Heidelberg ^{3}He-experiment is aiming at the first direct high-precision measurement of the nuclear magnetic moment of $^3He^{2+}$ with a relative uncertainty on the 10^{-9} level and an improved measurement of the ground-state hyperfine splitting of $^3He^+$ by at least one order of magnitude. The helion nuclear magnetic moment is an important parameter for the development of hyperpolarized ^{3}He-NMR-probes for absolute magnetometry. The HFS measurement of $^3He^+$ is sensitive to nuclear structure effects and would give information about such effects in a three-nucleon system. For both measurements a four Penning trap setup was designed and similar techniques as already demonstrated in proton and antiproton magnetic moment measurements [1,2] are going to be applied. The current status of the experiment is presented.

[1] Schneider et al., Science Vol 358, 1081 (2017)
[2] Smorra et al., Nature, Vol 550, 371 (2017)

A 15.3 Wed 11:45 f107

A robust clock transition on $^{40}Ca^+$ with a continuous dynamical decoupling scheme — •Kai Dietze[1,2], Lennart Pelzer[1,2], Nati Aharon[3], Ludwig Krinner[1,2], Nicolas Spethmann[1], Alex Retzker[3], and Piet Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig,D — [2]Leibniz-Universtität-Hannover,30167 Hannover,D — [3]The Hebrew University of Jerusalem, 91904 Jerusalem, IL

The statistical uncertainty of optical atomic clocks based on single trapped ions is limited by long averaging times. Referencing the clock laser simultaneously on large ensembles of ions can improve the laser frequency noise and thus allow longer probe times. However, trapping a larger number of ions introduces several systematic frequency shifts, resulting in inhomogeneous broadening of the clock transition. In our experiment, we couple the clock transition between the $4S_{1/2}$

and $5D_{5/2}$ Zeeman-substates of $^{40}Ca^+$ with radiofrequency fields, to engineer dressed states with significantly reduced systematic shifts. The scheme is based on up to four driving fields to suppress the linear Zeeman-, quadrupole-, and tensor ac-Stark shifts by orders of magnitude [1]. We present predictions on the performance of these strongly coupled systems as a reference transition for laser stabilization and experimental results implementing this scheme in our segmented Paul-trap as a multi-ion approach.

[1] Aharon *et al.*, New Journal of Physics **21** (2019) 083040.

A 15.4 Wed 12:00 f107

Collinear Laser Spectroscopy of Ca^+: Solving the field shift puzzle of the $4s \to 4p$ transitions — •Patrick Müller[1], Phillip Imgram[1], Kristian König[2], Jörg Krämer[1], Bernhard Maass[1], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]NSCL, Michigan State University

The ratio of the isotopic field shifts can be accessed well from theory as well as from experiment and hence, serves as a profound benchmark for atomic structure calculations. Experimentally, it can be determined solely from optical frequency measurements of two different transitions over the isotopic chain. Previous ion trap measurements of the $4s\,^2S_{1/2} \to 4p\,^2P_{1/2}$ (D1) and $4s\,^2S_{1/2} \to 4p\,^2P_{3/2}$ (D2) transition resulted in a field shift ratio of $F_{D2}/F_{D1} = 1.0085(12)$ which exceeds all theoretical predictions and even the boundaries set by the hydrogenic model [1].

We report on collinear laser spectroscopy measurements of the $4s \to 4p$ as well as the $3d \to 4p$ transition frequencies in naturally abundant Ca^+ isotopes at the 100-kHz precision level. The $4s \to 4p$ transitions were used to determine the field shift ratio F_{D2}/F_{D1} in a King plot analysis. The new experimental value agrees well with preceding atomic structure calculations and was successfully checked for self-consistency by combining the results of the $4s \to 4p$ and $3d \to 4p$ transitions to form ring closures across the contributing states.

Acknowledgement This work has been supported by BMBF under contract # 05P19RDFN1.

[1] Shi et al., Applied Physics B **123**, 2 (2016)

A 15.5 Wed 12:15 f107

Non-perturbative calculation of the two-loop self-energy contribution to the bound-electron g-factor — •Bastian Sikora[1], Vladimir A. Yerokhin[2], Natalia S. Oreshkina[1], Halil Cakir[1], Chrisoph 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

We present the status of our ongoing calculation of the two-loop self-energy contribution to the bound-electron g-factor, which currently gives rise to the largest uncertainty of theoretical g-factor predictions. In our approach, the interaction between electron and nucleus is taken into account exactly. We have obtained full results for the loop-after-loop diagrams, and partial results for the nested and overlapping loop diagrams.

Our results will be highly relevant for g-factor measurements with high-Z ions as well as for an independent determination of the fine-structure constant α from the bound-electron g-factor in the near future.– [1] B. Sikora, V. A. Yerokhin, N. S. Oreshkina *et al.*, in press, arXiv:1804.05733v1 [physics.atom-ph] (2018).

A 15.6 Wed 12:30 f107

Two-loop radiative corrections to the bound-electron g factor involving the magnetic loop — •Vincent Debierre, Bastian Sikora, Halil Cakir, Natalia S. Oreshkina, Zoltán Harman, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg

The g factor of bound electrons in light and medium-light hydrogen-like ions (e.g. C, Si) has been measured with an accuracy of a few parts in 10^{11} [S. Sturm *et al.*, Nature **506**, 467 (2014)]. Experiments such as ALPHATRAP and HITRAP aim at reaching this accuracy with heavy, few-electron ions, motivating the evaluation of two-loop radiative corrections.

We calculate a specific set of two-loop corrections to the bound-electron g factor in the hydrogen-like ground state. Diagrams belonging to this set include the magnetic loop as a subprocess and vanish in the free-loop approximation [V.A. Yerokhin and Z. Harman, Phys. Rev. A **88**, 042502 (2013)]. At the lowest nonvanishing order, they involve the scattering of the external magnetic field in the Coulomb field of the ionic nucleus. We computed the electric-loop-magnetic-loop diagram, the magnetic-loop-after-loop diagram, and the self-energy-magnetic-loop diagrams. Our approach treats the binding of the electron to the nucleus nonperturbatively.

The computed corrections to the g factor are of order up to 10^{-8} in the case of ^{82}Pb. These corrections will be relevant to the projected determination of the fine-structure constant from g-factor measurements.

A 15.7 Wed 12:45 f107

The g factor of bound electrons as a probe for physics beyond the Standard Model — •Vincent Debierre, Christoph H. Keitel, and Zoltán Harman — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg

We demonstrate the relevance of the g factor of bound electrons in few-electron ions to the search for physics beyond the Standard Model (SM). The contribution to the g factor from hypothetical forces beyond the SM can be computed and, when compared to existing and projected experimental data, used to derive competitive bounds on the parameters of these forces.

A first method to implement this program consists in comparing the best available theoretical and experimental results on the g factor. We also use data on the difference of g factors of different electronic levels [V.A. Yerokhin *et al.*, Phys. Rev. Lett. **116**, 100801 (2016)]. Stringent bounds can be obtained in the future with this method, through the furtherance of bound state QED calculations at the two-loop level.

Another method makes use of the isotope shift. Inspired by a recent proposal concerning optical frequencies in ions [J.C. Berengut *et al.*, Phys. Rev. Lett. **120**, 091801 (2018)], we propose to use precision spectroscopy of the isotope shifts in the g factor of few-electron ions, in order to obtain bounds on proposed new forces. By carefully considering subleading nuclear corrections to the g factor, our treatment allows for the precise interpretation of isotope shift data. We also combine the isotope shift with the above-mentioned weighted difference, which yields competitive bounds [V. Debierre *et al.*, arXiv:1901.06959].

A 15.8 Wed 13:00 f107

Laser photodetachment spectroscopy in a MR-ToF device — •D. Leimbach[1,2,3], V. Lagaki[1,4], for the GANDALPH[1,2], and MIRACLS collaboration[1,4] — [1]CERN, Geneva, Switzerland — [2]Dep. of Physics, University of Gothenburg, Sweden — [3]Inst. für Physik, Johannes Gutenberg-Universität, Germany — [4]Universität Greifswald, Germany

The electron affinity (EA) is the energy released when an additional electron is bound to a neutral atom, creating a negative ion. Due to the lack of a long-range Coulomb attraction, the EA is dominated by electron-correlation effects. Hence, EAs are strong experimental benchmarks on theoretical atomic-structure models which go beyond the independent particle approximation. Although the isotope shift (IS) in the EA of stable chlorine (Cl) isotopes has been measured, recent calculations improve the theoretical precision beyond the experimental one. For this reason, we plan to perform laser photodetachment spectroscopy to determine this IS more precisely. This will be achieved by reusing the ion beam when trapped in an MR-ToF device. Thereby, the measurement efficiency is increased which allows us to employ a narrow band cw laser compared to the previously used high-power and broad-band pulsed laser. Once successful, we will extend this type of studies for the first time to long-lived radionuclides by determining the IS of 36Cl(vs 35Cl). This novel approach can be applied to EA-IS measurements of short-lived radionuclides as well as EA determination of sparsely produced and eventually superheavy elements. We will present the technique and status of the experimental campaign.

A 16: Interaction with strong or short laser pulses I

Time: Wednesday 11:00–13:15 Location: a320

Invited Talk A 16.1 Wed 11:00 a320

Photoionization dynamics of many-electron atoms: an accelerated Green functions approach — •Michael Bonitz, Niclas Schlünzen, Jan-Philip Joost, and Maximilian Rodriguez Rasmussen — Institut für Theoretische Physik und Astrophysik, Universität Kiel, Leibnizstr. 15

The accurate description of the nonequilibrium dynamics of correlated electrons in atoms under laser excitation remains a key topic in many fields. Among others, the nonequilibrium Green functions (NEGF) method has proven to be a powerful tool to capture electron-electron correlations [1]. However, NEGF simulations are computationally expensive due to their T^3 scaling with the simulation duration T. With the introduction of the generalized Kadanoff-Baym ansatz [2] (GKBA), T^2 scaling could be achieved for second order Born (SOA) selfenergies [3], which has substantially extended the scope of NEGF simulations. Recently [4], we could achieve linear scaling with SOA and even GW selfenergies which is expected to lead to breakthroughs for simulating the correlated electron dynamics.

[1] K. Balzer and M. Bonitz, Lect. Notes Phys. **867** (2013)
[2] P. Lipavský *et al.*, Phys. Rev. B **34**, 6933 (1986)
[3] S. Hermanns, K. Balzer, and M. Bonitz, Phys. Scripta **T151**, 014036 (2012)
[4] N. Schlünzen *et al.*, submitted for publication, arXiv:1909.11489 (2019)

A 16.2 Wed 11:30 a320

Revealing the strongly suppressed laser-coherent photoelectron signal using phase-of-the-phase spectroscopy — •Vasily Tulsky, Bennet Krebs, Felix Trepkau, Josef Tiggesbäumker, and Dieter Bauer — University of Rostock, 18051 Rostock, Germany

When a many-electron system is exposed to intense laser radiation, the generated photoelectron spectrum may include a significant or even dominant contribution of laser-incoherent electrons. Those can originate from thermal emission (thus, initially incoherent) or be influenced by multiple scattering before reaching the detector (therefore, losing the coherence). We propose a way to study the coherent part of photoelectron spectra using the phase-of-the-phase (PoP) technique [1-3]. We demonstrate that PoP can be successfully applied even when the incoherent part of the photoelectron signal appears to be dominant [4].

[1] S. Skruszewicz, J. Tiggesbäumker, K.-H. Meiwes-Broer, M. Arbeiter, Th. Fennel, and D. Bauer, Phys. Rev. Lett. 115, 043001 (2015)
[2] M. A. Almajid, M. Zabel, S. Skruszewicz, J. Tiggesbäumker and D. Bauer, J. Phys. B 50, 19 (2017)
[3] V. A. Tulsky, M. A. Almajid, D. Bauer, Phys. Rev. A 98, 053433 (2018)
[4] V. A. Tulsky, B. Krebs, J. Tiggesbäumker, D. Bauer, arXiv:1911.0047 (2019) (submitted to J. Phys. B)

A 16.3 Wed 11:45 a320

A novel method to construct analytical solutions of the Dirac Equation — •Andre Gontijo Campos — Max Planck institute for Nuclear Physics

The complexity of the structure of the Dirac equation, which is a system of four coupled differential equations, renders it very difficult to study. The number of closed-form solutions is very limited due to the intricate structure of Dirac matrices, which couple the four components of the spinorial wave function. For this reason, only highly symmetric systems can be studied by analytical means; the mathematical description of more realistic systems should be based on approximation methods such as semi-classical theory or numerical calculations. However, the smallness of the time scale of relativistic electron dynamics renders the numerical solution notoriously difficult, requiring substantial computer resources. Here, we provide a very powerful method to arrive at the sought-after general analytical solutions to the Dirac equation, which fully explores the geometry of the Lorentz group. For instance, we construct time-dependent electromagnetic fields that coherently steer the electron's spinorial wave function to follow a given path. Moreover, we also present solutions involving a plane electromagnetic wave and a combination of generally inhomogeneous electric and magnetic fields. The newly developed solutions unravel exciting new insights on the complex quantum dynamics of relativistic electrons. The presented method constitutes an important tool with a broad range of applications.

A 16.4 Wed 12:00 a320

Excitations of forbidden transitions by twisted light in different polarization states — •Sabrina A.-L. Schulz[1,2], Anton A. Peshkov[1,2], Robert A. Müller[1,2], and Andrey Surzhykov[1,2] — [1]PTB Braunschweig, Germany — [2]TU Braunschweig, Germany

In recent years the interest in twisted light has been steadily increased both in experiment and theory. Twisted (or vortex) light beams differ substantially from plane waves: twisted photons with helical phase-fronts carry nonzero projection of orbital angular momentum (OAM) onto their propagation direction, and their characteristic intensity profile has an annular character with a minimum in the center. The combination of these properties makes twisted light excellent candidates for applications in precision experiments. In this contribution, we study the excitation of dipole-forbidden transitions in a single trapped atom by using twisted Bessel beams. A transition rate is derived for the general case when light propagation direction does not coincide with the atomic quantization axis defined by an applied magnetic field. Particular emphasis is paid to the electric octupole (E3) transition $^2S_{1/2} \to {}^2F_{7/2}$ in a single trapped $^{171}Yb^+$ ion, driven by linearly, radially, or azimuthally polarized Bessel beams. The work shows that the excitation rate for twisted light can be significantly enhanced under certain orientations of the external magnetic field.

A 16.5 Wed 12:15 a320

Theoretical Prediction of the Attoclock Angle — •Soumi Dutta, Ulf Saalmann, and Jan Michael Rost — MPI für Physik komplexer Systeme , Nöthnitzer Str. 38, 01187 Dresden, Germany

An intense, low-frequency, elliptically-polarized laser field lets an electron tunnel from an atom and drives it on a quivering trajectory. The asymptotic angle, measured in the famous attoclock experiment, indicating the electron's release time, is spoiled by the so-called laser-Coulomb interaction. The trajectory from a fully equivalent description with the time-dependent Kramers-Henneberger potential, shows a remarkable similarity with a conventional Kepler hyperbola, albeit with some notable deviations. We discuss those deviations, devise a correction compensating for those and give an (approximate) analytical expression for the attoclock angle.

A 16.6 Wed 12:30 a320

Intra-cavity velocity-map imaging at a rate of 100 MHz — •Jan-Hendrik Oelmann, Janko Nauta, Alexander Ackermann, Patrick Knauer, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Velocity-map imaging of xenon [1-3] is performed in the focus of a femtosecond enhancement cavity. The 100 MHz repetition rate of our frequency comb laser enables the detection of photoelectrons from multiphoton ionization even at very low intensity levels well below 10^{12} W/cm^2 [4]. Because of the highly nonlinear nature of the multiphoton ionization process, electron count rates would dramatically drop at such low laser intensities. For conventional amplified femtosecond laser systems at kHz repetition rates, data acquisition time then increases to technically non-manageable levels. Our setup overcomes this limitation and extends the accessible intensity range to much lower values. Recent results and developments towards the next generation of our experimental setup to study intra-cavity near-threshold ionization and multiphoton excitation will be presented.

[1] H. Helm et al., Phys. Rev. Lett. 70(21), 3221 (1993).
[2] V. Schyja et al., Phys. Rev. A 57(5), 3692 (1998).
[2] B. Wolter, Phys. Rev. X 5(2), 21034 (2015).
[4] J. Nauta et al., *in preparation.*

A 16.7 Wed 12:45 a320

Relativistic analytical model of multi-electron atoms — •Kamil D Dzikowski, Oleg D Skoromnik, Natalia S Oreshkina, and Christoph H Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

We develop a fully relativistic analytical model for computation of observable characteristics of multi-electron atoms and ions. We employ

a complete hydrogen-like basis with an effective nuclear charge parameter for the construction of a perturbation series in the secondary-quantized representation. We study the accuracy of the leading-order approximation for the total binding energies, electron densities, atomic scattering factors and spectra of highly charged ions. The accuracy of calculated characteristics is comparable with the one obtained via advanced numerical solutions of Hartree-Fock equations and thus can replace semi-classical models like the Thomas-Fermi-Dirac model for all applications where they are still utilized.

A 16.8 Wed 13:00 a320

Controlling collective enhancement of above threshold ionization by resonantly exciting helium droplets — •Rupert Michiels[1], Mahmoud Abu-samha[2], Lars Bojer Madsen[3], Ulrich Bangert[1], Marcel Binz[1], Lukas Bruder[1], Carlo Callegari[4], Rowan Duim[1], Raimund Feifel[5], Michele Di Fraia[4], Aaron Cristopher LaForge[6], Paolo Piseri[7], Oksana Plekan[4], Kevin Charles Prince[4], Richard James Squibb[5], Stefano Stranges[8], Daniel Uhl[1], Andreas Wituschek[1], Marcel Mudrich[3], and Frank Stienkemeier[1] — [1]University of Freiburg, Germany — [2]American University of the Middle East, Kuwait — [3]Aarhus University, Denmark — [4]Elettra-Sincrotrone Trieste, Italy — [5]University of Gothenburg, Sweden — [6]University of Connecticut, USA — [7]Università degli Studi die Milano, Italy — [8]University Sapienza Rome, Italy

Condensed matter, especially clusters and nanodroplets, holds the promise of enhancing high-order nonlinear optical effects due to their high local density. Here, we report on the observation of enhanced intensity from the emission of above threshold photoelectrons (ATI). ATI electrons are created by ionizing multiply excited helium nanodroplets in the 1s4p state using 400 nm laser radiation. The intensity of high-order ATI electrons is shown to be enhanced by several orders of magnitude when compared to excited helium in the gasphase. Furthermore, we show that the strength of the ATI enhancement can be tuned by changing the total number of excited atoms in the droplet.

A 17: Ultracold atoms, ions, and BEC IV (joint session A/Q)

Time: Wednesday 11:00–13:00 Location: f303

Invited Talk A 17.1 Wed 11:00 f303

Fate of the Amplitude Mode in a Trapped Supersolid — •Jens Hertkorn[1], Fabian Böttcher[1], Mingyang Guo[1], Jan-Niklas Schmidt[1], Tim Langen[1], Hans Peter Büchler[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Bose-Einstein condensates (BECs) with strong magnetic dipolar interactions have an excitation spectrum that can feature a minimum known as roton minimum. In a certain interaction parameter range, the roton can induce an instability to the ground state leading to the formation of quantum droplets purely stabilized by quantum fluctuations. These droplets have been shown to realize a counter-intuitive phase of matter called supersolid, which combines the frictionless flow of a superfluid with the crystalline order of a solid.

We theoretically investigate the spectrum of elementary excitations of a trapped dipolar quantum gas across the BEC-supersolid phase transition. The energetically low-lying excitations and the relation between the spectrum of the BEC and the supersolid reveal the existence of distinct Higgs amplitude and Nambu-Goldstone modes that emerge from the softening roton modes at the phase transition point [1].

[1] J. Hertkorn et al., Phys. Rev. Lett. **123**, 193002 (2019)

A 17.2 Wed 11:30 f303

The low-energy Goldstone mode in a trapped dipolar supersolid — •Mingyang Guo[1], Fabian Böttcher[1], Jens Hertkorn[1], Jan-Niklas Schmidt[1], Matthias Wenzel[1], Hans Peter Büchler[2], Tim Langen[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Stuttgart, Germany — [2]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Stuttgart, Germany

A supersolid is a counter-intuitive state of matter that combines the frictionless flow of a superfluid with the crystal-like periodic density modulation of a solid, simultaneously breaking the global gauge symmetry and translational symmetry. Although predicted more than 50 years ago, it is only recently that its defining properties are observed in ultracold quantum gases.

In this talk, I will focus on the realization of a supersolid state with a self-organized array of dipolar quantum droplets, where the crystallization arises owing to intrinsic interactions within the Dysprosium atoms. Besides the periodic density modulation and global phase coherence, the low-energy Goldstone mode, associated directly to the two broken symmetries, is observed. The dynamics of this mode features an out-of-phase oscillation of the crystal array and the superfluid density while keeping the center-of-mass constant. This mode exists only as a result of the phase rigidity of the state, and therefore confirms the superfluidity of the realized supersolid.

A 17.3 Wed 11:45 f303

Strongly correlated Bose-Einstein Condensates with spin-orbit coupling of the Rashba-Dresselhaus type — •Clemens Staudinger and Robert E. Zillich — Institute for Theoretical Physics, Johannes Kepler University Linz, Austria

In a Bose-Einstein condensate (BEC) it is possible to couple two internal states (pseudospin up and down) in a way that the resulting Hamiltonian contains a coupling between the linear momentum and the pseudospin (Rashba-Dresselhaus coupling). Experimentally this has been achieved by irradiating the BEC with lasers of different frequencies. Such BECs have been treated extensively within mean-field theories [1]. Instead, we propose a new variational Hyper-Netted-Chain method, which accounts for correlations nonperturbatively, but is orders of magnitude faster than quantum Monte-Carlo simulations [2]. With our method we a able to accurately calculate properties of the ground-state of the BEC such as the pair-distribution function, the structure factor and other thermodynamic quantities such as the energy or the chemical potential.

[1] Y.-J. Lin, K. Jiménez-García and I. B. Spielman, Nature 471, 83 (2011).

[2] A. Ambrosetti, P. L. Silvestrelli, F. Toigo, L. Mitas, and F. Pederiva, Phys. Rev. B 85, 045115 (2012).

A 17.4 Wed 12:00 f303

Probing the role of long-range coherence for superfluid dynamics by disorder quenches — •Jennifer Koch[1], Benjamin Nagler[1,2], Sian Barbosa[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

Quantum fluids exhibit a well-defined phase, which can be interferometrically measured. The direct connection of long-range coherence with superfluid transport and expansion dynnamics is, however, challenging to access experimentally. I report on experimentally revealing the role of long-range coherence for superfluid flow in an interacting gas of ^{6}Li atoms, quenched into and out of optical disorder. I will discuss our investigations about the density and superfluid-expansion response of a molecular Bose-Einstein condensate after quenching. We measure the breakdown and reoccurrence of superfluid hydrodynamics. We track the response times on which the system relaxes to a new equilibrium and relate the time scales to fundamental energy scales of the system. Our results shed light onto the importance of long-range phase coherence for superfluid flow, and also suggest a possible route of studying complex phase dynamics in superfluids by imprinting disordered phases.

A 17.5 Wed 12:15 f303

Tracking Rydberg atoms with Bose-Einstein Condensates — •Shiva Kant Tiwari and Sebastian Wüster — Indian Institute of Science Education and Research (IISER) Bhopal Bhopal Bypass Road, Bhauri Bhopal - 462066, M.P. India

We propose to track the position and velocity of mobile Rydberg excited impurity atoms through the elastic interactions of the Rydberg electron with a host condensate [1]. Tracks first occur in the condensate phase, but are then naturally converted to features in the condensate density or momentum distribution. The condensate thus acts analogously to the cloud or bubble chambers in the early days of elementary particle physics. The technique will be useful for exploring Rydberg-Rydberg scattering, rare inelastic processes involving the Rydberg impurities, coherence in Rydberg motion, and forces exerted by the condensate on the impurities [2]. Our simulations show that resolvable tracks can be generated within the immersed Rydberg lifetime and condensate heating is under control. Finally, we demonstrate the utility of this Rydberg tracking technique to study ionizing Rydberg collisions or angular momentum changing interactions with the condensate [3].

References: [1] R. Mukherjee, et al. Phys. Rev. Lett. 115, 040401 (2015). [2] G. E. Astrakharchik, et al. Phys. Rev. A 70, 013608 (2004). [3] M. Schlagmüller, et al. Phys. Rev. X 6, 031020 (2016).

A 17.6 Wed 12:30 f303

Rotons and Maxons in a Rydberg-Dressed Bose-Einstein Condensate — •Gary McCormack[1], Rejish Nath[2], and Weibin Li[1] — [1]School of Physics and Astronomy, and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, Nottingham, UK — [2]Indian Institute of Science Education and Research, Pune, India

We investigate a three-dimensional Bose-Einstein condensate with a long-range soft-core two-body interaction. This interaction is induced by laser coupling the condensed atom to a highly excited Rydberg state off-resonantly. We show that the long-range interaction drastically alters the dispersion relation, giving rise to both roton and maxon modes. While rotons are typically responsible for density modulations throughout the system, maxons are normally unstable and hence decay quickly once excited, as predicted in dipolar condensates. We show that maxon modes in the Rydberg-dressed condensate, on the contrary, is stable in the dynamics. We provide a scheme to trigger the maxon mode through a quench, i.e. suddenly activation of the strong soft-core interaction. The emergence of the maxon is accompanied by persistent, high frequency oscillations in the quantum depletion, while rotons cause much slower oscillations. Through a self-consistent Bogoliubov approach, we identify the dependence of maxon modes on the soft-core interaction. We also reveal how the maxons will modify the dynamics of density-density correlations and number fluctuations of the condensate. Our study paves a new route to probe exotic quasiparticles in ultracold Bose gases with Rydberg-dressed long-range interactions.

A 17.7 Wed 12:45 f303

Studies of circular Rydberg states in an ultracold atomic gas — •Christian Hölzl, Thomas Dieterle, Moritz Berngruber, Felix Engel, Robert Löw, Tilman Pfau, and Florian Meinert — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Hybrid systems of ions immersed in ultracold atomic gases provide appealing means for studies comprising cold collisions, ultracold chemistry, or strongly interacting impurities. Recently, we have demonstrated a new approach for embedding a single ionic impurity into a Bose-Einstein condensate exploiting a highly excited Rydberg atom [1,2]. Here, the Rydberg core acts as a sub-μK cold ion while the Rydberg electron protects the ion from detrimental stray electric fields. In this context, circular Rydberg states are appealing candidates to improve on lifetimes of the impurity. We will present the status of our work to access circular Rydberg states from an ultracold Rubidium sample.

[1] K. S. Kleinbach, F. Engel, T. Dieterle, R. Löw, T. Pfau, and F. Meinert, Phys. Rev. Lett. 120, 193401 (2018)
[2] F. Engel, T. Dieterle, T. Schmid, C. Tomschitz, C. Veit, N. Zuber, R. Löw, T. Pfau, and F. Meinert, Phys. Rev. Lett. 121, 193401 (2018).

A 18: Lunch talk: German Research Foundation (DFG) (joint session A/K/P/MO/MS/Q)

Time: Wednesday 13:10–13:55 Location: f303

Lunch Talk A 18.1 Wed 13:10 f303

Funding by the German Research Foundation (DFG) – a brief overview — •Andreas Deschner — Deutsche Forschungsgemeinschaft (DFG), Kennedyallee 40, 53175 Bonn, Germany

During the last 100 years, the German Research Foundation (DFG) and its predecessors have been funding research in Germany. Today, the DFG is the central third party funding organization for basic research in Germany. It offers a broad spectrum of funding opportunities from individual grants to larger coordinated programs.

This talk will give a brief outline of the financial framework, the decision-making processes and the funding portfolio of the DFG. I will mostly focus on the different programs that offer support to early career scientists, e.g. the new Walter Benjamin for postdoctoral positions and the Emmy Noether program for junior research groups.

A 19: Interaction with strong or short laser pulses II

Time: Wednesday 14:00–16:15 Location: f107

Invited Talk A 19.1 Wed 14:00 f107

Fragmentation of HeH^+ in strong laser fields — •Florian Oppermann[1], Philipp Wustelt[2], Saurabh Mhatre[3], Stefanie Gräfe[3], Gerhard G. Paulus[2], and Manfred Lein[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Deutschland — [2]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Deutschland — [3]Institut für Physikalische Chemie, Friedrich-Schiller-Universität Jena, Helmholtzweg 4, 07743 Jena, Deutschland

Our previous study of ionization and double ionization of HeH^+ in strong 800 and 400nm laser pulses has shown the important role of nuclear motion before and during the electron removal [1]. Here we move our focus to laser parameters where both dissociation and ionization are of comparable probability. According to simulations, this implies wavelengths around 1 to 2μm. For fixed molecular orientation the ratio ionization/dissociation can be controlled (sometimes even reversed) via the relative phase in a collinearly polarized ω-2ω laser pulse.

A Keldysh parameter can be defined not only for the ionization of HeH^+ but also for the dissociation process [2]. The ratio of the two Keldysh parameters is roughly 10, i. e. one pathway can be placed in the multi-photon regime while the other one is in the tunneling regime. Thus by changing the two-color delay on a subcycle scale the dominating process can be switched from multi-photon to tunneling and back.

[1] Wustelt et al., Phys. Rev. Lett. 121, 073203 (2018)
[2] Ursrey et al., Phys. Rev. A 85, 023429 (2012)

A 19.2 Wed 14:30 f107

Dynamic quantum state holography — •Kevin Eickhoff[1], Stefanie Kerbstadt[1,2], Tim Bayer[1], and Matthias Wollenhaupt[1] — [1]Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Str. 9-11, 26129 Oldenburg — [2]Center for Free-Electron Laser Science (CFEL), Deutsches Elektronen-Synchrotron DESY, Hamburg

We present a pulse-shaper-based holographic technique for the time-resolved and phase-sensitive observation of ultrafast quantum dynamics. The technique combines bichromatic white light polarization pulse shaping with the tomographic reconstruction of photoelectron wave packets. The physical scheme is based on the interference of a probe wave packet from $(3+1)$ resonance-enhanced multiphoton ionization (REMPI) via the target states and a reference wave packet from $(2+1)$ REMPI of the ground state. To create the wave packets, we employ

carrier envelope phase (CEP) stable bichromatic ($2\omega : 3\omega$) pump-probe pulse sequences. The scheme is demonstrated on femtosecond Rydberg wave packet dynamics in potassium atoms using corotating circularly polarized pulse sequences. The interference of continuum states with different angular momenta yields a crescent-shaped photoelectron wave packet rotating in the laser polarization plane due to the interplay of the optical phase and the accumulated quantum phase (Kerbstadt *et al.* Nat. Comm. **10**, 658 (2019)). Access to the photoelectron asymmetry is provided by CEP control of the wave packet's rotation, enabling background-free and time-resolved detection of the crescent's angular motion mapping the bound electron dynamics.

A 19.3 Wed 14:45 f107

Gouy's Phase Anomaly in Electron Waves Produced by Strong-Field Ionization — •Simon Brennecke, Nicolas Eicke, and Manfred Lein — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

Strong-field ionization of atoms in linearly polarized laser fields produces cylindrically symmetric photoelectron momentum distributions that exhibit interference patterns. Here, we solve the long-standing problem that the observed interference fringes could not be fully quantitatively explained in terms of interfering electron trajectories. For a faithful modeling, it is essential to include previously overlooked phase jumps occurring when trajectories pass through focal points. Such phase jumps are known as Gouy's phase anomaly in optics or as Maslov phases in semiclassical theory. When an outgoing wave packet crosses the polarization axis in three dimensions, it is focused due to the rotational symmetry leading to a phase shift of $\pi/2$ (in contrast to the 2D situation). This influences decisively the photoelectron holography fringes. In addition, there exist observable Maslov phases already in two dimensions. Clustering algorithms enable us to implement a semiclassical model with the correct preexponential factor that affects both the weight and the phase of each trajectory. We also derive a simple rule to relate two-dimensional and three-dimensional models.

A 19.4 Wed 15:00 f107

High-harmonic generation in topological graphene-like nanoribbons — •Christoph Jürss and Dieter Bauer — University of Rostock, Germany

The interaction of intense laser-pulses with graphene-like nanoribbons is investigated. The system becomes topological if a (sufficiently large) complex next-nearest neighbor hopping is included. In the topological phase, the ribbon can host edge states, which have no influence on the bulk of the system. The differences between the high-harmonic spectra from finite ribbons and the bulk are studied. These differences indicate the contributions of the edge states to the spectra. Further, the emitted photons show a change in the helicity at a certain energy which depends on the strength of the next-nearest neighbor hopping. This could allow a light source with a controlled helicity of the emitted radiation.

A 19.5 Wed 15:15 f107

Guiding-center motion for electrons in strong laser fields — •Jonathan Dubois[1], Simon Berman[2], Cristel Chandre[3], Turgay Uzer[4], Ulf Saalmann[1], and Jan-Michael Rost[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Strasse 38, 01187 Dresden, Germany — [2]School of Natural Sciences, University of California, Merced, Merced, California 95343, USA — [3]Aix Marseille Univ, CNRS, Centrale Marseille, I2M, Marseille, France — [4]School of Physics, Georgia Institute of Technology, Atlanta, Georgia 30332-0430, USA

The ultimate aim of contemporary ultrashort, ultra strong laser physics is to capture movies of electrons during chemical reactions. Apart from obvious technical difficulties, there has always been a fundamental obstacle to the interpretations of these scans: The motion of an electron in combined laser and electrostatic fields is an unsolved problem. We use a canonical change of coordinates in order to describe the electron motion in terms of its guiding-center. We describe a hierarchy of reduced models for the guiding-center motion based on time averaging of the electron dynamics. We use these reduced models to understand, interpret and assess the electron dynamics and to unravel mechanisms behind nonlinear phenomena observed in experiments.

A 19.6 Wed 15:30 f107

Semiclassical two-step model with quantum input — •Nikolay Shvetsov-Shilovski and Manfred Lein — Leibniz Universität Hannover

Semiclassical models employing classical trajectories are one of the main approaches in strong-field physics. The analysis of the classical trajectories makes it possible to understand the physical picture of the phenomenon under study.

Here we present a semiclassical two-step model with quantum input (SCTSQI) [1]. In the SCTSQI the initial conditions for classical trajectories are determined by the exact quantum dynamics. Therefore, the SCTSQI corrects the inaccuracies of the semiclassical two-step model (SCTS) [2] in description of the tunneling step. We show that for ionization of a one-dimensional atom the SCTSQI model yields quantitative agreement with the numerical solution of the time-dependent Schrödinger equation.

[1] N. I. Shvetsov-Shilovski and M. Lein, Phys. Rev A 100, 053411 (2019).

[2] N. I. Shvetsov-Shilovski, M. Lein, L. B. Madsen et al., Phys. Rev. A 94, 013415 (2016).

A 19.7 Wed 15:45 f107

Under-the-barrier reflections and and time delay in strong field ionization. — •Daniel Bakucz Canário, Michael Klaiber, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

We identify the time delay of an ionizing electron wave packet (with respect to the laser peak) in strong field ionization as a phenomenon induced by re-scatterings and interferences of the wavefunction under the Coulomb barrier, corroborating earlier findings relating under-the barrier-scattering to shifts in the momentum probability distribution[1]. We achieve this by separating incoming and outgoing components of the electronic wave function under the barrier, and observing the effect of manually removing the reflected wavefunction components. A simple 1D model of ionization within strong field approximation is considered but the conceptual framework is general. Finally, we compare the calculated electron trajectory after ionization with equivalent adiabatic and classical trajectories and find that, in the regime of small Keldysh parameters, the three trajectories rapidly become indistinguishable, potentially posing challenges for the oft used back propagation method.

[1] M. Klaiber *et al*, Phys. Rev. Lett. **120**, 013201 (2018)

A 19.8 Wed 16:00 f107

Polarization Shaping of High Harmonics generated by structured laser pulses — •Jonas Wätzel and Jamal Berakdar — Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Halle (Saale)

High-order harmonic generation (HHG) from atoms driven by IR vector beams and beams carrying orbital momentum has been demonstrated experimentally [1]. Here we show how a spatiotemporal shaping of the pulse allows to imprint locally circular polarization onto the emitted radiation. As shown analytically and numerically, the time-dependent Stokes parameters, representing the ratio between linear and circular polarization can be controlled by simply tuning the parameters of the IR field. The proposed scheme offers a method for a full polarization control of the emitted HHG by only one input light field.

[1] Carlos Hernández-Garcia et al. "Extreme ultraviolet vector beams driven by infrared lasers", Optica 4, 520-526 (2017)

A 20: Precision spectroscopy of atoms and ions III

Time: Wednesday 14:00–16:00 Location: f303

Invited Talk A 20.1 Wed 14:00 f303

Coherent laser spectroscopy of highly charged ions using quantum logic — •Peter Micke[1,2], Tobias Leopold[1], Steven A. King[1], Erik Benkler[1], Lukas J. Spiess[1], Lisa Schmöger[1,2], Maria Schwarz[1,2], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Max-Planck-Institut für Kernphysik, Heidelberg — [3]Institut für Quantenoptik, Leibniz Universität Hannover

Highly charged ions (HCI) are an extreme form of matter with favorable properties for novel high-accuracy atomic clocks and sensitive tests for physics beyond the Standard Model. We demonstrate the first coherent laser spectroscopy of HCI and improve the precision of the previous state-of-the-art spectroscopy by many orders of magnitude, thus unlocking the potential of HCI for applications in frequency metrology and the search for a time variation of fundamental constants [1].

We isolate a single Ar^{13+} HCI, produced in a hot plasma at a million kelvins, and confine it together with one Be^+ ion in a Paul trap. This two-ion crystal is then cooled to its quantum-mechanical ground state of motion. Using an ultra-stable clock laser and the quantum logic technique, we resolve the electric-dipole forbidden fine-structure transition of Ar^{13+} at 441 nm with a fractional frequency uncertainty of 3×10^{-15}. Furthermore we measure the lifetime and g-factor of the excited state. The latter one resolves a discrepancy between previous theoretical predictions.

[1] P. Micke, T. Leopold, S. A. King et al., *Nature* (accepted).

A 20.2 Wed 14:30 f303

Identification of clock transitions in highly charged ions by Penning-trap mass spectrometry — •R. X. Schüssler[1], H. Bekker[1], M. Brass[2], H. Cakir[1], J. R. Crespo López-Urrutia[1], M. Door[1], P. Filianin[1], Z. Harman[1], M. Haverkort[1], W. Huang[1], P. Indelicato[3], C. H. Keitel[1], C. M. König[1], K. Kromer[1], Yu. N. Novikov[4], A. Rischka[1], Ch. Schweiger[1], S. Sturm[1], S. Ulmer[5], S. Eliseev[1], and K. Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Intitute for Theoretical Physics, Heidelberg University, Germany — [3]Laboratoire Kastler Brossel, Sorbonne Université, Paris, France — [4]Petersburg Nuclear Physics Institute, Gatchina, Russia — [5]RIKEN, Fundamental Symmetries Laboratory, Saitama, Japan

Promising candidates for a new generation of clocks are transitions in highly charged ions (HCIs), as, due to their compact size, they are less sensitive to external perturbations. Insufficiently accurate atomic structure calculations often hinder the identification of suitable transitions in HCIs. High-precision Penning-trap mass spectrometry can be used to identify transitions of long-lived metastable states by determining the mass difference of the excited and ground state. Reaching uncertainties of mass-ratio measurements on the level of $\delta m/m \leq 10^{-11}$ or better, the Pentatrap experiment, synchronously operating five Penning traps, is able to identify long-lived metastable states in HCIs with a few eV uncertainty. The talk will cover the first such transition found in $^{187}Re^{29+}$ and plans for future measurements at Pentatrap.

A 20.3 Wed 14:45 f303

Electronic Bridge in ^{229}Th doped CaF_2 — •Brenden Nickerson[1], Martin Pimon[2], Pavlo Bilous[1], Thorsten Schumm[2], and Adriana Pálffy[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg — [2]Technical University of Vienna, Austria

The lowest known nuclear transition of only 8 eV in ^{229}Th could serve as basis for a novel nuclear clock. However, direct photoexcitation of this nuclear state has so far remained elusive. One promising approach is to use thorium-doped VUV-transparent crystals which can host a large number of ^{229}Th nuclei [1,2].

Here an alternative method of excitation using for the first time the concept of electronic bridge (EB) in the crystal is investigated theoretically. EB makes use of the electronic shell as an intermediate stepping stone for the transfer of energy between laser photons and nuclei [3]. In VUV-transparent crystals this process is facilitated by defects, i.e., states appearing in the band gap, caused by the Th doping. In the context of current crystal experiments the EB process promises excitation rates far above direct photoexcitation with current technology. Such results contribute to the development of a nuclear frequency standard based on ^{229m}Th.

[1] Stellmer, Schreitl, & Schumm, Sci. Rep. 5, 15580 (2015)
[2] Dessovic *et al.*, J. Phys.:Condens. Matter 26, 105402 (2014)
[3] Porsev & Flambaum, Phys. Rev. A 81, 032504 (2010)

A 20.4 Wed 15:00 f303

Electronic bridge excitation in highly charged ^{229}Th ions — •Pavlo Bilous, Hendrik Bekker, José R. Crespo López-Urrutia, and Adriana Pálffy — Max Planck Institute for Nuclear Physics, 69117 Heidelberg, Germany

Of all nuclei, the ^{229}Th isotope possesses an extremely low-lying nuclear isomer at approx. 8 eV. This nuclear transition has the potential to provide a first nuclear frequency standard at an unprecedented accuracy, a laser operating between nuclear sublevels, and the coherent control of a nuclear excitation with a VUV laser. The practical implementation of these applications requires however a way to directly drive the isomer with a narrow band VUV laser, and in turn the precise knowledge of its energy which according to the most recent experimental results is $E_m = 8.28 \pm 0.17$ eV [1].

In this theoretical work we investigate a method to populate the Th isomer in highly charged ions produced in an electron beam ion trap using a tunable UV laser. The employed excitation mechanism, the so-called electronic bridge, occurs via the electronic shell, which is first promoted by a laser photon to a virtual state with subsequent energy transfer to the nucleus. With the absorbed laser photon energy directly related to the isomer energy E_m, this mechanism promises the determination of E_m with an accuracy of 10^{-4} eV which is limited by the Doppler broadening of the ions in the trap. Our theoretical results show that this scheme is feasible under presently available experimental parameters.

[1] B. Seiferle *et al.*, Nature 573, 243–246 (2019).

A 20.5 Wed 15:15 f303

Setup and characterization of a source of highly charged ions with reduced momentum spread — •Michael Karl Rosner[1], Peter Micke[1,2], Sandra Bogen[1], Steffen Kühn[1], Julian Stark[1], Moto Togawa[1], Christian Warnecke[1], Sungnam Park[3], Keisuke Fujii[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland — [3]Ulsan National Institute of Science and Technology, Ulsan, Korea — [4]Department of Mechanical Engineering and Science, Kyoto University, Kyoto, Japan

Highly charged ions (HCI) exhibit strongly enhanced quantum-electrodynamic and nuclear size effects. In some HCI, the frequency of forbidden optical transitions is very sensitive to a possible variation of the fine-structure constant α. Electron beam ion traps (EBIT) can reliably produce HCI [1], but at temperatures too high for such frequency-metrology studies. For this, sympathetic cooling is applied to HCI in a radio-frequency trap [2], requiring also a beamline for HCI transfer, bunching, pre-cooling and deceleration. A new setup based on our earlier HC-EBIT [1] and beamline designs [3] has been built at MPIK. We characterize it with time-of-flight measurements of the HCI charge-state distribution, kinetic energy and momentum spread; the latter has been much reduced in our pre-cooling deceleration unit.

[1] P. Micke, et al., Rev. Sci. Instrum. **89**, 063109 (2018)
[2] L. Schmöger, et al., Science **347**, 1233 (2015)
[3] P. Micke, et. el., in preparation

A 20.6 Wed 15:30 f303

Higher order isotope shifts in highly charged ions — •Robert A. Müller[1,2], Vladimir A. Yerokhin[3], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Germany — [2]Technische Universität Braunschweig, Germany — [3]Peter the Great St. Petersburg Polytechnic University, Russia

A common way to search for physics beyond the standard model, is the investigation of quantities that can be both measured and calculated to a very high precision. One of these quantities is the isotope shift ratio of two transitions. As a function of the number of nucleons A this ratio results in the so-called King Plot. In first order of the electron-nucleus mass ratio (m_e/M_A) the King Plot is strictly linear. Modern spectroscopy, however, is able to measure isotope shifts up to

a precision, where higher order effects need consideration [1]. These effects manifest as nonlinearities in the King Plot. In this contribution we will discuss the quadratic mass shift that yields the dominating second-order isotope shift in light atoms and ions. Our calculations show that this shift can cause deviations from a linear King Plot up to several kHz. Moreover we use our theory to investigate King Plot nonlinearities introduced by a speculated new light boson and use existing measurements to restrict the properties of this particle [2].

[1] Miyake *et al.*, Phys. Rev. Res. **1**, 033113 (2019)
[2] Yerokhin *et al.*, arXiv:1910.05524 (2019)

A 20.7 Wed 15:45 f303

Towards efficient sympathetic laser cooling of highly charged ions in a Penning trap — •Felix Hahne, Bingsheng Tu, Alexander Egl, Tim Sailer, Ioanna Arapoglou, Andreas Weigel, Fabian Heisse, Sven Sturm, and Klaus Blaum — Max-Planck-Insitut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The electric fields of highly charged ions (HCI) enable stringent tests of bound-state quantum electrodynamics under extreme conditions. The Penning-trap based Alphatrap experiment at the Max-Planck-Institut für Kernphysik in Heidelberg aims for g-factor measurements of HCI's as well as laser spectroscopy of fine or hyperfine structure transitions. The achievable accuracy in those measurements depend strongly on the motional temperature of the ion.
However, direct laser cooling of the HCI is generally hindered by the absence of suitable optical transitions and co-trapping ions for sympathetic cooling would disturb the HCI's trap eigenmotion. To this end we propose the coupling of two ions in different traps via a common tank circuit. We discuss the electronic avoided crossing coupling scheme and present the first experimentally recorded energy transfer between Kr^{23+} and Ar^{11+} coupled by a common tank circuit, which lays the basis for a novel sympathetic cooling technique.

A 21: Ultracold plasmas and Rydberg systems I (joint session Q/A)

Time: Wednesday 14:00–16:00 Location: f342

A 21.1 Wed 14:00 f342

Free-space QED with Rydberg superatoms — •Nina Stiesdal, Hannes Busche, and Sebastian Hofferberth — University of Southern Denmark, Odense, Denmark

Rydberg quantum optics (RQO) allows to create strong optical nonlinearites at the level of individual photons by mapping the strong interactions between collective Rydberg excitations onto optical photons.

The strong interactions lead to a blockade effect such that an optical medium smaller than the blockaded volume only supports a single excitation creating a so-called Rydberg superatom. Due to the collective nature of the excitation, the superatom effectively represents a single emitter coupling strongly to few-photon probe fields with directional emission into the initial probe mode.

Here we discuss how we use Ryderg superatoms to study the dynamics of single two level systems strongly coupled to quantized propagating light fields, enabling e.g. the investigation of three-photon correlations mediated by a single quantum emitter.

We also show our experimental progress towards implementing a cascaded quantum system by interfacing multiple superatoms with a single probe mode.

A 21.2 Wed 14:15 f342

Self-Induced Transparency in Room-Temperature Dense Rydberg Gases — •Zhengyang Bai[1,2], Weibin Li[1], and Guoxiang Huang[2] — [1]School of Physics and Astronomy, and Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham, NG7 2RD, UK — [2]State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai 200062, China

Aggressively large Doppler effects is of the challenge to create static optical nonlinearities in atomic gases beyond ultracold temperatures. We show the creation of strong dispersive optical nonlinearities of nanosecond laser pulses in high number density atomic gases at room temperature. This is examined in a vapor cell setting where the laser light resonantly excites atoms to Rydberg P states through a single-photon transition. Using fast Rabi flopping and strong Rydberg atom interactions, both in the order of GHz, can overcome the Doppler effect as well as dephasing due to thermal collisions between Rydberg electrons and surrounding atoms. In this strong-driving regime both the light intensity and Rydberg interactions contribute to the generation of the optical nonlinearity. We show the emergence of a modified self-induced transparency (SIT) where the stable light propagation relies on the Rydberg interactions. We identify quantitatively that the SIT occurs at smaller (than 2π) pulse areas for higher Rydberg states. We furthermore demonstrate that a conditional optical phase gate can be implemented by harvesting strong Rydberg atom interactions and SIT.

A 21.3 Wed 14:30 f342

Vanishing-polarizability states of trappd Rydberg ions — •Fabian Pokorny, Chi Zhang, Gerard Higgins, and Markus Hennrich — Department of Physics, Stockholm University, 10691 Stockholm, Sweden

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 atoms [2], fast entanglement gates may be realized in large ion crystals [1,3].

Recently, we carried out a controlled-phase gate in a two-ion crystal with a gate time of 700ns and more than 70% entaglement fidelity [4]. In order to implement such a gate in large or even multidimensional ion crystals, Rydberg states with vanishing polarizability may be crucial to mitigate otherwise considerable line-broadening caused by phonon-dependent energy shifts of bare Rydberg states [4, 5]. Here we report the realization of microwave-dressed Rydberg states with vanishing polarizability. We observed negligible energy shifts even in presence of excess micro-motion and performed Rabi oscillations between low-lying electronic states and vanishing-polarizability Rydberg states with only Doppler cooling.

[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] C. Zhang, et al., arXiv:1908.11284 (2019)
[5] G. Higgins, et al., Phys. Rev. Lett. 123, 153602 (2019)

A 21.4 Wed 14:45 f342

Strong spin-spin interactions and fast spin squeezing via Rydberg antiblockade dressing — •Weibin Li[1], Huaizhi Wu[1,2], and Shibiao Zheng[2] — [1]School of Physics and Astronomy, Unversity of Nottingham, Nottingham, UK — [2]Fujian Key Laboratory of Quantum Information and Quantum Optics and Department of Physics, Fuzhou University, Fuzhou 350116, People's Republic of China

We propose an antiblockade Rydberg dressing (ARD) scheme with the atomic ground state optically dressed to two coupled Rydberg states. By tuning the laser frequency in proximity to the antiblockade resonance, we obtain an interaction potential where the Rydberg-dressed ground states experience weakly repulsive interactions at short distances, while undergo strongly attractive interaction at certain, larger distances. The dissipative dynamics of interacting atoms subjected to ARD can be effectively described by a dephasing process with both one-body and two-body losses. The ARD with significantly enhanced dressed interactions can be then applied for fast implementation of a spin-echo spin squeezing, and offers a new way for the study of complex collective dynamics and the simulation of many-body spin models.

A 21.5 Wed 15:00 f342

Ultrafast electron cooling in an expanding ultracold plasma — •Tobias Kroker[1,2], Mario Neundorf[1,2], Klaus Sengstock[1,2], Markus Drescher[1,2], Philipp Wessels[1,2], and Juliette Simonet[1,2] — [1]Zentrum für Optische Quantentechnologien (ZOQ), Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging (CUI), Luruper Chaussee 149, 22761 Hamburg

Local photoionization of a Bose-Einstein condensate with a femtosecond laser pulse provides access to an unprecedented regime of ultracold plasma. The accessible charge carrier density of $2{\cdot}10^{14}$ cm^{-3} enables the creation of micrometer-sized, strongly coupled plasma with an ini-

tial ion coupling parameter of $\Gamma = 4800$.
We create a tunable number of up to a few thousand charged particles by strong-field ionization of ^{87}Rb with an electron excess energy of 0.68 eV. Our dedicated experimental setup allows the measurement of the electronic kinetic energy distribution with meV resolution. We report on the direct observation of electron cooling from 5000 K to about 1 K in a few hundred nanoseconds.
The finite plasma size allows for charged particle tracing of the underlying plasma dynamics including mutual Coulomb coupling. The simulations are in excellent agreement with the measurements and provide access to the dynamics on sub-nanosecond timescales. We observe an ultrafast energy transfer of 50% of the excess energy from the electronic onto the ionic component within the first ten picoseconds.

A 21.6 Wed 15:15 f342

Does a disordered Heisenberg spin system thermalize under explicit symmetry breaking? — •Titus Franz[1], Martin Gärttner[2], Adrien Signoles[3], Renato Ferracini Alves[1], André Salzinger[1], Annika Tebben[1], Sebastian Geier[1], David Grimshandl[1], Carlos Brandl[1], Clément Hainaut[1], Gerhard Zürn[1], and Matthias Weidemüller[1,4] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg — [3]Laboratoire Charles Fabry, Institut d'Optique Fraduate School, CNRS, Universite Paris-Saclay, 91127 Palaiseau cedex, France — [4]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

The far-from equilibrium dynamics of generic disordered systems is expected to show thermalization, but this process is yet not well understood and shows a rich phenomenology ranging from anomalously slow relaxation to the breakdown of thermalization. While this problem is notoriously difficult to study numerically, we can experimentally probe the relaxation dynamics in an isolated spin system realized by a frozen gas of Rydberg atoms. By breaking the symmetry of the Hamiltonian with an external field, we can identify characteristics of the long time magnetization, including a non-analytic behavior at zero field. These can be understood from mean field, perturbative, and spectral arguments. The emergence of these distinctive features allows to falsify whether the experiment satisfies Eigenstate Thermalization Hypothesis (ETH).

A 21.7 Wed 15:30 f342

Quantum many-body dynamics of driven-dissipative Rydberg polaritons — •Tim Pistorius, Javad Kazemi, and Hendrik Weimer — Institut für theoretische Physik, Leibniz Universität Hannover, Deutschland

We study the propagation of Rydberg polaritons through an atomic medium in a one-dimensional optical lattice. We obtain an effective Hubbard model to describe the dark state polaritons under realistic assumptions. We analyse the driven-dissipative transport of polaritons through the system by considering a coherent drive on one side and by including the spontaneous emission of the metastable Rydberg state. Using a variational approch[1] to solve the many-body problem, we find strong antibunching of the outgoing photons despite the losses from the Rydberg state decay.

[1] H. Weimer, Phys. Rev. Lett. 114, 040402 (2015)

A 21.8 Wed 15:45 f342

Distinguishability-induced quantum-to-classical transitions in many-body interference — •Christian Haen, Christoph Dittel, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Federal Republic of Germany

We study how partial particle distinguishability induces a transition from the quantum to the classical regime in interference scenarios of many, possibly interacting particles. By continuously tuning the particles' indistinguishability with respect to their internal degrees of freedom, we investigate the transition's statistical imprint – as revealed by interference visibilities [1] or the variance of on-site densities [2] – on the particles' dynamical evolution. Moreover, we assess the impact of a dynamical evolution of the internal degrees on the quantum-to-classical transition. Such internal dynamics may be induced by interactions with an environment and, thus, pave the way towards an open system theory of identical particles.
[1] C. Dittel, et al., arXiv, 1901.02810 (2019)
[2] T. Brünner, et al., *Phys. Rev. Lett.* **120**, 210401 (2018)

A 22: Poster Session - Atomic Physics III

Time: Wednesday 16:00–18:00 Location: Empore Lichthof

A 22.1 Wed 16:00 Empore Lichthof

Single-photon double ionization in two-center atomic systems — •Alexandra Eckey, Alexander B. Voitkiv, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

We study double ionization of an atom (atom A) via single-photon absorption in the presence of a neighbouring atom of different atomic species (atom B) [1]. The process is driven by the combined effects of inter- and intraatomic electron correlations. In this process atom B is first resonantly photoexcited , then this excitation energy is transferred radiationlessly to atom A leading to its double ionization. We show that the total rate for this two-center process can exceed the direct double photoionization of atom A by several orders of magnitude at interatomic distances in the range up to a few nanometers. Moreover, we explain the characteristic influence of the neighbouring atom onto the angular distribution of the emitted electron by introducing an effective polarization vector which depends on the relative position between the atoms.

[1] A. Eckey, A.B. Voitkiv and C. Müller, J. Phys. B, accepted (arXiv:1906.08123)

A 22.2 Wed 16:00 Empore Lichthof

An ion microscope to study Rydberg physics and ultracold ions — •Nicolas Zuber, Christian Veit, Phatthamon Kongkhambut, Florian Meinert, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart, Germany

In addition to spectroscopic tools developed to study Rydberg atoms, spatially resolved detection enables the possibility to directly observe spatial correlations or transport phenomena. Information can be extracted on a single particle level, as it is done in quantum gas microscopes for ground state atoms or with several detection techniques for Rydberg atoms. Along the same lines we integrated an ion microscope, consisting of three electrostatic lenses combined with a spatially resolving delay line detector, to observe Rydberg atoms and ions in our ultracold rubidium gas. The ion microscope provides a high resolution below one micrometer and a tunable magnification between 200 and 1500 with single particle sensitivity. The field of view for the largest magnification 25 micrometer only limited by the detector size. Additionally the setup features an electric field control, which permits a well controlled suppression of electric stray fields. On the poster we present details of our experimental setup and first measurement results of the ion microscope.

A 22.3 Wed 16:00 Empore Lichthof

On-demand single-photon source based on thermal rubidium — •Florian Christaller[1], Max Mäusezahl[1], Felix Moumtsilis[1], Annika Belz[1], Hao Zhang[1], Oliver de Vries[2], Marco Plötner[2], Thomas Schreiber[2], Hadiseh Alaeian[1], Harald Kübler[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart, Germany — [2]Fraunhofer-Institut für Angewandte Optik und Feinmechanik IOF, Jena, Germany

Photonic quantum devices based on atomic vapors at room temperature are intrinsically reproducible as well as scalable and integrable. Besides a quantum memory for single photons one key device in the field of quantum information processing is an on-demand single-photon source. A promising candidate for realization relies on the combination of four-wave mixing and the Rydberg blockade effect, as demonstrated for ultracold atoms [1] and recently for room-temperature atoms in a micro-cell [2]. For the next generation single-photon source at high

repetition rates, we can exploit the latest developments in laser technology by using a 1010 nm fiber amplifier to reach the Rydberg state. At a repetition rate of 1 MHz we reach a peak pulse-power of 100 W for Fourier-limited nanosecond pulses. Here we report on the characterization of two fiber amplifiers and on the latest status towards the high repetition rate single-photon generation at room-temperature.

[1] Dudin et al., Science 336, 6083 (2012)
[2] Ripka et al., Science 362, 6413 (2018)

A 22.4 Wed 16:00 Empore Lichthof

Light-induced atomic desorption in thermal μ-cells — •Felix Moumtsilis, Florian Christaller, Max Mäusezahl, Fabian Ripka, Hadiseh Alaeian, Harald Kübler, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart, Germany

Micrometer-sized cells for atomic vapors are powerful devices in the realm of fundamental research and applied quantum technology. To reach significant optical densities along the short optical paths in such cells, temperatures exceeding 300°C have to be applied. This however is accompanied by stronger collisional effects, the excitation of surface-polaritons and technical difficulties in the experimental setups due to large temperature gradients. We present an experimental approach exploiting the effect of light-induced atomic desorption (LIAD) [1, 2]. In this configuration, atoms are desorbed from the cell's glass surface by intense nanosecond-pulses at 532 nm and provide a temporarily dense cloud of atoms. These atoms eventually reach the opposing glass surface, where they are adsorbed again. Using this technique, we locally increase the density to several hundreds of atoms per μm^3 on a nanosecond timescale. Here we report on the latest systematic time-resolved LIAD measurements in a thermal rubidium cell.

[1] Meucci et al., EPL 25, 639 (1993)
[2] Atunov et al., Phys. Rev. A 67, 053401 (2003)

A 22.5 Wed 16:00 Empore Lichthof

Circular Rydberg states for quantum many-body physics — Christian Hölzl, Muamera Basic, and •Florian Meinert — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Stuttgart, Germany

Highly excited low-L Rydberg atoms in configurable mircotrap arrays have recently proven highly versatile for studying quantum many-body spin systems with single particle control. I will report on the status of a new project pursuing to harness high-L circular Rydberg atoms for quantum simulation. When stabilized in a suitable cavity structure, circular Rydberg states promise orders of magnitude longer lifetimes compared to their low-L counterparts and thus provide an appealing potential to strongly boost coherence times in Rydberg-based interacting atom arrays. We propose a novel approach to stabilize circular Rydberg states against black-body decay in a room temperature setup combined with excellent optical access for generating flexible trap arrays.

A 22.6 Wed 16:00 Empore Lichthof

Rydberg molecules under a reaction microscope — •Daniel Fichtner, Max Althön, Philipp Geppert, and Herwig Ott — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern

We report on the first results of our MOTRIMS-type reaction microscope experiment. We prepare a sample of ^{87}Rb atoms in a 3D-MOT, which is loaded from a 2D-MOT. The atoms are then transferred to a crossed optical dipole trap. Using a 3-photon excitation scheme, atoms are excited to atomic or molecular Rydberg states and photoionized 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. This tool allows both momentum- and position-resolved measurements of few-body Rydberg dynamics. In this context, we are especially interested in measuring momentum distributions of Rydberg molecule vibrational states as well as momenta resulting from internal decay processes such as l-changing collisions. 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 an outlook we present a scheme to address heavy Rydberg systems via Rydberg molecules.

A 22.7 Wed 16:00 Empore Lichthof

Ultracold ytterbium Rydberg states in electric fields — Christian Halter, •Alexander Miethke, and Axel Görlitz — Heinrich-Heine-Universität, 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 the study of ultra cold ytterbium Rydberg states using traploss spectroscopy as well as direct ion detection. For the ion detection we are exciting atoms in a MOT to states of high principal quantum numbers n (n=30-90), followed by a short high voltage pulse. Making use of the variable delay between the excitation and ionization, information about the lifetimes of Rydberg states can be found. Additionally, by changing the high-voltage pulse the ionization threshold can be investigated. Various dependencies can be compared to theoretical quantum models.

A 22.8 Wed 16:00 Empore Lichthof

Construction of a Rydberg atom register — •Suthep Pomjaksilp, Sven Schmidt, Thomas Niederprüm, and Herwig Ott — Department of Physics and research center OPTIMAS, Technische Universität Kaiserslautern, Germany

Over the last years, arrays of assembled single atoms emerged as a ground-breaking platform in quantum physics. These setups do not only feature single-atom control, additionally exciting addressable atoms to Rydberg states introduces further possibilities to investigate interaction in arbitrary geometric configurations.

We plan to realize a two-dimensional array of up to 100 single ^{87}Rb atoms trapped with holographically created optical tweezers at 1064 nm. Cold atoms are provided by a magneto optical trap via a single laser serving as both, cooler and repumper. While stabilized at the repumper transition, an electro-optical modulator generates the necessary cooling light. This enables us to further cool and compress the atom cloud with a grey molasses scheme by sweeping the laser. In addition, exploiting light-induced atomic desorption prolongs the lifetime of the trapped atoms by allowing us to reduce the background pressure.

Finally, cooling of ^{85}Rb can be implemented all electronically by driving the modulator with additional frequencies. Combined with the single atom control and excitation to Rydberg states, a highly versatile, yet compact, experimental setup is obtained.

A 22.9 Wed 16:00 Empore Lichthof

Cold Rydberg Atoms as Ultrasensitive Quantum Sensors for Chiral Molecules — •Stefan Aull[1], Miriam Mendoza-Delgado[1], Steffen Giesen[3], Robert Berger[3], Peter Zahariev[1,2], and Kilian Singer[1] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [2]ISSP - Bulgarian Academy of Sciences — [3]Fb. 15 - Chemie, Hans-Meerwein-Straße 4, 35032 Marburg

Rydberg atoms show a variety of extreme properties, including a high sensitivity to external peturbations. We present an experimental setup for measuring molecular chirality with Rydberg atoms as a quantum probe. The goal of the project is to perform chiral discrimination based on far field interaction between chiral molecules and Rydberg dressed cold atoms. Chiral molecules in a supersonic beam will interact with a cloud of ultracold atoms in a MOT while Rydberg dressing will be applied to the atoms. A quantum measurement scheme allows for ultra-sensitive detection of chirality dependent interaction energy shifts.

A 22.10 Wed 16:00 Empore Lichthof

Dissipative dynamics of strongly interacting driven Rydberg gases — •Jana Bender, Patrick Mischke, Carsten Lippe, Tanita Klas, Erik Bernhart, Thomas Niederprüm, and Herwig Ott — Department of Physics and research center OPTIMAS, Technische Universität Kaiserslautern, Germany

By continuously driving open Rydberg many-body systems, we investigate the interplay between Rydberg blockade and facilitation. We discuss the dynamics and steady states of a system of mesoscopic Rydberg blockaded clouds loaded into a one-dimensional optical lattice

with a lattice constant tailored to match the facilitation distance of the 70S Rydberg state. Each cloud acts as an effective two-level system with an asymmetric excitation and deexcitation rate, a so-called superatom. The chain of superatoms created in the lattice allows to study dissipative Ising-like spin models.

Experimentally, we examine the correlations of excitations within these superatoms. The analysis of temporal correlations gives evidence of sub-poissonian behaviour in the resonantly driven system due to the Rydberg blockade.

A 22.11 Wed 16:00 Empore Lichthof

Continuous-wave absorption spectroscopy on the γ_{00} band of nitric oxide — •Yannick Schellander[1,2], Fabian Munkes[1,2], Patrick Kaspar[1,2], Johannes Schmidt[1,2,3], Robert Löw[1,2], Tilman Pfau[1,2], Edward Grant[4], and Harald Kübler[1,2] — [1]5. Physikalisches Institut — [2]Center for Integrated Quantum Science and Technology — [3]Institut für Großflächige Mikroelektronik — [4]Department of Chemistry University of British Columbia

We present first results on the continuous-wave absorption spectroscopy on the $A\,^2\Sigma^+ \leftarrow X\,^2\Pi_{1/2}$ transition of the γ_{00}-band in nitric oxide. The measurement is done at room temperature. The production of the necessary glass cells as well as technical challenges of the employed laser system are explained. To prove the validity of the results the needed theory is analyzed. For putting the results into perspective pulsed absorption spectroscopy was performed on the same transition at much lower temperature allowing for comparison and yielding important insights on the advantages of continuous- wave spectroscopy. The results are classed with the overall goal of building a trace-gas sensor for nitric oxide.

A 22.12 Wed 16:00 Empore Lichthof

Laser linewidth and phase noise measurements for EIT — •Carlos Brandl[1], Annika Tebben[1], Clément Hainaut[1], André Salzinger[1], David Grimshandl[1], Sebastian Geier[1], Titus Franz[1], Nithiwadee Thaicharoen[1], Gerhard Zürn[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Ruprecht-Karls Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, and CAS Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum Physics, Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

For experiments on electromagnetically induced transparency (EIT) with Rydberg atoms a narrow laser linewidth is desirable to achieve a full EIT transmission on two photon resonance and a wider EIT linewidth, which scales inversely with the laser linewidth. Moreover, the knowledge of the laser linewidth allows for a direct comparison between EIT measurements and theoretical models. Therefore, using a self-heterodyne setup, we can measure the linewidth and the phase noise components - white noise, flicker noise and random walk noise - of a 780nm laser, which is used as one of the two lasers in our Rydberg EIT scheme with 87Rb. Furthermore, the setup is mounted on a mobile panel to easily extend the measurement to other lasers.

A 22.13 Wed 16:00 Empore Lichthof

Towards Arrays of Cryogenic Traps for Improved Quantum Simulation — •Kai-Niklas Schymik, Florence Nogrette, Daniel Barredo, Thierry Lahaye, and Antoine Browaeys — Laboratoire Charles Fabry, Institut d'Optique Graduate School, Palaiseau, France

Large arrays of individually controlled atoms in optical tweezers are a promising platform for quantum engineering applications. In our group, we have realized several quantum simulations of spin models in 2D arrays of Rydberg atoms with up to 50 spins.

Here we report on the development of a novel cryogenic platform for performing quantum simulations with several 100s of spins with increased coherence times. Combining the techniques of the current setup and a closed-cycle, optical-access cryostat at 4 K, we will tackle two main limitations of scalability: the vacuum lifetime of the ground-state atom in the tweezers due to collisions with residual gas and the decoherence arising from black-body radiation induced transitions between neighboring Rydberg states.

A 22.14 Wed 16:00 Empore Lichthof

Reconstructing the optical transfer function by absorption imaging of disordered atom distributions. — •David Grimshandl[1], Carlos Brandl[1], Titus Franz[1], Sebastian Geier[1], Clément Hainaut[1], André Salzinger[1], Annika Tebben[1], Gerhard Zürn[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

Many cold atom experiments rely on absorption imaging as primary observation method. Here it is crucial to discriminate between the optical response of the imaged medium and the effects of the imaging apparatus. Common methods to retrieve the transfer function of an optical system require additional optics and instrumentation in the object plane which cannot be accessed in situ in most cold atom experiments. In our experiment with cold Rydberg atoms we employed a method to retrieve the wavefront error across the exit pupil and the coherent point spread function of the imaging apparatus from the spatial noise correlations in absorption images. This allows to evaluate the performance of the imaging system in situ and thus can be used to improve the optical system on-the-fly, e.g. by selectively cancelling aberrations from misalignment, defocus and tilts.

A 22.15 Wed 16:00 Empore Lichthof

Long-Range Interacting Quantum Systems via Rydberg Dressing in Microtraps — •Lea-Marina Steinert[1], Nikolaus Lorenz[1], Lorenzo Festa[1], Philip Osterholz[1], Joop Adema[1], Robin Eberhard[1], and Christian Gross[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

Individual neutral atoms trapped in optical tweezers offer a fast and flexible platform for the deterministic creation of atomic arrays. Off-resonant laser coupling to Rydberg states (Rydberg dressing) allow for the study of quantum many-body systems with engineered long-range interactions. By carefully choosing the laser parameters the strong dipolar interactions can be precisely controlled. We aim to realize synthetic quantum magnets based on this engineered inter-spin interaction. Here we report on the status of the project including a high power laser system for Rydberg coupling in the ultraviolett. We show coherent ground - Rydberg state Rabi oscillations for single and Rydberg superatoms and discuss the limits to their coherence. Finally, we discuss experiments aiming at the deterministic loading of a single potassium atom into each of the optical tweezers.

A 22.16 Wed 16:00 Empore Lichthof

Characterizing molecular symmetries with quantum gas microscopy — •Simon Hollerith[1], Jun Rui[1], Antonio Rubio-Abadal[1], David Wei[1], Kritsana Srakaew[1], Simon Evered[1], Christian Gross[1,2], and Immanuel Bloch[1,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München

Rydberg macrodimers - molecules consisting of two bound highly excited Rydberg atoms - provide enormous bond lengths even resolvable with optical wavelengths. Here we report on a microscopic study of macrodimers with different molecular symmetries in a gas of ultracold atoms in an optical lattice. The bond length of about 0.7 micrometers matches the diagonal distance of two atoms in the lattice. The geometry of the two-dimensional lattice initially unity filled with ground state atoms allows to control the relative orientation of the molecular axis to an ambient magnetic field and the polarization of the photoassociation light. Using our spatially resolved detection, we detect the associated molecules by correlated atom loss and find the excitation rates to be in agreement with theoretical predictions. Furthermore, we present how the molecular excitation rate can be significantly increased by the use of two color photoassociation. Our results highlight the potential of quantum gas microscopy for molecular physics and show how macrodimers might be used to study many body physics.

A 22.17 Wed 16:00 Empore Lichthof

Mixed dimension Rydberg Composites — •Andrew Hunter, Matt Eiles, Alex Eisfeld, and Jan M Rost — Max Planck Institute for the Physics of Complex Systems

Rydberg Composites are a Rydberg atom in a dense environment of neutral atoms [1]. Here we explore the properties of quasi one- and two-dimensional Rydberg composites, mapping out the transition from a lower dimensional lattice to a higher one as a function of its width. The dependence of the Rydberg Composite's properties on temperature-

dependent disorder and random arrangements is also investigated, elucidating paths to experimental realizations.

Hunter A L, Eiles M T, Eisfeld A and Rost J M 2019 arXiv:1909.01097

A 22.18 Wed 16:00 Empore Lichthof

Inner-Shell Multiple Photodetachment of Carbon Anions — •Alexander Perry-Sassmannshausen[1], Alexander Borovik Jr.[1], Ticia Buhr[1], Michael Martins[2], Alfred Müller[1], Simon Reinwardt[2], Sandor Ricz[3], Florian Trinter[4,5], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen, Germany — [2]Universität Hamburg, Germany — [3]Atomki, Debrecen, Hungary — [4]FS-PE, DESY, Hamburg, Germany — [5]Molecular Physics, Fritz-Haber-Institut, Berlin, Germany

Negative atomic ions play an important role in low temperature plasmas such as Earth's upper atmosphere or the interstellar medium [1,2]. A sensitive tool for studying the interactions between the valence and the core electrons is inner-shell ionization of negative ions [3].

Here we report on preliminary results from a recent beam time at the Photon-Ion-Spectrometer at P04 at PETRA III (PIPE) [4]. We investigated multiple photodetachment of carbon anions which led to final charge states up to C^{4+}. Absolute cross sections for all measurable product ion channels will be presented and discussed.

[1] T. Andersen, Phys. Rep. **394**, 157 (2004)
[2] T. Millar et al., Chem. Rev. **117**, 1765 (2017)
[3] S. Schippers et al., Phys. Rev. A **94** 041401(R) (2016)
[4] S. Schippers et al., J. Phys. B **47**, 115602 (2014)

A 22.19 Wed 16:00 Empore Lichthof

A community platform for just atomic computations (JAC) — •Stephan Fritzsche — Helmholtz Institute, Jena, Germany — Friedrich-Schiller University Jena

Electronic structure calculations of atoms and ions have a long tradition in physics with applications in basic research and spectroscopy. With the Jena Atomic Calculator (JAC), I here present a fresh implementation of a (relativistic) electronic structure code for the computation of atomic amplitudes, properties as well as a large number of excitation and decay processes for open-shell atoms and ions across the periodic table. JAC is based on Julia, a new programming language for scientific computing, and provides an easy-to-use but powerful platform to extent atomic theory towards new applications.

A 22.20 Wed 16:00 Empore Lichthof

Phase-sensitive spectroscopy of Mössbauer nuclei using oscillating reference absorbers — •Benedikt Herkommer and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Mössbauer nuclei feature exceptionally narrow resonances at hard x-ray energies, which form the basis for a multitude of applications across the natural sciences. However, a direct spectroscopy at modern x-ray sources such as synchrotrons or XFELs is challenging, because of the broad spectral bandwidth of the delivered x-ray pulses, and because of a limited spectral resolution offered by x-ray detectors.

Here, we present a novel spectroscopy technique based on a moving reference absorber mounted on a piezo transducer. The motion induces sidebands to the spectrum of the absorber, which we scan across the spectrum of an unknown sample to be measured. As compared to previous methods, the phase offset of the piezo motion at the x-ray time-of-arrival offers an additional controllable degree of freedom. We show that this phase not only allows us to accurately determine the spectrum of the unknown sample, but also to measure the spectral phase of the light scattered by the nuclei.

A 22.21 Wed 16:00 Empore Lichthof

X-ray quantum optics with Mössbauer nuclei — •Lukas Wolff, Dominik Lentrodt, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Ideas from quantum optics play an important role in studying, controlling, and utilizing light matter interactions in many regions of the electromagnetic spectrum. This raises the question, whether such concepts could also be exploited at hard x-ray energies. Particularly interesting candidates for this are Mössbauer nuclei. These nuclei feature resonances with exceptionally narrow line width, which form the basis for a broad range of applications in the natural sciences.

In recent years, Mössbauer nuclei have become a promising platform for quantum optics with x-rays, and various effects known from the optical domain have already been experimentally demonstrated with nuclei. This poster will review our recent progress in nuclear quantum optics, and will highlight new developments.

A 22.22 Wed 16:00 Empore Lichthof

Controlling excitation dynamics of Mössbauer nuclei with zeptosecond phase-stability — •Pim van den Heuvel[1], Kilian P. Heeg[1], Andreas Kaldun[1], Cornelius Strohm[2], Christian Ott[1], Rajagopalan Subramanian[1], Dominik Lentrodt[1], Johann Haber[2], Hans-Christian Wille[2], Stephan Goerttler[1], Rudolf Rüffer[3], Christoph H. Keitel[1], Ralf Röhlsberger[2], Thomas Pfeifer[1], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]ESRF - The European Synchrotron, Grenoble, France

In recent years Mössbauer nuclei have become a platform for quantum optics with x-rays and various effects from the optical domain have already been demonstrated. However, they are usually probed with single pulses, preventing straightforward realization of advanced optical schemes, such as those involving control fields. Here, an x-ray pulse shaping technique, which was previously employed for spectral narrowing, is presented. It produces a sequence of two pulses with controlled relative phase, allowing for controlling and steering the nuclear dynamics. The phase-stability of this set-up holds the promise to reach a sub-zeptosecond level, which is hitherto unachieved. New regimes of nuclear dynamics could be investigated with this technique.

A 22.23 Wed 16:00 Empore Lichthof

Simulation of multi-particle coincidence data acquisition — •Carolin Honisch, Andreas Hans, Catmarna Küstner-Wetekam, Lutz Marder, Xaver Holzapfel, Nils Kiefer, Alexander Schrodt, Arno Ehresmann, and André Knie — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Coincident particle detection is a powerful experimental technique, which substantially contributed to the progress in many fields of physics in the past. In the actual coincidence experiment and during data analysis, the distinction between so-called "true" and "random" coincidences is essential. In order to support real-time data interpretation, we have developed a simulation procedure for coincidence maps, which considers information about experimental parameters and boundaries. The simulation allows reproduction of the measurement results and can also deliver information on the relevance of random coincidences. This supports the experimental process as well as its preparation and the subsequent data analysis. We also demonstrate how the simulation may be utilized to apply novel coincidence schemes, e.g. with continuous excitation sources.

A 22.24 Wed 16:00 Empore Lichthof

Reaction Microscope Endstation at FLASH2 — •Patrizia Schoch[1], Hannes Lindenblatt[1], Florian Trost[1], Severin Meister[1], Kirsten Schnorr[2], Sven Augustin[2], Georg Schmid[1], Yifan Liu[1], Markus Braune[3], Marion Kuhlmann[3], Rolf Treusch[3], Claus Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Paul Scherrer Institut, Villigen, Schweiz — [3]DESY, Hamburg

Our group has installed a Reaction Microscope as permanent endstation at FLASH2. During the last years, first experiments and several upgrades where performed. Most notably, a gracing incidence mirror for focussing and split-and-delay was installed. An IR Laser as well as a HHG source is now available for the beamline. These allows for a multitude of pump-probe schemes. The poster will provide an overview of the setup including beam geometry, target preparation, diagnostics and data acquisition, as well as some exemplary results.

A 22.25 Wed 16:00 Empore Lichthof

Relaxation dynamics in rare gas dimers after XUV-photoionization at FLASH2 — •Hannes Lindenblatt[1], Kirsten Schnorr[2], Sven Augustin[2], Severin Meister[1], Florian Trost[1], Patrizia Schoch[1], Georg Schmid[1], Yifan Liu[1], Markus Braune[3], Marion Kuhlmann[3], Rolf Treusch[3], Claus Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Paul Scherrer Institut, Villigen, Schweiz — [3]DESY, Hamburg

We investigated the relaxation dynamics of Xenon and Argon dimers employing momentum coincidence spectroscopy at the reaction-

microscope beamline FL26 at FLASH2. Using the grazing incidence split, delay and focusing optics, a XUV-XUV pump-prope scheme was utilized to track dissociation dynamics. On the poster we present results for different relaxation channels, e.g. Interatomic Coulombic decay (ICD) or charge transfer.

A 22.26 Wed 16:00 Empore Lichthof

Relaxation dynamics of CH3I and CH2I2 following FEL-induced inner-shell ionisation — •Florian Trost[1], Kirsten Schnorr[2], Sven Augustin[2], Severin Meister[1], Hannes Lindenblatt[1], Patrizia Schoch[1], Yifan Liu[1], Marc Simon[3], Renaud Guillemin[3], Maria Novella Piancastelli[4], Farzad Hosseini[3], Mustafa Zmerli[3], Markus Braune[5], Marion Kuhlmann[5], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Paul Scherrer Institut, Villigen — [3]Université Pierre-et-Marie-Curie, Paris — [4]Uppsala Universitet, Uppsala — [5]DESY, Hamburg

Using the reaction microscope endstation at the free-electron laser (FEL) in Hamburg (FLASH2), the relaxation dynamics of methyl iodide (CH3I) and diiodomethane (CH2I2) after inner-shell ionisation have been studied. FLASH2's XUV (12.7 nm) photons were used to ionise the iodine 4d inner shell electrons twice sequentially using an XUV pump - XUV probe technique with variable delay. The first XUV photon induces the dissociation of the doubly charged molecule. The absorption of the second photon, leading to higer charged ions, allows to probe the dynamics of the dissociation. The momentum-resolved data of the coincident fragments of the dissociated molecules will be presented.

A 22.27 Wed 16:00 Empore Lichthof

Phase-cycling technique for extreme ultraviolet pulses — •Andreas Wituschek[1], Lukas Bruder[1], Oleg Kornilov[2], Tobias Witting[2], Laura Maikowski[2], Marc J.J. Vrakking[2], and Frank Stienkemeier[1] — [1]Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany

The advent of intense ultrashort light sources in the extreme ultraviolet (XUV) allows for extension of coherent nonlinear spectroscopy techniques (eg. four wave mixing, multidimensional spectroscopy, CARS) to this wavelength range, providing access to unprecedented temporal resolution and site/chemical selectivity. However, these techniques require interferometric stability and high sensitivity for weak nonlinear signals, which are experimentally difficult to achieve in the XUV.

In this work we developed a laboratory-scale XUV source suitable for applications in coherent spectroscopies. We generated a collinear UV pulse pair (262 nm, 50 μJ, 30 fs) in an interferometric setup with independent control over delay and relative phase of the pulses. With this pulse pair we generated the third (14.2 eV) harmonic in krypton and found that the resulting XUV pulse pair inherits the phase information of the UV pulses, allowing us to impart a phase-cycling scheme on the XUV pulse pair. To test the scheme, we isolated the coherent oscillations of an electronic wave-packet in argon atoms, where the states participating in the wave-packet are separated by 14.2 eV. Our approach provides the necessary stability and sensitivity to extent coherent nonlinear spectroscopy to the XUV spectral range.

A 22.28 Wed 16:00 Empore Lichthof

Development of a detector to register low-energy, charge-changed ions from ionization experiments at CRYRING@ESR — •Alexander Borovik Jr.[1], Günter Weber[2,3], Vinzenz Hilbert[2,3], Haifeng Lin[2,3], Philip Pfäfflein[2,3,4], Binghui Zhu[2,3], Christoph Hahn[2,3,4], Michael Lestinsky[4], Stefan Schippers[1], Thomas Stöhlker[2,3,4], and Jan Rothhardt[2,3] — [1]Justus-Liebig-Universität Gießen, 35392 Giessen, Germany — [2]Helmholtz-Institut Jena, 07743 Jena, Germany — [3]Friedrich Schiller University, 07743 Jena, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany

In the frame of the proof-of-principle experiment on photoionization of the stored C^+ ions by XUV laser pulses, a specially tailored detector setup has been developed for counting product ions. These hit the YAP:Ce scintillator plate producing light pulses which are registered by an array of silicon photomultipliers (SiPMs) placed on a custom-made interface board in a pocket tube outside of the vacuum. The detector can reliably operate in strong magnetic field and thus can be put directly inside the chamber of a dipole magnet. The developed array of mechanical actuators enables the detector's fine positioning to match the given product-ion trajectory, as well as the swift periodical retraction out of the product-ion trajectory area to avoid its unnecessary irradiation and possible primary-ion losses during the ion-beam preparation procedure. This detector enables a variety of photoionization experiments with stored highly-charged ions.

A 23: Interaction with VUV and X-ray light I

Time: Thursday 11:00–13:00 Location: f107

Invited Talk A 23.1 Thu 11:00 f107

Manipulating dissipative channels of highly excited systems — •Stefan Yoshi Buhmann — University of Freiburg, Germany

Highly excited atomic of molecular systems can loose their energy by a range of dissipative channels: via spontaneous or Auger decay for isolated systems or by means of interatomic Coulombic decay in the presence of neighbours.

We give an overview over how these competing channels can be manipulated by environments such as media or surfaces [1] in a generalised Purcell effect [2]. The basis for our investigation is coupling of charged matter with the environment-assisted quantised electromagnetic field within the framework of macroscopic quantum electrodynamics (QED) [3]. Inter alia, we show that Auger decay is much less susceptible to environment effects than radiative or interatomic Coulombic decay; that local-field effects need to be taken into account when considering systems embedded in media; and that some of the investigated channels can be enhanced by collective, superradiance-type effects [4].

[1] J.L. Hemmerich, R.Bennett, S.Y. Buhmann, Nat. Commun. **9**, 2934 (2018).
[2] E. M. Purcell, Phys. Rev. **69**, 674 (1946).
[3] S. Y. Buhmann, Dispersion forces I (Springer, Heidelberg, 2013).
[4] S. Fuchs, S. Y. Buhmann, Europhys. Lett. **124**, 34003 (2018).

A 23.2 Thu 11:30 f107

Cooper minimum in multi-photon ionization — •Jiri Hofbrucker[1,2,3], Andrey Volotka[2,3], and Stephan Fritzsche[1,2,3] — [1]Friedrich-Schiller University, Jena, Germany — [2]Helmholtz Institute, Jena, Germany — [3]GSI, Darmstadt, Germany

In one-photon ionization, the photon energy for which the dominant ionization channel vanishes is called the Cooper minimum. This concept is extended to nonlinear ionization of atoms. We study this *nonlinear Cooper minimum* in the two-photon ionization process. In our talk it will be shown that the nonlinear Cooper minimum leads to strong variation in practically all observable quantities of the two-photon ionization process. For example, by tuning the incident photon energy to the nonlinear Cooper minimum, it is possible to enhance the polarization transfer from the incident light to the photoion. The ion polarization can be observed either directly, or in the case of inner-shell ionization, via polarization of subsequent fluorescence and Auger decay particles. The nonlinear Cooper minimum also leads to the maximum elliptical dichroism in photoelectron angular distributions. As all the mentioned quantities are normalized quantities, they are less sensitive to experimental uncertainties. It is theorized that detection of the energy position of the nonlinear Cooper minimum via one of the mentioned methods could lead to comparison of experimental measurements and theoretical calculations at hitherto unreachable accuracy.

A 23.3 Thu 11:45 f107

K-shell photoionization of silicon ions — •Ticia Buhr[1], Sebastian Stock[2,3], Alexander Perry-Sassmannshausen[1], Simon Reinwardt[4], Michael Martins[4], Sándor Ricz[5], Alfred Müller[1], Stephan Fritzsche[2,3], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen, Germany — [2]Helmholtz-Institut Jena, Germany — [3]Friedrich-Schiller-Universität Jena, Germany — [4]Universität Hamburg, Germany — [5]Institute for Nuclear Research, Hungarian Academy of Sciences, Debrecen, Hungary

Silicon is one of the most abundant heavy elements in the Universe.

Therefore, the investigation of the electronic structure of the silicon atom, its ions and their response to radiation is fundamental from an astrophysical point of view. Single and multiple photoionization of Si^{q+} ($q = 1, 2, 3$) ions have been experimentally investigated in the photon energy range 1830 eV to 2100 eV using the PIPE setup [1, 2] at the synchrotron light source PETRA III. $Si^{q+} \rightarrow Si^{(q+n)+}$ reaction channels with n up to 4 were studied. Pronounced resonance structures are observed for all ions and are associated with excitation or ionization of a K-shell electron. The experimental cross sections are compared with the results of multiconfiguration Dirac–Hartree–Fock calculations (MCDHF). The theoretical description accounts for initial excitation or ionization and the subsequent cascade of Auger processes.
[1] S. Schippers *et al.*, J. Phys. B **47**, 115602 (2014).
[2] S. Schippers *et al.*, X-Ray Spectrometry, DOI:10.1002/xrs.3035.

A 23.4 Thu 12:00 f107

Inner-Shell Multiple Photodetachment of Silicon Anions — •Alexander Perry-Sassmannshausen[1], Ticia Buhr[1], Alfred Müller[1], Simon Reinwardt[2], Florian Trinter[3,4], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen, Germany — [2]Universität Hamburg, Germany — [3]FS-PETRA-S, DESY, Hamburg, Germany — [4]Molecular Physics, Fritz-Haber-Institut, Berlin, Germany

Negative atomic ions play an important role in low-temperature plasmas such as Earth's upper atmosphere or the interstellar medium [1,2]. A sensitive tool for studying the interactions between the valence and the core electrons is inner-shell ionization of negative ions [3]. The inner-shell photoionization dynamics is particularly rich since it is governed by strong multiple relaxation effects of the valence electrons upon creation of the inner-shell hole [4,5].
Here, we report on preliminary results from a recent beam time at the Photon-Ion-Spectrometer at beamline P04 at PETRA III (PIPE) [6]. We investigated multiple photodetachment of silicon anions which led to final charge states up to Si^{5+}. Relative cross sections for all measured product ion channels will be presented and discussed.
[1] T. Andersen, Phys. Rep. **394**, 157 (2004)
[2] T. J. Millar et al., Chem. Rev. **117**, 1765 (2017)
[3] S. Schippers et al., Phys. Rev. A **94** 041401(R) (2016)
[4] T. Gorczyca, Rad. Phys. Chem. **70**, 407 (2004)
[5] S. Schippers et al., Phys. Rev. A **94**, 041401 (R) (2016)
[6] S. Schippers et al., J. Phys. B **47**, 115602 (2014)

A 23.5 Thu 12:15 f107

XUV Transient Absorption Spectroscopy on Neon at 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], Patrick Rupprecht[1], Yonghao Mi[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], Stefano Cavaletto[1], 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 transient absorption spectroscopy employing extreme ultraviolet (XUV) pump and probe pulses delivered by the free-electron laser FLASH. We target the neon atom and trace its nonlinear XUV (photon energy 50 eV) interaction with joint high spectral and temporal resolution. This allows us to trace the time-dependent sequential two-photon ionization of neon, transient (2.4-fs time scale) coherence effects near resonances in the produced doubly-charged neon ions (Ne^{2+}), and the XUV-induced Stark shift of those ionic resonances. Furthermore, we show how this technique can be used to measure the frequency chirp of XUV-FEL pulses.

A 23.6 Thu 12:30 f107

Determination of the electric and magnetic Rayleigh scattering amplitudes — •Andrey Volotka[1], Andrey Surzhykov[2,3], and Stephan Fritzsche[1,4] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [3]Technische Universität Braunschweig, 38106 Braunschweig, Germany — [4]Theoretisch-Physikalisches Institut, Friedrich–Schiller-Universität Jena, 07743 Jena, Germany

The Rayleigh scattering being a dominant elastic-scattering process for a wide range of photon energies extensively investigated theoretically. Relativistic calculations based on the second-order S-matrix amplitude is accepted now as a benchmark for treating the Rayleigh scattering. However, its superior to other, simpler techniques, was mainly demonstrated for the case of the angle-differential cross sections. In contrast, much less attention has been paid to the polarization studies, especially in the case of initially polarized light. Within the present studies, we investigate the possibilities for separate extraction of the electric and magnetic scattering amplitudes as well as the phase difference between them. This "complete" experiment becomes possible now with the recent advent of novel solid-state photon detectors, which provide a good energy resolution in combination with submillimeter position resolution over a large detection area.

A 23.7 Thu 12:45 f107

Tabletop Intensity Interferometry of a Femtosecond Hard X-ray Source — •Leon Merten Lohse, Malte Vassholz, Hannes Hoeppe, and Tim Salditt — Institut für Röntgenphysik, Universität Göttingen, Deutschland

Laser-driven femtosecond Plasma X-ray sources (PXS) with solid targets offer a unique opportunity to produce hard X-ray pulses of a few 100fs with kHz repetition rate in the lab. In contrast to X-ray free electron lasers, the radiation from such a source consists of bremsstrahlung and characteristic radiation (fluorescence) and is fully (first-order) incoherent as such. The pulse lengths in the order of 100fs are, compared to the fluorescence lifetime in the order of 1fs, in principle short enough to produce intensity correlations and speckle patterns on a 2D detector. Using novel energy-resolving pixel detectors with kHz frame rate in the single photon regime allows to reliably discriminate between the fluorescence signal and the bremsstrahlung background on a single shot basis.

Here we present recent results from measurements with a charge-integrating hybrid pixel detector at our PXS.

A 24: Ultracold atoms, ions, and BEC V (joint session A/Q)

Time: Thursday 11:00–13:00 Location: f303

Invited Talk A 24.1 Thu 11:00 f303

Status update of the muonic hydrogen ground-state hyperfine splitting experiment — •A. Ouf and R. Pohl on behalf of the CREMA collaboration — Johannes Gutenberg-Universität Mainz, Institut für Physik, QUANTUM & Exzellenzcluster PRISMA +, Mainz, Germany

The ground state hyperfine splitting (1S-HFS) in ordinary hydrogen (the famous 21 cm line) has been measured with 12 digits accuracy almost 50 years ago [1], but its comparison with QED calculations is limited to 6 digits by the uncertainty of the Zemach radius determined from elastic electron-proton scattering. The Zemach radius encodes the magnetic properties of the proton and it is the main nuclear structure contribution to the hyperfine splitting (HFS) in hydrogen. The ongoing experiment of the CREMA Collaboration at PSI aims at the first measurement of the 1S-HFS in muonic hydrogen (μp) with the potential for a hundredfold improved determination of the proton structure effects (Zemach radius and polarizability), which will eventually improve the QED test using the 21 cm line by a factor of 100. The experiment introduces several novel developments toward the (μp) 1s-HFS spectroscopy. We will present the current efforts of the various developments from the pulsed 6.8 μm laser, to the novel multi pass cavity, and the scintillator detection system.
[1] L. Essen *et al*, Nature **229**, 110 (1971)
[2] R. Pohl *et al.*, Nature **466**, 213 (2010)
[3] A. Antognini *et al.*, Science **339**, 417 (2013)

A 24.2 Thu 11:30 f303

Precision Spectroscopy of an Interacting Ytterbium Fermi-Fermi Mixture — •Benjamin Abeln[1], Marcel Diem[1], Koen Sponselee[1], Nejira Pintul[1], Klaus Sengstock[1,2], and Christoph Becker[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Laserphysics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

We perform high precision spectroscopy on the $^1S_0$ to $^3P_0$ clock transition of ^{171}Yb and ^{173}Yb to investigate interactions in an ultracold Fermi-Fermi mixture of ^{171}Yb and ^{173}Yb. We find and characterize an SU(*2*) × SU(*6*) symmetric interspecies interorbital interaction. The Yb Fermi-Fermi mixture in the ground state is characterized by strongly attractive inter-species interactions, while the intra-species interactions are vanishing for ^{171}Yb and repulsive for ^{173}Yb. We discuss prospects of spectroscopic methods to gain information on the underlying many-body phase diagram.

A 24.3 Thu 11:45 f303

Status of a buffer gas cooled Low-Emittance Laser Ablation Ion Source with two RF funnels — •Tim Ratajczyk[1], Philipp Bollinger[1], Tim Lellinger[1], Victor Varentsov[2,3], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt — [2]Facility for Antiproton and Ion Re- search in Europe (FAIRGmbH), Darmstadt — [3]Institute for Theoretical and ExperimentalPhysics, Moscow, Russia

Ion sources of low-emittance are of interest in many applications of experimental low-energy physics, for example as ion sources for collinear laser spectroscopy or ion trap experiments, or as ion sources for accelerators and for production of fine focusing beams for industrial microelectronics technologies. Often, surface ion sources are used due to their simple construction and easiness of operation. However, they can only deliver a very small range of elements, mostly alkaline and alkaline earth ions and a few other species. Laser ablation in vacuum opens the possibility to produce ion beams even from transition metals or compound materials. The drawback of this technique is the high emittance of the beam. The presented ion source will counteract this drawback by using He buffer gas to stop the ions and extracting them through optimized RF funnels into high vacuum conditions.

This work is supported by BMBF 05P19RDFN1 and HIC for FAIR

A 24.4 Thu 12:00 f303

A cryogenic Penning trap system for sympathetic laser cooling of atomic ions and protons — •Johannes Mielke[1], Teresa Meiners[1], Matthias Borchert[1,3], Frederik Jacobs[1], Julian Pick[1], Amado Bautista-Salvador[2], Juan Manuel Cornejo[1], Ralf Lehnert[1,4], Malte Niemann[1], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [3]Ulmer Fundamental Symmetries Laboratory, RIKEN, Wako, Saitama 351-0198, Japan — [4]Indiana University Center for Spacetime Symmetries, Bloomington, IN 47405, USA

High precision comparisons of the fundamental properties of protons and antiprotons carried out within the BASE collaboration serve as tests of CPT invariance in the baryon sector. However, preparation and measurement schemes based on resistive cooling and image current detection are time-consuming and highly sensitive to the particle's motional energy. Thus, experimental schemes based on sympathetic cooling of single (anti-)protons through co-trapped atomic ions can contribute to the ongoing strive for improved precision through fast preparation times and low particle temperatures.

Here we present a cryogenic multi-Penning trap system for free space coupling of two single particles in an engineered double-well potential and report on latest results obtained with Doppler cooled $^9Be^+$ ions. Prospects for proton loading and sympathetic cooling in a micro-coupling trap will be discussed.

A 24.5 Thu 12:15 f303

Collinear laser spectroscopy of the $2s\ ^3S_1 \leftrightarrow 2p\ ^3P_2$ transition in He-like Boron — •Konstantin Mohr[1], Zoran Andelkovic[2], Axel Buss[3], Volker Michael Hannen[3], Phillip Imgram[1], Kristian König[4], Jörg Krämer[1], Bernhard Maass[1], Simon Rausch[1], Rodolfo Sánchez[2], Christian Weinheimer[3], and Wilfried Nörtershäuser[1] — [1]IKP, TU Darmstadt — [2]GSI, Darmstadt — [3]IKP, WWU Münster — [4]NSCL, Michigan State University

We aim for a determination of nuclear charge radii of light isotopes in an all-optical approach, i.e., without reference to elastic electron scattering. The calculations required for this approach can currently be only accomplished for hydrogen-like systems but will soon become established for He-like systems [1]. While the ground state of He-like systems is not easily accessible by laser spectroscopy, transitions starting from the metastable $^3S_1$-state can be adressed.

The $2s\ ^3S_1 \leftrightarrow 2p\ ^3P_j$ transitions of $^{11}B^{3+}$ have already been measured with a different technique [2]. At the HITRAP-facility at the GSI accelerator complex designed to prepare heavy highly charged ions for precision spectroscopy [3] we used an Electron Beam Ion Source (EBIS) and measured the $2s\ ^3S_1 \leftrightarrow 2p\ ^3P_2$ transition in ^{10,11}B. In this contribution we report about the current status of this experiment.

[1] V. A. Yerokhin et al., Phys. Rev. **A98**, 032503 (2018)
[2] T. P. Dinneen et al., Pys. Rev. Lett. **66**, 2859, (1991)
[3] Z. Andelkovic et al., Hyp. Int. **235**, 37 (2015)

We acknowledge support from BMBF (05P19RDFAA, 05P19PMFA1) and DFG (SFB 1245).

A 24.6 Thu 12:30 f303

Towards a high-accuracy Al^+ optical clock — •Johannes Kramer[1], Fabian Dawel[1], Lennart Pelzer[1], Ludwig Krinner[1], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt Braunschweig — [2]Gottfried Wilhelm Leibniz Universität Hannover

We aim to build an optical atomic clock taking advantage of the 8 mHz narrow clock transition of a single $^{27}Al^+$ ion stored inside a linear Paul trap together with a single $^{40}Ca^+$ ion acting as logic ion. The low sensitivity of the aluminium ion's $^1S_0$ to $^3P_0$ clock transition to external fields and its potential high Q-factor allow to reach accuracies on the level of 10^{-18}. Frequency standards with such high accuracy are candidates for a future redefinition of the SI second as well as for cm-scale resolution in measuring the gravity field of the Earth due to the gravitational redshift. In this talk we present our experimental setup as well as latest results on measuring the clock transition of the ground-state cooled Al^+-Ca^+ crystal by quantum logic protocols.

A 24.7 Thu 12:45 f303

World's first atom interferometer with a metastable He BEC — •Oleksiy Onishchenko, Rudolf F. H. J. van der Beek, Kjeld S. E. Eikema, Hendrick L. Bethlem, and Wim Vassen — LaserLaB, Department of Physics and Astronomy, Vrije Universiteit, Amsterdam, the Netherlands

Atom interferometry has established itself as a valuable precision measurement tool for the gravitational potential, the Einstein equivalence principle, and the fine structure constant (α) among other things. While most interferometry experiements with ultracold atoms up to now have been performed with alkali or alkaline-earth atoms, metastable helium (He*) stands apart with unique advantages. Among those are the possibility to do high-accuracy atom number detection on a multichannel plate, a very small second-order Zeeman shift, and a very high critical acceleration and recoil velocity [1]. Those advantages are especially suitable for a high-precision measurement of α in a manner independent of quantum electrodynamics calculations. We experimentally demonstrate a crucial tool for such a measurement with He*, namely a large number of Bloch oscillations in an optical lattice, performed with high efficiency. This technique coherently transfers a well-known quantity of linear momentum to the atoms, which strongly reduces the uncertainty in atom recoil velocity measurements for determining α. We also demonstrate a proof-of-principle Mach-Zehnder interferometer with He*.

[1] W. Vassen *et al.* "Ultracold metastable helium: Ramsey fringes and atom interferometry". *Appl. Phys. B* **122**, 289 (2016).

A 25: Ultra-cold plasmas and Rydberg systems II (joint session A/Q)

Time: Thursday 14:00–15:45 Location: a320

Invited Talk A 25.1 Thu 14:00 a320

Anderson localization in a Rydberg composite — •Matthew Eiles, Alexander Eisfeld, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, 38 Noethnitzer Str. Dresden 01187

We demonstrate the localization of a Rydberg electron in a Rydberg composite, a system containing a Rydberg atom coupled to a structured environment of neutral ground state atoms. This localization is caused by weak disorder in the arrangement of the atoms and increases with the number of atoms M and principal quantum number ν. We develop a mapping between the electronic Hamiltonian in the basis of degenerate Rydberg states and a tight-binding Hamiltonian in the so-called "trilobite" basis, and then use this concept to pursue a rigorous limiting procedure to reach the thermodynamic limit in this system, taken as both M and ν become infinite, in order to show that Anderson localization takes place. This system provides avenues to study aspects of Anderson localization under a variety of conditions, e.g. for a wide range of interactions or with correlated/uncorrelated disorder.

A 25.2 Thu 14:30 a320

Rydberg Dressed Quantum Many-Body Systems — •Nikolaus Lorenz[1], Lorenzo Festa[1], Lea Steinert[1], Philip Osterholz[1], Joop Adema[1], Robin Eberhard[1], and Christian Gross[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

Neutral atoms in microtrap arrays brought to interaction by Rydberg coupling offer a novel platform to study quantum magnetism. We have constructed a new experiment with potassium atoms, which aims to induce the magnetic interactions via near-resonant Rydberg coupling, so called Rydberg dressing. Here we report on coherent Rydberg coupling in a two dimensional array of single atoms. We observe fast coherent Rabi oscillations of single atoms as well as of small Rydberg superatoms. Finally we discuss first experiments towards Rydberg dressing induced interactions among atomic ground states.

A 25.3 Thu 14:45 a320

Extended coherently delocalized states in a frozen Rydberg gas — •Ghassan Abumwis, Matthew T. Eiles, and Alexander Eisfeld — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The long-range dipole-dipole interaction between excited Rydberg states of atoms can create highly delocalized states due to the exchange of excitation between the atoms. We show that even in a random gas many of the single-exciton eigenstates are surprisingly delocalized, composed of roughly one quarter of the participating atoms. We identify two different types of eigenstates: one which stems from strongly-interacting clusters, resulting in localized states, and one which extends over large delocalized networks of atoms. These two types of states can be excited and distinguished by appropriately tuned microwave pulses, and their relative contributions can be modified by the Rydberg blockade. The presence of these delocalized eigenstates could be relevant to puzzling results in several current experiments.

A 25.4 Thu 15:00 a320

Characterizing molecular symmetries with quantum gas microscopy — •Simon Hollerith[1], Jun Rui[1], Antonio Rubio-Abadal[1], David Wei[1], Kritsana Srakaew[1], Simon Evered[1], Christian Gross[1,2], and Immanuel Bloch[1,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München

Rydberg macrodimers - molecules consisting of two bound highly excited Rydberg atoms - provide enormous bond lengths even resolvable with optical wavelengths. Here we report on a microscopic study of macrodimers with different molecular symmetries in a gas of ultracold atoms in an optical lattice. The bond length of about 0.7 micrometers matches the diagonal distance of two atoms in the lattice. The geometry of the two-dimensional lattice initially unity filled with ground state atoms allows to control the relative orientation of the molecular axis to an ambient magnetic field and the polarization of the photoassociation light. Using our spatially resolved detection, we detect the associated molecules by correlated atom loss and find the excitation rates to be in agreement with theoretical predictions. Furthermore, we present how the molecular excitation rate can be significantly increased by the use of two color photoassociation. Our results highlight the potential of quantum gas microscopy for molecular physics and show how macrodimers might be used to study many body physics.

A 25.5 Thu 15:15 a320

energy level statistics in Rydberg Composites — •Andrew Hunter, Matthew Eiles, Alex Eisfeld, and Jan M Rost — Max Planck Institute for the Physics of Complex Systems

Rydberg Composites are a new class of Rydberg matter consisting of a single Rydberg atom interfaced with a dense environment of neutral ground state atoms organized in a lattice [1]. The properties of the Rydberg composite are directly linked to the discrete symmetry of the occupied sites in the lattice with characteristic but unusual footprints of quantum chaos in the energy level statistics of the composite. We have developed techniques to identify these effects and present a systematic study of broken lattice symmetry and the transition to full chaos as atoms are removed from the lattice. We also describe how these statistics change with decreasing lattice constant with a transition to a continuous environment when the Rydberg electron can no longer resolve the lattice spacing.

[1] Hunter A L, Eiles M T, Eisfeld A and Rost J M 2019 arXiv:1909.01097

A 25.6 Thu 15:30 a320

Stimulated decay and formation of antihydrogen atoms (arXiv:1912.03163) — •Tim Wolz[1], Chloé Malbrunot[1], Lilian Nowak[1], Daniel Comparat[2], and Mélissa Vieille-Grosjean[2] — [1]Physics Department, CERN, Genève 23, 1211, Switzerland — [2]Laboratoire Aimé Cotton, CNRS, Université Paris-Sud, ENS Paris Saclay, Université Paris-Saclay, 91405 Orsay, France

Antihydrogen atoms (Hbar) are routinely formed at the Antiproton Decelerator at CERN in a wide range of Rydberg states. However, precision measurements for stringent tests of the CPT theorem as well as first direct measurements of Earth's gravitational acceleration of antimatter require ground state (GS) atoms. Currently, experiments solely rely on spontaneous decay which so far only allowed for measurements in a neutral atom trap. We report on methods to stimulate the decay of the Rydberg atoms especially in the framework of a beam formation to extract the atoms into a field free region. We propose deexcitation schemes relying on E and B field mixing (applicable to a pulsed charge exchange Hbar production scheme) as well as THz and microwave mixing (applicable to a quasi continuous three body recombination Hbar production scheme). Both methods make use of a (visible) deexcitation laser. We obtain, in either case, close to unity ground state fractions within a few tens of microseconds. Combining such deexcitation methods with a stimulated radiative recombination allows for a direct formation of Hbar atoms in ground state. Finally, we report on first steps toward an experimental implementation of the proposed techniques.

A 26: Interaction with VUV and X-ray light II

Time: Thursday 14:00–16:00 Location: f107

Invited Talk A 26.1 Thu 14:00 f107

Towards fast adaptive resonant x-ray optics — Miriam Gerharz and •Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Visible light can easily be manipulated using reflective or refractive elements, such as lenses, phase plates, or mirrors. At x-ray energies, the real part of the complex refractive index approaches 1, such that these concepts require revision. As a result, an impressive toolbox of alternative methods has been developed, e.g., based on crystal optics.

In this talk, I will introduce a new concept for fast adaptive x-ray optics, which in particular aims at dynamical control during single experimental cycles. Our approach uses piezo-control methods, which allow one to mechanically displace a solid-state target containing resonances much faster than the lifetime of the resonances. Such displacements create relative phase shifts, which already have been employed successfully to manipulate the time- or energy spectra of x-ray pulses.

For applications in x-ray optics, we associate the phase shifts to an effective real part of the refractive index. The key idea then is that such mechanically-induced phase shifts are independent of the thickness of the target. As a result, the real part of the x-ray refractive index can effectively be increased substantially, without increasing its imaginary part. This approach provides access to high refractive index contrasts at x-ray energies together with low absorption, and thereby opens an avenue to entirely new concepts in x-ray optics.

Invited Talk A 26.2 Thu 14:30 f107

Control of complex Fano resonances by shaped laser pulses — Camilo Granados, Nicola Mayer, Evgenii Ikonnikov, Misha Ivanov, and •Oleg Kornilov — Max-Born-Institute, Berlin

Ultrafast pulsed lasers and high-order harmonic generation have opened access to time-dependent studies in the extreme ultriviolet (XUV) photon energy range. Excited states accessible in the XUV region often have a complex character combining several coupled electronic states, such as multi-state Fano resonances, and undergo ultrafast relaxation dynamics via autoionization, dissociation or relaxation at conical intersections. Recently we investigated dynamics of the complex excited molecular states using time-resolved photoelectron [1,2] and photoion [3] spectroscopy with wavelength-selected XUV pulses. In this contribution we explore how these dynamics can be controlled by temporal and frequency shaping of the near-infrared pulses used to probe the relaxation dynamics induce by XUV.

[1] M. Eckstein et al., Phys. Rev. Lett. 116, 163003 (2016). [2] M. Eckstein et al., Faraday Discuss. 194, 509 (2016). [3] G. Reitsma et al., J. Phys. Chem. A 123, 3068 (2019).

A 26.3 Thu 15:00 f107

Tracking Attosecond Electronic Coherences Using Phase-Manipulated Extreme Ultraviolet Pulses — •Andreas Wituschek, Lukas Bruder, and Frank Stienkemeier — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

Coherent control and nonlinear spectroscopy schemes are powerful tools that allow the study and control of the dynamics of quantum systems. Novel light sources in the extreme ultraviolet (XUV) region paved the way for the extension of these tools to the XUV, allowing experiments with an unprecedented temporal resolution and site selectivity. However, this promise has not yet been met due to the experimental challenges arising at these short wavelengths.

In this work we use an XUV pulse pair created at the FERMI free-electron laser to measure directly in the time domain the coherent evolution and dephasing of electronic XUV wave packets. Independent control over relative phase and delay of the pulse pair allowed us to introduce a phase-cycling scheme, readily used in the visible regime. This provided the necessary interferometric stability and sensitivity to track the ultrafast coherences (150 as). Our technique facilitates a wide range of nonlinear spectroscopy as well as coherent control schemes, and is universally applicable to the whole wavelength range accessible with seeded FELs. In addition, it can be combined with tabletop High Harmonic Generation sources. Additional information and a complete list of collaborateurs of this project can be found here: A. Wituschek et al., arXiv:1906.07112 (2019)

A 26.4 Thu 15:15 f107

Spectral Compression of XUV Radiation by Four-Wave-Mixing — •Lorenz Drescher, Vishal Shokeen, Tobias Witting, Oleg Kornilov, Marc Vrakking, and Bernd Schütte — Max-Born-Institut für nichtlineare Optik und Kurzzeitspektroskopie, Berlin, Germany

We present and demonstrate a novel concept for the efficient generation of narrowband extreme ultra-violet (XUV) radiation that is based on the conversion of broadband attosecond pulse trains and few-cycle NIR pulses via a four-wave mixing process. Spectral compression of broadband XUV radiation is achieved by exploiting the steep gradient of the frequency-dependent refractive index between two closely spaced resonances, while the nearly flat dispersion in the incident vacuum ultraviolet (VUV) and XUV regimes allows for broadband phase-matching. We demonstrate the concept by propagating XUV pulses created by high-harmonic generation through a dense krypton gas jet and observe a narrow emission peak in between the Kr 4d and 6s resonances. The non-resonant nature and generality of the reported process offers new opportunities for tailoring the spectral bandwidth of XUV beams.

A 26.5 Thu 15:30 f107

Dispersive soft x-ray absorption fine-structure spectroscopy in graphite with an attosecond pulse — •Themistoklis P. H. Sidiropoulos[1], Bárbara Buades[1], Dooshaye Moonshiram[2], Iker León[1], Peter Schmidt[1], Irina Pi[1], Nicola Di Palo[1], Seth L. Cousin[1], Antonio Picón[1], Frank Koppens[1,3], and Jens Biegert[1,3] — [1]ICFO-Institut de Ciencies Fotoniques, 08860 Castelldefels, Spain — [2]Institute of Chemical Research of Catalonia, 43007 Tarragona, Spain — [3]ICREA, 08010 Barcelona, Spain

X-ray absorption fine-structure (XAFS) spectroscopy is a powerful element-specific technique, providing electronic and structural information with atomic resolution. Electronic information is extracted from the near-edge XAFS (NEXAFS) spectrum, requiring high spectral resolution to resolve features that occur within a few eV near the absorption edge. Structural information is obtained from the extended XAFS (EXAFS), spreading over several hundred eV above the absorption edge. While XANES and EXAFS are both well-established methods, crucially lacking so far is the capability to connect electronic with structural information in real-time. Here, we present a decisive step towards such new methodology based on water-window-covering (280 eV to 540 eV) attosecond soft X-ray pulses that can simultaneously access electronic and lattice parameters via dispersive XAFS spectroscopy. We validate this approach with an identification of the orbital contributions to the density of states in graphite simultaneously with the four characteristic bonding distances. This work demonstrates the potential of dispersive attosecond XAFS as a powerful spectroscopic tool.

A 26.6 Thu 15:45 f107

An XUV frequency comb for precision spectroscopy of trapped highly charged ions — •Jan-Hendrik Oelmann, Janko Nauta, Alexander Ackermann, Patrick Knauer, Ronja Pappenberger, Nick Lackmann, Steffen Kühn, Julian Stark, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

In order to perform spectroscopy of highly charged ions in the extreme ultraviolet (XUV) with unprecedented resolution, we have built an XUV frequency comb by transferring a near-infrared frequency comb to the XUV by means of high-harmonic generation [1,2]. To reach the required peak intensity levels at a 100 MHz repetition rate, 200 fs laser pulses are amplified to 80 W in a chirped-pulse fiber amplifier and resonantly overlapped in a femtosecond enhancement cavity [3]. By this means, an average power of 25 kW, corresponding to a peak intensity of $\approx 3 \cdot 10^{14}\,\mathrm{W/cm^2}$, is reached in the cavity focus. High harmonics up to the 35^{th} order are coupled out of the cavity and will be guided to trapped and sympathetically cooled highly charged ions [4] in a superconducting Paul trap to perform direct XUV frequency comb spectroscopy.

[1] C. Gohle et al., Nature 436, 234-237 (2005).
[2] G. Porat et al., Nat. Photon, 12, 387 - 391 (2018).
[3] J. Nauta et al., Nucl. Instrum. Meth. B 408, 285 (2017).
[4] L. Schmöger et al., Science 347, 1233 (2015).

A 27: Ultra-cold atoms, ions, and BEC VI (joint session A/Q)

Time: Thursday 14:00–15:45 Location: f303

Invited Talk A 27.1 Thu 14:00 f303

Dynamics of a mobile hole in a Hubbard antiferromagnet — •Martin Lebrat, Geoffrey Ji, Muqing Xu, Christie Chiu, and Markus Greiner — Harvard University, Cambridge, MA, USA

The interplay between spin and charge underlies much of the phenomena of the doped Hubbard model. Quantum simulation of the Hubbard model using quantum gas microscopy offers site-resolved readout and manipulation, enabling detailed exploration of the relationship between the two. We use this platform to explore spin and charge dynamics upon the delocalization of an initially-pinned hole dopant. We first prepare a two-component quantum gas of Lithium-6 loaded into a square optical lattice at half-filling and strong interactions, where the atoms exhibit antiferromagnetic spin ordering. During the loading process, we use a digital micromirror device to pin a localized hole dopant into the antiferromagnet. We then release the dopant and examine how it interacts with and scrambles the surrounding spin environment. The microscopic dynamics of dopants may provide further insight into the phases that appear in the doped Hubbard model.

A 27.2 Thu 14:30 f303

Hubbard Parameters for Quasi-Two-Dimensional Optical Lattices — •Tobias Ilg and Hans Peter Büchler — Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, DE-70550 Stuttgart, Germany

We investigate a microscopic model of two particles interacting via a Feshbach resonance in a quasi-two-dimensional optical lattice. The transverse direction is confined by a harmonic trap, and in the quasi-two-dimensional regime we make the connection between the Hubbard parameter of a single band two-dimensional Hubbard model and the scattering length in three dimensions. Our procedure takes into account the proper renormalization of the low-energy scattering amplitude as well as contributions from all higher bands. We shows that in contrast to the three-dimensional case, higher bands always have an impact on the Hubbard parameter, even for deep optical lattices.

A 27.3 Thu 14:45 f303

Three-dimensional time-reversal-invariant Hofstadter-Hubbard model — •Bernhard Irsigler[1], Jun-Hui Zheng[1,2], Fabian Grusdt[3,4], and Walter Hofstetter[1] — [1]Goethe-University Frankfurt, Germany — [2]NTNU, Trondheim, Norway — [3]MCQST, Munich, Germany — [4]LMU, Munich, Germany

We report on the three-dimensional time-reversal-invariant Hofstadter model with finite spin-orbit coupling. We introduce three numerical methods for characterizing the topological phases based on twisted boundary conditions, Wilson loops, as well as the local topological marker. Besides the weak and strong topological insulator phases we find a nodal line semimetal in the parameter regime between the two three-dimensional topological insulator phases. Using dynamical mean-field theory combined with the topological Hamiltonian approach we find stabilization of these three-dimensional topological states due to the Hubbard interaction. We study surface states which exhibit an asymmetry between left and right surface originating from the broken parity symmetry of the system. Our results set the stage for further research on inhomogeneous three-dimensional topological systems, proximity effects, topological Mott insulators and non-trivially linked nodal line semimetals.

A 27.4 Thu 15:00 f303

Bilayer Fermi - Hubbard physics with a quantum gas microscope — •Sarah Hirthe[1], Joannis Koepsell[1], Dominik Bourgund[1], Jayadev Vijayan[1], Pimonpan Sompet[1], Guillaume Salomon[1], Immanuel Bloch[1,2], and Christian Gross[1,3] — [1]Max-Planck-Institute of Quantum Optics — [2]Ludwig-Maximilians Universität München — [3]Eberhard Karls Universität Tübingen

The bilayer Fermi-Hubbard model is of special interest for quantum simulation, as bilayered structures are prominent in materials such as the high-Tc superconducting cuprates. We have recently upgraded our Fermi gas microscope with a highly stable vertical superlattice, which now allows us full control over a strongly interacting fermionic bilayer system. We investigate the bilayer phase diagram by probing the Mott insulator to band insulator as well as the metal to band insulator transition. We confirm the expected transition point at an interlayer coupling of four times the intralayer coupling. Furthermore, making use of the full control over the lattice potential, we demonstrate a new technique based on topological charge pumping to reach single-site resolution of each layer. We benchmark the power of this technique by applying it to fully spin resolve a two-dimensional system. We find a strongly correlated system at temperatures consistent with the coldest temperatures reported in cold atoms.

A 27.5 Thu 15:15 f303

Coherent control in a driven Fermi-Hubbard system — •Anne-Sophie Walter, Frederik Görg, Kilian Sandholzer, Joaquín Minguzzi, Konrad Viebahn, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, Switzerland

Coherent control is a widely applied technique in fields ranging from chemistry to ultracold atoms. It aims at steering quantum dynamics by controlling the relative phase between external light fields. In the context of Floquet engineering in optical lattices, where the system is periodically driven in time, the drive can resonantly couple to higher Bloch bands leading to atom loss. To overcome this problem we apply a coherent control scheme which would allow for a wider range of possible driving frequencies.

In our experiment, we periodically modulate the potential depth of our 3D optical lattice at a frequency that excites atoms to a higher band. We apply coherent control by tuning the phase of an additional drive at twice the fundamental frequency which destructively interferes with the first. Through this technique we preserve both the band population as well as the fraction of double occupancies for two orders of magnitude longer compared to the single-frequency case. We find this technique to be effective even at strong Hubbard interactions. Strikingly, the lifetime of spin correlations, which are highly susceptible to heating, is also improved by two orders of magnitude and comparable to the static value. This successful application of coherent control in a periodically driven many-body system opens new possibilities for Floquet engineering in the presence of strong interactions.

A 27.6 Thu 15:30 f303

A single beam grating magneto optical trap on an atom chip — •Hendrik Heine[1], Alexander Kassner[2], Christoph Künzler[2], Marc C. Wurz[2], Waldemar Herr[1], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Mikroproduktionstechnik, Leibniz Universität Hannover

Matterwave interferometry with Bose Einstein Condensates (BEC) promises exciting prospects in inertial sensing and research on fundamental physics both on ground and in space. BECs can be created very efficiently by using an atom chip and compact realisations have already been shown. However for transportable or space applications, it is vital to reduce the complexity in order to lower size, weight and power demands of the device.

In this talk I will present a magneto optical trap and sub-Doppler cooling using only a single beam of light in combination with an optical grating on an atom chip. This reduces the complexity of the overall optical system and promises greater long-term stability. Finally, the atom chip allows for magnetic trapping and evaporative cooling by forced radio frequency evaporation towards a BEC.

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 number DLR 50WM1947 (KACTUS-II) and by the German Science Foundation (DFG) under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".

A 28: Poster Session - Atomic Physics IV

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

A 28.1 Thu 16:00 Empore Lichthof

Strong interacting polaron and bi-polaron in 1D: beyond the extended Fröhlich model — •Martin Will[1], Jonas Jager[2], Ryan Barnett[2], and Michael Fleischhauer[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Mathematics, Imperial College London, London SW7 2AZ, United Kingdom

We discuss the interaction of mobile impurities with a surrounding condensate in 1D. For a large impurity-condensate coupling the usual approach of linearizing around a constant condensate density (extended Fröhlich model) does not account correctly for deformations of the BEC and is therefore no longer applicable. We give an alternative approach, taking into account the condensate deformation already on a mean field level, which can be solved analytically [1]. The energy and effective mass of the polaron quasi-particle agree well with quasi exact quantum Monte-Carlo calculations and improve substantially on approaches based on an undepleted BEC [2]. We present the mean-field solution for one as well as two impurities immersed in the condensate from which an effective impurity-impurity interaction potential, mediated through the condensate, is derived.

[1] V. Hakim Phys. Rev. E 55, 2835-2845 (1997)

[2] F. Grusdt, G. Astrakharchik, E. Demler New J. of Phys. 19.10, 103035 (2017)

A 28.2 Thu 16:00 Empore Lichthof

Engineering of vibrational dynamics in a two-dimensional array of trapped ions — •Deviprasath Palaini, Matthias Wittemer, Frederick Hakelberg, Florian Hasse, Philip Kiefer, Ulrich Warring, and Tobias Schaetz — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Strasse 3, 79104 Freiburg

Trapped ions present a promising system for quantum simulations. Surface-electrode traps in contrast to conventional ion traps offer the advantage of scalability to larger system size and dimension while maintaining individual control: Dedicated radio-frequency electrode shapes allow the creation of two-dimensional arrays of individual micro traps, while control electrodes allow localised manipulation of the trapping potential tuning motional frequencies and mode orientations. Our setup consists of a basic but scalable array of three Mg^+ ions individually trapped in an equilateral triangle with 40μm inter-site distance. We present the first realisation of inter-site coupling, until now only realised for linear arrangements. We demonstrate its tuning in real time, and show interference of large coherent states [1]. Furthermore we employ the individual control for modulation of the local trapping potentials to realise phonon-assisted tunnelling between adjacent sites [2].

[1] Hakelberg, F. et al. Phys. Rev. Lett. 123, 100504 (2019)

[2] Kiefer, P. et al. Phys. Rev. Lett. 123, 213605 (2019)

A 28.3 Thu 16:00 Empore Lichthof

Ultracold bosonic $^{23}Na^{39}K$ spin polarized ground state molecules and collisional properties in an atomic ensemble — •Philipp Gersema, Kai Konrad Voges, Mara Meyer zum alten Borgloh, Torsten Hartmann, Torben Alexander Schulze, Alessandro Zenesini, and Silke Ospelkaus — Institute of Quantum Optics, Leibniz University Hannover

Ultracold polar ground state molecules provide an excellent basis for the studies of quantum chemistry and exotic dipolar quantum phenomena. Rovibrational NaK ground state molecules feature a large dipole moment as well as chemical stability against exchange reactions. While the fermionic isotope combination $^{23}Na^{40}K$ has been subject to several previous studies, investigations of the bosonic combination remained elusive.

We present for the first time the production of bosonic spin polarized ground state molecules, by transferring weakly bound molecules to the absolute ground state, utilizing the stimulated Raman adiabatic passage (STIRAP). Starting from an ultracold atomic ensemble we use a Feshbach resonance to create weakly bound molecules. Spectroscopic studies of the excited B1Π and c3Σ manifold and the X1Σ ground state of the NaK molecule were performed to find a bridging state between the triplet dominated weakly bound dimers and the singlet ground state. The STIRAP pulse is done within $12\,\mu$s and has an efficiency of around 70 %, creating up to 4200 molecules. Finally we investigate the collisional properties of the ground state molecules in the 1064 nm optical dipole trap with and without atoms in different spin states.

A 28.4 Thu 16:00 Empore Lichthof

Cloud shape of a molecular Bose-Einstein condensate in a disordered trap — •Sian Barbosa[1], Benjamin Nagler[1,2], Milan Radonjic[1,3], Jennifer Koch[1], Axel Pelster[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Straße 47, 67663 Kaiserslautern, Germany — [3]Scientific Computing Laboratory, Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia

The use of random potentials in experiments with ultracold atoms has proven to be a powerful tool to study disordered quantum systems. Here, we present our investigation of the static geometric properties of a harmonically trapped Bose-Einstein condensate of lithium-6 molecules in an optical speckle potential. We measure the in-situ column density profiles and the corresponding transverse cloud widths over many speckle realizations. We compare the measured widths with a theory that is non-perturbative with respect to the disorder and includes quantum fluctuations. In addition, we present a novel method to calibrate the optical speckle potential.

A 28.5 Thu 16:00 Empore Lichthof

Transport of a low-energy ion in a Bose-Einstein condensate. — •Moritz Berngruber, Thomas Dieterle, Felix Engel, Christian Hölzl, Tilman Pfau, and Florian Meinert — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Stuttgart, Germany

We study the transport properties of a cold ionic impurity in a Bose-Einstein condensate. To this end, we generate a single low-energy ion in an ultra-cold atomic sample starting from a single Rydberg excitation and investigate the interaction between the ionic impurity and the surrounding ground-state atoms. To produce the cold ion, we use methods relying either on a tailored photo-ionization scheme or field ionization. Subsequently the ion is dragged through the Bose-Einstein condensate by applying a weak electric field. Our experiments reveal strong deviations from a bare ballistic motion due to frequent ion-atom collisions and indicate diffusive transport. Furthermore, we discuss the role of three-body recombination on the transport dynamics.

A 28.6 Thu 16:00 Empore Lichthof

Shaping and Isotope-Purification of Ba^+ Ion Coulomb Crystals — •Daniel Hönig[1], Fabian Thielemann[1], Pascal Weckesser[1], Kai Lok Lam[1], Julian Schmidt[2], Leon Karpa[1], and Tobias Schätz[1] — [1]Albert-Ludwigs Universität Freiburg — [2]Laboratoire-Kastler-Brossel, Paris, Frankreich

Trapped ion Coulomb crystals are an interesting platform for quantum simulations. In order to study the dynamics of these crystals e.g. during structural phase transitions, robust methods for isotope-selective preparation as well as control over the ion number are needed.

We present two different methods for reliable ion removal: For isotope selectivity we use parametric excitation of the ions in a Paul trap. Here we achieve a mass resolution high enough to separate $^{137}Ba^+$ and $^{138}Ba^+$, reliably removing the unwanted isotope from the trap. The second method uses state-selective potentials within a 532nm single beam optical dipole trap. By preparing single ions of an ion Coulomb crystal in the $6S_{1/2}$ electronic ground state or the metastable $5D_{5/2}$ state, the dipole trap is attractive or repulsive, respectively. By pumping individual ions into the metastable state we can deterministically remove a single ion of choice.

On the poster we will present our experimental setup. Both theoretical simulations, as well as experimental data concerning the performance will be presented.

A 28.7 Thu 16:00 Empore Lichthof

Ultracold interaction between a single Ba^+-ion and spin-polarized Li — •Fabian Thielemann[1], Pascal Weckesser[1], Daniel Hoenig[1], Kai Lok Lam[1], Markus Debatin[1,2], Leon Karpa[1], and Tobias Schaetz[1] — [1]Physikalisches Institut, Albert-

Ludwigs Universität Freiburg — [2]Institut für Physik, Universität Kassel

The fields of ultracold atoms and trapped ions are important pillars of experimental quantum optics. Recently the expertise of both fields has been combined in hybrid trapping setups to prepare atom-ion mixtures at low temperatures. For joint systems features like Feshbach resonances at magnetic fields on the order of tens of Gauss and the formation of mesoscopic, weakly bound molecules have been predicted. As a first step towards this regime, reaching temperatures on the order of few μK in the combined system is necessary.

Here we present results of a single Ba^+-ion immersed in a cloud of fermionic Li. We observe that, depending on parameters such as the density of the atomic gas or the intensity of present light fields, the ion either undergoes chemical reactions or elastic collisions that result in sympathetic cooling. Further, we present a method that we developed to deterministically prepare a single ion in an rf or optical trap. In this method we make use of state dependent potentials in optical traps to eject selected ions from the trap.

A 28.8 Thu 16:00 Empore Lichthof

Loading of sub-Doppler cooled potassium-39 ensembles into a painted optical dipole trap — •Alexander Herbst, Henning Albers, Sebastian Bode, Knut Stolzenberg, Ernst M. Rasel, and Dennis Schlippert — Institute of Quantum Optics, Leibniz University Hannover

The all-optical creation of potassium BECs is of large interest for the field of guided atom interferometry and its application for quantum inertial sensors as this technique allows for the use of external magnetic fields to control inter-atomic interactions and suppress dephasing effects. However, the direct loading of a large, thermal potassium ensemble into an optical dipole trap remains a major challenge and is crucial for all following processes.

We report on the preparation of sub-Doopler cooled potassium using a gray molasses technique on the D1-line and its loading into an optical dipole trap at 2 um wavelength. Utilizing a time-averaged potential we are able to generate different trap geometries with position-depending AC-Stark-shifts. We analyze the resulting effects on the loading and cooling efficiency of the D1-scheme and discuss possible applications for traditional sub-Doppler schemes.

This work is funded by the Federal Ministry of Education and Research (BMBF) through the funding program Photonics Research Germany (contract number 13N14875), and the DFG under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".

A 28.9 Thu 16:00 Empore Lichthof

The Bose-Einstein and Cold Atom Laboratory (BECCAL) for the ISS — •Kai Frye[1], Tom-Marvin Rathmann[1], Daniel Röckrath[1], Hemanth Kalathur[1], Dennis Becker[1], Christian Schubert[1], Waldemar Herr[1], Sven Abend[1], Thijs Wendrich[1], Ernst Rasel[1], and BECCAL Team[1,2,3,4,5,6] — [1]Leibniz University Hannover — [2]University Ulm — [3]FBH Berlin — [4]Humboldt University Berlin — [5]Johannes Gutenberg-University Mainz — [6]ZARM, University Bremen

Microgravity enables a long free fall of matter waves and eliminates the gravitational sag in traps for atoms. An in-orbit accommodation for microgravity experiments is provided by the International Space Stations.

We present the multi-user and -purpose facility Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL), a joint DLR and NASA project. This apparatus opens up a vast variety of experiments on atom interferometry, atom optics, physics of quantum degenerate gases and their mixtures. These experiments will be a stepping stone for future missions advancing quantum technology for space.

The scientific capabilities and the design of the physics package subsystem as well as our solutions to the constraints set by an accommodation aboard the International Space Station and our approach to establish a multi-user facility is presented.

The BECCAL project is supported by the DLR with funds by the BMWi under grant numbers 50 WP 1431 and 1700. We acknowledge support by QuantumFrontiers under grant number EXC-2123.

A 28.10 Thu 16:00 Empore Lichthof

Creation and splitting of quantum degenerate gases in painted optical potentials - a toolbox for guided atom interferometry — •Knut Stolzenberg, Sebastian Bode, Alexander Herbst, Henning Albers, Ernst M. Rasel, and Dennis Schlippert — Institute of Quantum Optics, Leibniz University Hannover

Guided atom interferometers promise to be compact and robust inertial sensors with excellent long-term stability. An acousto-optic deflector (AOD) is used to create arbitrary time averaged optical dipole potentials by diffracting the beam of a high power 1064 nm laser. This allows for (i) a fast evaporation to quantum degeneracy of ^{87}Rb and (ii) the generation of multiple distinct potential wells. The latter are utilized to split and guide the ensemble. After a free evolution time of $T = 1$ s the clouds are spatially overlapped and interference patterns are observed. We show first results in single and differential matter wave interferometer configuration with magnetically sensitive and insensitive states and discuss future prospects of fully guided interferometry.

This work is funded by the Federal Ministry of Education and Research (BMBF) through the funding program Photonics Research Germany (contract number 13N14875), and the DFG under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".

A 28.11 Thu 16:00 Empore Lichthof

Inter-orbital Interactions in a Fermionic Ytterbium Mixture — •Marcel Diem[1], Benjamin Abeln[1], Koen Sponselee[1], Nejira Pintul[1], Klaus Sengstock[1,2], and Christoph Becker[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Laserphysics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

We present measurements on the inter-orbital interactions between $^1S_0$ ground state and $^3P_0$ metastable state atoms in different fermionic Ytterbium mixtures. We use clock transition spectroscopy in a three-dimensional optical lattice to determine the s-wave scattering lengths. Our first set of measurements is on the spin-exchange interaction of the fermionic Isotope ^{171}Yb. The interaction is antiferromagnetic, which makes ^{171}Yb a promising candidate for the quantum simulation of the Kondo lattice model. Our second set of measurements is on inter-orbital interactions in an SU(*2*) × SU(*6*) fermionic mixture of ^{171}Yb and ^{173}Yb. We measure the different interaction strengths and show its SU(N) symmetry.

A 28.12 Thu 16:00 Empore Lichthof

Sound in a Homogeneous Bose Gas - The Two Fluid Model and Nonlinear Damping — •Timon Hilker[1], Christoph Eigen[1], Jinyi Zhang[1], Lena Dogra[1], Jake Glidden[1,2], Robert Smith[1,2], Nir Navon[1,3], and Zoran Hadzibabic[1] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]Clarendon Laboratory, University of Oxford, UK — [3]Department of Physics, Yale University, New Haven, CT USA

The existence of two distinct sound velocities is one of the hallmarks of superfluids. In a compressible quantum gas both modes couple to density, which allows us to observe, for the first time, both sound velocities in a moderately interacting ultracold Bose gas. Using a magnetic field gradient, we excite centre-of-mass oscillations of a homogeneous K-39 Bose gas in a three-dimensional box trap, revealing two distinct resonant oscillations as described by Landau's two-fluid model. We study the speed, the damping and the microscopic structure of both modes for various interaction strengths and temperatures. At zero temperature, all standard damping vanishes for the lowest BEC mode giving us the unique opportunity to investigate purely nonlinear damping due to collisional coupling to higher modes.

A 28.13 Thu 16:00 Empore Lichthof

Setting up a sideband system and a digital ion trap in an atom-ion hybrid experiment — •Dominik Dorer, Shinsuke Haze, Joschka Wolf, Markus Deiss, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, 89069 Ulm, Germany

We report on two ongoing projects in our atom-ion hybrid trap experiment. First, we want to present the progress for implementing a resolved sideband cooling system for $^{138}Ba^+$ ions. For this we implement a narrow band laser addressing the $6S_{1/2} \rightarrow 5D_{5/2}$ shelving transition at 1762 nm. To achieve a linewidth much smaller than the typical trapping frequencies of our Paul trap (40 kHz) and a daily frequency shift in the sub kHz-regime, we set up a high-Q optical cavity made of ultra low expansion glass. We tested this optical cavity and have carried out first measurements of the shelving transition.

Second, we present our approach to realize a digital ion trap, which we want to use to perform Stark spectroscopy of Rydberg atoms in the electric field of trapped ions [1]. The strategy is to pulse the Rydberg excitation laser in periods where there is no electric field of the ion

trap.

[1] S. Haze et al., arXiv 1901.11069 (2019)

A 28.14 Thu 16:00 Empore Lichthof

Scattering an atom from a Rydberg composite — •Rajat Agrawal and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Here we analyze the collision of a slow atom with a 2D Rydberg composite [1] (changes the electron density of the composite). We will discuss the collision for different geometries like the atomic lattice of Rydberg composites is perpendicular and parallel to the trajectory of an atom. We will also discuss the lattice of the Rydberg composite which has just a single ground state atom (trilobite limit).

[1] Andrew L. Hunter, arXiv:1909.01097v1 (2019)

A 28.15 Thu 16:00 Empore Lichthof

Emergence of the Higgs mode in a two-dimensional few-fermion system — •Keerthan Subramanian, Luca Bayha, Marvin Holten, Ralf Klemt, Philipp Preiss, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, 69120 Heidelberg, Germany

Knowledge of collective excitations is indispensable for many-body systems since they can be used to determine the low-energy properties of the system while being completely ignorant of the dynamics of microscopic constituents. But how many constituents does a system have to contain to be considered many-body?

To gain an insight into this question, we study excitations of an ultracold few-fermion system consisting of ^{6}Li atoms. We first deterministically prepare few atoms in closed shell configurations of a 2D harmonic trapping potential and then excite the system by modulating interactions. We find that the lowest monopole mode shows a non-monotonic behavior and is composed predominantly of pair-excitations prescient of Higgs mode in the many-body limit. This resemblance to the Higgs mode becomes more striking with increasing particle number as more shells of the 2D harmonic oscillator are populated. We further find that the precursor to the Higgs mode can be coherently driven since it does not couple to other modes.

Future directions of investigation will involve spin-resolved single particle imaging of the system to observe Cooper paring and the onset of superfluidity.

A 28.16 Thu 16:00 Empore Lichthof

Interorbital spin-exchange dynamics in ultracold ytterbium — •Giulio Pasqualetti[1,2,3], Oscar Bettermann[1,2,3], Nelson Darkwah Oppong[1,2,3], Luis Riegger[1,2,3], Immanuel Bloch[1,2,3], and Simon Fölling[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ludwig-Maximilians-Universität, Munich, Germany — [3]Munich Center for Quantum Science and Technology, Munich, Germany

With an ultranarrow clock transition, ultracold ytterbium is a promising candidate for quantum simulation of impurity physics, where atoms in a "clock" state represent the impurities, and atoms in the ground state play the role of conduction electrons. The interorbital spin-exchange interaction of ytterbium-171 has recently been measured and proved to be antiferromagnetic, complementing the already known ferromagnetic value of ytterbium-173. Such an interaction is very similar to the one responsible in condensed matter for the Kondo effect, where spin-spin interaction dominates the interplay between localized magnetic moments and the conduction bath. In our experiment, we utilize state-dependent lattices to localize dilute "clock" impurities, and we investigate spin-exchange dynamics of ytterbium in a variety of regimes. Our work presents some milestones towards the quantum simulation of strongly-correlated many-body electronic systems and, in particular, Kondo physics with ultracold atoms.

A 28.17 Thu 16:00 Empore Lichthof

Engineering time-dependent disorder potentials for fermionic quantum gases — •Silvia Hiebel[1], Benjamin Nagler[1,2], Jennifer Koch[1], Sian Barbosa[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

While ultracold atomic gases in static random potentials have facilitated the investigation of Anderson and many-body localization, the impact of time-dependent disorder onto quantum systems is yet a new and uncharted territory.

We have developed a scheme to produce time-dependent optical speckle disorder by combining a stationary with a rotating diffuser. The diffusers are illuminated by a beam of coherent light, onto which they imprint a spatially and temporally varying phase. Subsequently, the light is focused onto the position of the atoms, which experience a dynamic speckle potential. The characteristic time scale of the dynamics is given by the rotation speed of the diffusor and, thus, can be tuned in broad range of parameters to match typical time scales of the quantum gas.

Here we present a characterization of the speckle pattern together with a characterization of the quantum gas in order to identify optimum parameters for the investigation of nonequilibrium physics in interacting quantum gases.

A 28.18 Thu 16:00 Empore Lichthof

Roadmap to Rb-Sr dipolar rovibronic ground-state molecules — •premjith thekkeppatt, lukas reichsöllner, vincent barbé, severin charpignon, benjamin pasquiou, klaasjan van druten, and florian schreck — Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam

Ultracold dipolar molecules offer an ideal platform for investigations in the fields of quantum simulation, precision measurements and quantum chemistry. Thus far, the ultracold polar molecules that have been produced are closed-shell molecules, which limits their range of application. Our goal is to produce RbSr ultracold, polar, open-shell molecules, in order to extend the range of possibilities offered by ultracold molecular physics. We present an efficient quantum-engineering approach to the production of RbSr molecules. The first step is the creation of Rb-Sr atom pairs in the ground-state of an optical lattice, starting from quantum-degenerate clouds of 87Rb and 84Sr. The following step is the magneto-association of these atom pairs into weakly-bound molecules, using a magnetic Feshbach resonance that we identified and that should allow efficient molecular association. With this aim, we designed a highly stable power supply for high magnetic fields, in order to achieve efficient adiabatic transfers from the atom pair state to the weakly-bound molecular state. We describe the laser system that we intend to use for the final step of the molecule production, which is the coherent state-transfer to the rovibronic ground-state using STImulated Raman Adiabatic Passage (STIRAP).

A 28.19 Thu 16:00 Empore Lichthof

Single-atom-resolved fluorescence detection in a magneto-optical trap — •Cebrail Pür, Mareike Hetzel, Jiao Geng, Andreas Hüper, Wolfgang Ertmer, and Carsten Klempt — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany

Atom interferometers, which belong to today's most precise sensors, are fundamentally limited by the standard quantum limit (SQL $\propto 1/\sqrt{N}$) when operated with uncorrelated particles. Within our project, we will employ spin-dependent collisional interactions in Bose-Einstein condensates to generate metrologically useful entanglement to overcome this limitation. The new level of precision is then given by the Heisenberg limit, which necessitates the precise determination of the atom number with an error below the single atom level. In a new dedicated apparatus we demonstrate our single-particle resolving detection scheme with fluorescence imaging of a 3D-MOT filled with ^{87}Rb atoms. In contrast to absorption imaging, the signal-to-noise ratio (SNR) is greatly enhanced due to the long lifetime of the MOT and the large signal of photons scattered per atom and per unit time.

Single-particle resolving fluorescence measurements for up to 30 atoms are presented. According to our noise analysis the single-atom resolution extends to a limiting atom number of 390(20) atoms. The variance in atom number resolution is currently restricted by the stability of our laser frequency and intensity, which will be improved by active stabilization. We outline a path to approach the Heisenberg limit in phase sensitivity with mesoscopic ensembles.

A 28.20 Thu 16:00 Empore Lichthof

Spontaneous density-modulation through Rydberg dressing: Cluster Gutzwiller mean-field study of a Bose-Hubbard model with next-nearest neighbor interaction — •Mathieu Barbier, Jaromir Panas, and Walter Hofstetter — Goethe Universität, Frankfurt am Main, Deutschland

Recently it became possible to experimentally create macrodimers in a lattice through coupling of an ultracold bosonic quantum gas to high lying Rydberg states[1]. As a follow-up study, it was proposed to use

the coupling to macrodimer states for the enhancement of Rydberg dressing schemes, which might lead to a rich phase diagram of non-trivial quantum phases.
We theoretically study a bosonic quantum gas trapped in an optical lattice with weak Rydberg dressing, resulting in an effective next-nearest neighbor interaction. In this work we consider both attractive and repulsive interaction. In order to capture additional quantum fluctuations and the expected broken translational symmetry, we treat the system with the Cluster Gutzwiller method [2].
We find various quantum phases, such as Mott insulating and superfluid phases as well as density wave phases between the Mott lobes that are stabilized by hopping processes. We propose how to access these phases with a range of experimentally feasible parameters.

[1] S. Hollerith *et al.*, Science **364**, 664 (2019)
[2] D. Lühmann, Phys. Rev. A **87**, 043619 (2013)

A 28.21 Thu 16:00 Empore Lichthof

Number squeezing transfer from spin to momentum states — •Alexander Idel[1], Fabian Anders[1], Polina Feldmann[2], Bernd Meyer[1], Jan Peise[1], Luis Santos[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für theoretische Physik, Leibniz Universität Hannover

Twin-Fock states can measure the phase of an interferometer more precise than the standard quantum limit (SQL)[1]. Future large-scale atomic gravimeters will employ Bose-Einstein condensed samples due to their well-controlled spatial mode and the low expansion rates. Entangled states such as Twin-Fock states can be used to overcome the SQL in these interferometers. Atomic entangled states are commonly produced in the spin degree of freedom and concepts for their transfer to momentum states have not been demonstrated so far. We apply Raman laser pulses to couple the internal spin state to external momentum states. I will show first results on the entanglement verification and a possible extension of the concept to atomic gravimetry beyond the SQL.

[1] B. Lücke *et al, Science*, **334**, 6057 (2011).

A 28.22 Thu 16:00 Empore Lichthof

A trapped dipolar supersolid with atomic Dysprosium — •Kevin Ng[1], Mingyang Guo[1], Fabian Böttcher[1], Jens Hertkorn[1], Jan-Niklas Schmidt[1], Hans Peter Büchler[2], Tim Langen[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

A supersolid is a counter-intuitive state of matter that combines the frictionless flow of a superfluid with the crystal-like periodic density modulation of a solid. Although first predicted to exist over 50 years ago, recent efforts to realize such a state have not exhibited propagating phonon modes. With a self-organized array of dipolar quantum droplets, we demonstrate the first true realization of a supersolid state, where global gauge symmetry and translational symmetry are simultaneously broken.

In our system, a periodic density modulation arises from intrinsic interactions between atoms. This, and in addition to global phase coherence, we observe the Goldstone mode associated with two broken translational symmetries. This low-energy mode, existing only as a consequence of superfluid stiffness, features an out-of-phase oscillation of the crystal array and the superfluid density while keeping the center-of-mass constant. At the phase transition between BEC and supersolid phases, we identify the low-energy Goldstone and Higgs amplitude modes as emerging from the softening roton modes of the dipolar BEC.

A 28.23 Thu 16:00 Empore Lichthof

A cooperative optical mirror formed by a subradiant subwavelength atomic array — •David Wei[1], Jun Rui[1], Antonio Rubio-Abadal[1], Simon Hollerith[1], Kritsana Srakaew[1], Simon Evered[1], Immanuel Bloch[1,2,3], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, München, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

Ensembles of closely spaced quantum emitters can respond cooperatively due to photon-mediated dipole-dipole interactions. Using atomic dipoles trapped in an optical lattice, we realize a two-dimensional subwavelength square array, which shows strong subradiant response and acts as a single-layered cooperative optical mirror.

By varying the density and the ordering of the atoms in the array, we are able to control the influence of the dipolar interactions and to study the role of spatial order for the collective properties. Using Bloch oscillations to change the atom positions, we dynamically modify the reflectivity of the atomic mirror due to breaking and restoring the array order. Our work demonstrates efficient optical meta-material engineering which might give rise to novel atomic light-matter interfaces.

A 28.24 Thu 16:00 Empore Lichthof

Building up a modular Na-K quantum gas experiment — •Lilo Höcker, Jan Kilinc, Rohit Prasad Bhatt, and Fred Jendrzejewski — Kirchhoff-Institute for Physics, Im Neuenheimer Feld 227, D-69120 Heidelberg

Ultracold quantum gases allow a precise control over experimental parameters enabling the simulation of complicated physical processes in nature. Adding a second atomic species offers a versatile experimental platform to study strongly interacting many-body phenomena extending the large range of applications. In this poster, we present the new Na-K experiment at Heidelberg, which we are setting up as a platform to study quantum many-body physics like quantum thermodynamics, lattice gauge theories, Kondo effect.

A 28.25 Thu 16:00 Empore Lichthof

A laser system for creating ground state ^{23}Na^{40}K molecules — •Akira Kamijo[1], Roman Bause[1], Xing-Yan Chen[1], Marcel Duda[1], Andreas Schindewolf[1], Immanuel Bloch[1,2], and Xin-Yu Luo[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ludwig-Maximilians-Universität, München, Germany

Ultra-cold polar molecules in their ground state offer unique possibilities to investigate quantum many-body systems due to their long-ranged dipole-dipole interaction. In our experiment, ultra-cold ^{23}Na^{40}K molecules are transferred to their electronic, vibrational and rotational ground state via stimulated Raman adiabatic passage (STIRAP). This work focuses on the design and construction of a new STIRAP system following previous work at MIT [1] and Hefei [2]. An intermediate state in the B/c manifold is used, resulting in STIRAP transitions at 805 nm and 567 nm. To generate the 567 nm laser, the output of a 1134 nm external cavity diode laser is injection amplified by a gain chip to 250 mW and subsequently converted to 567 nm light by a periodically poled Lithium Niobate waveguide. 805 nm light is generated by a diode laser and amplified by a tapered amplifier. Using only solid-state lasers allows the system to be robust and easy to maintain. To ensure mutual coherence of these lasers, they are locked to a dual wavelength ultra-low expansion cavity allowing relative line widths of 10^{12} or lower.

[1] Park, J. W. et al. Phys. Rev. Lett. 114, 205302 (2015)
[2] Liu, L. et al. Phys. Rev. Lett. 122, 253201 (2019)

A 28.26 Thu 16:00 Empore Lichthof

Towards trapping ultracold polar molecules in a dark repulsive dipole trap — •Ren-Hao Tao[1], Roman Bause[1], Marcel Duda[1], Xing-Yan Chen[1], Andreas Schindewolf[1], Immanuel Bloch[1,2], and Xin-Yu Luo[1] — [1]Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, Faculty of Physics, Schellingstrasse 4, 80799 Munich, Germany

Ultra-cold molecules, by virtue of their rich ro-vibrational states and significant dipole moments, offer us an exciting platform to study new quantum many-body physics. However, many experiments have shown loss behaviours of molecules consistent with two-body losses. For non-reactive species, this is not expected. A recent proposal suggests that the trapping light in these experiments, despite being far-detuned from molecule transitions, can still electronically excite two-molecule complexes. To test this theory, we plan to trap ^{23}Na^{40}K molecules using a blue-detuned light away from the transition $|X^1\Sigma^+, v = 0, J = 0\rangle \rightarrow |b^3\Pi, v = 0, J = 1, \Omega = 0\rangle$. Such a transition, owing to its small linewidth ($2\pi \times 297$ Hz), has a low photon scattering rate even if we go near-resonant. As a result, we can trap molecules with less trapping intensity due to their large polarizability at near-detuning. We achieve a trap depth of $4k_B \cdot \mu$K with an intensity in the dark region as low as 4W/cm^2, which is much lower than the predicted threshold intensity for destroying the scattering complex of ^{23}Na^{40}K molecules.

A 28.27 Thu 16:00 Empore Lichthof

Parametric Excitation of a Bose-Einstein Condensate: From Faraday Waves to Granulation — •Axel U. J. Lode[1], Jason H. V. Nguyen[2], Henry D. Luo[2], Gustavo D. Telles[3], Vanderlei S. Bagnato[3], Marios C. Tsatsos[3], and Randy G. Hulet[2] — [1]Albert-Ludwig University, Freiburg, Germany — [2]Rice University, Houston, USA — [3]University of São Paulo, São Carlos, Brazil

We explore, both experimentally and theoretically, the response of an elongated Bose-Einstein condensate to modulated interactions. We identify two distinct regimes differing in modulation frequency and modulation strength. Longitudinal surface waves are generated either resonantly or parametrically for modulation frequencies near the radial trap frequency or twice the trap frequency, respectively. The dispersion of these waves, the latter being a Faraday wave, is well reproduced by a mean-field theory that accounts for the 3D nature of the elongated condensate. In contrast, in the regime of lower modulation frequencies, we find that no clear resonances occur, but with an increased modulation strength, the condensate forms an irregular granulated distribution that is outside the scope of a mean-field approach. We find that the granulated condensate is characterized by large quantum fluctuations and correlations, which are well described with single-shot simulations obtained from wave functions computed by a beyond-mean-field theory at zero temperature, the multiconfigurational time-dependent Hartree for bosons method. See Phys. Rev. X **9**, 011052 (2019) and http://ultracold.org

A 28.28 Thu 16:00 Empore Lichthof

QUANTUS-2 - Quantum Gases under Microgravity — •Peter Stromberger[1], Merle Cornelius[2], Julia Pahl[3], Christian Deppner[4], André Wenzlawski[1], Patrick Windpassinger[1], and the QUANTUS-Team[1,2,3,4,5,6] — [1]JGU Mainz — [2]U Bremen — [3]HU Berlin — [4]LU Hannover — [5]U Ulm — [6]TU Darmstadt

QUANTUS-2 is a mobile rubidium BEC experiment used for experiments under microgravity in the drop tower in Bremen. Using magnetic lensing we decreased the expansion rate of the BEC in all three dimensions below 100 μm/s allowing for observations after evolution times greater than 2 seconds and enhancing the sensitivity of atom interferometers. We present preparatory measurements for the implementation of a double Bragg Mach-Zehnder type interferometer (MZI) under microgravity and the determination of the gravitational acceleration with a single Bragg MZI and a matter-wave cavity gravimeter.

Furthermore, under microgravity it is possible to implement dressed state shell potentials and confining Bose gases in two dimensions. Studying a quasi two-dimensional Bose gas allows for investigation of the Berezinskii-Kosterlitz-Thouless (BKT) phase transition. We intend to create shell potentials by radio-frequency dressing of magnetic sub-states of the hyperfine ground-state. We will discuss our progress towards implementation of dressed state potentials at the QUANTUS-2 experiment and present simulations and first experimental results.

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 28.29 Thu 16:00 Empore Lichthof

Realization of dual-species BEC for interferometry in space — •Jonas Böhm[1], Baptist Piest[1], Maike D. Lachmann[1], Wolfgang Ertmer[1], Ernst M. Rasel[1], and the MAIUS Team[1,2,3,4,5,6,7,8] — [1]Institute of Quantum Optics, LU Hanover — [2]Department of Physics, HU Berlin — [3]ZARM, University of Bremen — [4]DLR Institute of Space Systems, Bremen — [5]Institute of Physics, JGU Mainz — [6]DLR Simulation and Software Technology, Brunswick — [7]Ferdinand-Braun-Institut, Berlin — [8]DLR MORABA, Oberpfaffenhofen

Atom interferometry is a promising tool for measurements of the gravitational constant or the UFF. As the sensitivity scales with the squared interrogation time, conducting these experiments in microgravity is of great interest. The sounding rocket mission MAIUS-A demonstrated the first creation of a BEC in space and its use as a source for atom interferometry. Here, we present the current status of the follow-up mission MAIUS-B that extends the apparatus by another species to perform interferometry with K-41 and Rb-87. The steps to create a dual-species BEC, that includes to load atoms in a 3DMOT from a cold atomic beam created in a 2D MOT and using a sequence of polarization gradient and evaporative cooling, are discussed. Optimization routines relying on machine learning algorithms are highlighted.

The MAIUS project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number:50WP1431.

A 28.30 Thu 16:00 Empore Lichthof

Towards Quantum Simulation of Light-Matter Interfaces with Strontium Atoms in Optical Lattices — •Jan Trautmann, Andé Heinz, Annie Jihyun Park, Florian Wallner, Eva Casotti, Neven Šantić, Immanuel Bloch, and Sebastian Blatt — Max-Planck Institute of Quantum Optics, 85748 Garching, Germany

In the last two decades, quantum simulators based on ultracold atoms in optical lattices have successfully emulated strongly correlated condensed matter systems. With the recent development of quantum gas microscopes, these quantum simulators can now control such systems with single-site resolution. Within the same time period, atomic clocks have also started to take advantage of optical lattices by trapping alkaline-earth-metal atoms such as Sr, and interrogating them with precision and accuracy at the 10^{-18} level. Here, we report on progress towards a new quantum simulator that combines quantum gas microscopy with optical lattice clock technology. We have developed in-vacuum buildup cavities with large mode volumes that will be used to overcome the limits to system sizes in quantum gas microscopes. By using state-dependent optical lattices for the clock states, we aim to emulate strongly-coupled light-matter-interfaces in parameter regimes that are unattainable in real photonic systems.

A 28.31 Thu 16:00 Empore Lichthof

Dipolar quantum mixtures of erbium and dysprosium — •Claudia Politi[2], Philipp Ilzhöfer[2], Gianmaria Durastante[1,2], Maximilian Sohmen[1,2], Arno Trautmann[2], Manfred Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

In the last years, strongly-magnetic atoms drew great attention in the quantum-gas community motivated by the possibility of realizing exotic phases of matter arising from long-range and anisotropic dipole-dipole interactions. So far, experiments with dipolar lanthanides focused on single-species operation. We present an experimental setup, which for the first time, combines two highly magnetic atomic species, erbium and dysprosium. In order to access the numerous interesting regimes, a precise knowledge of the inter-species scattering length is essential. Several techniques are known to probe the collisional properties, including e.g. lattice modulation spectroscopy. We present an alternative method in which, making use of species-selective potentials together with theoretical simulations based on ground state calculations using an extended Gross-Pitaevskii equation, we investigate the unknown inter-species scattering length. Merging the field of dipolar quantum gases with heteronuclear mixtures makes our system an ideal candidate to study the unexplored dipolar immiscibility-miscibility phase diagram and impurity physics in dipolar gases.

A 28.32 Thu 16:00 Empore Lichthof

Supersolid states in dipolar quantum gases — •Gabriele Natale[1], Lauriane Chomaz[1], Daniel Petter[1], Alexander Patscheider[1], Rick van Bijnen[2], Manfred Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institut fuer Experimentalphysik, Universitaet Innsbruck, Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut fuer Quantenoptik und Quanteninformation, Technikerstraße 21a, 6020 Innsbruck, Austria

In the last years, experiments using highly magnetic lanthanide atoms proved the existence of novel many-body quantum states, e.g. quantum droplets and dipolar supersolids. When confined in a cigar-shaped trap, quantum gases show intriguing behaviors. The excitation spectrum of the regular superfluid can develop a roton mode. When the roton mode becomes unstable, new phases can be stabilized against collapse by quantum fluctuations. We explore the steady-state behavior of an erbium quantum gas in this regime and observe a supersolid state exhibiting a density modulation with global phase coherence. In follow-up work, we investigate the spectrum of elementary excitations across the superfluid supersolid phase transition. Theoretically, we show that, when entering the supersolid phase, two distinct excitation branches appear, associated with dominant crystal and superfluid character, respectively. Experimentally, we probe compressional excitations across the phase diagram. While in the Bose-Einstein condensate regime the system exhibits an ordinary quadrupole oscillation, in the supersolid regime we observe a striking two-frequency response of the system, related to the two spontaneously broken symmetries.

A 28.33 Thu 16:00 Empore Lichthof

Rydberg impurity dynamics in Bose-Einstein Condensates —

•Sebastian Wüster — Indian Institute of Science Education and Research (IISER) Bhopal

Rydberg atoms can be excited embedded in a Bose-Einstein Condensate (BEC) under controlled conditions, to study the coupling to phonons [1] and formation of polarons [2].

We theoretically study the short-time non-equilibrium dynamics of the coupled BEC-Rydberg system, using Gross-Pitaevskii and ogoliubov theory, and show that the BEC can act as a tracking device for Rydberg motion, akin to a Bubble chamber [3].

When the Rydberg atom is brought into a superposition of electronic states, the different coupling of the Rydberg electron to the condensate environment in those states will lead to decoherence. The resultant hybrid open quantum system then constitutes a rare occasion where both, system and environment are highly controllable and their dynamics can be read out in detail.

[1] J. B. Balewski et al. Nature 502, 664 (2013).
[2] F. Camargo et al. Phys. Rev. Lett. 120, 083401 (2018).
[3] S. Tiwari and S. Wüster, Phys. Rev. A. 99, 043616 (2019)

A 29: Ultra-cold plasmas and Rydberg systems III (joint session A/Q)

Time: Friday 11:00–13:00 Location: b305

Invited Talk A 29.1 Fri 11:00 b305

Coherent facilitation dynamics in Rydberg atomic lattice quantum simulators — •Paolo Pietro Mazza[1], Richard Schmidt[2,3], and Igor Lesanovsky[1,4] — [1]Institute of Theoretical physics, University of Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Strasse, 1, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [4]School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

The possibility to precisely control many-body systems at the quantum level has opened the era of quantum simulators. Rydberg atoms held in optical tweezer arrays represent currently one of the most advanced simulator platforms. They are particularly suited for the implementation and study of strongly interacting spin systems. In this talk I will present results on the coherent many-body dynamics in the so-called *facilitation regime*. The focus of my talk is on the understanding of the interplay between Rydberg excitations and lattice vibrations. Using both analytical arguments and numerical simulations, I will show how vibrations of the atoms around their local equilibrium positions can alter the dispersion relation of spin excitations or even leads to their spatial localization.

A 29.2 Fri 11:30 b305

Entanglement and Critical Dynamics in $(1+1)D$ (Rydberg) Quantum Cellular Automata — •Edward Gillman[1], Federico Carollo[1,2], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy,University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [2]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

The study of non-equilibrium phase transitions in dissipative quantum many-body systems presents a significant challenge [1,2]. One open problem relates to the relevance of quantum correlations, and particularly entanglement, on critical physics. Recently, quantum cellular automata (QCA) * realisable in quantum simulators based on Rydberg atoms * have been shown to constitute an ideal platform for investigating such questions. In this talk we present a framework for analysing QCA with absorbing states based on projected entangled pairs states. This permits the study and quantification of the effect of entanglement on non-equilibrium dynamics and critical behaviour.

[1] F. Carollo, E. Gillman, H. Weimer, and I. Lesanovsky, Phys. Rev. Lett. 123, 100604 (2019). [2] E. Gillman, F. Carollo, and I. Lesanovsky, New Journal of Physics 21, 093064 (2019).

A 29.3 Fri 11:45 b305

Fermi surface deformation and pairing of Rydberg-dressed fermions — •Yijia Zhou[1] and Weibin Li[1,2] — [1]School of Physics and Astronomy, University of Nottingham, University Park, Nottingham, NG7 2RD, UK — [2]Centre for the Theoretical Physics and Mathematics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham, NG7 2RD, UK

Anisotropic long-range interactions in cold Fermi gas have attracted broad interest in studying exotic many-body physics. Previous theories and experiments on magnetic dipolar atoms have revealed distorted Fermi surface, directional zero sound, anisotropic Cooper pair and Wigner crystallisation, etc. In this work, we study the laser dressing of fermions to Rydberg p-states and d-states. Due to the higher angular momentum, the Rydberg-dressed interaction is anisotropic and long-ranged. By controlling the strength and length of the interaction, the anisotropicity is enhanced in a controlled fashion. Focusing on a single component fermion gas, we show that the strong anisotropic interaction alters the many-body ground state, such that the Fermi surface is deformed. When two fermions with opposite momentum are paired through the long-range interaction, they exhibit interesting anisotropic features. We study dependences of the anisotropic physics of the fermion gas on the laser parameter, Rydberg state, and density of atoms.

A 29.4 Fri 12:00 b305

Precision Spectroscopy of Negative-Ion Resonances in Ultralong-Range Rydberg Molecules — •Thomas Dieterle[1], Felix Engel[1], Frederic Hummel[2], Christian Fey[4], Peter Schmelcher[2,3], Robert Löw[1], Tilman Pfau[1], and Florian Meinert[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Zentrum für optische Quantentechnologien, Fachbereich Physik, Universität Hamburg — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg — [4]Max-Planck-Institute of Quantum Optics, Garching

Negative ions constitute remarkable objects that, in contrast to their neutral relatives, are very weakly bound and typically feature only few bound states. Moreover, the level structure of negative ions near the electron detachment limit also dictates the low-energy scattering of an electron with the parent neutral atom.

Here, we demonstrate how ultralong-range Rydberg molecules (ULRM) can be used as an atomic-scale system to precisely probe details of the underlying near-threshold anion states. For the first time, we present measurements of the so-far unobserved fine structure of the ^3P_J triplet of Rb^-. In addition, these measurements allow us to extract s- and p-wave scattering lengths with unprecedented precision and determine the positions of the p-wave shape resonances associated with the ^3P_J fine-structure triplet of Rb^-.

A 29.5 Fri 12:15 b305

Engineering non-binary Rydberg interactions via electron-phonon coupling — •Filippo Maria Gambetta[1,2], Weibin Li[1,2], Ferdinand Schmidt-Kaler[3,4], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham, United Kingdom — [3]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [4]Helmholtz-Institut Mainz, Mainz, Germany

Coupling electronic and vibrational degrees of freedom of Rydberg atoms held in optical tweezer arrays offers a flexible mechanism for creating and controlling atom-atom interactions. In our work, we demonstrate that the state-dependent coupling between Rydberg atoms and local oscillator modes gives rise to two- and three-body interactions which are controllable through the strength of the local confinement. This approach even permits the cancellation of two-body terms such that three-body interactions become dominant. We analyze the structure of these interactions on two-dimensional bipartite lattice geometries and explore the impact of three-body interactions on system ground state on a square lattice. Our work shows a highly versatile handle for engineering multi-body interactions of quantum many-body systems in most recent manifestations on Rydberg lattice quantum simulators.

Reference: F. M. Gambetta, W. Li, F. Schmidt-Kaler, I. Lesanovsky,

arXiv:1907.11664

A 29.6 Fri 12:30 b305

Engineering Rydberg-spin Hamiltonian using microwave pulse sequences — •Sebastian Geier[1], Nithiwadee Thaicharoen[1], Clement Hainaut[1], Titus Franz[1], Andre Salzinger[1], Annika Tebben[1], Carlos Brandl[1], David Grimshandl[1], Gerhard Zürn[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

We present engineering of general classes of spin Hamiltonians differing from the underlying Rydberg interaction Hamiltonian to experimentally study quantum spin models in an isolated environment. A system of Rydberg atoms in two distinct Rydberg states, interacting via Van der Waals or dipolar interaction, can already be mapped onto a spin system with a Heisenberg XX- and XXZ-Hamiltonian. In order to obtain access to more general classes of XYZ-Hamiltonians, we dynamically engineer terms in the given interaction Hamiltonian using global microwave pulses which couple the two different Rydberg states. With a sequence widely used in nuclear magnetic resonance that is called WAHUHA sequence, we show the ability to transform a system with XX-like interactions into an isotropic XXX-model. Magnetization measurements reveal that this sequence can be used to preserve the magnetization of any arbitrary initial state even if it is far-from-equilibrium. By modifying the delay time between the pulses we implement XXZ-models with different anisotropies and observe their relaxation dynamics.

A 29.7 Fri 12:45 b305

An optogalvanic flux sensor for trace gases — •Fabian Munkes[1,2], Patrick Kaspar[1,2], Yannick Schellander[1,2], Johannes Schmidt[1,2,4], Denis Djekic[2,3], Patrick Schalberger[2,4], Holger Baur[2,4], Robert Löw[1,2], Tilman Pfau[1,2], Jens Anders[2,3], Norbert Frühauf[2,4], Edward Grant[5], and Harald Kübler[1,2] — [1]5. Physikalisches Institut — [2]Center for Integrated Quantum Science and Technology — [3]Institut für Intelligente Sensorik und Elektrotechnik — [4]Institut für Großflächige Mikroelektronik — [5]Department of Chemistry University of British Columbia

We demonstrate the applicability of a new kind of gas sensor based on Rydberg excitations. From a gas mixture the molecule in question is excited to a Rydberg state. By succeeding collisions with all other gas components this molecule becomes ionized and the emerging electron can be measured as a current, which is the clear signature of the presence of this particular molecule. As a first test we excite Alkali Rydberg atoms in an electrically contacted vapor cell [1,2] and demonstrate a detection limit of 100 ppb to a background of N_2. For a real life application, we employ our gas sensing scheme to the detection of nitric oxide at thermal temperatures and atmospheric pressure [3]. We show first results of cw spectroscopy of the $A\,^2\Sigma^+ \leftarrow X\,^2\Pi_{1/2}$ transition in NO.

[1] D. Barredo, et al., *Phys. Rev. Lett.* **110**, 123002 (2013)
[2] J. Schmidt, et al., SPIE **10674** (2018)
[3] J. Schmidt, et al., *Appl. Phys. Lett.* **113**, 011113 (2018)

A 30: Ultra-cold atoms, ions, and BEC VII (joint session A/Q)

Time: Friday 11:00–13:00 Location: f303

Invited Talk A 30.1 Fri 11:00 f303

Interaction-induced lattices for bound states: Designing flat bands, quantized pumps and higher-order topological insulators for doublons — •Grazia Salerno, Giandomenico Palumbo, Nathan Goldman, and Marco Di Liberto — Center for Nonlinear Phenomena and Complex Systems,Universit *e Libre de Bruxelles, CP 231, Campus Plaine, B-1050 Brussels, Belgium

Bound states of two interacting particles moving on a lattice can exhibit remarkable featuresthat are not captured by the underlying single-particle picture. Inspired by this phenomenon, weintroduce a novel framework by which genuine interaction-induced geometric and topological effectscan be realized in quantum-engineered systems. Our approach builds on the design of effectivelattices for the center-of-mass motion of two-body bound states, which can be created throughlong-range interactions. This general scenario is illustrated on several examples, where flat-bandlocalization, topological pumps and higher-order topological corner modes emerge from genuineinteraction effects. Our results pave the way for the exploration of interaction-induced topologicaleffects in a variety of platforms, ranging from ultracold gases to interacting photonic devices.

A 30.2 Fri 11:30 f303

Spectroscopy of interorbital dimers and pair states in Ytterbium-171 — •Oscar Bettermann[1,2], Nelson Darkwah Oppong[1,2], Giulio Pasqualetti[1,2], Luis Riegger[1,2], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ludwig-Maximilians-Universität, Munich, Germany

An outstanding feature of alkaline-earth-(like) atoms is the existence of a metastable excited electronic state connected to the ground state via an ultranarrow "clock" transition. The interactions between atoms in the different electronic states are governed by the molecular interaction potentials between the atoms and the bound states formed inside these potentials.

Here, we report on the direct production and spectroscopy of the least bound state in Ytterbium-171 and characterization of the interactions between atoms in different electronic states. The dimers are produced by direct single-photon photoassociation via the clock line, in a deep three-dimensional optical lattice. In strong contrast to the shallow bound state present in Ytterbium-173, we find a much larger binding energy, with a much smaller molecular wavefunction therefore largely independent of the external potentials. We also show that the free-to-bound transition can be made insensitive to the depth of the trapping potential, an important aspect in the realization of optical molecular clocks.

A 30.3 Fri 11:45 f303

A subradiant two-dimensional atomic array forming an optical mirror — •David Wei[1], Jun Rui[1], Antonio Rubio-Abadal[1], Simon Hollerith[1], Kritsana Srakaew[1], Simon Evered[1], Immanuel Bloch[1,2,3], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, München, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

When quantum emitters are positionally structured on sub-wavelength scales, photon-mediated dipole-dipole interactions can strongly alter the spectral and directional radiative response. Tightly trapped atoms in optical lattices, only coupled to the electromagnetic vacuum, constitute ideal dipolar emitters to study such cooperative behaviour.

In our experiment, we probe the collective properties of a two-dimensional square array of atomic dipoles by performing spectroscopic absorption and reflection measurements. We directly observe considerably subradiant response and demonstrate that the array acts as a reflective mirror formed by a single mono-layer of a few hundred atoms. By varying the atom density within the array, we are able to control the influence of the dipolar interactions. By introducing positional disorder in the atomic ensemble, we analyze the role of the array structure. Its importance is emphasized by dynamically breaking and restoring the order using atomic Bloch oscillations to control the reflectivity of the atomic mirror.

A 30.4 Fri 12:00 f303

State-dependent optical lattices for the clock states of strontium — •Annie Jihyun Park[1], Andre Heinz[1], Trautmann Jan[1], Neven Santic[1], Sergey G Porsev[2,3], Marianna S Safronova[2,4], Immanuel Bloch[1,5], and Sebastian Blatt[1] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]U. Delaware, Newark, USA — [3]Petersburg Nuclear Physics Institute, Gatchina, Russia — [4]JQI, NIST and U. Maryland, College Park, USA — [5]LMU, Munich, Germany

We demonstrate state-dependent optical lattice for the clock states in strontium at the tune-out wavelength for the 1S0 ground state, where

its dipole polarizability vanishes. Using a novel spectroscopic method, we measure 689.222225(14) nm for this tune-out wavelength in Sr-88, one of the most precise and accurate measurements of a tune-out wavelength to date. Since our method does not require quantum degenerate gases, it is also suited for measuring tune-out wavelengths for atoms in metastable states, molecules, fermionic species and trapped ions. Furthermore, we measure the polarizability of the excited 3P0 clock state at the tune-out wavelength using high-resolution clock spectroscopy, demonstrating the first excited state polarizability measurement in an alkaline-earth-metal atom. In a proof-of-principle experiment, we trap 3P0 atoms in a one-dimensional optical lattice at the tune-out wavelength. Our measurements benchmark state-of-the-art atomic structure calculations and pave the way for state-dependent manipulations of strontium atoms for high-fidelity quantum simulations and quantum computation schemes.

A 30.5 Fri 12:15 f303

Atom number stabilization with single-atom precision — Andreas Hüper[1], Cebrail Pür[1], •Mareike Hetzel[1], Jiao Geng[1], Mick Kristensen[2], Jan Arlt[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Institut for Fysik og Astronomi, Aarhus Universitet, Denmark

The preparation and evaluation of quantum states for optimal entanglement-enhanced metrology relies on an accurate determination of the number of atoms. We present an accurate fluorescence detection of atoms trapped in a miniature magneto-optical trap. We utilize the accurate atom number detection for a number stabilization of a laser-cooled atomic ensemble. For a target ensemble size of seven atoms prepared on demand, we achieve a 92 % preparation fidelity and reach number fluctuation 18 dB below the shot noise level using real-time feedback on the magneto-optical trap.

A 30.6 Fri 12:30 f303

Continuous measurement of a quantum driven top — •Jessica Eastman[1], Stuart Szigeti[2], Joseph Hope[2], and André Carvalho[3] — [1]Imperial College London, London, UK — [2]Australian National University, Canberra, Australia — [3]Q-CTRL, Australia

The need to understand many-body quantum chaos is motivated by a growing area of research with connections to topics such as random unitaries, holographic duality and information scrambling in black holes, nonequilibrium thermodynamics and quantum sensing. We theoretically investigate the effect that continuous weak measurement can have on the emergence of chaos in many-body quantum systems by looking at a system that can be easily realisable in ultra cold atom experiments: the Quantum driven top. The corresponding classical system in this case is a closed system with no dissipation. By adding weak coupling to a measurement device, we introduce decoherence to the system.

A 30.7 Fri 12:45 f303

Bulk topological proximity effect in multilayer systems — Jaromir Panas[1], •Bernhard Irsigler[1], Jun-Hui Zheng[1,2], and Walter Hofstetter[1] — [1]Goethe-University Frankfurt, Germany — [2]NTNU, Trondheim, Norway

We investigate the bulk topological proximity effect in multilayer lattice systems. We show that one can introduce topological properties into a system composed of multiple trivial layers by coupling to a single nontrivial layer described by the Haldane model. This phenomenon depends not only on the number of layers but also on their arrangement, which can lead to the emergence of dark states in multilayer systems. The response of a trivial system to the proximity of a topological insulator appears to be highly nonlocal, in contrast to the proximity effect observed in context of superconductivity. We also find a range of parameters where our system is semimetallic with features similar to the ones observed in three-dimensional topological states. This is promising from the perspective of bridging two- and three-dimensional topologically protected states of matter.