Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture rooms S HS 1 Physik, S HS 2 Physik, and S HS 3 Physik; Poster S Fobau Physik)

Invited Talks

A 4.1	Mon	10:30–11:00	S HS 3 Physik	**Odd electron wave packets from cycloidal ultrashort laser fields** — •Stefanie Kerbstadt, Kevin Eickhoff, Tim Bayer, Matthias Wollenhaupt
A 6.1	Mon	14:00–14:30	S HS 2 Physik	**Laser spectroscopy of transferium elements** — •S. Raeder, D. Ackermann, H. Backe, M. Block, B. Cheal, P. Chhetri, Ch. E. Düllmann, M. Eibach, J. Even, R. Ferrer, F. Giacoppo, S. Götz, F.P. Hessberger, O. Kaleja, J. Khuyagbaatar, P. Kunz, M. Laatiaoui, W. Lauth, L. Lens, N. Lecesne, A. K. Mistry, E. Minaya Ramirez, T. Murböck, P. van Duppen, Th. Walther, A. Yakushev
A 7.1	Mon	14:00–14:30	S HS 3 Physik	**Multielectron polarization effects and ionization of the hydrogen molecule within the semiclassical two-step model** — •Nikolay Shvetsov-Shilovski, Manfred Lein, Lars Madsen, Karoly Tokesi
A 9.1	Mon	16:15–16:45	S HS 2 Physik	**Non-equilibrium Dynamics of Ion Coulomb Systems** — •Tanja E. Mehlstäubler
A 10.5	Mon	17:15–17:45	S HS 3 Physik	**Towards testing physics beyond the Standard Model with the bound-electron g factor** — •Vincent Debierre, Christoph H. Keitel, Zoltán Harman
A 15.1	Wed	10:30–11:00	S HS 3 Physik	**Decomposition of the Temporal and Spectral Response in Attosecond Transient Absorption Spectroscopy** — •Lorenz Drescher, Vishal Shokeen, Tobias Witting, Serguei Patchkovskii, Marc Vrakking, Jochen Mikosch
A 18.7	Wed	15:30–16:00	S HS 2 Physik	**Towards a precise energy determination of the ^{229}Th nuclear isomer** — •Benedict Seiferle, Lars v.d. Wense, Ines Amersorffer, Peter G. Thirolf
A 19.1	Wed	14:00–14:30	S HS 3 Physik	**Imaging ultrafast dynamics in nanoparticles with resonant multicolor XUV pulses** — L Hecht, B Langbehn, J Zimmermann, J Jordan, K Kolatzki, N Monserud, Y Ovcharenko, M Sauppe, B Schütte, R Tanyag, A Ulmer, B Kruse, K Sander, C Peltz, A Colombo, A D'Elia, M diFraia, L Giannessi, P Piseri, O Plekan, K Prince, M Zangrando, C Callegari, MJJ Vrakking, A Rouzée, T Möller, T Fennel, •D Rupp
A 19.2	Wed	14:30–15:00	S HS 3 Physik	**Multi-coincidence experiments on electron and photon emission** — •Andre Knie
A 31.8	Thu	15:45–16:15	S HS 1 Physik	**String patterns in the doped Hubbard model** — •Daniel Greif
A 32.1	Thu	14:00–14:30	S HS 3 Physik	**Time-resolved dynamics of slow photoelectrons in the rescattering regime** — •Martin Ranke, Sophie Walther, Anastasios Dimitriou, Mark J. Prandolini, Markus Pfau, Thomas Gebert, Marek Wieland, Markus Drescher, Ulrike Frühling
A 36.1	Fri	10:30–11:00	S HS 3 Physik	**Attoclock with tailored polarization** — Nicolas Eicke, •Manfred Lein

A 36.2	Fri	11:00–11:30	S HS 3 Physik	**Chiral fragmentation of a planar molecule** — •Kilian Fehre, Sebastian Eckart, Maksim Kunitski, Martin Pitzer, Stefan Zeller, Christian Janke, Daniel Trabert, Jonas Rist, Miriam Weller, Alexander Hartung, Lothar Schmidt, Till Jahnke, Robert Berger, Reinhard Dörner, Markus Schöffler
A 36.3	Fri	11:30–12:00	S HS 3 Physik	**Simple and robust control of resonant few-photon ionization** — •Ulf Saalmann

Invited talks of the joint symposium SYPS

See SYPS for the full program of the symposium.

SYPS 1.1	Mon	14:00–14:30	U Audimax	**Optimal control of many-body quantum systems** — •Simone Montangero
SYPS 1.2	Mon	14:30–15:00	U Audimax	**Light matter quantum interface based on single colour centres in diamond** — •Fedor Jelezko
SYPS 1.3	Mon	15:00–15:30	U Audimax	**Principles of Quantum Systems Theory and Control Engineering** — •Thomas Schulte-Herbrüggen
SYPS 1.4	Mon	15:30–16:00	U Audimax	**Quantum metrology with Rydberg atoms** — •Sebastien Gleyzes, Arthur Larrouy, Remi Richaud, Sabrina Patsch, Jean-Michel Raimond, Michel Brune, Christiane Koch

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	10:30–11:00	U Audimax	**Quantum States and their Marginals: from Multipartite Entanglement to Quantum Error-Correcting Codes** — •Felix Huber
SYAD 1.2	Tue	11:00–11:30	U Audimax	**The Uniform Electron Gas at Warm Dense Matter Conditions** — •Simon Groth
SYAD 1.3	Tue	11:30–12:00	U Audimax	**Relativistically intense laser-microplasma interactions (and potential applications)** — •Tobias Ostermayer
SYAD 1.4	Tue	12:00–12:30	U Audimax	**Motional quantum state engineering for quantum logic spectroscopy of molecular ions** — •Fabian Wolf

Invited talks of the joint symposium SYSI

See SYSI for the full program of the symposium.

SYSI 1.1	Wed	10:30–11:00	U Audimax	**The redefinition of the SI in November 2018** — •Terry Quinn
SYSI 1.2	Wed	11:00–11:30	U Audimax	**Quantum Hall effect and the new SI** — •Klaus von Klitzing
SYSI 1.3	Wed	11:30–12:00	U Audimax	**The electron charge for the definition and realisation of the ampere** — •Jan-Theodoor Janssen
SYSI 1.4	Wed	12:00–12:30	U Audimax	**The Planck constant and the realization of the kilogram** — •Stephan Schlamminger

Invited talks of the joint symposium SYXR

See SYXR for the full program of the symposium.

SYXR 1.1	Thu	14:00–14:30	U Audimax	**Superradiance of an ensemble of nuclei excited by a free electron laser** — •Aleksandr Chumakov
SYXR 1.2	Thu	14:30–15:00	U Audimax	**Quantum imaging with incoherently scattered light from a Free-Electron Laser** — •Joachim von Zanthier
SYXR 1.3	Thu	15:00–15:30	U Audimax	**Stimulated X-Ray Emission Spectroscopy for Chemical Analysis** — •Nina Rohringer
SYXR 1.4	Thu	15:30–16:00	U Audimax	**X-Ray Multiphoton Ionization of Atoms and Molecules** — •Daniel Rolles

Invited talks of the joint symposium SYQM

See SYQM for the full program of the symposium.

SYQM 1.1	Fri	10:30–11:00	U Audimax	**Robust symmetry-protected metrology with a topological phase** — •Stephen Bartlett, Gavin Brennen, Akimasa Miyake
SYQM 1.2	Fri	11:00–11:30	U Audimax	**Diamond quantum sensors for nanoscale magnetic resonance** — •Fedor Jelezko
SYQM 1.3	Fri	11:30–12:00	U Audimax	**Quantum metrology for subdiffraction incoherent optical imaging** — •Mankei Tsang
SYQM 1.4	Fri	12:00–12:30	U Audimax	**Learning Hamiltonians using quantum and classical resources** — •Nathan Wiebe

Sessions

A 1.1–1.2	Sun	16:00–18:00	U HS 326	**Tutorial X-Ray Lasers (joint session AKjDPG/A)**
A 2.1–2.7	Mon	10:30–12:15	S HS 1 Physik	**Ultra-cold atoms and molecules I (joint session A/MO/Q)**
A 3.1–3.8	Mon	10:30–12:30	S HS 2 Physik	**Precision Spectroscopy of atoms and ions I (joint session A/Q)**
A 4.1–4.7	Mon	10:30–12:30	S HS 3 Physik	**Atomic systems in external fields**
A 5.1–5.8	Mon	14:00–16:00	S HS 1 Physik	**Ultra-cold atoms and molecules II (joint session A/MO/Q)**
A 6.1–6.6	Mon	14:00–15:45	S HS 2 Physik	**Precision Spectroscopy of atoms and ions II (joint session A/Q)**
A 7.1–7.7	Mon	14:00–16:00	S HS 3 Physik	**Interaction with strong or short laser pulses**
A 8.1–8.6	Mon	16:15–17:45	S HS 1 Physik	**Ultra-cold atoms, ions and BEC (joint session A/Q)**
A 9.1–9.6	Mon	16:15–18:00	S HS 2 Physik	**Precision Spectroscopy of atoms and ions III (joint session A/Q)**
A 10.1–10.5	Mon	16:15–17:45	S HS 3 Physik	**Highly charged ions and their applications**
A 11.1–11.15	Tue	16:30–18:30	S Fobau Physik	**Ultra-cold plasmas and Rydberg systems**
A 12.1–12.30	Tue	16:30–18:30	S Fobau Physik	**Ultra-cold atoms, ions and BEC**
A 13.1–13.8	Wed	10:30–12:30	S HS 1 Physik	**Ultra-cold atoms (joint session A/Q)**
A 14.1–14.7	Wed	10:30–12:15	S HS 2 Physik	**Precision Spectroscopy of atoms and ions IV**
A 15.1–15.7	Wed	10:30–12:30	S HS 3 Physik	**Attosecond physics**
A 16	Wed	12:45–13:45	S HS 1 Physik	**FV Atomic Physics: General Assembly**
A 17.1–17.8	Wed	14:00–16:00	S HS 1 Physik	**Ultra-cold plasmas and Rydberg systems (joint session A/Q)**
A 18.1–18.7	Wed	14:00–16:00	S HS 2 Physik	**Precision Spectroscopy of atoms and ions V (Th 229)**
A 19.1–19.7	Wed	14:00–16:15	S HS 3 Physik	**Cluster I (joint session A/MO)**
A 20.1–20.8	Wed	14:00–16:00	S HS 002 Biologie	**Cold Molecules (joint session MO/A)**
A 21.1–21.10	Wed	16:15–18:15	S Fobau Physik	**Cluster II (joint session A/MO)**
A 22.1–22.7	Wed	16:15–18:15	S Fobau Physik	**Highly charged ions and their applications**
A 23.1–23.3	Wed	16:15–18:15	S Fobau Physik	**Collisions, scattering and correlation phenomena**
A 24.1–24.1	Wed	16:15–18:15	S Fobau Physik	**Atomic collisions and ultracold plasmas**
A 25.1–25.9	Wed	16:15–18:15	S Fobau Physik	**Attosecond physics**
A 26.1–26.7	Wed	16:15–18:15	S Fobau Physik	**Atomic systems in external fields**
A 27.1–27.6	Thu	10:30–12:00	S HS 1 Physik	**Quantum gases (Bosons) (joint session A/Q)**
A 28.1–28.8	Thu	10:30–12:30	S HS 3 Physik	**Interaction with VUV and X-ray light**
A 29.1–29.7	Thu	10:30–12:30	S HS 001 Biologie	**Cluster III (joint session MO/A)**
A 30.1–30.8	Thu	10:30–12:30	S HS 002 Biologie	**Atomic Physics, Molecular Physics, and Quantum Optics with X-ray FELs (joint session MO/A)**
A 31.1–31.8	Thu	14:00–16:15	S HS 1 Physik	**Quantum gases (Fermions) (joint session A/Q)**
A 32.1–32.7	Thu	14:00–16:00	S HS 3 Physik	**Collisions, scattering and correlation phenomena**
A 33.1–33.10	Thu	16:15–18:15	S Fobau Physik	**Interaction with strong and short laser pulses**
A 34.1–34.8	Thu	16:15–18:15	S Fobau Physik	**Interaction with VUV and X-ray light**
A 35.1–35.22	Thu	16:15–18:15	S Fobau Physik	**Precision Spectroscopy of atoms and ions**
A 36.1–36.4	Fri	10:30–12:15	S HS 3 Physik	**Quantum dynamics in tailored waveforms**

Annual General Meeting of the Atomic Physics Division

Wednesday 12:45–13:45 S HS 1 Physik

A 1: Tutorial X-Ray Lasers (joint session AKjDPG/A)

Time: Sunday 16:00–18:00 Location: U HS 326

Tutorial A 1.1 Sun 16:00 U HS 326
Freie-Elektronen Laser für Röntgenstrahlen: Physikalische Prinzipien und technische Realisierung — •Jörg Rossbach — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

In diesem Tutorium werden die physikalischen Grundprinzipien des Freie-Elektronen Lasers erklärt. Für die Anwendung des Prinzips im Röntgenbereich ist der High-Gain-Modus besonders wichtig, der einen Betrieb ohne Spiegel erlaubt. Ebenso bedeutsam ist das SASE-Prinzip (Self-Amplified Spontaneous Emission), durch welches ein besonders robuster Betrieb ermöglicht wird.

Die resultierenden Eigenschaften der FEL-Strahlung werden erklärt, und es wird ein Einblick in die wesentlichen technischen Herausforderungen bei der Realisierung eines Röntgen-FELs gegeben.

Tutorial A 1.2 Sun 17:00 U HS 326
Introduction to x-ray quantum optics — •Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg

Over the last decades, tremendous progress has been made in the understanding and control of light-matter interactions. A particular driver in the field is quantum optics, which exploits quantum mechanical effects in this interaction, up to a point that now quantum technologies move into the focus of research. This progress was fueled and to a large degree relied on the parallel development of of suitable laser sources. Motivated by these developments, recent improvements in existing and upcoming x-ray light sources prompt the question, whether similar concepts could also be exploited at x-ray energies. From the viewpoint of x-ray physics, this would not only be essential for fully exploiting the potential of these machines, but could also pave the way for new applications. In turn, from the viewpoint of light-matter interactions, x-ray quantum optics could also evolve into a fruitful new platform complementary to the existing ones. In this tutorial, I will introduce x-ray quantum optics, review some of the recent progress, and point out future challenges.

A 2: Ultra-cold atoms and molecules I (joint session A/MO/Q)

Time: Monday 10:30–12:15 Location: S HS 1 Physik

A 2.1 Mon 10:30 S HS 1 Physik
Quantum state-dependent reactive collisions of OH^- with ultracold Rubidium in a hybrid trap — •Saba Zia Hassan[1], Jonas Tauch[1], Eric Endres[1], Markus Nötzold[2], Henry Lopez[1], Bastian Höltkemeier[1], Roland Wester[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut Heidelberg, INF 226, 69120 Heidelberg — [2]Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, 6020 Innsbruck

The study of ion-molecule reactions plays a vital role in cold chemistry, implying the need of well-controlled ion ensembles in a cold environment. The internal and external degrees of freedom of molecular ions, trapped in multipole radio frequency ion traps, can be cooled via collisions, with pre-cooled neutral atoms, to cryogenic temperatures of about 4 K. This lower temperature limit can be overcome using a laser-cooled buffer-gas localized at the center of the ion cloud.
In our hybrid atom-ion trap, the hydroxyl anions are stored in a 8-pole radio frequency wire trap and a dense cloud of ultracold rubidium is confined in a dark spontaneous-force optical trap (Dark-SPOT). The overlap of atoms and anions leads to elastic and inelastic collisions, cooling the external and internal degrees of freedom respectively. However, losses via associative detachment between OH^- and rubidium also occur, as predicted by ab-initio calculations. By varying the ratio of excited to ground state atoms, quantum state-dependent reactive collisions can be studied. Accurate measurements of these reactions can allow us to probe into the effective core potentials used in theoretical studies. In this contribution the latest results will be presented.

A 2.2 Mon 10:45 S HS 1 Physik
State-to-state chemistry in a magnetic field — •Joschka Wolf, Markus Deiss, Shinsuke Haze, and Johannes Hecker Denschlag — Institut für Quantenmaterie and Center for Integrated Quantum Science and Technology IQ^{ST}, Universität Ulm, 89069 Ulm, Germany

State-to-state chemistry describes the determination of the quantum states of the final products given the quantum state of reactants. We have developed and demonstrated a method to probe diatomic molecular product states of reactive processes both qualitatively and quantitatively [1]. Using the given method, we have investigated the recombination of three neutral rubidium atoms in an ultracold atomic gas. We have extended the scheme of [1], to also resolve the magnetic quantum number of molecular product states. In this talk, we present the measurements of product molecules for different reactant states as a function of the magnetic field. We find a propensity rule that the magnetic quantum number of the two reactants forming the molecule is conserved.

J. Wolf *et al.*, Science 358, 921 (2017)

A 2.3 Mon 11:00 S HS 1 Physik
Sisyphus Optical Lattice Decelerator (SOLD) — •Rodrigo Gonzalez Escudero, Chun-Chia Chen, Shayne Bennetts, Benjamin Pasquiou, and Florian Schreck — Van der Waals - Zeeman Institute, Institute of Physics, University of Amsterdam

In this talk, we present our implementation of a novel deceleration scheme that slows and cools atoms without using radiation pressure [1]. This scheme can enhance the efficiency of standard laser cooling techniques, requiring fewer photons to bring fast atoms to rest, making it a good decelerator candidate for exotic species [2] and molecules.

The SOLD works by having atoms selectively excited to an electronic state whose energy is spatially modulated by an optical lattice. Excited Atoms decelerate solely by climbing the conservative potential landscape created by the lattice. The ensuing spontaneous decay brings atoms to the ground state, and completes one Sisyphus cooling cycle.

This deceleration method might prove useful for our attempt to create a steady-state strontium atom laser machine [3], breaching the gap from the currently achieved, and unprecedented steady-state phase-space density of near unity to the first steady-state Bose-Einstein condensate from which a continuous atom laser can be outcoupled.

[1] C-C.Chen et al., arXiv:1810.07157 (2018).
[2] S. Wu et al., Phys. Rev. Lett. 106, 213001 (2011).
[3] S. Bennetts et al., Phys. Rev. Lett. 119, 223202 (2017).

A 2.4 Mon 11:15 S HS 1 Physik
Sympathetic cooling of molecular anions by a localized laser-cooled buffer gas — •Jonas Tauch[1], Saba Zia Hassan[1], Eric Endres[1], Markus Nötzold[3], Henry López[1], Bastian Höltkemeier[1], Roland Wester[3], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut Heidelberg, INF 226, 69120 Heidelberg — [2]University of Science and Technology of China, Shanghai Branch, Shanghai, China — [3]Institut für Ionenphysik und Angewandte Physik, Technikerstrasse 25/3, 6020 Innsbruck

Sympathetic cooling has become a powerful and universal method for preparing ultracold ions confined in radio frequency traps. This technique enables the study of cold molecular ions, as precision spectroscopy and chemistry at temperatures near to the absolute zero. In the past few years there has been a large debate about the limitations of this method, due to the mass ratio between the ions and the coolant. We developed a theoretical description which predicts that this limitations can be overcome by a localized buffer gas cloud and/or a higher order radio frequency trap. In this contribution I will present recent results of our hybrid atom-ion trap system, consisting of an 8-pole radio frequency wire trap and a dark spontaneous-force optical Rubidium trap. First signs of translational and rotational cooling of the trapped hydroxyl anions are observed. To probe the translational energy distributions of the anions, their time-of-flight is measured after extraction from the trap. The internal degrees of freedom are probed via near threshold photodetachment, revealing an increase of the population in lower rotational states. Thus cooling of the internal degrees of freedom.

A 2.5 Mon 11:30 S HS 1 Physik

Using a Quartz Crystal Micro-Balance for the characterization of a Zeeman Slower — •A. Chavarria Sibaja[1,2], A. Godinez Sandi[1,2], K. Hernandez Jimenez[1,2], S. Thiel Pizarro[1,2], M. Guevara Bertsh[3], and O.A. Herrera Sancho[1,2,4] — [1]Escuela de Física. University of Costa Rica — [2]CICIMA. University of Costa Rica — [3]Institut fur Quantenoptik und Quanteninformation. University of Innsbruck — [4]CICANUM. University of Costa Rica

We present here the developement of an experimental apparatus that consists of a Gd atoms source and 1 m-long multi-layer solenoidal Spin-Flip Zeeman Slower, and the propose of an alternative method to measure the atoms velocity, based on using of a Quartz Crystal micro-balance (QCM), which is normally used in thin film deposition process in solid-state physics. We observed that the measurement of the perturbations induced in the natural frequency of the QCM by the deposition mass process and the momentum exchange of the particles when they hit the crystal surface, allow to determine the change in the kinetic energy of Gd atoms. In this experiment, we focus a 447,2 nm laser into a counter-propagating beam of Gd atoms in order to drive the strongest dipole atomic transition from the ground 9D 0 state to the exited state 9D. Additionally we measure the variations of velocity of the atoms at the end of our Zeeman-Slower with a QCM,in order to characterize the effectiveness of our apparatus, as part of the future developement of magneto-optical trap system. We obtain preliminary results of 39% of reduction of the velocity of the Gd atoms respect to their initial velocity using a current of 3 A.

A 2.6 Mon 11:45 S HS 1 Physik

Locking of multiple Lasers to a Frequency Comb — •Benjamin Sprenger[1], Dag Schmidt[1], Ronald Holzwarth[1,2], Bastian Hacker[2], Dominik Niemietz[2], and Gerhard Rempe[2] — [1]Menlo Systems GmbH, Am Klopferspitz 19a, 82152 Martinsried — [2]Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

Cold atom experiments usually require a whole set of lasers with different and precisely defined optical frequencies. A frequency comb offers the possibility to stabilize all lasers in the visible and near IR part of the spectrum (and even far beyond in the IR regime if needed) to the same reference, thereby providing the same stability and accuracy as well as mutual coherence to all lasers. We present a setup in which a frequency comb is used to stabilize more than 20 CW Lasers in 7 different laboratories. The comb light is distributed via optical fibers from the central comb laboratory to all other labs. Many applications, like quantum information experiments with single atoms and photons or molecular spectroscopy can be simplified with this setup and allows for reliable operations with improved accuracy.

A 2.7 Mon 12:00 S HS 1 Physik

Improved Setup for Optoelectric Sisyphus Cooling of Formaldehyde Using a Detection Scheme Based on Laser Induced Fluorescence — •Martin Ibrügger, Maximilian Löw, Alexander Prehn, Martin Zeppenfeld, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermannstr. 1, 85748 Garching

Ultracold molecules are ideal systems for the investigation of fundamental physics with applications ranging from quantum simulation over high-precision spectroscopy to ultracold chemistry. We showed in the past that optoelectrical Sisyphus cooling is one of the most promising techniques to provide the high number of molecules and the temperatures required for those applications [1]. We now implemented a new detection scheme for formaldehyde based on laser induced fluorescence (LIF), thereby increasing the signal by up to a factor of 30 compared to the previously used quadrupole mass spectrometer, and furthermore allowing state selective detection of the molecules.

Here, we present the current status of the experiment. In particular, we investigate trap dynamics of individual rotational M-sublevels which were previously hard to resolve. Results are very promising for the development of an improved cooling sequence which will pave the way for exciting applications such as high-precision spectroscopy and collisional studies of trapped formaldehyde.

[1] A. Prehn *et al.*, *Phys. Rev. Lett.* **116**, 063005 (2016).

A 3: Precision Spectroscopy of atoms and ions I (joint session A/Q)

Time: Monday 10:30–12:30 Location: S HS 2 Physik

A 3.1 Mon 10:30 S HS 2 Physik

An Atomic Lab on a Chip — •Artur Skljarow[1], Ralf Ritter[1], Wolfram H.P. Pernice[2], Harald Kübler[1], Tilman Pfau[1], Robert Löw[1], and Hadiseh Alaeian[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany — [2]Institute of Physics, University of Münster, Heisenbergstr. 11, D-48149 Münster, Germany

The integration of photonic structures with thermal atomic vapors on a chip provides efficient atom-light coupling on a miniaturized scale well beyond the diffraction limit hence, opening a new regime in the field of cavity quantum electrodynamics. In this talk, we present the results of our study on interactions of thermal Rb atoms with integrated Si_3N_4 and Si Nano-devices. In the former case, the atoms are probed with a laser at the D_2 transition, whereas in latter the atoms are further excited to the 4D states with an additional excitation at telecom wavelength. Our studies on Si structures benefit from a stronger mode confinement due to the large reflective index as well as a larger dipole moment. Moreover, we demonstrate novel measurements on the effects of Si surface potentials on Rb 4D states. Promising results on ring resonators pave the way towards further investigations of high-Q photonic crystal cavities in order to reach the strong coupling regime.

[1] R. Ritter et al., *New Journal of Physics* **18**, 103031 (2016)
[2] R. Ritter et at., *Phys. Rev. X* **8**, 021032 (2018)

A 3.2 Mon 10:45 S HS 2 Physik

Spectroscopy of the $^1S_0 - {}^3P_1$ intercombination line of calcium — •Markus Kirkines and Simon Stellmer — Physikalisches Institut der Universität Bonn, Nussallee 12, 53115 Bonn

Over the past decades, microwave frequency references have been outperformed by optical frequency standards, and there is a worldwide quest to build optical clocks that can be operated outside the laboratory. We aim to build an atomic beam clock of calcium that is not only compact in size and firm against external influences, but also has a fractional frequency stability in the order of 10^{-16}. As a preparatory experiment, we will perform Doppler-free spectroscopy on the $^1S_0 - {}^3P_1$ intercombination line of calcium which is the designated clock transition ($\lambda = 657\,\text{nm}$ and $\Gamma = 2\pi \times 370\,\text{Hz}$). The spectroscopy cell is designed such that the linewidth broadening (e.g. collisional and transient broadening) of the atomic transition linewidth are kept below a few kHz. The cell should not only minimize the line broadening of the atomic transition, but should also provide high durability so that it can run without maintenance for years. We investigate different spectroscopy cell setups which will be presented in the talk.

A 3.3 Mon 11:00 S HS 2 Physik

Relative and absolute limitations of wavelength meters for accurate laser stabilization — •Kristian König, Phillip Imgram, Jörg Krämer, Tim Ratajczyk, and Wilfried Nörtershäuser — Institut für Kernphysik, TU Darmstadt

High-precision laser spectroscopy experiments at TU Darmstadt indicated a non-linear behavior of the employed wavelength meters. In a dedicated analysis of these interferometers with a frequency comb, surprising results were obtained. Especially the limited relative accuracy observed even for small frequency changes that are in the range of typical laser scans, was unexpected. We will present the results and discuss its consequences for experiments that base on the relative precision of wavelength meters. Furthermore, we will present a frequency-comb based stabilization scheme of a Ti:Sa laser which offers high short- and long-term stability.

A 3.4 Mon 11:15 S HS 2 Physik

A cold lithium target for quantum interference studies — •Marcel Willig, Stefan Schmidt, Jan Haack, Andreas Wieltsch, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA$^+$, Mainz, Germany

Precision laser spectroscopy of light atoms provides unique information about the atomic and nuclear structure of these systems and thus represents a way to access fundamental interactions, properties and constants. A particular interesting candidate for these kind of studies is atomic lithium with its unique level structure. We will use a cold sample of lithium atoms to perform high-precision laser spectroscopy and to access fundamental nuclear properties. This includes studies of (higher-order) quantum interference effects [1]. In addition, we plan to investigate cold neutral-neutral collision between hydrogen and lithium as a first step towards a cold sample of tritium atoms confined inside a magnetic trap [2].

In this contribution, we will present the current status of our apparatus and present first results. This includes detailed tests of our Zeeman-slower as well as our laser setup which will be used to generate the magneto-optical trap. Furthermore, we want to give an outlook on our future project: trapping and sympathetically cooling hydrogen in a second-generation Li-MOT.

[1] M. Horbatsch, and E. A. Hessels, PRA 82, 052519 (2010)
[2] S. Schmidt et al., J. Phys. Conf. Ser. accepted (2018), arXiv 1808.07240

A 3.5 Mon 11:30 S HS 2 Physik

Spectroscopy of the 1001 nm transition in atomic dysprosium — •Niels Petersen[1,2], Marcel Trümper[1], Florian Mühlbauer[1], Gunther Türk[1], and Patrick Windpassinger[1,2] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany

Dysprosium is a rare-earth element with one of the largest ground-state magnetic moments (10 Bohr magnetons) in the periodic table. Therefore, the dipole-dipole interaction is not a small perturbation but becomes comparable in strength to the s-wave scattering in ultracold dysprosium gases. The physical properties of the trapped atomic sample, such as its shape and stability are significantly influenced by the long-range and anisotropic dipole-dipole interaction.

Narrow-linewidth transitions constitute highly sensitive probes for external fields, internal properties and interactions between atoms in quantum gases. Due to the long lifetimes of the upper states these transitions can be utilized to generate and precisely control mixtures of long-living excited state atoms and ground state atoms. The lifetime of the excited state of the 1001 nm ground state transition in atomic dysprosium is predicted to be on the order of a few milliseconds. We report on spectroscopy of cold dysprosium atoms in an optical dipole trap on the 1001 nm transition and present measurements of the excited state lifetime.

A 3.6 Mon 11:45 S HS 2 Physik

Towards a ^{171}Yb$^+$ single-ion frequency standard in the 10^{-19} uncertainty range — •Richard Lange[1], Nils Huntemann[1], Christian Sanner[1,2], Jiehang Zhang[1], Moustafa Abdel Hafiz[1], Hu Shao[1], Christian Tamm[1], and Ekkehard Peik[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]present address: JILA, Boulder, CO 80309, USA

Two ^{171}Yb$^+$ single-ion traps are employed in our laboratory and realize optical clocks based on the $^2S_{1/2} \rightarrow {}^2D_{3/2}$ electric quadrupole (E2) [PRA **89**, 023820] and the $^2S_{1/2} \rightarrow {}^2F_{7/2}$ electric octupole (E3) [PRL **108**, 090801] reference transitions. For the E3 transition, which is less prone to external perturbations, a frequency uncertainty of 3×10^{-18} has recently been evaluated and demonstrated in a long-term comparison between two independent clock setups [arXiv:1809.10742]. The achieved uncertainty was essentially limited by trap imperfections, which will be further reduced with an improved ion trap design.

We will discuss the dominant contributions to the present uncertainty and show the advantages of the new trap design, e.g. low loss insulators causing smaller blackbody radiation (BBR) shift, polished gold-coated electrodes for low heating rates and large optical access for rigorous minimization of excess micromotion. In combination with a more precise measurement of the scalar differential polarizability for a precise correction of the BBR shift, the new clock setup is expected to reach an uncertainty below 10^{-18}.

A 3.7 Mon 12:00 S HS 2 Physik

Quantum Logic Laser Spectroscopy of Ar^{13+} — •Peter Micke[1,2], Steven A. King[1], Tobias Leopold[1], Steffen Kühn[2], Janko Nauta[2], Lisa Schmöger[1,2], Julian Stark[2], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig — [2]Max-Planck-Institut für Kernphysik (MPIK), Heidelberg — [3]Institut für Quantenoptik, Leibniz Universität Hannover

Highly charged ions (HCI) are extremely sensitive testbeds of fundamental physics. In next-generation atomic clocks, their forbidden optical transitions can be used to test a possible time variation of fundamental constants. Until now, optical spectroscopy was limited by the large Doppler broadening of hot HCIs. However, in a Paul trap advanced cooling techniques can be applied. In collaboration with MPIK, we have commissioned a cryogenic Paul trap experiment at PTB. After production in an electron beam ion trap, Ar^{13+} is extracted, decelerated, and retrapped in a Coulomb crystal of laser-cooled Be$^+$ ions. Next, an Ar^{13+}-Be$^+$ two-ion crystal is prepared in the motional ground-state by sideband cooling. Using quantum logic, we demonstrate coherent laser spectroscopy on HCIs for the first time. We resolve the 441 nm $^2P_{1/2}$-$^2P_{3/2}$ M1 transition on a sub-kHz level, already improving previous work by seven orders of magnitude. Soon, after further stabilizing our clock laser, we will resolve the natural linewidth of 17 Hz and evaluate minuscule systematic shifts of the unperturbed transition frequency with sub-Hz accuracy, measuring relative to the SI second.

A 3.8 Mon 12:15 S HS 2 Physik

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

Simple muonic atoms have proven to be of particular interest for studies of nuclear properties, such as the charge [1] and (magnetic) Zemach radii [2], and the nuclear polarizabilities. 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 1S-HFS in ordinary hydrogen (the famous 21 cm line) has been measured with 12 digits accuracy almost 50 years ago [3], but its comparison with QED calculations is limited to 6 digits by the uncertainty of the Zemach radius determined from elastic electron-proton scattering. We will present the ongoing measurement of the CREMA Collaboration at PSI which aims at a first measurement of the 1S-HFS in muonic hydrogen 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.

[1] R. Pohl *et al.*, Nature **466**, 213 (2010)
[2] A. Antognini *et al.*, Science **339**, 417 (2013)
[3] L. Essen *et al*, Nature **229**, 110 (1971)

A 4: Atomic systems in external fields

Time: Monday 10:30–12:30 Location: S HS 3 Physik

Invited Talk A 4.1 Mon 10:30 S HS 3 Physik

Odd electron wave packets from cycloidal ultrashort laser fields — •Stefanie Kerbstadt, Kevin Eickhoff, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Oldenburg

By combining bichromatic white light supercontinuum polarization pulse shaping with high resolution photoelectron tomography, we devise a general optical scheme [1] for three-dimensional quantum control. The scheme is exemplified on an atomic model system to create and manipulate carrier-envelope phase (CEP)-sensitive electron wave packets with arbitrary rotational symmetry. In the experiments, we use CEP-stable bichromatic counter- and corotating femtosecond laser pulses with continuously tunable center frequencies to generate 7-fold rotational symmetric and completely asymmetric photoelectron momentum distributions from multiphoton ionization of sodium atoms. To elucidate the physical mechanisms, we investigate the interplay between the symmetry properties of the driving field and the resulting electron wave packets by varying the optical field parameters. In addition, the generated photoelectron wave packets are shown to be a suitable tool for holographic and spectroscopic measurements of relative quantum phases, as demonstrated on excited Rydberg states.

[1] S. Kerbstadt et al., Ultrashort polarizationtailored Bichromatic, Opt. Express 25(11), 12518-12530 (2017).

A 4.2 Mon 11:00 S HS 3 Physik

Imaging multiple Rydberg wave packets from shaper-generated two-color femtosecond pump-probe sequences — •Kevin Eickhoff, Stefanie Kerbstadt, Lukas Gabrisch, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität, Oldenburg

Background-free detection of Rydberg dynamics is performed using shaper-generated bichromatic linearly and circularly polarized femtosecond pump-probe pulse sequences. We combine a bichromatic white light polarization pulse shaping scheme with angle- and energy-resolved photoelectron imaging to map the resulting Rydberg wave packet dynamics. Photoelectron momentum distributions from linearly polarized bichromatic fields feature pronounced time-, energy- and angle-dependent dynamics, which result from the coherent superposition of s-, d- and g-type photoelectron wave packets from ionization of the Rydberg np- and nf-series. Detailed analysis of the highly differential data allows us to extract the dynamics of the involved Rydberg wave packets separately. The results are verified by measurements with circularly polarized pump-probe pulse sequences which exclusively address the Rydberg nf-series and probe its dynamics into the g-type continuum. Further studies with CEP-stabilized bichromatic femtosecond pulse sequences and holographic measurements of the Rydberg wave packet's quantum phases are presented.

A 4.3 Mon 11:15 S HS 3 Physik

Extracting laser-coherent information from a photoelectron spectrum of a complex target using the phase-of-the-phase — •Vasily Tulsky and Dieter Bauer — University of Rostock, Rostock, Germany

Electron spectra produced from many-electron systems irradiated by an intense laser field can include a significant or even dominant fraction of laser-incoherent electrons that are influenced by multiple scattering on other atoms or produced by thermal emission. A possible way to subtract all the laser-incoherent part is the application of the recently developed phase-of-the-phase (PoP) technique [1-3]. In order to demonstrate it, we model strong-field ionization of argon atoms trapped inside helium droplets. Corresponding photoelectrons experience multiple elastic scattering on helium atoms before reaching the detector and generate a dominant incoherent signal. We show that the PoP successfully reveals the features encoded in the coherent part of the total output signal.

[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).

A 4.4 Mon 11:30 S HS 3 Physik

Topological effects in high-harmonic generation by planar sheets — •Helena Drüeke and Dieter Bauer — Institute of Physics, University of Rostock, 18051 Rostock, Germany

The vacant terrain between traditional strong-field attosecond and condensed matter physics is currently explored with an increasing effort both experimentally and theoretically. As topological effects play an important role in modern condensed matter physics, questions about their consequences for typical strong-field observables such as high-harmonic spectra naturally arise. Recently, we investigated the simplest system with topological edge states in a laser field (i.e., linear chains, [1,2]) and found huge differences in the harmonic yield from different topological phases. We now extend this work towards 2D materials. We are interested in the strong-field laser-driven transport along the edges and its signatures in high-harmonic spectra. We use time-dependent density functional theory, as it is not clear a priori whether the common tight-binding models are applicable for strong fields.

[1] Dieter Bauer and Kenneth K. Hansen, *High-harmonic generation in solids with and without topological edge states*, Phys. Rev. Lett. 120, 177401 (2018)

[2] Helena Drüeke and Dieter Bauer, *(manuscript in preparation)*

A 4.5 Mon 11:45 S HS 3 Physik

Many-body Kinetics of Dynamic Nuclear Polarization by the Cross Effect — •Federica Raimondi, Alexander Karabanov, Daniel Wisniewski, Igor Lesanovsky, and Walter Kockenberger — School of Physics & Astronomy, University of Nottingham, UK

Dynamic Nuclear Polarization (DNP) provides significant signal enhancement compared to conventional thermal polarization techniques used in typical nuclear magnetic resonance applications. The Cross Effect (CE) DNP mechanim, involving triple spin-flips between two interacting electrons and a nucleus, is the most efficient at low temperature and microwave irradiation amplitude. In silico optimization of parameters affecting CE enhancement, such as radical concentration and design, requires simulation of large spin systems. However, solving the Liouville-von Neumann equation for such systems quickly becomes intractable. Here, we show that the non-equilibrium nuclear polarization build-up is effectively driven by incoherent Markovian dissipative processes. These can be modelled using a highly efficient classical Kinetic Monte Carlo algorithm, which can accurately simulate systems consisting of over 100 spins within a reasonable time frame. With our theoretical approach, we have for the first time been able to study many-body processes such as spin diffusion.

We have since started to develop a fast simulation algorithm for the experimentally more relevant case of Magic Angle Spinning CE-DNP.

A 4.6 Mon 12:00 S HS 3 Physik

Penning Traps in Gravity: Implications for Free Electron g-factor Measurements — •Sebastian Ulbricht[1,2], Robert A. Müller[1,2], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Germany — [2]Technische Universität Braunschweig, Germany

Today, the gyromagnetic ratio of a free electron is known to a very high accuracy of g/2=1.001 159 652 180 73 (28) [1] and the improvement of this value is still an ongoing process in modern research. The g-factor is currently determined by spectroscopy of spin-flip and cyclotron transitions of a single electron in a Penning trap. These experiments, however, are not performed in an isolated environment, but in the gravitational field of the Earth. In this contribution, therefore, we present investigations of gravitational effects on the trapped electron *and* the Penning trap itself. More specifically, we take into account gravitational effects on the electromagnetic field of the Penning trap, which in turn effect the motion of the electron. We derived the resulting relativistic corrections of order $1/c^2$ to transition frequencies, used to determine the free electron g-factor. As a consequence an extension of the well known g-factor formula introduced by L. S. Brown and G. Gabrielse [2] is presented.

[1] D. Hanneke, S. Fogwell, and G. Gabrielse, Phys. Rev. Lett. **100**, 120801 (2008).

[2] L. S. Brown and G. Gabrielse, Rev. Mod. Phys. **58**, 233 (1986).

A 4.7 Mon 12:15 S HS 3 Physik

Hamiltonian engineering for studying many-body dynamics in strongly interacting Rydberg systems — •Nithiwadee Thaicharoen[1], Renato Ferracini Alves[1], Titus Franz[1], Sebastian Geier[1], Alexander Müller[1], Andre Salzinger[1], Annika Tebben[1], Clément Hainaut[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

Dipolar interacting Rydberg spin systems have been ideal platforms to study non-equilibrium phenomena of isolated quantum systems. Their tunable strong, long-range interactions provide new opportunities to investigate the dynamics of strongly correlated many-body quantum systems with beyond nearest-neighbor coupling. Here, the system can either relaxes to a thermal equilibrium or reaches nonthermal-fixed points, where effect of disorders, external fields and fluctuations play important roles. In this work, we present an experimental realization of a dipolar spin-1/2 model by coupling two strongly interacting Rydberg states utilizing a microwave field. We propose a scheme to engineer the Hamiltonian of the system using dynamical pulse sequence of the microwave field to identify if the initial order of the system persist after time evolution of the system. The global magnetization and its variance extracted from state-selective detection reveal if the system is localized or reaches a thermal equilibrium.

A 5: Ultra-cold atoms and molecules II (joint session A/MO/Q)

Time: Monday 14:00–16:00 Location: S HS 1 Physik

A 5.1 Mon 14:00 S HS 1 Physik

Spectroscopic studies on bosonic NaK — •Kai K. Voges, Philipp Gersema, Jannis Schnars, Torsten Hartmann, Torben A. Schulze, Alessandro Zenesini, Eberhard Tiemann, and Silke Ospelkaus — Institut für Quantenoptik, Universität Hannover

With their large electric dipole moments and their rich internal level structures heteronuclear polar ground state molecules yield a rich test bed for a variety of dipolar quantum phenomena.

In our experiment, we aim at the creation of ultracold bosonic ensembles of ground state polar ^{23}Na^{39}K molecules by means of Feshbach molecule association and subsequent two-photon transfer to rovibrational ground state polar molecules. This is a challenging task which requires detailed knowledge of the molecular level structure both at atomic threshold and at the bottom of the molecular potential.

In this talk we present our spectroscopic investigations on bosonic ^{23}Na^{39}K molecules. We perform microwave and radio frequency spectroscopy on bound Feshbach states identifying promising candidates for the initial association into shallow-bound states. Furthermore, we perform laser spectroscopy of the electronic excited $B^1\Pi(v = 8)$ and $c^3\Sigma(v = 30)$ coupled states. These data allow us to model the excited state manifold and determine the singlet-triplet mixing between these states. Moreover, we perform dark-resonance spectroscopy locating the two lowest lying rotational states in the molecular ground state potential. Finally, we will report on our progress to combine the different spectroscopic results for the creation of an ensemble of rovibrational ground state polar molecules.

A 5.2 Mon 14:15 S HS 1 Physik

Pair superfluid phases in quasi one dimensional dipolar gases — •Rebecca Kraus[1], Krzysztof Biedroń[2], Jakub Zakrzewski[2,3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Instytut Fizyki imienia Mariana Smoluchowskiego, Uniwersytet Jagielloński, Łojasiewicza 11, 30-048 Kraków, Poland — [3]Mark Kac Complex Systems Research Center, Jagiellonian University, Łojasiewicza 11, 30-348 Kraków, Poland

We consider ultracold dipolar bosons in an optical lattice in a quasi-one dimensional geometry. We focus on the stability of pair superfluidity [1,2] as a function of the dipole interaction strength. We discuss the phases also for different power laws, such as van der waals interaction between Rydberg dressed atoms.

[1] K. Biedroń et al., PRB 97, 245102 (2018) [2] T. Sowiński et al., PRL 108, 115301 (2012)

A 5.3 Mon 14:30 S HS 1 Physik

Dipolar quantum droplets — •Fabian Böttcher, Jan-Niklas Schmidt, Matthias Wenzel, Julian Kluge, Viraatt Sai, Jens Hertkorn, Tim Langen, Arup Bhowmick, Mingyang Guo, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

The interplay of the short-range and isotropic contact interaction and the long-range and anisotropic dipolar interaction, allows for many interesting phenomena. In the case of the interactions competing with each other the mean-field contribution can get very small so that beyond mean-field effects start to play an important role and can actually stabilize an otherwise collapsing system. In our experiment with dysprosium atoms we observed a phase-transition between a gas and a liquid, characterized by the formation of self-bound droplets. These droplets show a saturation of the peak density with higher number of atoms like other liquids, even though they are 100 million times less dense than liquid helium droplets. The self-bound character of them opens up the mew perspective of a truly isolated quantum system.

With our experiment we can study a single self-bound droplet and measure the critical atom number for the phase transition between liquid droplet and expanding gas for more than an order of magnitude. For a single droplet we can also observe its anisotropic density distribution in-situ, as well as study the collective excitations. Furthermore the tendency of the system to form self-organized structures opens the possibility to reach a supersolid ground state.

A 5.4 Mon 14:45 S HS 1 Physik

Anisotropic Superfluid Behavior of a Dipolar Bose-Einstein Condensate — •Jan-Niklas Schmidt, Matthias Wenzel, Fabian Böttcher, Tim Langen, Igor Ferrier-Barbut, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Superfluidity still represents a hallmark of quantum physics. Its discovery in liquid helium was one of the first proofs for the influence of quantum effects at the macroscopic scale. The famous Landau criterion connects the maximal velocity for fritionless flow, mainly a transport property of such a superfluid, and its spectrum of elementary excitations. Later various transport measurements could show that also a Bose-Einstein condensate (BEC) features these properties, where the breakdown of superfluid flow can be probed by moving a microscopic impurity through the condensate. In case of a BEC of atoms with strong magnetic dipole-dipole interaction the breakdown of superfluid flow becomes directional, which directly can be seen as a probe of the anisotropic dipolar excitation spectrum.

During this talk we present transport measurements using a dipolar BEC of highly magnetic ^{162}Dy atoms, where we move an attractive laser beam through the condensate and observe an anisotropic superfluid flow. The critical velocity and the above starting heating rate is in excellent agreement with fully numerical simulations of the extended Gross-Pitaevskii equations that mimic our particular system.

A 5.5 Mon 15:00 S HS 1 Physik

Self-bound ultracold Bose mixtures — •Clemens Staudinger[1], Ferran Mazzanti[2], and Robert E. Zillich[1] — [1]Institute for Theoretical Physics, Johannes Kepler University Linz, Austria — [2]Departament de Física i Enginyeria Nuclear, Universitat Politècnica de Catalunya, Spain

Recent experiments confirmed that fluctuations beyond the mean-field approximation can lead to self-bound liquid droplets of ultradilute binary Bose mixtures at very low temperatures. We study liquid Bose mixtures by using the variational hypernetted-chain Euler–Lagrange method, which accounts for correlations nonperturbatively. For the case of a uniform mixture, as it is found in the center of large droplets at saturation density, we study the conditions for stability against evaporation of one of the components (both chemical potentials need to be negative) and against liquid-gas phase separation, the spinodal instability. We discover that dilute Bose mixtures are stable only in a narrow range near an optimal ratio ρ_1/ρ_2 and in the vicinity of the total energy minimum. Despite the low density, deviations from a universal dependence on the s-wave scattering lengths are significant. We show how our results for uniform Bose mixtures can be extended to finite liquid droplets based on local density approximations.

A 5.6 Mon 15:15 S HS 1 Physik

Bose polaron scenario in an ultracold Fermi-Bose mixture of ^{6}Li and ^{133}Cs — •Eleonora Lippi[1], Binh Tran[1], Manuel Gerken[1], Lauritz Klaus[1], Bing Zhu[1,2], Moritz Drescher[3], Manfred Salmhofer[3], Tilman Enss[3], 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 — [3]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 19, 69120, Heidelberg, Germany

An ultracold Fermi-Bose mixture of ^{6}Li and ^{133}Cs is an appealing playground to investigate the Bose polaron, a quasi-particle describing a single fermionic Li impurity immersed into a Bose-Einstein condensate (BEC) of Cs and dressed by the phononic excitations of the condensate. The well-suited Feshbach resonances at high magnetic field provide a great degree of tunability of intra- and inter-species interactions, enabling us to explore both the repulsive and the attractive regime of the polaron. Due to the large Li-Cs mass ratio, signatures of 3-body Efimov physics in the energy spectrum of the polaron are expected. The observation of different polaron states from the Landau-Pekar polaron to the bubble polaron is also predicted for a Li-Cs mixture [1].

I will discuss how to combine a large BEC of Cs with Li impurities trapped into a microtrap, and our strategy for investigating Bose polaron's properties by means of radio-frequency spectroscopy.

[1] M.Drescher et al., arXiv:1810.11296 (2018)

A 5.7 Mon 15:30 S HS 1 Physik

Exploring Fermi polarons across an orbital Feshbach resonance — •Nelson Darkwah Oppong[1,2], Luis Riegger[1,2], Oscar Bettermann[1,2], Moritz Höfer[1,2], Jesper Levinsen[3], Meera M. Parish[3], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]Ludwig-Maximilians-Universität, München, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]School of Physics and Astronomy, Monash University, Victoria, Australia

Ultracold atoms are a particularly clean system for probing polaronic states of interacting particles. Fermi polarons in particular have been studied with several realizations, all of which were using alkali atoms. Here, we report on the observation of attractive and repulsive Fermi polarons across the orbital Feshbach resonance (OFR) in a two dimensional gas of ^{173}Yb. This novel type of Feshbach resonance allows tuning the s-wave scattering length of atoms in the $^1S_0$ ground state and the metastable $^3P_0$ state. In our experiment, we prepare a spin-imbalanced Fermi gas for various interaction parameters $\ln(k_F a_{2D})$ in the vicinity of the OFR. We spectroscopically identify two distinct energy branches corresponding to attractive and repulsive Fermi polarons. In addition, we probe the quasiparticle properties, namely the quasiparticle residue and the lifetime of the repulsive polaron. We find good agreement between the experimental results and the predictions from our many-body theory.

A 5.8 Mon 15:45 S HS 1 Physik

Quantum Zeno-based Detection and State Engineering of Ultracold Polar Molecules — •Amit Jamadagni Gangapuram and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany.

We present a toolbox for the controlled manipulation of ultracold polar molecules, consisting of detection of molecules, atom-molecule entanglement and engineering disspative dynamics. Our setup is based on fast chemical reactions between molecules and atoms leading to a quantum zeno based collisional blockade in the system. We discuss the optimization of the relevant parameters as well as the consequences of residual imperfections.

A 6: Precision Spectroscopy of atoms and ions II (joint session A/Q)

Time: Monday 14:00–15:45 Location: S HS 2 Physik

Invited Talk A 6.1 Mon 14:00 S HS 2 Physik

Laser spectroscopy of transferium elements — •S. Raeder[1,2], D. Ackermann[2,3], H. Backe[4], M. Block[1,2,4], B. Cheal[5], P. Chhetri[2,6], Ch. E. Düllmann[1,2,4], M. Eibach[2], J. Even[7], R. Ferrer[8], F. Giacoppo[1,2], S. Götz[1,2,4], F.P. Hessberger[2], O. Kaleja[2,4,9], J. Khuyagbaatar[1,2], P. Kunz[10], M. Laatiaoui[1,4], W. Lauth[4], L. Lens[2,4], N. Lecesne[3], A. K. Mistry[1,2], E. Minaya Ramirez[11], T. Murböck[1,2], P. van Duppen[8], Th. Walther[6], and A. Yakushev[1,2] — [1]HI Mainz — [2]GSI — [3]GANIL — [4]JGU Mainz — [5]U. of Liverpool — [6]TU Darmstadt — [7]KVI-CART, U. of Groningen — [8]KU Leuven — [9]MPIK — [10]TRIUMF — [11]IPNO

Laser spectroscopy of the heaviest elements is a versatile tool to precisely measure the energies of shell electrons, which are strongly influenced by electron-electron correlation, relativity and QED effects. The study of transfermium elements with $Z>100$ is hampered by low production rates and the fact that any atomic information is at best available from theoretical predictions. Using the sensitive radiation detected resonance ionization spectroscopy 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. In further studies the isotopes ^{252,253,254}No were measured and high-lying Rydberg levels were identified which enabled the extraction of the first ionization potential with unreached precision. These results will be discussed as well as the prospects for future investigations involving the study of additional nobelium isotopes and the exploration of the atomic structure of the next heavier element, lawrencium (Z=103).

A 6.2 Mon 14:30 S HS 2 Physik

High-resolution laser resonance ionization spectroscopy of $^{143-147}$Pm — •Dominik Studer[1], Reinhard Heinke[1], Sebastian Raeder[2], Jiri Ulrich[3], Rugard Dressler[3], Dorothea Schumann[3], Nicholas van der Meulen[3], Saverio Braccini[4], Tommaso Stefano Carzaniga[4], and Klaus Wendt[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Helmholtz Institut Mainz — [3]Paul Scherrer Institut Villigen — [4]AEC-LHEP, University of Bern

Due to its exclusively radioactive nature with a maximum half-life of 17 years, the light lanthanide element promethium (Z = 61) is scarcely studied. In order to extract atomic and nuclear properties using the accessible miniscule sample amounts, extensive spectroscopic studies were performed at Mainz University by laser resonance ionization spectroscopy.

In the 2017 campaign we could reveal over 1000 new atomic transitions and determine the first ionization potential experimentally for the first time. Recent results focus on the extraction of isotope shifts and nuclear moments from hyperfine spectra of two different ground state transitions at 452 nm and 468 nm. For these studies the long-lived isotopes $^{143-147}$Pm were produced by irradiation of natural neodymium oxide using the external beam line of the 18 MeV medical cyclotron at the Bern University Hospital, followed by chemical separation and purification at PSI Villigen. In this talk we present our dedicated spectroscopy ion source and laser setup as well as the spectroscopic results.

A 6.3 Mon 14:45 S HS 2 Physik

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

High resolution laser spectroscopy is a very precise method for investigations of the atomic structure, being sensitive to the smallest effects (*e.g.* relativity, QED). In order to challenge modern theory, few-electron ions are interesting because of their strong EM fields. These ions can be studied at heavy-ion facilties, such as GSI in Darmstadt, or IMP in Lanzhou, China. In order to create high charge states, the ions must be accelerated to almost the speed of light. Laser spectroscopy of *e.g.* fine structure transitions is then possible by exploiting the huge Doppler shift (anti-collinear laser). We report on results from experiments performed at the ESR (GSI) and the CSRe (IMP) storage rings, using C^{3+} and O^{5+} ion beams, respectively. Finally, we present our preparations for laser spectroscopy of Be-like krypton.

A 6.4 Mon 15:00 S HS 2 Physik

Spectroscopy of an electric-dipole-forbidden fine structure transition with a single $^{40}Ar^{13+}$ ion at ALPHATRAP — •Alexander Egl[1], Ioanna Arapoglou[1], Martin Höcker[1], Kristian König[2], Tim Ratajczyk[2], Tim Sailer[1], Bingsheng Tu[1], Andreas Weigel[1], Robert Wolf[1], Wilfried Nörtershäuser[2], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institut für Kernphysik,Technische Universität Darmstadt, Germany

Highly charged ions are excellent candidates to test fundamental theories such as bound-state quantum electrodynamics (BS-QED). The strong electromagnetic fields which can be found in those systems can shift the energies of fine structure or even hyperfine structure transitions into the optical regime. Measuring such transitions constitutes a stringent test on BS-QED including relativistic many electron calculations and nuclear contributions.

We present a novel method that does not rely on any fluorescence signal which allows to find straight forward a transition by using the continuous Stern Gerlach effect. Using this method we have recently performed laser spectroscopy of the magnetic dipole (M1) $2p\,^2P_{1/2}-^2P_{3/2}$ fine structure transition in $^{40}Ar^{13+}$ stored in a cryogenic Penning-trap system of the ALPHATRAP *g*-factor experiment at the Max-Planck-Institut für Kernphysik. Results of this will be presented.

A 6.5 Mon 15:15 S HS 2 Physik

Determination of the electron affinity of astatine for IS615 — •David Leimbach — CERN, Geneva, Switzerland — Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — Department of Physics, University of Gothenburg, Gothenburg, Sweden

Astatine is a purely radioactive and the rarest naturally occurring element on earth, exhibiting a number of short lived alpha emitting isotopes. E.g. one of the longer lived isotopes, 211At, is of special interest as an agent for targeted alpha therapy (TAT), a method of treating cancer directly at the location of a tumor with alpha emitting particles. On the other hand, the fundamental quantity of the electron affinity (EA) of astatine is not known. Together with the just recently measured first ionization potential (IP) this value is of importance to determine the unknown electronegativity of this element which could give valuable benchmarks for quantum chemical calculations predicting the chemical properties of this element and its compounds. In order determine the EA of radioisotopes via laser photodetachment, the Gothenburg Anion Detector for Affinity measurements by Laser PHotodetachment (GANDALPH) was built. Following the first ever measurement of the EA of a radiogenic isotope in 2016 [4], GANDALPH has recently received multiple upgrades to facilitate beam tuning and detection of low intensity (<1pA) ion beams. During an experimental campaign at CERN-ISOLDE in 2018, the GANDALPH beamline was used to successfully measure the EA of astatine. Experiment and results of these measurements will be presented and compared to expectations and recent theoretical calculations.

A 6.6 Mon 15:30 S HS 2 Physik

Laser Spectroscopy of Boron Isotopes — •Bernhard Maass[1], Jason Clark[2], Phillip Imgram[1], Simon Kaufmann[1], Kristian König[1], Jörg Krämer[1], Jan Krause[1], Alessandro Lovato[2], Peter Müller[2], Krzysztof Pachucki[3], Mariusz Puchalski[3], Maria Piarulli[4], Robert Roth[1], Rodolfo Sánchez[5], Guy Savard[2], Felix Sommer[1], Robert Wiringa[2], and Wilfried Nörtershäuser[1] — [1]IKP, TU Darmstadt, DE — [2]ANL, Lemont, IL, USA — [3]University of Warsaw, PL — [4]Washington University, St. Louis, MO, USA — [5]GSI Darmstadt, DE

We report on the first determination of the nuclear charge radius of stable boron isotopes by resonance ionization mass spectrometry (RIMS). By combining high-resolution measurements of the isotope shift in an atomic ground state transition and high-accuracy *ab initio* mass-shift calculations of the five-electron system, the difference in the mean-square charge radius between the stable isotopes $^{10,11}B$ can be extracted. The result is then used to benchmark new *ab initio* nuclear structure calculations using the no-core shell model and Greens-Function Monte Carlo approaches. In near future, collinear laser spectroscopy will be performed in the same transition on the short-lived (770 ms) proton halo candidate ^8B at Argonne National Laboratory. The difference in mean-square charge radius will deliver a model-independent test of its proton halo character.

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

A 7: Interaction with strong or short laser pulses

Time: Monday 14:00–16:00 Location: S HS 3 Physik

Invited Talk A 7.1 Mon 14:00 S HS 3 Physik

Multielectron polarization effects and ionization of the hydrogen molecule within the semiclassical two-step model — •Nikolay Shvetsov-Shilovski[1], Manfred Lein[1], Lars Madsen[2], and Karoly Tokesi[3] — [1]Leibniz Universität Hannover, Hannover, Germany — [2]Aarhus University, Aarhus, Denmark — [3]Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary

The semiclassical two-step model (SCTS) for strong-field ionization describes quantum interference and accounts for the ionic potential beyond the semiclassical perturbation theory [1]. We extend the SCTS model to take into account multielectron polarization effects [2]. We predict a pronounced narrowing of the longitudinal momentum distributions due to the polarization-induced focusing of photoelectrons. We show that the polarization of the core also modifies interference structures in the photoelectron momentum distributions.

Furthermore, we apply the SCTS model to ionization of the hydrogen molecule. In the simplest case of the molecule oriented along the polarization direction of a linearly polarized field, we predict significant deviations in the electron momentum distributions from the case of atomic hydrogen.

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

[2] N. I. Shvetsov-Shilovski, M. Lein, and L. B. Madsen, Phys. Rev. A 98, 023406 (2018).

A 7.2 Mon 14:30 S HS 3 Physik

Carrier-envelope phase measurement at short-wave infrared wavelengths and Gouy-phase effects in strong-field ionization — •Yinyu Zhang[1,2], Danilo Zille[1,2], Philipp Wustelt[1,2], Dominik Hoff[1,2], Slawomir Skruszewicz[1,2], A. Max Sayler[1,2], and Gerhard G. Paulus[1,2] — [1]Helmholtz Institute, Jena, Germany — [2]Institute of Optics and Quantum Electronics, Jena, Germany

Here, we report on the implementation of a single-shot, real-time, carrier-envelope phase (CEP) measurement based on the measurement of stereographic above-threshold ionization (ATI) at 1.8 μm [1], which is so-called the carrier-envelope phasemeter (CEPM). A specific feature of the CEPM is the ability for simultaneous characterization of the pulse duration. In addition, the CEP dependent stereo-ATI spectra of Xenon at 0.8 μm and 1.8 μm are simulated by using a semiclassical model and 1D-TDSE model. Simulation results for both models show larger CEP-dependence than the measurements for different pulse lengths and this discrepancy increases with decreasing the pulse length. Inspired by the observation of the axial phase shift, known as Gouy phase, or Porras phase (for broadband pulses) [2], such phase shifts are then introduced in the simulation. The new results show a better match with the measurements and it also provides us a more precise calibration for pulse lengths measurement. [1] Y. Zhang et al., Opt. Lett. 42, 5150 (2017). [2] D. Hoff et al., Nat. Phys. 13 947-951 (2017)

A 7.3 Mon 14:45 S HS 3 Physik

Tailored orbital angular momentum in high-order harmonic generation with bicircular Laguerre-Gaussian beams — •Willi Paufler[1], Birger Böning[1], and Stephan Fritzsche[1,2] — [1]Helmholtz Institut Jena — [2]Theoretisch Physikalisches Institut Jena

We report on a method to generate extreme ultraviolet vortices from high-order harmonic generation with two-color counter-rotating Laguerre-Gaussian beams that carry a well-defined orbital angular momentum. Our calculations show that the OAM of each harmonic can be directly controlled by the OAM of the incident LG modes. Furthermore, we show how the incoming LG modes have to be tailored, in order to generate every possible value of OAM in the emitted harmonics. In addition, we analyze the emitted harmonics with respect to their divergence and find that it decreases with the harmonic order and increases with the OAM of the emitted harmonic.

A 7.4 Mon 15:00 S HS 3 Physik

Floquet-Bloch bands in solid-state high harmonic generation — •Lukas Medišauskas, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

High harmonic generation (HHG) in solid state materials is conventionally divided into intra- and inter- band contributions. In time-dependent Schrödinger equation (TDSE) calculations, the inter-band high-harmonic spectra is generally unstructured and fast dephasing times have to be included into the calculation to observe well pronounced harmonic peaks.

We analyse solid state HHG in terms of Floquet-Bloch (FB) bands, i.e., the field-dressed bands in the presence of the laser pulse. We show that the harmonic spectra can be split into a contributions from a single FB band and a contributions between two FB bands. The former consists of clean well pronounced odd harmonics. The latter consists of harmonics at positions depending on crystal momenta. Combining the contributions from the whole Brillouin zone leads to a featureless spectra. Finally, we show that the role of dephasing in TDSE simulations is that of suppressing the noisy inter FB band harmonics and leaving only the clean intra FB band harmonics.

A 7.5 Mon 15:15 S HS 3 Physik

Evidence of Freeman resonances in intense two-color counter-rotating laser fields — •Philipp Stammer[1,2], Felipe Morales[1], Olga Smirnova[1,2], and Misha Ivanov[1,3,4] — [1]Max Born Institut — [2]Technische Universität Berlin — [3]Humboldt Universität Berlin — [4]Imperial College London

We present results of the numerical solution of the TDSE for the Hydrogen atom, and a short range Yukawa potential, exposed to an intense bi-circular laser field. We study the photoelectron angular distributions after strong field ionization.

In the case of the Yukawa potential, we observe a 3-fold symmetry, imposed by the bi-circular field. Additionally we observe many features predicted by SFA for linear fields, including Low Energy Structures due to re-scattered trajectories.

However, when including the Coulomb potential new features appear, and the 3-fold symmetry can be broken. In particular, we focus on the first ATI peak, where a more complex pattern arises. This pattern is born out of the field induced resonant ionization of states shifted by the ponderomotive potential, or Freeman resonances, and could be used to identify the electron dynamics prior to ionization.

A 7.6 Mon 15:30 S HS 3 Physik

Photoelectron holography beyond the electric dipole approximation — •Simon Brennecke and Manfred Lein — Institut für Theoretische Physik, Appelstraße 2, 30167 Hannover, Germany

Photoelectron holography is an ultrafast laser-based imaging technique which produces measurable interference patterns in electron momentum distributions. Its interpretation is usually carried out in electric dipole approximation. However, today's experiments [Phys. Rev. Lett. **113**, 243001 (2014)] are capable of revealing beyond-dipole effects such as a counter-intuitive shift of the momenta into the direction opposite to the laser propagation direction for low electron energies in linearly-polarized fields. We calculate the momentum-dependent shift of the holographic structure by extending the quantum trajectory-based Coulomb-corrected strong-field approximation (CCSFA) beyond the electric dipole approximation. The theory is set up such that in the limit of vanishing potential, it reproduces the beyond-dipole strong-field approximation. The comparison with the numerical solution of the time-dependent Schrödinger equation in 2D and 3D shows that the point of constructive interference between different trajectories describes quantitatively the position of the central maximum in the momentum distribution. Interestingly, this point of constructive interference coincides with the position of the classical ridge due to Coulomb-focusing in 3D [Phys. Rev. A. **97**, 063409 (2018)].

A 7.7 Mon 15:45 S HS 3 Physik

Gaussian-process optimization of photoionization dynamics of many-electron systems — •Yi-Jen Chen[1], Ulf Saalmann[1], Robin Santra[2], and Jan M. Rost[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Center for Free-Electron Laser Science, Hamburg, Germany

Advances in light-source technology have opened up the possibility to manipulate the properties of light and, thus, the possibility to dynamically steer a quantum system in a desired manner. Since the simulation and measurement of light-driven quantum dynamics are costly, for a given control task, the optimal set of laser parameters has to be found as quickly as possible.

In this talk, we present a Bayesian active learning algorithm based on Gaussian-process regression to tackle such optimal control problems. This algorithm converts the search for the optimum of an expensive target function into that of a relatively cheap cost function. As the derivatives of the cost function permit an analytical form, its optimum can be located efficiently using gradient-based optimization schemes.

We apply this algorithm to maximize the degree of coherence of a photoion created by attosecond photoionization. The reduced density matrix of the ionic wave packet, obtained here by ab-initio solution of the N-electron Schrödinger equation, may be probed experimentally using ultrafast spectroscopy. In addition to numerical efficiency, we discuss how to extract physical insights and to select an experimentally accessible maximum by exploiting the global and local information of the target-function landscape.

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

Time: Monday 16:15–17:45 Location: S HS 1 Physik

A 8.1 Mon 16:15 S HS 1 Physik

Rydberg Excitation of Ultracold Atoms Interacting with Trapped Ions — •Norman V. Ewald, Thomas Feldker, Henrik Hirzler, Matteo Mazzanti, Henning A. Fürst, and Rene Gerristma — Universiteit van Amsterdam, Amsterdam, Netherlands

We report on the observation of interactions between ultracold Rydberg atoms and ions in a Paul trap [1]. The observed inelastic collisions, manifested in charge transfer between the Rydberg atoms and ions, exceed Langevin collisions for ground state atoms by almost three orders of magnitude in rate. This indicates a huge increase in interaction strength. The ion loss spectrum exhibits a long tail on the red side of the Rydberg resonance which we attribute to the electric field of a single ion. We study the effect of the bare Paul trap's electric fields on the Rydberg excitation spectra. Furthermore, we demonstrate Rydberg excitation on a dipole-forbidden transition with the aid of the electric field of a single trapped ion. Our results demonstrate the possibility of tuning interactions between ultracold atoms and ions by laser coupling to Rydberg states. These techniques may allow to create spin-spin interactions between atoms and ions [2] and to overcome recently observed heating due to ionic micromotion in atom-ion hybrids [3,4].

[1] N. V. Ewald, T. Feldker, H. Hirzler, H. Fürst, and R. Gerritsma, *arXiv*:1809.03987 (2018). [2] T. Secker, R. Gerritsma, A. W. Glätzle, and A. Negretti, *Phys. Rev. A* **94**, 013420 (2016). [3] T. Secker et al., *Phys. Rev. Lett.* **118**, 263201 (2017). [4] Z. Meir et al., *Phys. Rev. Lett.* **117**, 243401 (2016).

A 8.2 Mon 16:30 S HS 1 Physik

Rydberg blockade induced by a single ion — •Thomas Dieterle, Felix Engel, Marian Rockenhäuser, Christian Hölzl,

Sophia Ten Huisen, Robert Löw, Tilman Pfau, and Florian Meinert — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Ultracold Rydberg atoms with their strong mutual interactions provide an interesting platform for e.g. quantum simulation or quantum information exploiting the so-called Rydberg blockade. A similar concept applies to hybrid systems of Rydberg atoms and ions leading to single charge-induced blockade phenomena over macroscopic distances.

We demonstrate the excitation blockade of a single Rydberg atom by a single low-energy ion. The ion is produced from a single Rydberg excitation in an ultracold sample exploiting a novel optical two-photon ionization scheme, especially suited for the creation of very low-energy ions. We precisely control the ion's motion by applying small electric fields to analyze the blockade mechanism for a range of principal quantum numbers. Finally, we demonstrate the applicability of the ion as a high-sensitivity single-atom based electric field sensor.

Our method may in the future be used for controlling cold collisions, chemistry or charge mobilities in ion-atom mixtures.

A 8.3 Mon 16:45 S HS 1 Physik

Rydberg spectroscopy in an atom-ion hybrid trap — •Shinsuke Haze[1], Joschka Wolf[1], Markus Deiss[1], Limei Wang[1], Georg Raithel[2], Christian Fey[3], Frederic Hummel[3], Florian Meinert[4], Peter Schmelcher[3], and Johannes Hecker Denschlag[1] — [1]Institut für Quantenmaterie, Universität Ulm, 89069 Ulm, Germany — [2]Department of Physics, University of Michigan, Ann Arbor, MI 48109, USA — [3]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [4]Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Hybrid atom-ion trap has been a key technology for intriguing applications such as cold chemistry, molecular physics and so on. The good controllability of ion's and atomic states provides an opportunity for studying atom-ion interaction in an unprecedented regime. Here, we demonstrate Rydberg spectroscopy of rubidium atoms within an atom-ion hybrid trap, where an optical dipole trap and a Paul trap are combined for simultaneous trapping of neutral and charged particles. This versatility enables for capturing an ionized product following an optical excitation to Rydberg states. The trapped ions elastically collide with the rubidium atoms leading to an atom loss, which gives rise to a high sensitivity of observing the underlying Rydberg excitation. In this presentation, we show results for spectroscopy of Rydberg states, where we measured avoided level crossings. We will discuss our data by comparing with the calculated Stark map of Rydberg states.

A 8.4 Mon 17:00 S HS 1 Physik

Quench dynamics of Rydberg dressed atoms in two-dimensional optical lattices — •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, The University of Nottingham, Nottingham, NG7 2RD, UK

Recent experiments have demonstrated that long-range interactions can be induced by laser dressing ground state atoms to electronically excited Rydberg states. When trapped in optical lattices, this permits us to realize extended Bose-Hubbard models with tunable interactions. In this work, we study quench dynamics of the dressed atoms in a two-dimensional optical lattice. Here, by decreasing the lattice potential height, the tunneling rate increases from a Mott insulator to supersolid and then superfluid phases. Using a Gutzwiller approach, we find a sudden birth of superfluid order parameters after Mott-supersolid phase boundary. However, superfluid order parameter does not increase monotonically due to the supersolid phase as an intermediate state, which is largely affected by long-range interactions. The details of the exotic dynamics can be observed by, e.g., time-of-flight experiments. Our study paves a route to exploring non-equilibrium many-body physics with Rydberg dressed atoms in lattice systems.

A 8.5 Mon 17:15 S HS 1 Physik

State Selective Field Ionization in Asymmetric Geometries — •Alexander Müller[1], Titus Franz[1], Sebastian Geier[1], Andre Salzinger[1], Annika Tebben[1], Clément Hainaut[1], Nithiwadee Thaicharoen[1], Gerhard Zürn[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, University Heidelberg, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

Precise control of field ionization ramps enables time resolved detection of different Rydberg states, making the method state selective. In our Experiment the ion detector is tilted and off-centered from the axis of the field electrodes to increase optical accessibility, but in cost of simple ion trajectories.

This talk will present our implementation of electric potentials to ionize the Rydberg states selectively and at the same time guide the ions to the detector. Limitations of the method in terms of suitable states and local Rydberg densities will be discussed.

A 8.6 Mon 17:30 S HS 1 Physik

Investigation of Förster resonant energy transfer between polar molecules and Rydberg atoms — •Martin Zeppenfeld and Ferdinand Jarisch — MPI für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

A quantum hybrid system composed of polar molecules and Rydberg atoms provides wideranging opportunities for future experiments, ranging from control and readout of molecular states to quantum information processing. As a first step, we have investigated Förster resonant energy transfer between molecules and Rydberg atoms at room temperature [1]. This includes a detailed analysis of Rydberg states involved in the molecule-Rydberg-atom interactions via mm-wave state transfer and investigation of electric field dependent collisions. We will also discuss progress on the next-generation experiment involving cold molecules and ultracold atoms.

[1] F. Jarisch *et al.*, New J. Phys. **20**, 113044 (2018).

A 9: Precision Spectroscopy of atoms and ions III (joint session A/Q)

Time: Monday 16:15–18:00 Location: S HS 2 Physik

Invited Talk A 9.1 Mon 16:15 S HS 2 Physik

Non-equilibrium Dynamics of Ion Coulomb Systems — •Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

Single trapped and laser-cooled ions in Paul traps allow for a high degree of control of atomic quantum systems. They are the basis for modern atomic clocks, quantum computers and quantum simulators. Our research aims to use ion Coulomb crystals, i.e. many-body systems with complex dynamics, for precision spectroscopy. This paves the way to novel optical frequency standards for applications such as relativistic geodesy and quantum simulators in which complex dynamics become accessible with atomic resolution. The high-level of control of self-organized Coulomb crystals open up a fascinating insight into the non-equilibrium dynamics of coupled many-body systems, displaying atomic friction and symmetry-breaking phase transitions. We discuss the creation of topological defects and Kibble-Zurek tests in 2D crystals and present recent results on the study of tribology and transport mediated by the topological defect.

A 9.2 Mon 16:45 S HS 2 Physik

High intensity laser cooling with electromagnetically induced transparency beyond the Lamb-Dicke limit — •Javier Cerrillo — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr 36 10623 Berlin

Laser techniques for ground state cooling of trapped ions, cold atoms or nanomechanical oscillators are well understood in the limit of slow cooling but lack a comprehensive description for very large laser intensities or, equivalently, beyond the well-studied Lamb-Dicke limit. The exploration of this regime has so far been uncommon due to the laser intensity limitations imposed by heating effects of carrier and blue sideband transitions. We present a scheme where coherent combination of scattering paths based on electromagnetically induced transparency (EIT) can cancel both carrier and blue-sideband excitations, so that all heating contributions vanish within the Lamb-Dicke limit. The use of multiple EIT features also facilitates simultaneous cooling of several modes and has been experimentally demonstrated. For all these schemes, a new theoretical tool based on a generalized master equation formalism is proposed for the analysis and optimization of cooling rate and final temperature which automatically incorporates polaronic and squeezing effects.

A 9.3 Mon 17:00 S HS 2 Physik

Towards Sympathetic Cooling of Protons and Antiprotons — •Matthew Bohman[1,2], Pascal Blessing[2,3], Jack Devlin[2], James Harrington[1], Andreas Mooser[1,2], Gerog Schneider[2,5], Christian Smorra[2], Markus Wiesinger[1,2], Elise Wursten[2,6], Klaus Blaum[1], Yasuyuki Matsuda[4], Wolfgang Quint[3,7], Jochen Walz[5,8], and Stefan Ulmer[2] — [1]Max-Planck-Institut für Kernpysik, Germany — [2]Fundamental Symmetries Laboratory, RIKEN, Japan — [3]GSI, Germany — [4]University of Tokyo, Japan — [5]Mainz University, Germany — [6]CERN, Switzerland — [7]Heidelberg University, Germany — [8]Helmholtz-Institut Mainz, Germany

High precision measurements on trapped protons and antiprotons provide some of the most stringent tests of CPT symmetry in the baryon sector. In particular, these experiments confirm CPT symmetry and provide further evidence of Lorentz invariance at the level of 10e-24 GeV on an absolute energy scale. Further precision, however, is limited by high particle energies and requires moving beyond the traditional techniques available in high precision cryogenic Penning trap experiments. We present a novel technique to sympathetically cool protons and antiprotons stored in separate traps, by coupling single particles to laser cooled ions via image currents induced in a common endcap electrode. We place our work in the context of an improved g-factor measurement of the proton and show early results including the application of methods to measure sub-thermal single particle energy distributions in the laser cooled limit.

A 9.4 Mon 17:15 S HS 2 Physik

Experimental setup for sympathetic laser cooling of single atomic ions and protons in a Penning trap — •Juan M. Cornejo[1], Johannes Mielke[1], Teresa Meiners[1], Malte Niemann[1], Nicolás Pulido[1], Jonathan Morgner[1], Matthias Borchert[1,3], Amado Bautista-Salvador[2,1], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Ulmer Fundamental Symmetries Laboratory, RIKEN

High-precision measurements of the (anti-)proton g-factor provide a stringent test of CPT invariance in the baryonic sector [1]. However, current cooling and state detection schemes are highly sensitive on the motional energy of the particles. For faster cooling to mK temperatures and efficient detection, we pursue an approach where a single, well-controlled atomic ion serves as a link to manipulate and detect the motional and spin state of a single (anti-)proton [2, 3].

An overview of the experimental setup including a cryogenic Penning trap stack for first demonstrations of the motional coupling between two $^9Be^+$ ions in a double well potential is given. We report on the latest progress regarding trapping, manipulation and detection of the atomic ion. Prospects for proton loading and a micro-coupling trap are discussed.

[1] C. Smorra *et al.*, Nature **550**, 371-374 (2017)
[2] D. J. Heinzen and D. J. Wineland, Phys. Rev. A **42**, 2977 (1990)
[3] D. J. Wineland *et al.*, J. Res. NIST, **103**, 259-328 (1998)

A 9.5 Mon 17:30 S HS 2 Physik

Resistive cooling of highly charged ions in a Penning trap to a fluidlike state — Mohammad Sadegh Ebrahimi[1], •Zhexi Guo[1,2,3], Manuel Vogel[1], Marco Wiesel[1,4], Wolfgang Quint[1,3], and Gerhard Birkl[4] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [3]Physikalisches Institut, Universität Heidelberg, 69120 Heidelberg, Germany — [4]Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany

Resistive cooling of large ensembles of highly charged ions such as Ar13+ was studied in detail in a cryogenic Penning trap. In contrast to earlier measurements by Vogel et al. [Phys. Rev. A 90, 043412 (2014)], purely exponential cooling behaviour was observed when conditions were chosen to allow collisional thermalisation of the ions. The results obtained under such conditions indicate that resistive cooling time constants and final temperatures are independent of the initial ion energy and that the cooling time constant of a thermalised ion ensemble is identical to the single-ion cooling time constant. For sufficiently high ion number densities, measurements showed discontinuities in the spectra of motional resonances which indicate a transition of the ion ensemble to a fluidlike state when cooled to temperatures below approximately 14 K. With the final ion temperature at 7.5 K, ions of the highest charge states are expected to form ion crystals solely through resistive cooling without the need for laser cooling.

A 9.6 Mon 17:45 S HS 2 Physik

Staggered-immersion cooling of a quantum gas in optical lattices — •Bing Yang[1,2,3], Hui Sun[1,2,3], Chun-jiong Huang[2,3], Han-yi Wang[1,2,3], You-jin Deng[2,3], Han-ning Dai[1,2,3], Zhen-sheng Yuan[1,2,3], and Jian-wei Pan[1,2,3] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [3]CAS Centre for Excellence and Synergetic Innovation Centre in Quantum Information and Quantum Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Here we realize efficient cooling of ten thousand ultracold bosons in staggered optical lattices. By immersing Mott-insulator samples into removable superfluid reservoirs, thermal entropy is extracted from the system. Losing less than half of the atoms, we lower the entropy of a Mott insulator by 65-fold, achieving a record-low entropy per particle of 0.0019 k_B (k_B is the Boltzmann constant). We further engineer the sample to a defect-free array of isolated single atoms and successfully transfer it into a coherent many-body state. The present staggered-immersion cooling opens up an avenue for exploring novel quantum matters and promises practical applications in quantum information science.

A 10: Highly charged ions and their applications

Time: Monday 16:15–17:45 Location: S HS 3 Physik

A 10.1 Mon 16:15 S HS 3 Physik

Commissioning of a High-Power Electron-Gun for Electron-Ion Crossed-Beams Experiments — •B. Michel Döhring[1,2], Alexander Borovik Jr[1], Benjamin Ebinger[1,2], Kurt Huber[1], Tobias Molkentin[1], Alfred Müller[1], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt (Germany)

Reliable atomic data for electron impact ionisation of ions are required for a thorough understanding and modelling of plasmas. This affects a wide range of research fields such as, e. g. astrophysics, space propulsion, EUV-lithography, and fusion research. Recently, a new electron gun has been integrated into the Gießen crossed-beams experiment which permits to extend the measurements to much higher electron energies than before. This electron gun provides a ribbon-shaped electron beam with energies ranging from 10 to 3500 eV [1,2,3]. For a high flexibility, we can choose between different operation modes. Here, we present the latest achievements in the commissioning of this gun as well as new cross-section measurements for multiply charged xenon ions.

[1] W. Shi et al., NIMB 205 (2003) 201-206.
[2] A. Borovik Jr. et al., J. Phys.: Conf. Ser. 488 (2014) 142007.
[3] B. Ebinger et al., NIMB 408 (2017) 317-322.

A 10.2 Mon 16:30 S HS 3 Physik

Statistical completion and validation of the NIST Atomic Spectral Database — •Keisuke Fujii[1] and José R. Crespo López-Urrutia[2] — [1]Kyoto University, Department of Mechanical Engineering and Science, Graduate School of Engineering, Kyoto 615-8540, Japan — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The NIST Atomic Spectral Database (ASD) [1] contains the electronic energy levels of most elements in all known degrees of ionization, and has for decades been an essential standard tool in atomic science, spectroscopy and plasma physics. However, there are substantial gaps in the data, and many energy levels of highly charged ions are still missing owing to the difficulties of measurements. In this work, we utilize a machine learning method to find structures in the atomic data compiled in the ASD database. With the extracted data structure, we predict the missing data values and provide probabilistic Bayesian uncertainty information. Furthermore, we identify some anomalies in the existing entries, which may be due to typographic mistakes or misidentifications.

[1] Kramida, A., Ralchenko, Yu., Reader, J. and NIST ASD Team (2018). NIST Atomic Spectra Database (version 5.6.1), https://physics.nist.gov/asd . National Institute of Standards and Technology, Gaithersburg, MD. DOI: https://doi.org/10.18434/T4W30F

A 10.3 Mon 16:45 S HS 3 Physik

Direct determination of ion numbers and energies by a single-pass non-destructive charge counter — •Markus Kiffer[1], Stefan Ringleb[1], Nils Stallkamp[1,2], Sugam Kumar[3], Ilya Blinov[4], Manuel Vogel[2], Stefan Stahl[5], Wolfgang Quint[2,6], Thomas Stöhlker[1,2,7], and Gerhard G. Paulus[1,7] — [1]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]Inter-University Accelerator Centre, 110067 New Delhi, India — [4]Fachbereich Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [5]Stahl Electronics, 67582 Mettenheim, Germany — [6]Physikalisches Institut, Ruprecht Karls-Universität Heidelberg, 69120 Heidelberg, Germany — [7]Helmholtz-Institut Jena, 07743 Jena, Germany

The HILITE Penning trap will provide well-defined ion targets to investigate laser-matter interactions in both the high-intensity and high-energy regime with highly-charged ions. For ion counting we have implemented two distinct single-pass non-destructive charge counters. They measure the time-dependent image charge induced by an ion bunch. From these signals we can directly extract the kinetic energy, the number of ions and the bunch length. We will show a brief overview of the HILITE experiment and present the implemented ion counting technique with detailed characterization results. Here we will focus on the sensitivity of the device and the minimum detectable number of ions. Furthermore, we will outline actions to further increase the signal-to-noise ratio to be even sensitive to less than ten ions per bunch.

A 10.4 Mon 17:00 S HS 3 Physik

Laser beamline for laser cooling of stored relativistic heavy-ion beams at the SIS100 — •Max Horst[1,2], Daniel Albach[3,5], Gerhard Birkl[2], Michael Bussmann[3], Volker Hannen[4], Daniel Kiefer[2], Sebastian Klammes[1,2], Thomas Kühl[1], Markus Löser[3,5], Ulrich Schramm[3,5], Mathias Siebold[5], Peter Spiller[1], Thomas Stöhlker[1,6,7], Johannes Ullmann[1,4], Thomas Walther[2], Daniel Winzen[4], and Danyal Winters[1] — [1]GSI Darmstadt — [2]TU Darmstadt — [3]HZDR Dresden — [4]Uni Münster — [5]TU-Dresden — [6]HI-Jena — [7]Uni-Jena

At relativistic velocities, laser cooling is an efficient technique to minimize the momentum spread of stored heavy-ion beams in storage rings. For the future facility FAIR in Darmstadt, this cooling method will be the only one applied to the heavy-ion synchrotron SIS100. The distance from the laser lab to the accelerator, in which the laser beam will be overlapped with an ion beam, is about 25 m crossing two tunnels. For several good reasons, it is best to transport the laser light through a vacuum beamline. However, due to the required mirror setup and multiple optical components, the polarization of the light emerging from the laser beamline will be somewhat modified. To avoid unwanted effects during laser cooling, such as optical pumping, we need to control the polarization of the laser light at the interaction section. We will present the design of the laser beamline, mention some important aspects, and discuss results from recent polarization measurements using a demo setup of the laser beamline.

Invited Talk A 10.5 Mon 17:15 S HS 3 Physik

Towards testing physics beyond the Standard Model with the bound-electron g factor — •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 calculated and, when compared to existing and potential 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, including data on the weighted 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 ongoing advancement 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, to obtain bounds on a hypothetical fifth fundamental force. This method is based on experimental King plots, which are built from isotope shift data. By carefully considering subleading nuclear corrections to the g factor, our treatment allows for the precise interpretation of King plots.

A 11: Ultra-cold plasmas and Rydberg systems

Time: Tuesday 16:30–18:30 Location: S Fobau Physik

A 11.1 Tue 16:30 S Fobau Physik

On-demand single-photon source based on thermal Rubidium — •Florian Christaller, Fabian Ripka, Hao Zhang, Harald Kübler, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

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

An important ingredient for strong cooperative interaction effects, like the Rydberg blockade, is the optical thickness in the micro-cell. The effect of light-induced atomic desorption (LIAD) [3] has demonstrated to be a suitable technique. With it, atoms absorbed at the glass surfaces of the micro-cell are desorbed optically by an intense ns-pulse of green light. By this, the optical thickness can be optically triggered from near zero to above one on the ns-timescale. Here we report on the latest LIAD measurements and on the 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)
[3] Atunov et al., Phys. Rev. A 67, 053401 (2003)

A 11.2 Tue 16:30 S Fobau Physik

A gas sensor based on Rydberg excitations — •Johannes Schmidt[1,2,5], Patrick Kaspar[1,5], Fabian Munkes[1,5], Denis Djekic[3,5], Patrick Schalberger[2,5], Holger Baur[2,5], Robert Löw[1,5], Tilman Pfau[1,5], Jens Anders[3,5], Norbert Frühauf[2,5], Edward Grant[4], and Harald Kübler[1,5] — [1]5th Institute of Physics — [2]Institute for Large Area Microelectronics — [3]Institute for Smart Sensors — [4]Department of Chemistry, UBC — [5]University of Stuttgart, Center for integrated quantum science and technology (IQST)

Sensitive and selective gas sensors become increasingly important for the analysis of the exhaled breath of mammals. Our scheme is based on the excitation of Rydberg states in the molecule of interest. Subsequent collisions with the background gas and predissociation will lead to ionization. The emerging charges can then be measured as a current. The occurrence of a current is an unequivocal indication of the presence of the molecule under consideration. We demonstrate technology readiness level 3 of our scheme at the example of the detection of 100 ppb Rb in a background gas of N_2 with a sensitivity of 10 ppb/$\sqrt{\text{Hz}}$. We further experimentally verify the applicability in real life on the detection of nitric oxide in a gas mixture up to ambient pressure.

[1] J. Schmidt, et al., *SPIE* **10674** (2018)
[2] J. Schmidt, et al., *Appl. Phys. Lett.* **113**, 011113 (2018)

A 11.3 Tue 16:30 S Fobau Physik

Background gas induced line broadening in a rubidium vapor — •Fabian Munkes[1,4], Johannes Schmidt[1,2,4], Patrick Kaspar[1,4], Denis Djekic[3,4], Patrick Schalberger[2,4], Holger Baur[2,4], Robert Löw[1,4], Tilman Pfau[1,4], Jens Anders[3,4], Norbert Frühauf[2,4], and Harald Kübler[1,4] — [1]5th Institute of Physics — [2]Institute of Large Area Microelectronics — [3]Institute of Smart Sensors — [4]University of Stuttgart, Center for Integrated Quantum Science and Technology (IQST)

We investigate elastic and inelastic collisions of rubidium in a background gas of either nitrogen or argon. Rubidium is excited to different Rydberg S-states in an electrically contacted vapor cell [1,2]. This system implements a model for our future trace-gas sensor. The line broadening in various states is analyzed showing different behavior depending on the principal quantum number. While inelastic n- and l-changing collisions dominate for nitrogen, in contrary for argon elastic collisions prevail. A current signal in the nano-Ampere regime is generated by collisional ionization of the excited atoms for detection. For a more thorough understanding, the collisional ionization cross sections are calculated. The gained knowledge is employed to develope a trace-gas sensor based on Rydberg excitations in a thermal gas of nitric oxide [3], which is an important trace gas in medical and environmental applications.

[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 11.4 Tue 16:30 S Fobau Physik

Automated imaging optimization of an ion microscope for ultracold Rydberg experiments — •Phatthamon Kongkhambut, Thomas Schmid, Christian Veit, Nicolas Zuber, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

The experimental study of ion-atom scattering in the ultracold regime has so far remained elusive. We propose a novel method using Rydberg molecules to reach the quantum regime of ion-atom collisions [1] and present our new experimental setup which allows for the spatially resolved detection of the scattering process. The scattering process is initialized by the photoionization of a Rydberg molecule, providing well defined starting conditions for the collision. The scattered ions are imaged by an ion microscope and a delay line detector. Using automated feedback and optimization algorithms, we plan to tune the operation parameters of the ion microscope and minimize the aberrations. A magnification of more than 1000x can be realized with a field of view of 34 micrometers and depth of view of 25 micrometers. The expected resolution is below one micrometer.

[1] T. Schmid et al., Phys. Rev. Lett. **120**, 153401 (2018).

A 11.5 Tue 16:30 S Fobau Physik

Upgrading pairinteraction — •Johannes Block[1], Sebastian Weber[2], and Henri Menke[3] — [1]Institut für Physik, University of Rostock, Deutschland — [2]Institute for Theoretical Physics III, University of Stuttgart, Germany — [3]Department of Physics and MacDiarmid Institute for Advanced Materials and Nanotechnology, University of Otago, New Zealand

The open-source software pairinteraction [1,2] is a valuable tool to calculate interactions between Rydberg atoms. It has been used by the Rydberg community to determine two-body interactions between Rydberg atoms in a number of studies [3-5]. In order to increase the range of application, we introduced a Green tensor formalism [6] in the code. This allows for the simple implemantation of macroscopic bodies in proximity of the interacting atoms. We present sections of the improved code and first results that were produced with it.

[1] http://pairinteraction.github.io/
[2] Weber, S., Tresp, C., Menke, H., Urvoy, A., Firstenberg, O., Büchler, H. P., & Hofferberth, S. (2017), Journal of Physics B, 50(13), 133001.
[3] De Léséleuc, S., Barredo, D., Lienhard, V., Browaeys, A., & Lahaye, T. (2017), Physical Review Letters, 119(5), 053202.
[4] Kim, H., Park, Y., Kim, K., Sim, H. S., & Ahn, J. (2018), Physical Review Letters, 120(18), 180502.
[5] Ripka, F., Kübler, H., Löw, R., & Pfau, T. (2018), Science, 362(6413), 446-449.
[6] Block, J., & Scheel, S. (2017), Physical Review A, 96(6), 062509.

A 11.6 Tue 16:30 S Fobau Physik

Coupling Rydberg atoms and superconducting coplanar resonators — •Jens Grimmel, Conny Glaser, Manuel Kaiser, Lörinc Sárkány, Reinhold Kleiner, Dieter Kölle, and József Fortágh — CQ Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

The creation of hybrid systems consisting of Rydberg atoms and coplanar superconducting resonators has been proposed to enable efficient state transfer between solid state systems and ultracold atoms. Due to the large dipole moment of Rydberg atoms, the coupling strength to the cavity is expected to be much larger than for ground state atoms. At the same time, Rydberg states are strongly affected by any detrimental fields, such as the electric field of adsorbates on the chip-surface, which lead to spatially inhomogeneous energy shifts. We aim to transfer population between neighbouring Rydberg states using the microwave field of a driven coplanar waveguide resonator on a superconducting atom chip. The state transfer in the presence of adsorbate fields is detected via selective field ionisation. Ultimately, this method may aid in the observation of Rabi oscillations between neighbouring Rydberg states.

A 11.7 Tue 16:30 S Fobau Physik

Spectroscopy of Rydberg states in ultra cold ytterbium — •Christian Halter, Alexander Miethke, Eileen Trede, Stuti Gugnani, 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 a spectroscopy study of the Rydberg states of ultra cold ytterbium. For the detection of the Rydberg states we are using the induced loss of atoms in a MOT when atoms are excited to a Rydberg state. Using this method we could measure the energy and polarizability of several states in the region of a high principal quantum number n=70-90.

A 11.8 Tue 16:30 S Fobau Physik

Dissipative dynamics of strongly interacting driven Rydberg gases — •Carsten Lippe[1], Tanita Eichert[1], Jana Bender[1], Erik Bernhart[1], Oliver Thomas[1,2], Thomas Niederprüm[1], Fabian Letscher[1,2], Michael Fleischhauer[1], and Herwig Ott[1] — [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

We investigate the dynamics of Rydberg blockade and facilitation by continuously driving open Rydberg many-body systems in different spatial configurations.

We discuss the facilitation dynamics of an off-resonantly driven 3-dimensional lattice gas in a Mott insulator state with single site occupancy in the regime of strong decoherence. Our experimental results give evidence for the formation of finite-sized Rydberg excitation clusters in the steady state. A scaling analysis with a numerical rate-equation model provides evidence against the existence of a global bistable phase because finite correlation lenghts of Rydberg excitations suggest that many small Rydberg clusters form.

Furthermore, we discuss the dynamics and steady states of a system of mesoscopic Rydberg blockaded clouds loaded into a 1-dimensional optical lattice with a lattice constant equal to the facilitation radius. Each cloud represents an effective two-level system with an asymmetric excitation and deexcitation rate, a so-called superatom. Thus, a chain of superatoms is a realization of a dissipative Ising-like spin model.

A 11.9 Tue 16:30 S Fobau Physik

Rydberg Dressed Quantum Many-Body Systems — •Lorenzo Festa, Nikolaus Lorenz, and Christian Gross — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

We are setting up a novel experiment for the study of quantum many-body systems with engineered long-range interactions. These interactions are induced by off-resonant laser coupling to Rydberg states, so called Rydberg dressing. A great potential of this dressing technique lies in the combination of Rydberg induced interactions and atomic motion in the quantum regime. This requires the long-range interaction between Rydberg atoms to be coherent on the timescale set by the atomic motion. By the choice of the laser parameters the extremely strong dipolar interactions can be balanced with the rate of dissipative light scattering. Studying two-dimensional Rydberg dressed system in an optical lattice will allow us to explore Hubbard models beyond onsite interactions and to realize quantum magnets with engineered inter-spin interactions.

A first intermediate goal of our experiment is to study tailored quantum magnets in microtrap arrays, where Potassium provides interesting prospects for deterministic array loading. The microtrap approach has been chosen in order to have a flexible and fast system for experiments that require high statistics. We are also developing the high power laser system for the ultraviolett light designed to maximize the coupling to Rydberg states.

Here we report on the status of the project and the progress done in the last year with the construction of the experimental apparatus.

A 11.10 Tue 16:30 S Fobau Physik

Dipole-Dipole blockade in strong fields close to the ionization limit — •Raphael Nold, Lea-Marina Steinert, Sonja Lorenz, Jens Grimmel, József Fórtagh, and Andreas Guenther — CQ center for quantum science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

We have developed a quantum gas microscope based on ionization of atoms and a high resolution ion optics. The system serves as a microscope for ultracold ground state and Rydberg atoms and achieves a magnification up to 1000 with a theoretical resolution limit below 100nm. In our experiments, we focus on the research towards strong correlations between Rydberg atoms in electric fields. We were able to use our high temporal resolution of the ion-microscope to measure the resonant energy transfer at Förster resonances via state selective field ionization. Additionally, we show a direct measurement of the excitation blockade for strongly Stark-shifted Rydberg states close to the classical ionization limit. We developed a detection scheme for controlled ionization in which we excite Rydberg atoms close to an avoided crossings between a weakly and a strongly ionizing state. This allows us to change the ionization rate over three orders of magnitude by applying small changes to the electric field. We investigate the dipole blockade by analyzing the spatial correlations of the excited Rydberg atoms for different values of the initial dipole moment and different dipole-diploe orientations.

A 11.11 Tue 16:30 S Fobau Physik

Interaction of Rydberg excitons with thin electron-hole plasmas in cuprous oxide (Cu_2O) — •Sjard Ole Krüger and Stefan Scheel — Institut für Physik, Universität Rostock, D-18059 Rostock, Germany

Wannier excitons are bound electron-hole states inside semiconductors showing striking similarities to hydrogen atoms. The observation of their Rydberg states and signs of a Rydberg blockade in Cu_2O [1] has sparked a lot of research into their properties. Not unlike their atomic counterparts, Rydberg-excitons are very sensitive to the existence of a plasma in their surrounding. It has been shown that plasma densities of less than one electron-hole pair per one hundred exciton volumes may suffice to ionise the Rydberg excitons [2]. Such electron-hole plasmas can be created by a variety of processes, like Auger-decay of ground-state excitons and direct or phonon-assisted excitations of unbound electron-hole pairs. It is therefore necessary to develop a good understanding of the plasma induced effects in order to distinguish them from the sought after exciton-exciton interactions such as the Rydberg blockade. In our poster, we investigate the ionisation of the Rydberg excitons in Cu_2O via the micro-fields induced by the plasma's free charges in a static Stark-interaction model.

[1] T. Kazimierczuk et *al.*, Nature **514**, 343 (2014).
[2] J. Heckötter et *al.*, Phys. Rev. Lett. **121**, 097401 (2018).

A 11.12 Tue 16:30 S Fobau Physik

A Rydberg atom coupled to a 2D lattice of ultracold ground state atoms — •Andrew Hunter, Matthew Eiles, Alexander Eisfeld, and Jan-Michael Rost — Max-Planck Institute for the Physics of Complex Systems

We investigate the spectrum of a Rydberg atom embedded in a two-dimensional lattice of ground state atoms. The strength of the interaction between the Rydberg electron and the neutral atoms is determined by the s-wave electron-atom scattering length. In the high lattice density regime, where many hundreds of atoms lie within the Rydberg wave function, we find that a class of perturbed states breaks away energetically from the others. These are circular states, highly localised in angular momentum. This is in stark contrast to the more familiar scenario of the “trilobite" molecule, where just one perturbing atom couples together many angular momenta and a single state, highly localised in space, splits away from the degenerate Rydberg manifold. We derive new scaling laws which stem from the planar structure of the perturbers, and with these we obtain a universal form of the energy spectrum in the high density limit. We also investigate the perturbed spectrum's dependence on the lattice properties.

A 11.13 Tue 16:30 S Fobau Physik

Using heteronuclear Rydberg dimers and trimers to probe ultracold mixtures — •Matthew Eiles — Max Planck Institut fur Physik komplexer Systeme

Long-range Rydberg molecules are composed of a Rydberg atom and a distant ground state atom tens of nanometers away. These unusual molecules have been studied extensively in the last decade as experimentalists searched for them in ultracold gases. They showed that these molecules can indeed be formed in the laboratory, and have confirmed all the original theoretical predictions. Interest in these molecules has hence shifted in two complementary directions: Can other similar bound systems akin to these fragile molecules be created, and, following more practical considerations, can these molecules be used to probe their environment? We have studied two extensions of the original Rydberg molecule concept: polyatomic molecules containing several ground state atoms, and heteronuclear molecules. Their vibrational energies and Franck-Condon factors are highly sensitive to the geometry of the ground state atoms and the properties of the constituent atomic species. Using these different types of Rydberg molecules we have found some promising avenues in which they can be used to probe their environment over large and controllable length scales [1].

[1] M. T. Eiles Phys. Rev. A 98, 042706 (2018).

A 11.14 Tue 16:30 S Fobau Physik

Optical activation of dipole-forbidden exciton transitions in cuprous oxide (Cu_2O) using orbital angular momentum light — •Annika Konzelmann and Harald Giessen — 4th Physics Institute, Center for Integrated Quantum Science and Technology IQST, and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Inspired from Rydberg atoms, we investigate the semiconductor equivalent of macroscopic quantum states in cuprous oxide, which have been discovered only recently. Cu_2O has a direct bandgap of 2.17 eV and is unique due to its large Rydberg energy of 90 meV and its large effective permittivity ϵ_1=9.8, resulting in the formation of excitons (electron-hole pairs), which are spatially extended over many thousands of lattice sites and spectroscopically well resolvable. Atomic transitions can be driven if the overlap of ground state of the crystal and excited exciton state contains the symmetry of the corresponding light excitation. We want to modify the selection rules by tuning the properties of the light, in particular, by adding angular momentum to the light. This is done by imposing a phase delay to the light beam by, e.g., using a spiral phase plate, resulting in a Laguerre-Gauss mode. We show theoretically (by symmetry considerations), that the transition selection rules can be modified, and that 1-photon-forbidden transition states become allowed states, as the spatial mode of the light is transferred to the exciton states due to phase (angular momentum) conservation.

A 11.15 Tue 16:30 S Fobau Physik

Tweezer Arrays for Rydberg States in Erbium for Quantum Simulation — •Arno Trautmann[1], Philipp Ilzhöfer[1], Benedict Hochreiter[1], Manfred J. Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institute for Quantum Optics and Quantum Information Innsbruck, Austria — [2]University of Innsbruck, Austria

We present our design for a novel platform for quantum simulation based on erbium-Rydberg atoms in optical tweezers. Rydberg atoms are promising candidates for quantum simulation due to their extremely strong and long-range interactions, and have been applied already very successfully in alkali atoms. However, the simple electronic structure with only one valence electron limits the possible manipulation of Rydberg states, such as trapping, cooling or direct imaging. The extension to Rydberg states in multi-electron atoms is natural, and recently strontium and ytterbium have been studied. We plan to use erbium atoms, which have two valence electrons in their outer 6s shell and 12 electrons in an open, sub-merged, 4f shell. The properties of Rydberg states in such a complex system are not yet well understood and require intense spectroscopic effort. We here present our design for a new experiment dedicated to the study of these states in controllable arrays of optical tweezers.

A 12: Ultra-cold atoms, ions and BEC

Time: Tuesday 16:30–18:30 Location: S Fobau Physik

A 12.1 Tue 16:30 S Fobau Physik

Low-temperature phases in the two-band Hubbard model realized with ultracold atomic four-component mixtures in optical lattices — •Yeimer Zambrano[1], Andrii Sotnikov[2], and Agnieszka Cichy[1] — [1]Adam Mickiewicz University, Poznań, Poland — [2]Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine

We study ultracold quantum gases of alkaline-earth-like atoms loaded into three dimensional optical lattice. In particular, we focus on the fermionic mixture of ytterbium-173 atoms due to their unique properties, in particular, low-lying metastable excited (e) electronic state, decoupling of the nuclear spin from the electronic degrees of freedom, and different AC-polarizabilities of the ground- (g-) and e-states. This allows to realize and investigate in detail strongly-correlated many-body physics and emerging low-temperature phases in these mixtures. We focus on the recent realization of the two-band Hubbard model [1,2] and study potential long-rang ordered states. The theoretical analysis is performed in the region of applicability of the tight-binding approximation at different lattice depths and different fillings in the g- and e-bands. By means of dynamical mean-field theory, we obtain dependencies for relevant physical observables, in particular, magnetization, particle density in each band, double occupancy, and compressibility. We construct the phase diagram at finite temeperature and various latice depths.

[1] F. Scazza et al., Nat. Phys. **10**, 779 (2014)
[2] L. Riegger et al., Phys. Rev. Lett. **120**, 143601 (2018)

A 12.2 Tue 16:30 S Fobau Physik

A New Experiment for the Measurement of the Nuclear Magnetic Moment of ^{3}He^{2+} — •Antonia Schneider[1,2], Klaus Blaum[1], Andreas Mooser[1], Alexander Rischka[1], Stefan Ulmer[3], and Jochen Walz[4,5] — [1]Max-Planck-Institute for Nuclear Physics — [2]University of Heidelberg — [3]RIKEN, Ulmer Fundamental Symmetries Laboratory — [4]Institute for Physics, Johannes-Gutenberg University Mainz — [5]Helmholtz-Institute Mainz

We construct a new experiment aiming at the first direct high-precision measurement of the ^{3}He^{2+} nuclear magnetic moment μ_{He} with a relative precision of 10^{-9} or better. The direct measurement of μ_{He} will complement hyper-polarized ^{3}He as an independent magnetometer, which exhibits smaller systematic corrections concerning sample shape, impurities and environmental dependencies compared to water NMR probes. Thus it has the potential to second magnetic field measurements using H_2O as e.g. in the case of the $g-2$ measurement of the muon at Fermilab and J-PARC. In our experiment we will apply methods similar to those used in proton and antiproton magnetic moment measurements [1,2]. If applied to μ_{He} the methods would lead to an insufficient detection fidelity, which is limited by the ions' energy. Thus, we rely on sympathetic laser-cooling to deterministically decrease the ions' energy and a novel Penning trap design optimized for nuclear spin-flip detection. The status of the experiment is presented.

[1] Schneider et al., Science, 1081 (2014)
[2] Smorra et al., Nature, 371 (2017)

A 12.3 Tue 16:30 S Fobau Physik

Fast and dense magneto-optical traps for Strontium — Stepan Snigirev[1], •Annie Jihyun Park[1], André Heinz[1], Immanuel Bloch[1,2], and Sebastian Blatt[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München, Germany

Over the last few years, ultracold strontium atoms have become a platform for realizing optical atomic clocks, atom interferometers, and quantum simulators. All such experiments require producing cold and dense strontium samples from an atomic beam at high duty cycles and with large atom numbers to increase their precision. Here, we improve on a recently demonstrated laser cooling method (sawtooth-wave adiabatic passage, SWAP) to dramatically decrease the preparation time, increase the final atom number, and improve the robustness of our sample preparation. By combining SWAP cooling with narrow-line magneto-optical trapping, we create samples at microkelvin temperatures for both bosonic (Sr-88) and fermionic (Sr-87) strontium isotopes. Our preparation step is optimized for fast cooling and large atom number and combines the advantages of previously demonstrated sample preparation methods for both precision measurements (high duty cycle) and quantum simulation (large atom number).

A 12.4 Tue 16:30 S Fobau Physik

Planar diffraction optics on an atom chip — •Hendrik Heine[1], Alexander Kassner[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

Atom interferometry with Bose-Einstein condensates (BECs) promises great improvements of atomic gravimeters, especially when combined with an atom chip source. These have proven their ability to create BECs with a high flux in an efficient and reliable way giving access to the BEC's unique properties to utilise large momentum transfer beamsplitters and a reduced spatial expansion rate by delta-kick collimation. Although power and size consumption is already quite reduced with the chip technology, further reduction and simplification is still desirable.

On this poster I will present a prototype that combines optical gratings with an atom chip in order to create a magneto-optical trap above the chip surface from a single beam of light. This will intrinsically increase the robustness and bring chip-scale sensors within reach, paving the way for compact quantum sensors on ground and future missions with ultra cold atoms in space.

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 50WM1650 (KACTUS) and by the Deutsche Forschungsgemeinschaft (DFG) within the SFB 1128 geo-Q.

A 12.5 Tue 16:30 S Fobau Physik

Dynamics and optimization of trapped atomic Sagnac interferometer — •Yijia Zhou[1], Igor Lesanovsky[1,2], Thomas Fernholz[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, The University of Nottingham, Nottingham, NG7 2RD, UK

Sagnac interferometers with massive particles promise unique advantages in achieving high precision measurements of rotation rates over their optical counterparts. Recent proposals and experiments are exploring non-ballistic Sagnac interferometers where trapped atoms are transported along a closed path. This is achieved by using superpositions of internal quantum states and their control with state-dependent potentials. We address emergent questions regarding the dynamical behaviour of Bose-Einstein condensates in such an interferometer and its impact on rotation sensitivity. We investigate complex dependencies on atomic interactions as well as trap geometries, rotation rate, and speed of operation. We find that temporal transport profiles obtained from a simple optimization strategy for non-interacting particles remain surprisingly robust also in the presence of interactions over a large range of realistic parameters. High sensitivities can be achieved for short interrogation times far from the adiabatic regime.

This highlights a route to building fast and robust guided ring Sagnac interferometers with fully trapped atoms. [arXiv: 1811.11107]

A 12.6 Tue 16:30 S Fobau Physik

Towards Quantum Simulation of Light-Matter Interfaces with Strontium in Optical Lattices — •Neven Šantić[1], André Heinz[1], Annie Jihyun Park[1], Etienne Staub[1], Rudolf Haindl[1], Stepan Snigirev[1], Jean Dalibard[3], Immanuel Bloch[1,2], and Sebastian Blatt[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany — [3]Collège de France and Laboratoire Kastler Brossel, CNRS, ENS-PSL Research University, UPMC-Sorbonne Universités, 11 place Marcelin Berthelot, 75005 Paris, France

In the last two decades, quantum simulators based on ultracold atoms in optical lattices have successfully explored many different phenomena encountered in strongly correlated condensed matter systems. The latest addition to the quantum simulation toolbox includes quantum gas microscopes with fermionic alkali metal atoms. On the other hand, optical lattice clocks with alkaline earth atoms achieve relative frequency precisions reaching below the 10^{-18} level.

Here we report on the construction of a new quantum gas microscope with Sr atoms prepared in large-mode-volume state-dependent lattices. Our experiment will thus combine the advantages of quantum gas microscopes with the precision control over the internal degrees of freedom enabled by optical lattice clock techniques. With this experimental platform we aim to extend the capabilities of quantum simulators to simulate strongly coupled light-matter interfaces that are challenging or unattainable in real systems.

A 12.7 Tue 16:30 S Fobau Physik

Quench dynamics in Rydberg dressed Bose gases — •Gary McCormack and Weibin Li — School of Physics and Astronomy, and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, University of Nottingham, NG7 2RD, UK

We study the dynamics of three-dimensional Bose Gases in which interactions between atoms are changed by suddenly turning on a detuned laser, coupling the ground state to a Rydberg state. This dressing laser induces an isotropic, long-range interaction between ground state atoms. Using a self-consistent Bogoliubov approach, we numerically investigate dynamical responses of a Bose-Einstein condensate (BEC) to the interaction quench. We find that large momentum states can be excited significantly, which goes beyond the linear dispersion regime. Our self-consistent calculations show that quantum depletion exhibits persistent oscillations even at large times, and its asymptotic value is increased largely when compared to situations of weakly interacting BECs. We show that the dynamical evolution of density-density correlations and number fluctuations depends strongly on the strengths and shapes of the induced long-range interaction.

A 12.8 Tue 16:30 S Fobau Physik

A ground-based, transportable testbed for space-borne dual species atom interferometers — •Alexander Herbst, Dennis Becker, Kai Frye, Maike D. Lachmann, Baptist Piest, and Ernst M. Rasel — Leibniz Universität Hannover

Space-borne atom interferometers are promising candidates for a new generation of tests of the universality of free fall. After the sounding rocket mission MAIUS-1 which demonstrated the first Bose-Einstein condensate (BEC) in space using Rb-87, we aim to add K-41 and perform two-species atom interferometry on the upcoming missions MAIUS-2 and -3. Due to the complexity of the experiment and the strict requirements for space missions, extensive testing of the experimental procedures is required. We present a ground-based and transportable testbed for the creation of a dual species BEC of Rb-87 and K-41 in the MAIUS-B physics package. The overall layout and the control electronics closely resembles the flight system that will be used for MAIUS-2. The modular, fiber-based design of the laser system allows for independent operation at 780 nm and 767 nm, transportation to different testing facilities and easy extension regarding the tests of future experiments like the upcoming ISS multi-user facility BECCAL.

A 12.9 Tue 16:30 S Fobau Physik

A reaction microscope for few-body Rydberg dynamics — •Max Althön, Kai Hawerkamp, Philipp Geppert, Cihan Sahin, and Herwig Ott — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern

We report on the current status of our MOTRIMS-type reaction microscope experiment. Every experiment cycle starts with the preparation of a sample of ^{87}Rb atoms in a 3D-MOT, which is loaded from a 2D-MOT. The atoms can then be transferred to a crossed optical dipole trap. Using a 3-level excitation scheme, some atoms can be 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 wavefunctions as well as momenta resulting from internal decay processes. Special focus lies on butterfly and trilobite molecules, which can be addressed efficiently due to the opportunity of exciting Rydberg p- and f-states. Apart from technical details of the fully assembled experimental setup, first results are presented.

A 12.10 Tue 16:30 S Fobau Physik

Rydberg atoms in ultracold gases: from electrons to ion impurities — •Marian Rockenhäuser, Thomas Dieterle, Felix Engel, Christian Hölzl, Sophia Ten Huisen, Robert Löw, Tilman Pfau, and Florian Meinert — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We report on our endeavour to exploit Rydberg impurities immersed in degenerate atomic gases for investigating the interaction of the Rydberg electron and the Rydberg core-ion with the quantum gas. Specifically, we have recently demonstrated access to the interaction of the core-ion with the surrounding ground state-atoms at temperatures well below a microkelvin. For this, we suppress the typically dominant electron-neutral interaction by exciting a giant Rydberg atom (n=190) to reach a regime where the Rydberg orbit exceeds the size of the atomic sample by far. Evidence for ion-atom interaction is found in the analysis of the Rydberg excitation spectra. This may allow investigation of charged quantum impurities and associated polaron physics. Further, we make use of a novel two-photon ionisation scheme to create very low-energy ions and study the interaction of a single ion with a single Rydberg atom. By applying high-precision electric fields we control the ion's motion probe the ion induced blockade of a Rydberg excitation for a range of principle quantum numbers. Furthermore, this high level of electric field control can pave the way for controlling cold collisions or studying the chemistry of ultracold hybrid atom-ion systems or charge mobilities in ion-atom mixtures.

A 12.11 Tue 16:30 S Fobau Physik

A deterministic single-ion source for microscopy and implantation — Felix Stopp, Luis Ortiz-Gutierrez, •Henri Lehec, and Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

We developed a deterministic single ion source based on cold ions extracted from a Paul trap and demonstrated a beam focus of 5.8(1.0) nm [1]. Using this first generation ion source, implantation of single N_2^+ in diamond and Pr^+ in YAG [2] was performed, with an accuracy of about 20 nm. In this poster, the development of a second generation single ion source will be presented. This apparatus is more compact, highly stable, and modular. We aim for a focus spot of 1 nm and we envision a single ion extraction rate of 1 kHz for fast data acquisition. Our source will be used to implant arrays of single phosphorus ion in silicon surfaces in collaboration with the Australian cluster of excellence [3,4].

[1] G. Jacob et al., Phys. Rev. Lett. 117, 043001 (2016)
[2] K. Groot-Berning et al., to be published
[3] B.E. Kane, Nature 393, 133 (1998), G. Tosi et al., Nat. Comm. 8, 450 (2017)
[4] www.cqc2t.org

A 12.12 Tue 16:30 S Fobau Physik

A versatile strontium quantum gas machine with a microscope — •Sergey Pyatchenkov, Oleksiy Onishchenko, Alex Urech, Ivo Knotternus, Carla Sanna, Georgios Siviloglou, Robert Spreeuw, and Florian Schreck — Institute of Physics, University of Amsterdam

Ultracold quantum gases provide an opportunity to engineer Hamiltonians that model condensed matter phenomena in a well-controlled environment. Strontium, being an alkaline-earth element, has narrow intercombination lines, metastable excited electronic states, and ten collisionally-stable SU(N)-symmetric nuclear spin states. These properties open new perspectives for Hamiltonian engineering, studying quantum simulation of many-body systems and quantum optics.

To enrich the existing toolbox to manipulate Sr atoms, we have determined the frequency of the mHz-linewidth $^1S_0$-$^3P_2$ transition to within 250 kHz relative to molecular iodine lines. This transition is useful for quantum simulation since it enables nuclear spin state dependent light shifts, Raman couplings, and more. We are currently integrating a microscope objective into our apparatus, which will initially enable the preparation and detection of single Sr atoms in optical tweezers and ultimately will lead to a Sr quantum gas microscope.

A 12.13 Tue 16:30 S Fobau Physik

Quantum simulation of dynamical gauge fields: Experimental approach — •Apoorva Hegde, Alexander Mil, Andy Xia, Fabian Olivares, Markus Oberthaler, and Fred Jendrzejewski — Kirchhoff Institute of Physics, Im Neuenheimer Feld 227, 69120 Heidelberg

Gauge theories are the fundamental aspects of the Standard Model of High Energy Physics. They are essential for the description of the dynamics between the matter particles, the fermions and the force carriers, the bosons with which the gauge fields are associated. Here we discuss experimental methods to simulate these dynamic gauge fields using an ultracold mixture of sodium and lithium atoms, following the proposals by Kasper and Zache [1, 2]. In this approach, we use an optical lattice structure with alternatingly populated sites of sodium and lithium. The fermionic matter field is described by the lithium atoms whereas the bosonic gauge field is described by the sodium atoms. The gauge coupling is engineered by interspecies spin changing collision between sodium and lithium. Importantly this interaction locally conserves angular momentum therefore satisfying Gauss' law. In this poster, I will present our progress towards the realization of simple lattice gauge theories within ultracold atomic gases.

[1] Kasper et al. NJP 19, 023030 (2017).
[2] Zache et al. Quantum Sci. Technol. 3, 034010 (2018).

A 12.14 Tue 16:30 S Fobau Physik

A new Na-K apparatus for simulating quantum many-body phenomena — •Rohit Prasad Bhatt, Lilo Höcker, Jan Kilinc, Alexander Hesse, 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, effect of spin impurity presence in a lattice (Kondo effect) etc. In this poster, we present the new Na-K experiment at Heidelberg, which we are setting up as a platform to study some of those problems.

A 12.15 Tue 16:30 S Fobau Physik

Coherent oscillations between anisotropic Bose-Einstein condensates — •Marc Ruben Momme, Yuriy Mikhailovich Bidasyuk, and Michael Weyrauch — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany

Josephson effects in Bose-condensed atomic gases receive a considerable interest from experimental and theoretical studies as a prominent manifestation of quantum coherence on macroscopic scale.

The common theoretical description for such systems is the two-mode model. Its validity relies on the assumption that the coupling between two BECs is much weaker then the energy required to create excitations inside each condensate. However if such excitations are present in the same low-energy region, the two-mode model may no longer be valid.

Our results focus on one particular example of such a system: a BEC in a highly anisotropic, cigar-shaped harmonic trap with a barrier parallel to the long axis. The dynamics are modeled within a mean-field framework of the two-dimensional Gross-Pitaevskii equation. We compare the predictions of the two-mode model with the spectrum of the Bogoliubov-de Gennes equation and we show how the lowest Bogoliubov excitations contribute to the dynamics of the system.

A 12.16 Tue 16:30 S Fobau Physik

A dipolar quantum gas of Dysprosium: superfluidity and droplets — •Mingyang Guo, Fabian Böttcher, Jan-Niklas Schmidt, Matthias Wenzel, Tim Langen, Julian Kluge, Viraatt Anasuri, Jens Hertkorn, Arup Bhomwick, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Ultracold dipolar gases have great potential to realize novel quantum many-body phases arising from the long-range and anisotropic dipolar interactions, distinct from the mostly studied contact interaction. The existence of strongly dipolar interactions directly induce modifications to the superfluid properties, including the anisotropic critical velocities and collective excitations.

Furthermore, tuning the contact interaction weaker than the dipolar interaction, we observed formation of quantum droplets instead of collapse, predicted by the mean-field theory, due to the corrections from quantum fluctuations. By changing the external confinement, we can realize droplet arrays as well as a single self-bound droplet. The self-bound droplets possess saturated peak densities and small compressibility, similar to the properties of classical fluids. The critical atom number for the self-bound droplets is also measured over a wide range of scattering length with almost an order change of the critical number.

A 12.17 Tue 16:30 S Fobau Physik

Rydberg-excited bosons in frustrated optical lattices: numerical study of quantum phases emerging due to the long-range interaction — •Jaromir Panas[1], Andreas Geissler[1,2], and Walter Hofstetter[1] — [1]Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]University of Strasbourg and CNRS, 67000 Strasbourg, France

Recent experiments with ultracold Rydberg-excited atoms have shown that long-range interactions can give rise to spatially ordered structures. Observation of such crystalline phases in a system with Rydberg atoms loaded into optical lattices is also within reach. Theoretical studies have been conducted for Rydberg-dressed bosons in a square lattice. A rich phase diagram has been obtained, with a series of supersolid and density wave phases characterized by different spatial orderings. Here we present results of equilibrium numerical calculations performed for long-range interacting bosons in a triangular lattice within state-of-the-art bosonic dynamical mean-field theory. We discuss differences between the frustrated and square lattice geometries. We also investigate a method of extending lifetime of the system, which is finite due to decay and dephasing inherent to the Rydberg excitations.

A 12.18 Tue 16:30 S Fobau Physik

Non-equilibrium dynamics induced by interaction quenches in ultra-cold Fermi gases — •Benjamin Rauf[1], Andreas Kell[1], Martin Link[1], Kuiyi Gao[1], Johannes Kombe[2], Jean-Sebastien Bernier[2], Corinna Kollath[2], Timothy-Joseph Harrison[1], Alexandra-Bianca Behrle[1], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Bonn, Germany — [2]HISKP, University of Bonn, Bonn, Germany

Ultra-cold Fermi gases with tuneable interactions have gathered much interest in the last decade as an excellent tool for the investigation of the BEC-BCS crossover. The Cooper-pairing dynamics and thermalisation in a strongly interacting Fermi gas are not well understood, as the non-equilibrium dynamics upon a quench of the interaction strength $1/k_F a$ are difficult to study both in theory and in experiment. We present our recent measurement results on the dynamics observed in fast changes of the interaction parameter.

A 12.19 Tue 16:30 S Fobau Physik

Magnetic Polarons and Spin-Charge Separation in Fermi-Hubbard Systems — •Sarah Hirthe[1], Jayadev Vijayan[1], Joannis Koepsell[1], Pimonpan Sompet[1], Guillaume Salomon[1], Dominik Bourgund[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max Planck Institute of Quantum Optics, Garching — [2]Ludwig-Maximilians-Universität München

Ultracold fermions in optical lattices have emerged as a powerful tool in the quantum simulation of the Fermi-Hubbard model. With access to full density and spin resolution, our quantum gas microscope has enabled the study of the interplay between spin and charge in doped antiferromagnets. In 1D, the phenomena of spin-charge separation decouples the spin and charge degrees of freedom, creating holons and spinons. We probe this phenomena by locally quenching an antiferromagnet to form holons and spinons and dynamically observing their propagation. In 2D, the competition between the spin and charge degrees of freedom leads to the formation of a polaron. We identify the formation of such a polaron by looking at the dressed spins around a dopant.

A 12.20 Tue 16:30 S Fobau Physik

Feshbach spectroscopy, Feshbach molecule creation and molecular spectroscopy in an ultracold bosonic mixture of ^{23}Na and ^{39}K — •Philipp Gersema, Kai Konrad Voges, Jannis Schnars, Torsten Hartmann, Torben Alexander Schulze, Eberhard Tiemann, Alessandro Zenesini, and Silke Ospelkaus — Institute of Quantum Optics, Leibniz University Hannover

Ultracold mixtures of alkaline atoms are a versatile tool to investigate mixture phenomena and can be used to create ultracold polar ground state molecules, utilizing the STIRAP technique. Among the alkali atoms, sodium and potassium serve as ideal candidates for the production and investigation of such molecules. Cooling strategies for both species are well explored and NaK molecules in their rovibrational ground state 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 bosonic combinations have remained elusive.

We present a detailed study of 21 different scattering features in various spin state combinations of ^{23}Na^{39}K up to a magnetic field strength of 750 G. These comprise Feshbach resonances, zero crossings of the scattering length as well as inelastic loss channels. With this results we refine the potential energy curves for the NaK molecule, giving an improvement not only for the bosonic but also the fermionic case. Furthermore we use this knowledge to create Feshbach molecules and perform spectroscopy to the excited $B^1\Pi$ and $c^3\Sigma$ manifold and the $X^1\Sigma$ ground state of the NaK molecule.

A 12.21 Tue 16:30 S Fobau Physik

Repumping a strontium Zeeman slower — •Jens Samland[1,2], Rodrigo Gonzalez Escudero[1], Chun-Chia Chen[1], Shayne Bennetts[1], Benjamin Pasquiou[1], and Florian Schreck[1] — [1]Van der Waals - Zeeman Institute, Institute of Physics, University of Amsterdam, Amsterdam, The Netherlands — [2]Physik-Department, Technische Universität München, Munich, Germany

We study a new repumping scheme for Sr aiming to reduce atom loss in Zeeman slowers (ZS). Typically, Sr atoms are laser-cooled in a ZS using the 5s5s1S0-5s5p1P1 transition. This transition is not fully cycling and about 1 in 50 000 atoms fall from the upper 5s5p1P1 state into the 5s4d1D2 state. There, they cannot be addressed and are therefore not decelerate and ultimately lost. Using the 448nm 5s4d1D2-5s8p1P1 transition we calculate that 98% of atoms can be repumped back to the 5s5s1S0 ground state within ~3 μs. To test this theory we are building a 448 nm external cavity diode laser which can be incorporated with the ZS of our steady-state atom laser experiment to measure any flux improvement [1]. The demonstration of an efficient repumper for strontium ZS could provide a performance boost for the rapidly expanding global fleet of strontium quantum gas and optical clock machines.

[1] S. Bennetts et al., Phys. Rev. Lett. 119, 223202 (2017).

A 12.22 Tue 16:30 S Fobau Physik

Few ultracold fermions in a two-dimensional trap — •Ram-Janik Petzold — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Systems of ultracold atoms are one of the best experimental demonstration platforms for the investigation of various quantum phenomena appearing at low temperatures. Such artificial quantum simulators offer a high controllability through tunable interparticle interaction strength, particle density as well as trapping potential, together with a high-fidelity state preparation and detection.

Here a novel experimental setup is presented, which was designed to explore the emergence of many-body quantum effects of ultracold fermion gases in two dimensions starting from the few particle level. It mainly consists of a quasi-two-dimensional optical dipole trap for a system of countable few fermionic ^{6}Li atoms. The trap is created by two red-detuned laser beams interfering in their crossing region and providing a strong vertical confinement by a standing wave pattern. An additional single focused beam trap on top of the light-sheet structure allows the independent control over the radial restriction of the harmonic trapping potential. Furthermore, the setup should enable the accurate control over the absolute number of particles in the trap and spin-resolved single-atom detection, which has already been demonstrated in a quasi-one-dimensional configuration.

It is expected, that this experimental simulator will allow the analyses of quantum phenomena in two dimensions by mapping out correlations in position and momentum space.

A 12.23 Tue 16:30 S Fobau Physik

Ultracold and Ultrafast: Probing Quantum Gases with Femtosecond Laser Pulses — •Mario Neundorf[1,2], Tobias Kroker[1,2], Bernhard Ruff[1,2], Donika Imeri[1], Philipp Wessels[1,2], Markus Drescher[1,2], Klaus Sengstock[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

Combining ultracold atoms with ultrashort laser pulses offers novel experimental possibilities such as the instantaneous creation of hybrid quantum systems by local ionization of quantum gases.

Here we present a quantum gas machine allowing to simultaneously detect atoms, electrons and ions after photoionization of ultracold gases. After evaporative cooling in a combined magnetic quadrupole and dipole trap, the ultracold atomic gas is transferred into the interaction region by optical transport within 1.7 seconds. A femtosecond laser beam with actively stabilized beam pointing is focused down to 1 μm allowing for local ionization of Bose-Einstein condensates in a crossed dipole trap. High-speed micro-channel plate and phosphor screen detectors surround the interaction region. To reduce external perturbations on the photoelectron trajectories, an active magnetic field compensation has been set up.

A 12.24 Tue 16:30 S Fobau Physik

Nitrogen vacancy centers as a sensor for active magnetic field stabilization — •Alexander Hesse[1], Kerim Köster[1], Jakob Steiner[2], Julia Michl[2], Jörg Wrachtrup[2], Durga Dasari[2], and Fred Jendrzejewski[1] — [1]Kirchhoff Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [2]3. Physikalisches Institut, Center for Applied Quantum Technologies and IQST, Pfaffenwaldring 57, 70569 Stuttgart, Germany

In recent years the nitrogen-vacancy (NV) center in diamond has emerged as a versatile sensor for magnetic fields, temperature, pressure or electric fields.

As a large quantity of them can be contained in a single diamond, NV centers are especially suitable for performing high precision measurements in very confined spaces. Such highly sensitive local probes would allow for interesting applications in ultracold quantum gas experiments when placed in immediate vicinity to the atoms.

In this poster we present our first steps towards this, using Nitrogen-Vacancy centers to stabilize and control the magnetic fields in our experiment up to 500 G.

A 12.25 Tue 16:30 S Fobau Physik

Fast transport of single atoms in optical lattices using quantum optimal control — •Manolo Rivera[1], Natalie Peter[1], Thorsten Groh[1], Carsten Robens[1], Wolfgang Alt[1], Antonio Negretti[2], Tommaso Calarco[3], Simone Montagero[3], Dieter Meschede[1], and Andrea Alberti[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany — [3]Institut für komplexe Quantensysteme, Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany

We report on fast, high-fidelity transport of single atoms in spin-dependent optical lattices. To transport atoms spin dependently, we use a high-precision polarization synthesizer, which allows us to displace the lattice potentials with angstrom precision with MHz bandwidth. The transport sequences computed from quantum optimal control theory are believed to reach the fundamental speed limit of our optical lattice system, corresponding to one lattice site displacement in 30μs. During transport operations close to the quantum speed limit, the atoms are excited by several motional quanta, but are refocused back to the ground state at the end of the transport. This is confirmed by measuring after transport the fraction of atoms in the ground state using a novel detection scheme based on microwave sideband spectroscopy. Finally, we demonstrate applications of fast atom transport in atom interferometry and quantum walks.

A 12.26 Tue 16:30 S Fobau Physik

Strongly interacting Ytterbium Fermi gases for impurity physics — •Oscar Bettermann[1,2], Nelson Darkwah Oppong[1,2], Luis Riegger[1,2], Giulio Pasqualetti[1,2], Moritz Höfer[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

As an alkaline-earth-like atom, ytterbium features a metastable "clock" state which allows for the implementation of Fermionic gases with orbital degree of freedom. State-dependent lattices enable the realization of two-orbital Hamiltonians such as Kondo-type systems, where particles in the two orbital states interact with spin-exchanging interactions. We have characterized the interaction properties of fermionic ytterbium, which we have shown to be tuneable.

In ytterbium-173, an interorbital Feshbach resonance between one atom in the ground state and another in the clock state enables the study of strongly interacting two-orbital many-body systems. By preparing a gas in a 1D optical lattice with extreme spin-imbalance and with the spin components in separate orbitals, a system of impurity particles interacting strongly with the surrounding Fermi sea is realized. We characterize the spectrum of these two-dimensional quasi-particles as a function of the interaction parameter and identify the attractive and repulsive Fermi polaron branches. We also investigate the quasi-particle residue as well as the lifetime of the repulsive polaron, finding good agreement with a two-orbital many-body theory.

A 12.27 Tue 16:30 S Fobau Physik

Two-compnent spinor Bose-Einstein condensate coupled with twisted light — •Yuriy Bidasyuk — Physikalisch Technische Bundesanstalt, Braunschweig, Germany

Twisted light beams and their interactions with matter atract considerable attention within last years. In the present work we investigate the interaction of twisted light with atomic Bose-Einstein condensates (BEC). To this end we analyze the stationary states of the two-component spinor BEC with coherent coupling by the twisted light beam. Such Rabi coupling has a nontrivial spatial dependence of both amplitude and phase. We develop a simplified analytical model for a ring-shaped BEC and compare it's predictions with a full numerical calculations based on the system of coupled Gross-Pitaevskii equations. Performing a comprehensive study of a ground-state phase portrait of the system we reveal several distinct phases and characterize corresponding phase transitions.

A 12.28 Tue 16:30 S Fobau Physik

Flat band physics in an optical kagome lattice — •Max Melchner — University of Cambridge, United Kingdom

We are currently building a cold-atom experiment to study ultracold atoms in an optical kagome lattice. In the tight-binding approximation, the three lowest motional bands of the kagome lattice are separated from higher-lying bands by a large energy gap. The third lowest energy band is analytically flat. We aim to populate the flat band with ultracold atoms, which should allow us to study effects that arise in strongly correlated many-body systems (e.g. the spin liquid state).

One of the major experimental challenges will be to stabilize the atomic cloud in the flat band of the kagome lattice. Since the flat band is not the lowest band, it will not be occupied by an ultracold atomic gas. There are two basic ways of occupying the flat band: Either one changes the sign of hopping, thereby inverting the band structure such that the flat band is the lowest, or one creates a stable population inversion. In the experiment we are building, we want to do the latter. By using attractive interactions in potassium, we intend to set an upper bound on energy, which will naturally lead to a negative temperature state.

With our experiment we will be able to study transport in a flat motional band. With the addition of interactions and the ability of switching between fermionic and bosonic atoms, we believe this to be an extremely versatile platform for research into single- and many-body localization as well as frustration effects and macroscopic degeneracy.

A 12.29 Tue 16:30 S Fobau Physik

3D ground state cooling in a polarization synthesized optical lattice — •Gautam Ramola, Richard Winkelmann, Muhib Omar, Karthik Chandrashekara, Weiqi Zhou, Wolfgang Alt, Dieter Meschede, and Andrea Alberti — Institute for Applied Physics, University of Bonn

Cooling atoms to their motional ground state allows us to prepare ensembles of indistinguishable atoms. Moreover, it extends their coherence times in interferometric applications. We use two polarization synthesized lattice beams to transport Cs atoms deterministically along the x- and y-directions, based on their internal state [1]. State-dependent shifts of our lattice potentials allow us to drive microwave sideband transitions with a tunable Frank-Condon factor, which in turn are used to cool atoms to the ground state along the two dimensions. Alongside microwave sideband cooling, we use a pair of Raman lasers to cool the atoms along the third dimension. With a 3D ground state population of more than 90%, we plan to perform a direct interferometric measurement of the exchange phase for identical quantum particles [2].

[1] C. Robens, S. Brakhane, W. Alt, D. Meschede, J. Zopes and A. Alberti,*Fast, High-Precision Optical Polarization Synthesizer for Ultracold-Atom Experiments*, Phys. Rev. Applied **9** (2018)

[2] C. F. Roos, A. Alberti, D. Meschede, P. Hauke and H. Häffner, *Revealing Quantum Statistics with a Pair of Distant Atoms*, Phys. Rev. Lett. **119** (2017)

A 12.30 Tue 16:30 S Fobau Physik

Light-Induced Coherence in an Atom-Cavity System — •Christoph Georges, Jayson Cosme, Ludwig Mathey, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg

We demonstrate a light-induced formation of coherence in a cold atomic gas system that utilizes the suppression of a competing density wave (DW) order. The condensed atoms are placed in an optical cavity and pumped by an external optical standing wave, which induces a long-range interaction mediated by photon scattering and a resulting DW order above a critical pump strength. We show that the light-induced temporal modulation of the pump wave can suppress this DW order and restore coherence. This establishes a foundational principle of dynamical control of competing orders analogous to a hypothesized mechanism for light-induced superconductivity in high-Tc cuprates.

A 13: Ultra-cold atoms (joint session A/Q)

Time: Wednesday 10:30–12:30 Location: S HS 1 Physik

A 13.1 Wed 10:30 S HS 1 Physik

Developing an experimental toolbox for the quantum simulation of high energy physics — •Alexander Mil, Apoorva Hedge, Fabian Olivares, Markus K. Oberthaler, and Fred Jendrzejewski — Kirchhoff Institut für Physik, Universität Heidelberg

Within the Standard Model of Particle Physics, the interaction between fundamental particles is described by gauge theories. These theories have an enormous predictive power, but in many regimes, especially out of equilibrium, their theoretical treatment is exceedingly difficult. Consequently, high-energy physics contains many unsolved problems, for instance Schwinger pair production [1]. Our aim is to build an analog quantum simulator for simple lattice gauge theories with ultracold atomic gases.

We follow the proposal by Kasper et al. [2] and Zache et al. [3] to engineer a model system for quantum electrodynamics (QED) in one dimension using atomic mixtures. In this approach, we use an optical lattice structure with alternatingly populated sites of sodium and lithium. The fermionic matter field in the QED Hamiltonian is described by the lithium atoms whereas the bosonic gauge field is described by the sodium atoms. The gauge coupling is engineered by interspecies spin changing collision between sodium and lithium. In this talk, I will present our progress towards the realization of such simple lattice gauge theories.

[1] Kasper et al. Phys.Let. B 760, 742 (2016) [2] Kasper et al. NJP 19, 023030 (2017). [3] Zache et al. Quantum Sci. Technol. 3, 034010 (2018).

A 13.2 Wed 10:45 S HS 1 Physik

Effect of Fermi seas on the Efimov spectrum of three ultracold fermionic atoms — •Ali Sanayei[1], Pascal Naidon[2], and Ludwig Mathey[1,3] — [1]Center for Optical Quantum Technologies, Institute for Laser Physics, University of Hamburg, Germany — [2]RIKEN Nishina Centre, RIKEN, Japan — [3]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

We consider two same-species ultracold fermionic atoms in different hyperfine splitting states in a lower band that are subject to an inert Fermi sea and interact attractively in the short range. We include an additional third fermionic atom in an otherwise empty band that interacts attractively in the short range with other two atoms. For three species with the same mass and also for some higher mass imbalances, we show that for either two- or three-resonantly interacting pairs the Fermi sea deforms the Efimov spectrum of the trimer states systematically. We also demonstrates that the Fermi sea modifies the Efimov universal scaling factor.

A 13.3 Wed 11:00 S HS 1 Physik

Observation of many-body localization in a one-dimensional system with single-particle mobility edge — •Thomas Kohlert[1,2], Sebastian Scherg[1,2], Xiao Li[3], Henrik Lüschen[1,2], Sankar Das Sarma[3], Immanuel Bloch[1,2], and Monika Aidelsburger[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstr. 4, 80799 Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [3]Condensed Matter Theory Center and Joint Quantum Institute, University of Maryland, College Park, Maryland 20742-4111, USA

In this work we experimentally study many-body localization (MBL) in a one-dimensional bichromatic quasiperiodic potential with a single-particle mobility edge (SPME) using ultracold atoms. We measure the time evolution of the density imbalance between even and odd lattice sites from an initial charge density wave, and analyze the corresponding relaxation exponents. We find clear signatures of MBL in this system when the corresponding noninteracting model is deep in the localized phase. We also critically compare and contrast our results with those from a tight-binding Aubry-André model, which does not exhibit an SPME.

A 13.4 Wed 11:15 S HS 1 Physik

Bound states in a one-dimensional three-body system. — •Lucas Happ[1], Maxim A Efremov[1], and Wolfgang P Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm — [2]Hagler Institute for Advanced Study, Institute for Quantum Science and Engineering (IQSE), and Texas A&M AgriLife Research, Texas A&M University, College Station, TX 77843-4242, USA.

We study a three-body system confined to one space dimension, consisting of two identical, non-interacting, heavy particles and a light particle with arbitrary mass ratio interacting with the two heavy particles. In this talk we focus on contact heavy-light interactions, and therefore apply the integral equations of Skorniakov and Ter-Martirosian, in order to obtain the three-body energy spectrum together with the corresponding wave functions. Both spectrum and wave functions are compared to the ones obtained within the Born-Oppenheimer approximation.

A 13.5 Wed 11:30 S HS 1 Physik

Ultracold and Ultrafast: Coherent manipulation of matter-waves on femtosecond timescales — •Tobias Kroker[1,2], Bernhard Ruff[1,2], Juliette Simonet[1,2], Klaus Sengstock[1,2], Philipp Wessels[1,2], and Markus Drescher[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

Ultrashort laser pulses, even far detuned from atomic resonances, can significantly modify coherent matter-waves, as the high laser intensities produce considerable AC Stark shifts.
We show that phases up to several π can be imprinted within femtoseconds, resulting in accelerations of the atomic cloud up to 10^9 m/s^2.
The interplay between the phase gradient and atomic interactions can lead to a stable matter wave. Numerical simulations of the 3D Gross-Pitaevskii equation are in good agreement with our experimental data. Such high laser intensities can even give rise to a coherent superposition between ground and excited states during the femtosecond pulse. Ultracold atoms allow revealing this transient effect, which is not accessible using standard spectroscopy techniques, since they can be trapped in such shallow average light shifts. Accurate measurement of the trapping frequencies indeed demonstrate the transient population of the excited states.

A 13.6 Wed 11:45 S HS 1 Physik

Light-Induced Coherence in an Atom-Cavity System — •Christoph Georges and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg

We demonstrate a light-induced formation of coherence in a cold atomic gas system that utilizes the suppression of a competing density wave (DW) order. The condensed atoms are placed in an optical cavity and pumped by an external optical standing wave, which induces a long-range interaction mediated by photon scattering and a resulting DW order above a critical pump strength. We show that the light-induced temporal modulation of the pump wave can suppress this DW order and restore coherence. This establishes a foundational principle of dynamical control of competing orders analogous to a hypothesized mechanism for light-induced superconductivity in high-Tc cuprates.

A 13.7 Wed 12:00 S HS 1 Physik

Dynamical topological transitions in the massive Schwinger model with a θ-term — •Torsten V. Zache[1], Niklas Mueller[2], Jan T. Schneider[1], Fred Jendrzejewski[3], Jürgen Berges[1], and Philipp Hauke[1,3] — [1]Heidelberg University, Institut für Theoretische Physik — [2]Physics Department, Brookhaven National Laboratory — [3]Heidelberg University, Kirchhoff-Institut für Physik

Aiming at a better understanding of anomalous and topological effects in gauge theories out-of-equilibrium, we study the real-time dynamics of the massive Schwinger model with a θ-term. We identify dynamical quantum phase transitions between different topological sectors that appear after sufficiently strong quenches of the θ-parameter. Moreover, we establish a general dynamical topological order parameter, which can be accessed through fermion two-point correlators and, importantly, which can be applied for interacting theories. Enabled by this result, we show that the topological transitions persist beyond the weak-coupling regime. This phenomenon constitutes an ideal target for quantum computing as it can be observed with table-top experiments based on existing cold-atom, superconducting-qubit, and trapped-ion technology. Our work, thus, presents a significant step towards quantum simulating topological and anomalous real-time phenomena relevant to nuclear and high-energy physics.

A 13.8 Wed 12:15 S HS 1 Physik

The parity anomaly of 2+1 dimensional strong-field QED — •Robert Ott[1], Torsten V. Zache[1], Niklas Mueller[2], and Jürgen Berges[1] — [1]Universität Heidelberg, Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg, Germany — [2]Physics Department, Brookhaven National Laboratory, Building 510A, Upton, New York 11973, USA

Quantum Electrodynamics (QED) in one and two spatial dimensions has recently attracted interest in the context of quantum simulations of gauge theories. Currently there is much effort in extending present ideas to higher dimensions and in identifying relevant phenomena accessible with state-of-the art technology.

To this end, we investigate the non-equilibrium dynamics of massive 2+1 dimensional QED for strong electric fields focussing on the broken parity symmetry. In this regime, symmetry violation induces anomalous charge currents which lead to a non-linear electric field rotation. This scenario is analyzed using classical-statistical lattice simulations, which we compare to analytical predictions.

A 14: Precision Spectroscopy of atoms and ions IV

Time: Wednesday 10:30–12:15 Location: S HS 2 Physik

A 14.1 Wed 10:30 S HS 2 Physik

High-resolution astrophysical applications of the PolarX-EBIT — •Steffen Kühn[1], Sven Bernitt[2], Peter Micke[1], Michael Karl Rosner[1], Chintan Shah[1], René Steinbrügge[3], Moto Togawa[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Friedrich-Schiller-Universität Jena — [3]Deutsches Elektronensynchrotron, Hamburg

For the interpretation of x-ray emission lines of stellar sources in astrophysics, a good knowledge of fundamental atomic parameters of Highly Charged Ions (HCI) is crucial. High resolution observations of the Perseus cluster by the Hitomi satellite mission showed a variety of lines for which atomic databases are incomplete or incorrect. For the upcoming satellite missions, e.g. XRISM and Athena, it is vital to fill these gaps for the most abundant elements in space.

For this application we developed a compact electron beam ion trap (EBIT) employing an off-axis gun, leaving the main axis free of any obstacles, which allows to install the EBIT parasitically at high brilliant photon light sources such as synchrotrons for photon plasma interaction investigations.

We demonstrate high-precision measurements of dielectronic recombination and resonant photo excitation of Ne- up to He-like systems. Furthermore, we were able to shed a light on an astrophysical puzzle regarding the interstellar atomic oxygen 1s-2p absorption line energy deviating from laboratory measurements, which led to the dubious conclusion that the mean radial velocity of the atomic oxygen in the interstellar medium is 340km/s larger than the galactic escape velocity.

A 14.2 Wed 10:45 S HS 2 Physik

Interplay between Coulomb and nuclear forces in the low-energy three-body reaction $\bar{\text{p}} + {}^2\text{H}_\mu \to (\bar{\text{p}}\text{D}) + \mu^-$ — •Renat A. Sultanov — 201 W. University Blvd., Department of Mathematics and Engineering, Odessa College, Wood Building of Math and Science (WOOD) Room 213, Odessa, TX 79764

Since $\bar{\text{p}}$ is an antibaryonic particle with the baryonic number $B = -1$, it would be interesting to discover the strong nuclear interaction between, for example, $\bar{\text{p}}$ and a proton, p. This is also known as the $\bar{\text{p}}$-p interaction in a protonium atom - a bound state of the particles: Pn $= (\bar{\text{p}}\text{p})_\alpha$. The two-body system is also called antiprotonic hydrogen. Additionally, it would be useful to consider and compare results of similar Coulomb-nuclear atomic systems: $\bar{\text{p}}$-D and $\bar{\text{p}}$-T, where D=^{2}H$^+$ is the deuterium nucleus and T=^{3}H$^+$ is tritium. It is possible to prepare such atomic systems with the use of muons [1,2], for example, in the framework of the three-body reactions:

$$\bar{\text{p}} + (\text{p}\mu^-) \to (\bar{\text{p}}\text{p})\alpha + \mu^-, \quad \text{and} \tag{1}$$

$$\bar{\text{p}} + (\text{D}\mu^-) \to (\bar{\text{p}}\text{D})\alpha + \mu^-. \tag{2}$$

Here: μ^- is a negative muon and α is the final atomic state of Pn or the $\bar{\text{p}}$D atoms. In the current work, a detailed few-body treatment is carried out for these low-energy reactions with the use of a set of coupled few-body Faddeev equations and a modified close coupling approximation approach.

1. R.A. Sultanov et al., Few-Body Systems, (Springer) 56, 793 (2015).

2. R.A. Sultanov et al., Atoms (MDPI) 6, 18, (2018).

A 14.3 Wed 11:00 S HS 2 Physik

The Alphatrap *g*-factor experiment — •Tim Sailer[1,2], Ioanna Arapoglou[1,2], Hendrik Bekker[1], José R. Crespo López-Urrutia[1], Alexander Egl[1,2], Martin Höcker[1], Bingsheng Tu[1], Andreas Weigel[1,2], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg

The 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 hydrogenlike ^{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. So far, a table-top Electron Beam Ion Trap (EBIT) has been used successfully to produce and inject ions up to ^{40}Ar^{13+} into the trap. Furthermore, a laser ion source (LIS) has been attached to the beamline and tested to produce and inject ^{9}Be$^+$ ions. These will be used for sympathetic laser cooling of the HCI which lack suitable transitions for direct laser cooling.

To produce heavy HCI, which requires ionization energies on the order of several 10 keV, the Alphatrap setup has been connected via a UHV beamline to the Heidelberg-EBIT. The extraction of the produced HCI, their transport and injection into the Alphatrap setup are in the final phase of the commissioning of which the first results will be presented.

A 14.4 Wed 11:15 S HS 2 Physik

***g*-factor Measurement of Boronlike ^{40}Ar^{13+} at Alphatrap** — •Bingsheng Tu[1], Ioanna Arapoglou[1], Alexander Egl[1], Martin Höcker[1], Tim Sailer[1], Timo Steinsberger[1,2], Andreas Weigel[1], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg, 69120 Heidelberg

The Alphatrap experiment is a Penning-trap setup to perform high-precision *g*-factor measurement on highly charged ions (HCI) up to hydrogenlike ^{208}Pb^{81+}. By determining the bound eletron's *g*-factor, the most stringent test of Bound-State Quantum Electrodynamics (BS-QED) in the strong field can be carried out. Furthermore, Alphatrap can provide access to fundamental constants, such as the fine-structure constant α or the electron's atomic mass. The first measurement campaign of Alphatrap has been dedicated to the determination of the ground-state *g*-factor of a single boronlike ^{40}Ar^{13+}. Using non-destructive detection techniques for the stored ion's motion, the cyclotron as well as the Larmor frequency can be determined, allowing for a parts per billion precision measurement of the *g*-factor. Prominent systematic effects in predecessor experiments are highly suppressed in our optimised setup. The leading systematic effect during this measurement is the axial frequency drift, caused by the slow thermalisation of the voltage source. In this contribution the Alphatrap status, its results on ^{40}Ar^{13+} as well as the future perspectives will be presented.

A 14.5 Wed 11:30 S HS 2 Physik

Quantum electrodynamic effects in many-electron highly charged ions — •Halil Cakir[1], Vladimir A. Yerokhin[2], Natalia S. Oreshkina[1], Bastian Sikora[1], Zoltán Harman[1], and Christoph H. Keitel[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

Highly charged ions provide a natural source of strong electric fields and, thus, allow us to test QED predictions under extreme conditions. For these kinds of systems, perturbative expansions in the nuclear coupling strength $Z\alpha$ are not feasible and calculations need to be done to all orders in $Z\alpha$.

A combination of experimental and theoretical values of the *g*-factor of hydrogen-like ions allowed a significant improvement of the electron mass in terms of atomic mass units in the past and a similar interplay of experiment and theory for highly charged boron-like systems is expected to provide a new access to the value of the fine-structure constant [1] (see also [2]). In this context, we present calculations of the theoretical contributions to the *g*-factor of boron-like Ar^{13+}, which has been recently measured by the ALPHATRAP Penning-trap setup at the Max Planck Institute for Nuclear Physics. – [1] V. M. Shabaev *et al.*, Phys. Rev. Lett. **96**, 253002 (2006); [2] V. A. Yerokhin *et al.*, Phys. Rev. Lett., **116**, 100801 (2016).

A 14.6 Wed 11:45 S HS 2 Physik

Towards setup, characterization and operation of a highly charged ion beamline. — •Michael K. Rosner[1], Sandra Bogen[1], Steffen Kühn[1], Julian Stark[1], Moto Togawa[1], Christian Warnecke[1], Peter Micke[1,2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck Institut für Kernphysik, Heidelberg — [2]Physikalisch Technische Bundesanstalt

Highly charged ions (HCI) have high sensitivity to quantum electrodynamics and other fundamental interactions, making some species candidates to test the time variation of the fine-structure constant $\dot{\alpha}$. They are a promising target for high precision laser spectroscopy, aiming to measure their narrow optical transitions using quantum logic spectroscopy, as recently been demonstrated on Ar^{13+}.

While an electron beam ion trap (EBIT) produces ions in the necessary charge states, the spectral resolution there is limited by Doppler broadening. This requires the transfer of the HCI into a cooler trapping environment, in our case a Coulomb crystal of laser-cooled Be^+ ions prepared in a superconducting Paul trap.

We present a beamline between an EBIT and a Paul trap we designed to transfer, bunch and decelerate the HCI while also providing vibration decoupling between the Paul trap and its environment. It consists of an arrangement of ion optics, diagnostic elements and a decelerating unit. We perform time-of-flight measurements in order to determine the charge state distributions of extracted ions as well as their kinetic energy spread.

A 14.7 Wed 12:00 S HS 2 Physik

Development of a Low-Emittance Laser Ablation Ion Source — •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 Research 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. 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. We are developing a more versatile ion source based on ion creation by laser ablation inside a helium buffer gas cell and extraction through optimized RF funnels. The design is based on a RF-only ion funnel design, but extended by a second compact original RF-funnel that allows for bunching of the beam and even better performance. We expect a supreme ion beam quality that will first being studied by collinear laser spectroscopy to determine its longitudinal emittance and present the current status of the buffer gas cell, the extraction funnels and a compact collinear laser spectroscopy design.

A 15: Attosecond physics

Time: Wednesday 10:30–12:30 Location: S HS 3 Physik

Invited Talk A 15.1 Wed 10:30 S HS 3 Physik

Decomposition of the Temporal and Spectral Response in Attosecond Transient Absorption Spectroscopy — •Lorenz Drescher, Vishal Shokeen, Tobias Witting, Serguei Patchkovskii, Marc Vrakking, and Jochen Mikosch — Max-Born-Institut, Berlin, Deutschland

Attosecond Transient Absorption Spectroscopy (ATAS) of core-excited states provides the opportunity to study ultrafast phenomena in organic molecules from the local perspective of a reporter atom. In molecules, high densities of states and broad natural linewidths may complicate the analysis of overlapping features, while the low flux of current-generation attosecond sources requires high detector sensitivity and long acquisition times. Here we discuss the use of Singular Value Decomposition for ATAS to extract spectral and temporal dynamics associated with the state-dependent light-induced phase, while efficiently separating contributions from energy-and-time correlated features and detector noise. We apply the technique to our recent results of ATAS in iodomethane (CH_3I) [1] to extract the state-resolved polarizability of the molecule. We also discuss the possibility to *in-situ* characterize the electric-field of the laser from the molecular ATAS measurement.

[1] L. Drescher et al., submitted to J. Phys. Chem. Lett. (2018)

A 15.2 Wed 11:00 S HS 3 Physik

Tunneling time in attosecond experiments and time operator in Quantum Mechanics — •Ossama Kullie — Institute of Physics, Department of Mathematics and Natural Science, University of Kassel, Germany

Attosecond science is of a fundamental interest in physics. The measurement of the tunneling time in attosecond experiments, offers a fruitful opportunity to understand the role of time in quantum mechanics. We discuss in this paper, our tunneling time model in relation to two time operator definitions introduced by Bauer (Phys. Rev. A 2017, **96**, 022139) and Aharonov-Bohm (Phys. Rev. 1961, **122**, 1649). We found that both definitions can be generalized to the same type of time operator. Moreover, we found that the introduction of a phenomenological parameter by Bauer to fit the experimental data is unnecessary. The issue is resolved with our tunneling model by considering the correct barrier width, which avoids a misleading interpretation of the experimental data. Our analysis shows that the use of the so-called classical barrier width, to be precise, is incorrect [1,2].

[1] O. Kullie. open access Mathematics 2018, 6, 192; doi:10.3390/math6100192

[2] O. Kullie. Phys. Rev. A, 2015 **92**, 052118

A 15.3 Wed 11:15 S HS 3 Physik

Analysis of sub-cycle XUV-NIR-induced excitation dynamics in helium by UV photoelectron spectroscopy — Jesse Klei[1], Renate Pazourek[2,3], Christian Neidel[1], Arnaud Rouzee[1], Martin Galbraith[1], Mette Gaarde[2], Ken Schafer[2], Marc J. J. Vrakking[1], and •Jochen Mikosch[1] — [1]Max-Born-Institut, Berlin, Germany — [2]Louisiana State University, Louisiana, USA — [3]University of Technology, Vienna, Austria

We use UV photoelectron spectroscopy to study the excitation dynamics of 1snp neutral states in helium from XUV-NIR excitation with an attosecond pulse train and a co-propagating NIR field. The excited state population is found to oscillate with the XUV-NIR delay at twice the NIR field frequency. We measure the phase of the 1s3p population oscillation with respect to the oscillating NIR-dressed ionization yield related to the 17th harmonic order, as a function of energy shift of the XUV frequency comb. Numerical TDSE calculations are performed and found to be in good agreement with the experimental results. The observed oscillation of the 1s3p population is the result of interference between two independent two-color excitation channels, which are out-of-phase: Apart from the previously identified NIR-assisted interference of excitation pathways involving the 15th and the below-ionization-threshold 13th harmonic, we find the phase-shifted interference of excitation pathways involving the 15th harmonic and the above-ionization-threshold 17th harmonic to contribute to the 1s3p excitation yield. Importantly, the relative yield of the two channels is found to depend on the frequency comb spectral position.

A 15.4 Wed 11:30 S HS 3 Physik

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

Phase retrieval of electronic wavefunctions generated by photoionization has been a long-standing challenge. Here we measure the time-reversed process of photo-ionization – photo-recombination – 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 simple 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., arXiv:1810.05021, Nature Photonics in press.

[2] D. Azoury et al., accepted for publication in Nature Photonics.

A 15.5 Wed 11:45 S HS 3 Physik

Spatio-temporal characterisation of laser pulses in the single-cycle regime — •Tobias Witting[1,2], Federico Furch[1], and Marc J.J. Vrakking[1] — [1]Max-Born-Institut, Max-Born-Strasse 2A, 12489 Berlin — [2]Max-Born-Straße 2A

We review spatio-temporal laser pulse characterisation technology for single cycle laser pulses. We show results obtained using spatially-encoded arrangement filter-based spectral phase interferometry for direct electric field reconstruction (SEA-F-SPIDER). We discuss spatio-temporal pulse measurements of hollow fibre-based pulse compressors [1,2] and non-collinear optical parametric chirped pulse amplifier (NOPCPA) laser systems [3]. Recently, we demonstrated pulse characterisation based on time-domain ptychography [4]. We show how time-domain ptychography can be multiplexed for spatio-temporal measurements and compare the results to SEA-F-SPIDER. [1] T. Witting, D.R. Austin, T. Barillot, D. Greening, P. Matia-Hernando, D. Walke, J. P. Marangos, and J. W. G. Tisch. Optics Letters 41, 2382 (2016) [2] D.R. Austin, T. Witting, S.J. Weber, P. Ye, T. Siegel, P. Matía-Hernando, A.S. Johnson, J.W.G. Tisch, and J.P. Marangos. Optics Express 24, 24786 (2016) [3] F. Furch, T. Witting, A. Giree, C. Luan, F. Schell, G. Arisholm, C.P. Schulz, and M.J.J. Vrakking. Optics Letters 42, 2495 (2017) [4] T. Witting, D. Greening, D. Walke, P. Matia-Hernando, T. Barillot, J. P. Marangos, and J. W. G. Tisch. Optics Letters 41, 4218 (2016)

A 15.6 Wed 12:00 S HS 3 Physik

Isolated attosecond pulse generation at 100 kHz repetition rate — •Tobias Witting[1], Federico Furch[1], Mikhail Osolodkov[1], Felix Schell[1], Peter Susnjar[1], Carmen Menoni[2], Claus-Peter Schulz[1], and Marc JJ. Vrakking[1] — [1]Max-Born-Institut, Max-Born-Strasse 2A, 12489 Berlin — [2]Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, CO 80523, USA

We aim to perform attosecond pump-probe experiments with coincidence detection of photoelectrons and -ions in a reaction microscope. To increase the data-rates we have developed a non-collinear optical parametric chirped pulse amplification (NOPCPA) laser system providing 7 fs, 190 μJ laser pulses at 100 kHz repetition rate [1]. We achieved further compression to 3.2 fs near single-cycle pulses and demonstrate their use for attosecond pulse generation by high harmonic generation up to 55 eV at 100 kHz. Our source provides an XUV flux of 10^{13} photons/sec. We present our progress towards a complete attosecond pump-probe beamline coupled to a reaction microscope. By means of velocity map imaging we characterised the attoseocond pulse trains produced by the 7 fs pulses from the NOPCPA system with the RABBITT technique. The isolated attosecond pulses produced by the post compressed near single-cycle pulses have been characterised with attosecond streaking.

[1] F.J. Furch, T. Witting, A. Giree, C. Luan, F. Schell, G. Arisholm, C.P. Schulz, and M.J.J. Vrakking. Optics Letters 42, no. 13 (2017)

A 15.7 Wed 12:15 S HS 3 Physik

Attosecond-resolved petahertz carrier motion in semimetallic TiS2 — Barbara Buades[1], Antonio Picon[1,2], Iker Leon[1], •Nicola Di Palo[1], Seth Cousin[1], Caterina Cocchi[3], Eric Pellegrin[4], Javier Herrero Martin[4], Samuel Mañas Valero[5], Eugenio Coronado[5], Thomas Danz[6], Claudia Draxl[3], Mitsuharo Uemoto[7], Katsuhiro Yabana[7], Martin Schultze[8], Simon Wall[1], and Jens Biegert[1,9] — [1]ICFO-Institut de Ciencies Fotoniques, 08860 Castelldefels, Spain — [2]Grupo de Investigación en Óptica Extrema, Universidad de Salamanca, Salamanca 37008, Spain — [3]Institut für Physik Adlershof, Humboldt-Universität Berlin, Berlin, Germany — [4]ALBA Synchrotron Light Source, 08290 Barcelona, Spain — [5]Instituto de Ciencia Molecular, Universitat de València, Paterna, Spain — [6]4th Physical Institute, University of Göttingen, Göttingen, Germany — [7]Center for Computational Sciences, University of Tsukuba, Tsukuba 305-8577, Japan — [8]Fakultät für Physik, Ludwig-Maximilians-Universität, 85748 Garching, Germany — [9]ICREA, 08010 Barcelona, Spain

We examine the opto-electronic response of TiS2 by means of attosecond soft x-ray spectroscopy at the L-edges of Ti at 460 eV. Using weak-field infrared single-photon excitation, we demonstrate the efficient carrier injection into the conduction band and observe petahertz opto-electronic response of its carriers. Our results are an important step towards understanding the dynamics of carriers and their control under field conditions.

A 16: FV Atomic Physics: General Assembly

Time: Wednesday 12:45–13:45 Location: S HS 1 Physik

Mitgliederversammlung

A 17: Ultra-cold plasmas and Rydberg systems (joint session A/Q)

Time: Wednesday 14:00–16:00 Location: S HS 1 Physik

A 17.1 Wed 14:00 S HS 1 Physik

An optogalvanic flux sensor for trace gases — •Patrick Kaspar[1,4], Johannes Schmidt[1,2,4], Fabian Munkes[1,4], Denis Djekic[3,4], Patrick Schalberger[2,4], Holger Baur[2,4], Robert Löw[1,4], Tilman Pfau[1,4], Jens Anders[3,4], Norbert Frühauf[2,4], Edward Grant[5], and Harald Kübler[1,4] — [1]5th Institute of Physics — [2]Institute of Large Area Microelectronics — [3]Institute of Smart Sensors — [4]University of Stuttgart, Center for Integrated Quantum Science and Technology (IQST)) — [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 gets ionized and the emerging electron and ion can then 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 are planning to reduce the detection limit to 1 ppb using state of the art cw lasers for the Rydberg excitation of NO. This is a competitive value for applications in breath analysis and environmental sensing.

[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 17.2 Wed 14:15 S HS 1 Physik

Alignment of *s*-state Rydberg molecules in magnetic fields — •Frederic Hummel[1], Christian Fey[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We unravel some peculiar properties of ultralong-range Rydberg molecules formed by an *s*-state ^{87}Rb Rydberg atom and a corresponding ground-state atom whose electronic orbitals are spherically symmetric and therefore should not be influenced by the presence of weak magnetic fields. However, the electron-atom interaction, which establishes the molecular bond, is under certain conditions subject to a sizeable spin-orbit coupling and, hence, sensitive to the magnetic field. This mechanism can be harnessed to counterintuitively align the *s*-state molecules with respect to the field axis. We demonstrate this by analyzing the angular-dependent Born-Oppenheimer potential energy surfaces and the supported vibrational molecular states. Our predictions open novel possibilities to access the physics of relativistic electron-atom scattering experimentally.

A 17.3 Wed 14:30 S HS 1 Physik

Decay dynamics of P-state Rydberg molecules — •Tanita Eichert[1], Carsten Lippe[1], Oliver Thomas[1,2], Thomas Niederprüm[1], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, 67663 Kaiserslautern,

Germany

Rydberg molecules are formed when a ground state atom binds into the oscillatory potential resulting from a scattering interaction between this ground state atom and the highly excited electron of a Rydberg atom. The observation of different lifetimes characterizing each molecule gives reason to investigate the dynamics of Rydberg molecules as well as the relation between the lifetime and the bound state in a potential well. We use time-of-flight spectroscopy of different molecular states adiabatically connected to the Rubidium 25P-state to obtain time resolved ion signals representing the molecular decay. We describe the dynamics in a rate model and identify the different decay channels. From this we find that the molecule lifetimes are in addition to the decay processes of the atomic Rydberg state, determined by the tunneling process of the bound ground state atom to smaller internuclear distance. For different molecular states the tunneling rates range between 10kHz to beyond 1MHz. Since in our intuitive expectation the tunneling rate is connected to the binding depth in a potential well, the lifetime is reduced for high lying molecular states and similar to the atomic Rydberg state for molecules deeply bound in the potential well.

A 17.4 Wed 14:45 S HS 1 Physik

Localization, scarring, and the effects of disorder on Rydberg atoms and other excited systems — •Matthew Eiles, Alexander Eisfeld, and Jan-Michael Rost — Max Planck Institut fur Physik komplexer Systeme

Due to their intrinsic properties, such as a high density of states and strong coupling to external perturbations, excited states of separable quantum systems provide intriguing opportunities with which to explore the relationship between quantum and classical physics and wave function localization. Rydberg atoms are perhaps the most common example of such excited systems in atomic physics, while other excited systems include quantum dots and optical microcavities. These excited states can be strongly modified in the presence of disordered impurities which break the symmetry of the unperturbed Hamiltonian. Two recent examples of this are the "trilobite" state of a Rydberg molecule and the "perturbation-induced scars" recently studied theoretically in 2D potentials [1]. We attempt to understand the commonalities between these systems and provide a framework revealing the classical physics underlying these perturbed quantum excited states. We also explore if this behavior can be connected to Anderson-like localization, drawing on the analogies between the highly excited wave functions in disordered potentials and the properties of electron transport in solids.

[1] P. J. Luukko and J. M. Rost, Phys. Rev. Lett. 119, 203001 (2017)

A 17.5 Wed 15:00 S HS 1 Physik

High-resolution spectroscopy of ^{39}K atoms and ^{39}K$_2$ long-range Rydberg molecules — •Michael Peper[1], Frédéric Merkt[1], and Johannes Deiglmayr[1,2] — [1]Laboratory of Physical Chemistry, ETH Zurich, Vladimir-Prelog-Weg 2, 8093 Zurich, Switzerland — [2]Felix-Bloch-Institut, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

The interaction of a Rydberg atom with a ground-state atom can be treated using scattering theory, which predicts oscillatory interaction potentials. These interaction potentials may support bound states of diatomic molecules, called long-range Rydberg molecules [1,2,3].

I will present accurate values for the ionization potential and quantum defects of the s, p, d, f and g series of ^{39}K, obtained by precision spectroscopy using frequency-comb-referenced ultraviolet and millimeter-wave radiation. The results of the spectroscopy of atomic potassium where used in the theoretical modeling and the first experimental determination of the binding energies of ^{39}K$_2$ long-range Rydberg molecules. These studies reveal a regime with strong hyperfine-induced mixing [3,4].

[1] C. H. Greene, A. S. Dickinson, and H. R. Sadeghpour, Phys. Rev. Lett. 85, 2458 (2000). [2] V. Bendkowsky et al., Nature 458, 1005 (2009). [3] H. Saßmannshausen, F. Merkt, and J. Deiglmayr, Phys. Rev. Lett. 114, 133201 (2015). [4] D. A. Anderson, S. A. Miller, and G. Raithel, Phys. Rev. A 90, 062518 (2014).

A 17.6 Wed 15:15 S HS 1 Physik

Coupling Rydberg atoms and superconducting coplanar resonators — •Conny Glaser, Manuel Kaiser, Lőrinc Sárkány, Jens Grimmel, Reinhold Kleiner, Dieter Kölle, and József Fortágh — CQ Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

The creation of hybrid systems consisting of Rydberg atoms and coplanar superconducting resonators has been proposed to enable efficient state transfer between solid state systems and ultracold atoms. Due to the large dipole moment of Rydberg atoms, the coupling strength to the cavity is expected to be much larger than for ground state atoms. At the same time, Rydberg states are strongly affected by any detrimental fields, such as the electric field of adsorbates on the chip-surface, which lead to spatially inhomogeneous energy shifts. We aim to transfer population between neighbouring Rydberg states using the microwave field of a driven coplanar waveguide resonator on a superconducting atom chip. The state transfer in the presence of adsorbate fields is detected via selective field ionisation. Ultimately, this method may aid in the observation of Rabi oscillations between neighbouring Rydberg states.

A 17.7 Wed 15:30 S HS 1 Physik

Experimental realization of a symmetry protected topological phase of interacting bosons with Rydberg atoms — Sylvain de Léséleuc[1], Vincent Lienhard[1], Pascal Scholl[1], Daniel Barredo[1], •Sebastian Weber[2], Nicolai Lang[2], Hans Peter Büchler[2], Thierry Lahaye[1], and Antoine Browaeys[1] — [1]Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Université Paris-Saclay, France — [2]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, Germany

The paradigm of Landau symmetry breaking has proven very successful for characterizing phases of matter. However, not all phases follow this paradigm: some of them are characterized in the framework of topological phases, which is a powerful concept to characterize ground states of quantum many-body systems. While a few topological phases appear in condensed matter systems (such as quantum Hall states), a current challenge is the implementation and study of such phases in artificial matter. Here, we report the experimental realization of a symmetry protected topological phase of interacting bosons in a one-dimensional lattice, and demonstrate a robust ground state degeneracy attributed to protected edge states. The setup is based on atoms trapped in an array of optical tweezers and excited into Rydberg levels, which gives rise to hard-core bosons with an effective hopping by dipolar exchange interaction.

A 17.8 Wed 15:45 S HS 1 Physik

Quantum gas microscopy of Rydberg macrodimers — •Simon Hollerith[1], Jun Rui[1], Johannes Zeiher[3], Antonio Rubio-Abadal[1], Valentin Walther[2], Thomas Pohl[2], Dan M. Stamper-Kurn[3], Immanuel Bloch[1,4], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Department of Physics and Astronomy, Aarhus University, DK 8000 Aarhus C, Denmark — [3]Department of Physics, University of California, Berkeley, CA 94720, USA — [4]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München, Germany

Rydberg macrodimers - molecules consisting of two bound highly-excited Rydberg atoms - provide enormous bond lengths even resolvable with optical wavelengths. Here we report on the microscopic observation, characterization and control over the formation of such Rydberg macrodimers in a gas of ultracold atoms in an optical lattice. The huge size of about 0.7 micrometers matches the diagonal distance of two atoms in the lattice. Starting from a two-dimensional array of one atom per site, the discrete spatial density provided by atoms in their motional ground state combined with a narrow-linewidth ultraviolet laser enables the resolved two-photon photoassociation of more than 50 theoretically predicted vibrational states. Using our spatially resolved detection, we observe the macrodimers by correlated atom loss and demonstrate control of the molecular alignment by the vibrational state and the polarization of the excitation light. Our results allow for a detailed test of Rydberg interactions and establish quantum gas microscopy as a powerful tool for quantum chemistry.

A 18: Precision Spectroscopy of atoms and ions V (Th 229)

Time: Wednesday 14:00–16:00 Location: S HS 2 Physik

A 18.1 Wed 14:00 S HS 2 Physik

Excitation of ^{229}Th^{2+} with a two-photon electron transition — •Robert A. Müller[1,2], Andrey V. Volotka[3], Stephan Fritzsche[2,4], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Germany — [2]Technische Universität Braunschweig, Germany — [3]Helmholtz-Institute Jena, Germany — [4]Friedrich-Schiller-Universität Jena, Germany

About one decade ago a clock based on the optical nuclear transition in ^{229}Th has been proposed [1]. For this purpose many mechanisms to excite the ^{229}Th nucleus have been discussed. In particular such processes involving an energy transfer from electronic transitions to the nucleus are expected to be very efficient. There is, however, a major drawback that comes with these so-called *electron bridge* processes: The electronic transition has to be in resonance with the nuclear one. To overcome this problem we propose the process of nuclear excitation by a two-photon transition (NETP) to excite the ^{229}Th nucleus. In this process the electron shell deexcites via the emission of two photons, where one of them is emitted and the other one excites the nucleus. We employ a combination of configuration interaction and many-body perturbation theory to calculate the NETP probability in resonance approximation. With these calculations we propose a circular process consisting of a pumping stage and subsequent NETP. In particular we make recommendations wich electron level to pump to achieve the highest NETP probability.

[1] E. Peik and C. Tamm, Europhys. Lett. **6**1, 181 (2003)

A 18.2 Wed 14:15 S HS 2 Physik

Excitation of ^{229}Th in VUV-transparent crystals — •Brenden Nickerson and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The isomeric state of ^{229}Th near 7.8 eV holds the interest of the scientific community as a candidate for the first nuclear clock. Laser excitation of thorium-doped vacuum-ultraviolet (VUV) transparent crystals could be used a means to study this interesting transition. Thorium can be doped into VUV-transparent crystals at higher densities than can be realized in an ion trap. Furthermore, this environment enforces the Mössbauer regime, allowing for recoil-free emission, absorption and collective behavior [1].

Here, we investigate collective effects in the nuclear forward scattering (NFS) regime using narrowband pulsed lasers, coincident pulses, varying pulse phases and magnetic fields to generate unique intensity spectrum [2].

Before the exact energy of the isomeric state is found, broadband excitation must be used in its search in the crystal environment. To this end, and as a prequel to NFS, we look at the opportunity to excite the nuclear transition via the initial driving of a defect state, a color center in the crystal, which then can efficiently transfer its energy to the isomer in a process reminiscent of electron bridge [3].

[1] W.-T. Liao *et al.*, Phys. Rev. Lett. 109, 262502 (2012).
[2] B.S. Nickerson *et al.*, Accepted to PRA, arXiv:1809.01857
[3] S.G. Porsev and V.V. Flambaum, Phys. Rev. A 81, 032504 (2010)

A 18.3 Wed 14:30 S HS 2 Physik

Electronic level structure investigations in Th^{+} for the excitation of the nuclear isomer — •David-Marcel Meier, Johannes Thielking, Gregor Zitzer, Maksim Okhapkin, Robert Müller, Andrey Surzhykov, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Among all known isotopes ^{229}Th possesses a uniquely low-lying nuclear excitation state at 7.8(5) eV with a lifetime of about ≈1000 s. Since this energy corresponds to a wavelength in the VUV region of about ≈160 nm, it makes direct laser excitation of the isomer challenging.

For the search of the transition's frequency we attempt to excite the nucleus via the NEET [1] or electronic bridge [2] mechanisms by two-photon laser excitation which rely on the hyperfine coupling between electron shell and nucleus. Since the Th^{+} ion is a three valence electron system, it possesses a dense electronic level structure which leads to an enhanced hyperfine coupling and therefore to a higher excitation probability and strong decrease of the lifetime of the isomeric state.

For this reason, an extensive knowledge about the electronic level structure of Th^{+} in the range of the isomer energy is required. In our experiment we investigate two-photon laser excitation of high-lying levels in ^{232}Th^{+} ions and we will present the latest results of the level search in the energy range from 7.8 to 9.8 eV. We found 177 previously unknown energy levels and we will furthermore report on ab-initio calculations of electronic levels in the same energy range.

[1] F.F. Karpeshin, et al., Nucl. Phys. A, 654, 579 (1999).
[2] S. G. Porsev et al., Phys. Rev. Lett. 105, 185501 (2010).

A 18.4 Wed 14:45 S HS 2 Physik

Towards a ^{229m}Th energy determination with 40 μeV accuracy — •L. von der Wense[1], B. Seiferle[1], Ch. Schneider[2], J. Jeet[2], I. Amersdorffer[1], N. Arlt[1], F. Zacherl[1], R. Haas[3,4,5], D. Renisch[3,4], Pa. Mosel[6], Ph. Mosel[6], M. Kovacev[6], U. Morgner[6], Ch.E. Düllmann[3,4,5], E.R. Hudson[2], and P.G. Thirolf[1] — [1]Ludwig-Maximilians-Universität München — [2]University of California, Los Angeles — [3]Johannes Gutenberg-Universität Mainz — [4]Helmholtz-Institut Mainz — [5]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [6]Leibniz Universität Hannover

The development of a nuclear clock has been a long-standing objective [1]. There is only one nuclear excitation known which could allow for the development of a nuclear clock due to its exceptionally low energy of only a few eV above the ground state. This is the metastable first excited state in ^{229}Th [1, 2]. The development of a ^{229}Th-based nuclear clock is so far hindered by an insufficient knowledge of the excited state's energy. A new scheme of experimental search will be presented, which could allow to pin down the isomeric energy value to 40 μeV accuracy, thereby paving the way to the development of a nuclear clock [3]. The concept makes use of a direct nuclear laser excitation scheme.

[1] L. v.d.Wense et al., Nature 533, 47-51 (2016).
[2] B. Seiferle et al., PRL 118, 042501 (2017).
[3] L. v.d.Wense et al., PRL 119, 132503 (2017).

Supported by DFG grant TH956/3-2 and Horizon 2020 research and innovation programme under grant agreement 664732 "nuClock".

A 18.5 Wed 15:00 S HS 2 Physik

Gamma spectroscopy to measure the ^{229}Th isomer energy using a 2-dimensional array of metallic magnetic microcalorimeters — •Jeschua Geist[1], Daniel Hengstler[1], Christian Schötz[1], Sebastian Kempf[1], Loredana Gastaldo[1], Andreas Fleischmann[1], Christian Enss[1], Georgy A. Kazakov[2], Simon Stellmer[2], and Thorsten Schumm[2] — [1]Heidelberg University — [2]Vienna University of Technology

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

We developed the detector array maXs-30 consisting of 8x8 metallic magnetic calorimeters with an expected energy resolution below 6 eV, providing a large detection area of 16 mm^2 to face the low rate of the 29.18 keV transitions. We present a new value for the isomere energy with a detector performance of 11 eV FWHM for photons up to 60 keV, show latest recorded ^{229}Th spectra and discuss different ways to derive the isomer energy from these spectra.

A 18.6 Wed 15:15 S HS 2 Physik

Measurement of Fundamental Constants by Spectroscopy of the Molecular Hydrogen Ion — Soroosh Alighanbari[1], Gouri Giri[1], Michael Hansen[1], Florin Constantin[1,2], Vladimir Korobov[3], and •Stephan Schiller[1] — [1]Heinrich-Heine-Univ. Düsseldorf — [2]PhLAM, Univ. Lille, Villeneuve d'Ascq — [3]Joint Inst. for Nuclear Research, Dubna

Bound three-body quantum systems are important systems for fundamental physics. They allow for tests of quantum electrodynamics theory, and provide access to fundamental constants of atomic physics and to nuclear properties. Molecular hydrogen ions, the simplest molecules, are representatives of this class. They provide an independent access to the Rydberg constant, to the ratios of electron mass to proton and to deuteron mass, and to the radiative energy contributions arising from quantum electrodynamics.

By using trapped and sympathetically laser-cooled HD^+ molecules together with a newly developed rotational spectroscopy technique and highly accurate ab initio theory, we determine $R_\infty m_e(m_p^{-1} + m_d^{-1})$ with an uncertainty of 1×10^{-10}, comparable to CODATA2014.

Invited Talk A 18.7 Wed 15:30 S HS 2 Physik

Towards a precise energy determination of the ^{229}Th nuclear isomer — •Benedict Seiferle, Lars v.d. Wense, Ines Amersorffer, and Peter G. Thirolf — LMU Munich, 85748 Garching, Germany.

The nuclear first excited state in ^{229}Th (^{229m}Th) offers the unique possibility of a direct optical control of a nucleus with today's laser technology. The energy of 7.8(5) eV and it's lifetime make it a promising candidate for a nuclear optical clock. The large uncertainty of the excitation energy, however, impedes progress towards a nuclear clock. Therefore the objective of our experiment is a precise determination of the excitation energy of ^{229m}Th via the measurement of electrons emitted during the internal conversion decay of the excited state [1,2]. The experimental setup as well as first measured spectra will be presented.

This work was supported by DFG (Th956/3-2) and by the European Union's Horizon 2020 research and innovation programme under grant agreement 6674732 "nuClock".

[1] L.v.d. Wense et al., Nature 553, 47 (2016). [2] B. Seiferle et al., PRL 118, 042501 (2017).

A 19: Cluster I (joint session A/MO)

Time: Wednesday 14:00–16:15 Location: S HS 3 Physik

Invited Talk A 19.1 Wed 14:00 S HS 3 Physik

Imaging ultrafast dynamics in nanoparticles with resonant multicolor XUV pulses — L Hecht[2], B Langbehn[2], J Zimmermann[1], J Jordan[2], K Kolatzki[1], N Monserud[1], Y Ovcharenko[3], M Sauppe[1], B Schütte[1], R Tanyag[1], A Ulmer[2], B Kruse[4], K Sander[4], C Peltz[4], A Colombo[5], A D'Elia[6], M diFraia[7], L Giannessi[7], P Piseri[5], O Plekan[7], K Prince[7], M Zangrando[7], C Callegari[7], MJJ Vrakking[1], A Rouzée[1], T Möller[2], T Fennel[2], and •D Rupp[1] — [1]MBI Berlin, Germany — [2]TU Berlin, Germany — [3]E-XFEL, Schenefeld, Germany — [4]Uni Rostock, Germany — [5]Uni Milano, Italy — [6]Uni Trieste, Italy — [7]Elettra, Trieste, Italy

Diffraction imaging with intense, coherent, short-wavelength light pulses is a unique method to determine the structure of individual nanometer-sized objects such as viruses or fragile superfluid helium nanodroplets. In addition, diffraction imaging can be also used as a probe for ultrafast electronic processes within the particle. As the photons are elastically scattered by the electrons bound to the particle, the scattering response will be altered if the particle's electronic structure changes, with particularly strong effects at electronic resonances. In two experiments we employed this concept using extreme ultraviolet (XUV) multicolor pulses from an intense high-harmonic generation source and two-color pulses from the FERMI free-electron laser, respectively, to resonantly image helium nanodroplets and trace light induced excitation and ionization processes within them.

Invited Talk A 19.2 Wed 14:30 S HS 3 Physik

Multi-coincidence experiments on electron and photon emission — •Andre Knie — Institut für Physik und CINSaT, Universität Kassel

The coincident detection of particles is a powerful method in experimental physics, enabling the reconstruction of diverse projectile-target interactions. The overwhelming majority of coincidence experiments is performed detecting exclusively charged particles. When neutrals or photons are of interest, experiments typically suffer from small solid angles. Here, a new approach is shown maximizing the available solid angle for photon detection, confining the interaction volume within focusing optics. With it a series of experiments was performed on atomic and cluster samples to underline its capabilities. With this technique it was possible to disentangle Auger processes in argon otherwise unresolvable by spectroscopic means. Additionally, the coincident detection was used to circumvent the typical signal to noise ratio of an ultra low cross section process, e.g. luminescent shake up satellites in helium. The final example shows that completely new processes can be unraveled with this technique: A new energy transfer process in weakly bound heterogeneous noble gas clusters will be presented.

A 19.3 Wed 15:00 S HS 3 Physik

Auger Emission from the Coulomb Explosion of Helium Nanoplasmas — •Michael Zabel, Michael Kelbg, Bennet Krebs, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universität Rostock, Institut für Physik, Albert-Einstein-Strasse 23-24, 18059 Rostock

The long-time correlated decay dynamics of strong-field exposed helium nanodroplets is studied by means of angular resolved electron spectroscopy. As a result of the adiabatic expansion of the fully innerionized plasma, delocalized electrons in the laser-produced deep confining mean field potential are shifted towards the vacuum level, whereas some electrons may localize in bound levels of the helium ion. The simple hydrogen-like electronic structure of He^+ results in clear signatures in the experimental electron spectra. The pronounced features in the electron yields can be traced back to bound-free and bound-bound transitions in He^+. Auger electron emission takes place as a result of the transfer of the excess energy to weakly bound electrons in the quasifree electron band. Hence, the spacial and temporal development of the nanoplasma cloud is encoded in the experimental spectra, whereas the special electronic properties of helium helps to clearly resolve the different contributions.

A 19.4 Wed 15:15 S HS 3 Physik

Plasmon resonances of polyanionic metal clusters — •Klara Raspe[1], Norman Iwe[1], Madlen Müller[2], Franklin Martinez[1], Josef Tiggesbäumker[1], Lutz Schweikhard[2], and Karl-Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18059 Rostock — [2]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

In the interaction of metal clusters with light the occurrence of plasmon resonances is a well known effect. We present photoelectron spectra of negatively charged silver clusters which indicate such a plasmon resonance, and - in the case of higher charge states - show also the Coulomb Cut-Off. In this contribution we discuss the plasmon energies with respect to well-defined cluster sizes and charge states and compare them to literature values of smaller silver clusters. The project has been supported by the collaborative research center SFB 652 of the DFG.

A 19.5 Wed 15:30 S HS 3 Physik

Time-resolved coherent diffraction imaging of helium nanodroplets in free flight with intense high-harmonic XUV-pulses — •J Zimmermann[1], K. Kolatzki[1], N. Monserud[1], M. Sauppe[1], B. Schütte[1], R. M. Tanyag[1], M.J.J. Vrakking[1], A. Rouzee[1], J. Jordan[2], B. Langbehn[2], A. Ulmer[2], T. Möller[2], B. Kruse[3], T. Fennel[3], and D. Rupp[1] — [1]MBI Berlin — [2]IOAP, TU Berlin — [3]Univ. Rostock

Coherent diffraction imaging (CDI) of single particles in free flight enables studying the structural composition of fragile nano-scaled matter. Such experiments demand high-intensity extreme ultraviolet or X-ray light pulses, until recently only achievable at large-scale free-electron laser (FEL) facilities. We have demonstrated [1] that high harmonic generation (HHG) sources can be used for single-shot single-particle CDI with great prospects for time-resolved experiments due to high stability and extremely short pulse durations. Here we report on the first time-resolved CDI measurements using a HHG laser system on helium nanodroplets in an IR pump - XUV probe scheme. We obtained bright multicolor diffraction patterns in a setup that allowed for few femtoseconds time-resolution. First results of the ongoing analysis will be presented and discussed. [1] Rupp et al., Nat.Com.8,493(2017)

A 19.6 Wed 15:45 S HS 3 Physik

Investigation of polyanionic metal clusters by photoelec-

tron spectroscopy — •Madlen Müller[1], Franklin Martinez[2], Norman Iwe[2], Klara Raspe[2], Steffi Bandelow[1], Josef Tiggesbäumker[2], Lutz Schweikhard[1], and Karl-Heinz Meiwes-Broer[2] — [1]Institute of Physics, University of Greifswald, Germany — [2]Institute of Physics, University of Rostock, Germany

One of the most prominent features of polyanionic systems is the Coulomb barrier (CB), already confirmed by photoelectron spectroscopy (PES) on molecules and fullerenes. Recently such studies have been extended to the field of polyanionic metal clusters. While offering a variety of sizes and charge states to analyze, metal clusters also serve as model systems with a simplified access e.g. by the liquid drop model (LDM).

The contribution presents an overview of our measurements on polyanionic metal clusters. The study includes the determination of threshold binding energies, that support the LDM along a wide range of cluster sizes and extending to negative binding energies. Furthermore, multiphoton processes and the Coulomb cut-off dominate the structure of the PE spectra. In particular, the evolution of the Coulomb cut-off with charge state and cluster size leads to further insights into the nature of the Coulomb barrier. The project has been funded by the collaborative research center SFB 652 of DFG.

A 19.7 Wed 16:00 S HS 3 Physik

Ultrafast Ionization Dynamics of Methane Clusters — •A. Heilrath[1], M. Sauppe[1,2], K. Kolatzki[1,2], B. Langbehn[1], B. Senfftleben[2], A. Ulmer[1], J. Zimmermann[1,2], L. Flückiger[3], T. Gorkhover[4], C. Bostedt[5], Y. Kumagai[6], S. Düsterer[7], B. Erk[7], C. Passow[7], D. Ramm[7], D. Rolles[7,8], D. Rompotis[7], R. Treusch[7], T. Feigl[9], T. Möller[1], and D. Rupp[1,2] — [1]Technische Universität Berlin — [2]Max-Born-Institut, Berlin — [3]La Trobe University, Australia — [4]SLAC Menlo Park, USA — [5]Paul Scherrer Institut, Switzerland — [6]Argonne National Lab, USA — [7]FLASH@DESY — [8]Kansas State University, USA — [9]optiX fab, Jena

Intense short wavelength femtosecond pulses from free-electron lasers (FELs) allow to study individual nanoparticles with high resolution in time and space. Exposing samples to intense extreme ultraviolet (XUV) pulses is inevitably linked to ionization and subsequent disintegration of the sample, limiting the accuracy of diffraction imaging. Molecular clusters are an ideal sample system to approach light-induced dynamics of large heteronuclear systems. We studied methane clusters in an XUV pump - XUV probe experiment with 90 eV photon energy at CAMP@FLASH with delays up to 650 ps. Ionic fragments were measured with a time-of-flight spectrometer and diffraction images were taken simultaneously. The ion spectra exhibit a variety of fragments, including higher adducts forming in molecular recombination processes. A general increase of the ion yield with delay as well as the delay-dependencies of fragments will be discussed.

A 20: Cold Molecules (joint session MO/A)

Time: Wednesday 14:00–16:00 Location: S HS 002 Biologie

A 20.1 Wed 14:00 S HS 002 Biologie

Progress towards ultracold RbSr molecules in an optical lattice — •Vincent Barbé, Lukas Reichsöllner, Séverin Charpignon, Klaasjan van Druten, and Florian Schreck — University van Amsterdam, Amsterdam, Netherlands

Our group recently reported on the observation of Feshbach resonances between Rb and Sr atoms in an optical dipole trap [1], and on the experimental investigation of the Rb-Sr electronic ground-state interaction potential [2]. We will present our current efforts aimed at building an optical lattice system that supports a Rb-Sr double-Mott insulator with a high filling fraction, and a high magnetic-field stabilization system for magnetoassociation.

[1] V. Barbé, A. Ciamei, B. Pasquiou, L. Reichsöllner, F, Schreck, P. Zuchowski, and J. Hutson, Nature Physics 14, 881-884 (2017)

[2] A. Ciamei, J. Szczepkowski, A. Bayerle, V. Barbé,L. Reichsöllner, S. M. Tzanova, C.C. Chen, B. Pasquiou, A. Grochola, P. Kowalczyk, W. Jastrzebskib and F. Schreck, Phys. Chem. Chem. Phys., 20, 26221-26240 (2018)

A 20.2 Wed 14:15 S HS 002 Biologie

Phase protection of Fano-Feshbach resonances — Alexander Blech[1], Yuval Shagam[2], Nicolas J. Hölsch[2], Prerna Paliwal[2], Wojciech Skomorowski[1], John W. Rosenberg[2], Daniel Zajfman[3], Oded Heber[3], •Daniel M. Reich[1], Edvardas Narevicius[2], and Christiane P. Koch[1,2] — [1]Theoretische Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Department of Chemical Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [3]Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot 76100, Israel

Fano-Feshbach resonances (FFR) describe the decay of a quantum system due to coupling of quantum-mechanical bound states to a continuum of scattering states. They serve as a key mechanism to controlling interactions in ultracold atomic gases. The position of FFR was shown to follow quantum chaotic statistics. In contrast, their lifetimes have so far escaped a similarly comprehensive understanding, despite the intriguing observation of spanning many orders of magnitude. We attribute this phenomenon, which has also been observed in predissociation FFR, to phase protection: For each scattering energy, there exists a phase for which the lifetime becomes infinite. Any bound state which is resonantly coupled to the scattering state with exactly this phase is phase protected. Supported by lifetime measurements of rovibrational FFR, we demonstrate that both the reduced mass and the shape of the potential can significantly influence the occurence of phase-protected resonances. Our results provide a blueprint for identifying naturally long-lived states in a decaying quantum system.

A 20.3 Wed 14:30 S HS 002 Biologie

The Dipolar Ground State of Ultracold LiK Molecules — •Sofia Botsi[1], Anbang Yang[1], Sunil Kumar[1], and Kai Dieckmann[1,2] — [1]Centre for Quantum Technologies, 3 Science Drive 2, 117543 Singapore — [2]Depatment of Physics, National University of Singapore, 2 Science Drive 3, 117542 Singapore

Ultracold polar molecules are an ideal tool for the quantum simulation of a large class of many-body effects, for quantum information processing, controlled ultracold chemistry, and quantum metrological applications. We report on our experiments that identified the ground state of bosonic heteronuclear dimers of ^{6}Li and ^{40}K. In the ground state these molecules possess a large permanent electric dipole moment of 3.6 Debye, which makes them a suitable candidate for a quantum gas with long-range anisotropic dipole interaction. Starting from closed channel dominated Feshbach molecules we describe a new spectroscopy route to the ground state that is different from schemes previously used for other alkali heteronuclear dimers. Only strong transitions between molecular spin singlet states are involved avoiding the need to identify suitable perturbed triplet states. We demonstrate how only a sole hyperfine component can be addressed, even if the hyperfine structure is not resolved. Effectively creating a three level system the resulting scheme is the most straight forward to date and takes full advantage of the closed molecular channel that can be discussed by means of the simple asymptotic bound state model for our case. Further, we present results from rotational spectroscopy that facilitates to exploit the high electric dipole moment for use of the molecules as a quantum bit.

A 20.4 Wed 14:45 S HS 002 Biologie

Ultracold $^{23}Na^{40}K$ Ground-State Molecules in a 3D Optical Lattice — •Marcel Duda[1], Roman Bause[1], Scott Eustice[1], Frauke Seesselberg[1], Xing-Yan Chen[1], Christoph Gohle[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, Schellingstraße 4, 80799 München, Germany

Ultracold polar molecules represent an interesting platform to study quantum many-body physics. In contrast to atoms, molecules exhibit a rich rotational and vibrational structure. Additionally, ground-state molecules have a strong permanent electric dipole moment which allows the investigation of spin models beyond nearest-neighbor interactions. In this talk, we will report on the progress of creating a fermionic low entropy gas of $^{23}Na^{40}K$ ground-state molecules in a three-dimensional optical lattice.

After loading an ultracold mixture of ^{23}Na and ^{40}K atoms into the 3D lattice, we produce NaK molecules in the rotational-vibrational ground-state by associating Feshbach molecules from atoms followed by stimulated Raman adiabatic passage. We observe a significantly extended lifetime of NaK molecules in the 3D optical lattice and anticipate an improved Feshbach molecule association efficiency.

With sufficiently high filling and lifetimes of the ground-state NaK molecules in the 3D lattice, it is possible to observe intriguing spin dynamics such as condensate of rotational excitations or anisotropic propagation of spin waves.

A 20.5 Wed 15:00 S HS 002 Biologie

Reaction and Spectroscopy Studies of Astrophysically relevant Anions in Multipole Traps — •Markus Nötzold, Robert Wild, Malcolm Simpson, Thomas Zurin, and Roland Wester — Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, Austria

Multipole ion traps are versatile tools for the study of cold molecular ions. After the radioastronomical discovery of the first interstellar anions, interest has grown in understanding the formation and destruction pathways of negative ions in the interstellar medium (ISM). Our group has previously performed photodetachment studies on C_nH^- [1], CN^- and C_3N^- anions [2], and recently begun to study the three-body recombination mechanism $H_2 + H^- + X \Rightarrow H_3{}^- + X$. We report on progress and the current status of these experiments. In addition to the foregoing, our group is currently developing a new multipole wire trap for our setup. We present the main features of this improvement compared to our existing 22-pole trap.

[1] T. Best, R. Otto, S. Trippel, P. Hlavenka, A. von Zastrow, S. Eisenbach, S. Jézouin, R. Wester, E. Vigren, M. Hamberg, Astrophys. J. 742, (2011).

[2] S. S. Kumar, D. Hauser, R. Jindra, T. Best, Š. Roučka, W. D. Geppert, T. J. Millar, and R. Wester, Astrophys. J. 776, (2013).

A 20.6 Wed 15:15 S HS 002 Biologie

A Cold and Slow Molecular Beam of Barium Monofluoride — •Ralf Albrecht, Michael Scharwaechter, Tobias Sixt, and Tim Langen — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We report on our progress towards the direct laser cooling and trapping of barium monofluoride molecules.

Laser cooling of molecules had long been considered impossible due to their complex vibrational and rotational level structure. However, beneficial Franck-Condon factors and selection rules allow for optical cycling in many molecular species, including barium monofluoride.

In our experiment, molecules are generated through laser ablation of a sintered precursor target inside a cryogenic cell. Subsequently, the initially $\sim 10^4$ K hot molecules are precooled to the few Kelvin regime by collisions with a cold buffer gas of helium atoms. The precooled molecules exit the cell through a millimeter-sized aperture and enter a room-temperature high-vacuum region, where they form a cold and intense molecular beam. We present measurements characterizing this beam using laser-induced fluorescence and outline our strategy for future laser cooling.

A 20.7 Wed 15:30 S HS 002 Biologie

Cold beam of water dimer — •Helen Bieker[1,2,4], Jolijn Onvlee[1], Melby Johny[1], Lanhai He[1,5], Thomas Kierspel[1,2,4], Boris Sartakov[3], Andrey Yachemenev[1], Sebastian Trippel[1,3], Daniel A. Horke[1,2], and Jochen Küpper[1,2,4] — [1]Center for Free-Electron Laser Science, DESY — [2]The Hamburg Center for Ultrafast Imaging, University Hamburg — [3]General Physics Institute, Russian Academy of Sciences — [4]Department of Physics, University of Hamburg — [5]Institute of Atomic and Molecular Physics, Jilin University, Changchun, China

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

Here, we aim to develop an understanding of the structures of water clusters containing a few monomer units. We present our first results on the production of size-selected samples using supersonic expansions - subsequent separation of water dimer, extending previous studies.

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

A 20.8 Wed 15:45 S HS 002 Biologie

Manipulation of molecular hydrogen on a chip to study cold collisions with a merged beam apparatus — •Katharina Höveler[1], Johannes Deiglmayr[2], Pitt Allmendinger[1], Josef Agner[1], Hansjürg Schmutz[1], and Frédéric Merkt[1] — [1]Laboratorium für Physikalische Chemie, ETH Zürich, 8093 Zurich, Switzerland — [2]Felix-Bloch Institut, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

The exothermic, barrierless $H_2^+ + H_2 \rightarrow H_3^+ + H$ reaction has been studied in the collision-energy range $E_{\mathrm{coll}}/k_{\mathrm{b}} = 0.3 - 50\,\mathrm{K}$. To reach such low collision energies, we use a merged-beam approach and substitute the H_2^+ reactants by the ionic cores of H_2 molecules in high-n Rydberg-Stark states. The Rydberg electron does not influence the reaction but shields the ion from heating by space-charge effects and stray electric fields. A curved surface-electrode device is used to deflect a supersonic beam of H_2 molecules excited to high-n Rydberg-Stark states and to merge it with a supersonic beam containing ground-state H_2 molecules. The collision energy is tuned by varying the temperature of the valve generating the H_2 ground-state beam for selected velocities of the deflected H_2 beam. The reaction cross section is found to follow the classical Langevin capture model down to $E_{\mathrm{coll}}/k_{\mathrm{b}} = 5\,\mathrm{K}$. At lower temperatures, a deviation is observed and attributed to ion-quadrupole long-range interactions. Investigation of the reaction $H_2^+ + D_2$ enables us to distinguish between charge transfer, D atom transfer and H^+ ion transfer and to determine the ratio of the two competing reaction channels leading to the product ions H_2D^+ and D_2H^+.

A 21: Cluster II (joint session A/MO)

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

A 21.1 Wed 16:15 S Fobau Physik

Investigation of 2p Auger decay in argon clusters by electron-electron and electron-photon coincidences — •Catmarna Küstner-Wetekam[1], Philipp Schmidt[1], Christian Ozga[1], Huda Otto[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]Leibniz Institute of Surface Modification, Permoserstr. 15, 04318 Leipzig, Germany

The response of prototype systems to ionizing soft X-ray irradiation is of crucial interest for the study of fundamental processes in radiation chemistry. Here we investigate Auger processes following 2p inner-shell ionization of argon atoms and clusters and discuss differences in the spectra of the atomic and the condensed sample. These Auger processes are important for the population of the initial states of various interatomic processes such as the Interatomic Coulombic Decay (ICD) and Radiative Charge Transfer (RCT). The coincident measurement of two electrons or one electron and one photon makes it possible to gain new insights into these processes.

A 21.2 Wed 16:15 S Fobau Physik

Modular He nanodroplet source and doping setup for the SQS instrument at the European XFEL — •Anatoli Ulmer[1], Rico Mayro P. Tanyag[1,2], Katharina Kolatzki[1,2], Georg Noffz[1], Patrick Behrens[1], Fabian Seel[1], Bruno Langbehn[1], Mario Sauppe[2], Yevheniy Ovcharenko[3], Daniela Rupp[2], and Thomas Möller[1] — [1]Technische Universität Berlin — [2]Max-Born-Institut Berlin — [3]European XFEL GmbH

Ultra-cold helium nanodroplets gain growing attention in many fields, which can be attributed to their fascinating properties: they are superfluid, form quantized vortices and can be doped with various atomic or molecular samples. With the advance of Free-Electron Lasers (FEL), it has become feasible to determine the outer shapes as well as the structures of embedded nanometer-sized samples by using flash X-ray imaging. This opens a variety of experimental roads, such as cluster growth in a superfluid environment, using different droplet sizes, shapes and dopants. We developed a modular source and doping setup, which will be permanently available for user experiments at the SQS instrument of the European XFEL. A wide range of experiments will be enabled by using either an Even-Lavie Valve, a commercial Parker Valve, or a continuous jet nozzle. Furthermore, a doping system, consisting of a gas cell and two metal ovens, was designed to explore the formation and interaction of structures nested inside superfluid He droplets. The layout and characterization measurements of the setup will be presented.

A 21.3 Wed 16:15 S Fobau Physik

Time-resolved imaging of the dynamics of free metal clusters and nanocrystals — I. Barke[3], N. Bernhardt[2], P. Behrens[2], •S. Dold[1], S. Düsterer[4], B. Erk[4], T. Fennel[3,5], H. Hartmann[3], L. Hecht[2], A. Heilrath[2], R. Irsig[3], B. v. Issendorff[1], N. Iwe[3], J. Jordan[2], B. Kruse[3], B. Langbehn[2], B. Manschwetus[4], F. Martinez[3], K.-H. Meiwes-Broer[3], T. Möller[2], K. Oldenburg[3], C. Passow[4], C. Peltz[3], D. Rupp[2,5], F. Seel[2,5], R. Tanyag[5], R. Treusch[4], A. Ulmer[2], and S. Walz[2] — [1]Univ. Freiburg — [2]TU Berlin — [3]Univ. Rostock — [4]FLASH@DESY — [5]MBI Berlin

Wide angle X-Ray diffraction has been proven a viable tool to determine the 3D structure of single metal clusters in gas phase with a single X-Ray Pulse. We utilize the fs X-Ray pulses at the FLASH Free-Electron Laser in Hamburg to resolve ultrafast processes in metal clusters by reconstructing their shape in a time-dependent manner and simultaneous time-of-fight spectrometry of the ionic fragments. Exploiting the plasmon resonance of silver nanoparticles we use optical picosecond-second laser pulses to efficiently pump their electronic system. Picoseconds later we retrieve the resulting shape of the cluster. For moderate pumping energies (0.5 eV/Atom) we expect so see melting effects, whereas high energy input leads to the formation of a nanoplasma and disintegration of the cluster. To meet the demanding requirements for such experiments a carefully taylored source for clusters was developed. This source as well as a novel optical cluster detector will be presented and an overview of preliminary results from our recent experiments at FLASH will be given.

A 21.4 Wed 16:15 S Fobau Physik

Correlation method for velocity map imaging of electrons and time- of-flight detection of ions emitted by individual mid-IR induced helium nanoplasmas. — •Cristian Medina[1], Dominik Schomas[1], Marcel Mudrich[3], Marcus Debatin[1], Frank Stienkemeier[1], Robert Moshammer[2], and Thomas Pfeifer[2] — [1]Albert-Ludwigs- University of Freiburg, Freiburg im Breisgau, Germany — [2]Max plank Institute for nuclear physics, HEIDELBERG, GERMANY — [3]Aarhaus University, Aarhus, Denmark

Velocity map imaging (VMI) and time-of-flight (TOF) are standard techniques to probe the photodynamics of molecules and clusters. Using a combined VMI-TOF setup, we study nanoplasmas created from doped helium nanodroplets irradiated with intense mid-infrared femtosecond laser pulses. Quasi-free electrons created by tunnel ionization couple very efficiently to the laser field, thereby acquiring high energy and resulting in an avalanche of impact ionization. The large number of charged particles emitted from a single helium nanoplasma allows us to collect both full electron energy distributions (VMI) and ion mass-over-charge distributions (TOF) from a single hit. Our technique relies on linking the camera used for VMI to the oscilloscope that measures TOF spectra. We discuss the impact of doping the He nanodroplets with various species (Xe, Ca and H2O) to trigger the nanoplasma formation.

A 21.5 Wed 16:15 S Fobau Physik

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]University of Rostock, Albert-Einstein-Straße 23, D-18059 Rostock — [2]Max-Born-Institute, Max-Born-Straße 2A, D-12489 Berlin

Just recently, 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 in both single-shot and pump-probe scenarios.

[1] D. Rupp et al., Nat. Commun. **8**, 493 (2017)
[2] I. Barke et al., Nat. commun. **6**, 6187 (2015)

A 21.6 Wed 16:15 S Fobau Physik

Coulomb interaction in the photoemission of polyanionic silver clusters — •Norman Iwe[1], Madlen Müller[2], Klara Raspe[1], Franklin Martinez[1], Steffi Bandelow[2], Josef Tiggesbäumker[1], Lutz Schweikhard[2], and Karl-Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18059 Rostock — [2]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

Not only the size but also the charge state is an important parameter of free, nanoscopic particles. In particular the properties of negatively charged metal clusters are strongly influenced by Coulomb interaction between the cluster components. For two and more excess electrons, this results in a Coulomb barrier potential, whose detailed properties are however largely unknown.

This contribution presents photoelectron spectroscopy studies on mass separated silver clusters, after they have been multiply negatively charged in a radiofrequency ion trap. The emitted electron interacts with the still negatively charged cluster which leads to a Coulomb cutoff, as known from molecular anions. To investigate this effect, PE spectra for different photon energies are compared. These spectra are qualitatively described by electrons coming from a Fermi distribution in a Jellium-like potential that either overcome or tunnel through the Coulomb barrier. The project has been supported by the collaborative research center SFB 652 of the DFG.

A 21.7 Wed 16:15 S Fobau Physik

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 laser-driven nanoplasma expansion.

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

A 21.8 Wed 16:15 S Fobau Physik

Characterisation of a doping oven for embedding metals in helium droplets for the SQS instrument at the European XFEL — •Georg Noffz[1], Anatoli Ulmer[1], Rico Mayro Tanyag[1,2], Katharina Kolatzki[1,2], Daniela Rupp[1,2], Yevheniy Ovcharenko[3], and Thomas Möller[1] — [1]IOAP, Technische Universität Berlin, Germany — [2]MBI, Berlin, Germany — [3]European XFEL, Hamburg, Germany

One of the most fascinating applications of the European XFEL is the study of nanostructures by means of scattering experiments using ultra-short and extremely intense X-ray pulses. A challenge in these experiments is the loss of phase information needed for image reconstructions in order to make statements about the morphology of the diffracting object. The Droplet Coherent Diffracitve Imaging (DCDI) [Struct. Dyn. 2, 051102 (2015)] technique provides a fast method for retrieving phase information of nanostructures, such as clusters grown in helium droplets. In this case, the droplet serves as a reference object and as a container. This poster deals with the design and characterisation of a doping oven for embedding metals in helium droplets for an approved XFEL beamtime. Quadrupole mass analyzer and time-of-flight mass spectrometer measurements are performed for the investigation of the doping process. Furthermore, the structures of the embedded metals are deposited and afterwards investigated by transmission electron microscopy. This setup will be available at the SQS instrument at the European XFEL. In a final beamtime nanostructure formation in the droplets will be investigated.

A 21.9 Wed 16:15 S Fobau Physik

Setup and characterization of a helium liquid jet for diffractive imaging experiments — •Katharina Kolatzki[1,2], Rico Mayro P. Tanyag[1,2], Georg Noffz[2], Anatoli Ulmer[2], Daniela Rupp[1,2], and Thomas Möller[2] — [1]MBI, Germany — [2]IOAP TU Berlin, Germany

State-of-the-art XUV and X-ray facilities like high-harmonic generation sources and free-electron lasers enable the in-depth investigation of light-matter interaction via novel methods such as single-particle coherent diffractive imaging.

For such experiments, large helium droplets constitute a suitable target; they have a simple electronic structure and exhibit interesting properties like superfluidity. One way of creating these droplets is a helium liquid jet, which disintegrates in a Rayleigh-type breakup, forming large droplets with diameters of a few microns. Compared to the other regimes of helium droplet generation, droplets produced from jet disintegration have a narrower size distribution. This makes them eligible for time-resolved diffractive imaging experiments, where a reproducible target is indispensable.

Recently, we have constructed and characterized a source for a helium liquid jet, which will be put into use for example at the SQS endstation at the European XFEL. Via shadowgraphy methods, we can analyze the jet's shape and the droplet size. Complementary, our setup allows to determine the average droplet size via collision with external gas particles. First results will be presented.

A 21.10 Wed 16:15 S Fobau Physik

Direct evidence of radiative charge transfer in heterogenous noble gas clusters — •Xaver Holzapfel[1], Andreas Hans[1], Christian Ozga[1], Vasili Stumpf[2], Huda Otto[1], Catmarna Küstner-Wetekam[1], Arno Ehresmann[1], and André Knie[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg, Germany

Weakly bound noble gas clusters are artificial systems which can be used for the understanding of non-local energy transfer processes. In the case of the so called radiative charge transfer (RCT) the system can relax by redistributing the charges by emitting the excessive energy as a photon. Therefore, these photons can be used as a fingerprint of the electronic structure of the system if they are measured energy resolved. Here we present the direct observation of (RCT) in heterogeneous NeKr and NeXe clusters by dispersed ultravioletphoton detection.

A 22: Highly charged ions and their applications

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

A 22.1 Wed 16:15 S Fobau Physik

A Single Particle Scintillation Detector for Recombination Experiments at CRYRING@ESR — •Esther Babette Menz[1,3], Christoph Hahn[1,2,3], Michael Lestinsky[2], Philip Pfäfflein[1,2,3], Felix Kröger[1,3], Uwe Spillmann[2], Anton Kalinin[2,4], Jan Glorius[2], and Thomas Stöhlker[1,2,3] — [1]Helmholtz-Institut Jena, 07743 Jena — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt — [3]Friedrich-Schiller-Universität Jena, 07743 Jena — [4]Goethe-Universität Frankfurt, 60323 Frankfurt am Main

A YAP:Ce scintillation detector for counting beamlike reaction products has been installed and tested at the CRYRING@ESR heavy ion storage ring at GSI. YAP:Ce is a durable and non-hygroscopic crystal that is bakeable to a certain degree and is thus suitable for installation directly in the ultrahigh vacuum of the storage ring. The detector system is intended for observation of electron-ion recombination in the electron cooler section of CRYRING@ESR. Electron capture by the orbiting ions causes only a minimal change to their momentum but the resulting reduced charge state means that they diverge from the closed orbit at the next downstream dipole magnet. The scintillator can be moved into the path of the respective product beam for the given initial-to-final charge-state ratio and measure with an efficiency of nearly 100% in single-particle counting mode. The setup will be used for e.g. dielectronic recombination and 1s Lamb shift measurements on slow, heavy, highly-charged ions of all species the GSI accelerator complex is able to produce and transport through ESR.

A 22.2 Wed 16:15 S Fobau Physik

The impact of dielectronic recombination on the charge state distribution at REXEBIS — •Hannes Pahl[1,2], Niels Bidault[1,3], and Fredrik Wenander[1] — [1]CERN, 1211 Geneva 23, Switzerland — [2]Universität Heidelberg, 69120 Heidelberg, Germany — [3]INFN & Sapienza University of Rome, 00185 Rome, Italy

In an electron beam ion source, charge breeding is primarily achieved through successive electron impact ionisation. During this process, it is possible to selectively increase the recombination rate for a given charge state by adjusting the electron beam energy such that it matches the resonance energy of a Dielectronic Recombination (DR) transition. This inhibits the breeding into higher charge states and causes a shift of the charge state distribution of the extracted ion beam. This study addresses the significance of DR for the operation of a charge breeder and the question whether this effect can be exploited to actively improve the charge breeding selectivity. We have performed simulations and measurements using REXEBIS at ISOLDE for the example of highly charged potassium ions (12+ to 17+). The preliminary results show a good agreement between the theoretical predictions and the measured charge state distribution and suggest that the impact of DR depends strongly on the ion species and the electron beam parameters. We conclude that DR can be of operational interest and potentially serve as a diagnostic mechanism in special cases.

A 22.3 Wed 16:15 S Fobau Physik

Status of the free-electron target for CRYRING@ESR — Carsten Brandau[1,2], Alexander Borovik Jr[1], •B. Michel Döhring[1,2], Benjamin Ebinger[1,2], Alfred Müller[1], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt (Germany)

The anti-proton and heavy-ion accelerator facility FAIR which is currently under construction in Darmstadt will provide excellent conditions for novel investigations in atomic physics. One of the first operational devices will be the storage ring CRYRING@ESR [1], where we will install a transverse free-electron target for electron-ion crossed-beams in-ring experiments. Such a crossed-beams setup has never been realised at a heavy-ion storage ring before. The transverse target is based on an earlier development in Gießen [2] and will be commissioned at a test bench there soon. A multi-electrode assembly is used that controls beam parameters such as beam size, electron density, and electron energy. The target is envisaged for electron energies up to 12.5 keV and will reach electron densities of up to 10^9 cm^{-3} electron density. The present status of the project will be presented.

[1] M. Lestinsky et al., 2016 Eur. Phys. J. ST 225 797.
[2] B. Ebinger et al., 2017 Nucl. Instrum. Meth. B 408 317.

A 22.4 Wed 16:15 S Fobau Physik

Development of a stabilized laser system for Raman sideband cooling of ^{9}Be$^+$ atoms — •Lena Haaga, Julian Stark, Sandra Bogen, Christian Warnecke, Lukas Spiess, Lisa Schmöger, and José R. Crespo López-Urrutia — Max-Planck-Institut, Heidelberg, Deutschland

Forbidden optical transitions in highly charged ions (HCIs) are less sensitive to external influences than state-of-the-art atomic transitions used for metrology [1]. Also, they are promising candidates to probe physics beyond the Standard Model, as they feature an enhanced sensitivity to variation of fundamental constants [2]. As HCIs lack suitable optical transitions they cannot be laser-cooled directly. Thus, co-trapped laser-cooled ^{9}Be$^+$ ions are used for sympathetic cooling in a cryogenic Paul trap [3]. To reach Temperatures beyond the Doppler limit, sideband cooling using a Raman transition at 313 nm is applied, transferring the HCIs and ^{9}Be$^+$ to their motional ground state [4]. We present the design of this Raman laser setup based on [5], where light at 626 nm is frequency doubled to 313 nm and then shifted to the motional sidebands of the trapped ions by passing acousto-optic modulators.

[1] V.A. Dzuba et al., Phys. Rev. A 86, 054502 (2012)
[2] J.C. Berengut et al., Phys. Rev. Lett. 106, 210802 (2011)
[3] L. Schmöger et al., Rev. Sci. Instrum. 86, 103111 (2015)
[4] D.J. Wineland et al., Phys. Rev. A 20, 1521 (1979)
[5] A.C. Wilson et al., Appl. Phys. B 105, 741 (2011)

A 22.5 Wed 16:15 S Fobau Physik

UV laser systems for sympathetic cooling of highly charged ions using ^{9}Be$^+$ — •Sandra Bogen, Julian Stark, Lukas Spiess, Lisa Schmöger, Lena Haaga, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Narrow optical transitions in highly charged ions (HCI) are promising candidates to search for physics beyond the Standard Model [1]. For the purpose of such high-precision experiments, the HCI need to be trapped and cooled. As HCI generally lack suitable optical transitions for laser cooling, sympathetic cooling with laser-cooled ^{9}Be$^+$ is employed [2]. In order to photo ionize ^{9}Be atoms, a laser at 235 nm based on [3] is used. It is generated by cavity-enhanced frequency doubling of a 940 nm diode laser twice, first using a PPKTP crystal and then a BBO crystal. This laser is resonant with the $2s^1S_0 - 2p^1P_1$ transition of the ^{9}Be atom, which is used for resonance-enhanced two-photon-ionization. The ^{9}Be$^+$ ions are Doppler-cooled via the $^2S_{1/2} -^2 P_{3/2}$ transition at 313 nm based on [4]. This laser is generated from two fiber lasers at 1051 nm and 1550 nm. By sum frequency generation inside a PPLN crystal, 626 nm light is produced, which subsequently is frequency doubled using cavity-enhanced second harmonic generation in a BBO crystal to generate the needed 313 nm light.

[1] M. G. Kozlov et al., arXiv:1803.06532 (2018)
[2] L. Schmöger et al., Science 347 (2015)
[3] H.-Y. Lo et al., Appl. Phys. B, 114:17-25 (2014)
[4] A.C. Wilson et al., Appl. Phys. B 105:741-748 (2011)

A 22.6 Wed 16:15 S Fobau Physik

CryPTEx II: A superconducting radio-frequency trap for long-time storage of highly charged ions — •Julian Stark[1], Sandra Bogen[1], Lena Haaga[1], Steffen Kühn[1], Christian Warnecke[1], Steven A. King[2], Tobias Leopold[2], Peter Micke[2], Janko Nauta[1], Jan-Hendrik Ölmann[1], Lisa Schmöger[1], Lukas Spiess[1], Thomas Pfeifer[1], Piet O. Schmidt[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundeanstalt, Braunschweig, Germany

Cold highly charged ions (HCI) are excellent candidates for the development of novel optical clocks and will serve for stringent tests of the constancy of natural constants, as they feature narrow optical transitions with an enhanced sensitivity to a possible variation of the fine-structure constant or of the proton-to-electron mass ratio [1,2]. At the cryogenic Paul trap experiment (CryPTEx), a broad range of HCI can be trapped and sympathetically cooled down to the mK range by laser-cooled Be$^+$ ions, which allows for high-precision laser spectroscopy. Here, we present the commissioning of the successor experiment, CryPTEx II, which features a novel superconducting quadrupole resonator to confine ions in extremely stable radio-frequency potentials. Furthermore, in order to increase the storage times of cold HCI, a low-vibration cryogenic system was developed in collaboration with the QUEST institute at PTB in Braunschweig.

[1] J. C. Berengut et al., Phys. Rev. Lett. 106, 210802 (2011)
[2] M. G. Kozlov et al., arXiv:1803.06532 (2018)

A 22.7 Wed 16:15 S Fobau Physik

Imaging of Coulomb crystals in a cryogenic Paul trap experiment — •Christian Warnecke, Julian Stark, Sandra Bogen, Lena Haaga, Alexander Ackermann, Steffen Kühn, Janko Nauta, Jan-Hendrik Ölmann, Michael Karl Rosner, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Cold highly charged ions (HCI) are proposed to be excellent candidates for tests of Standard Model extensions as they feature low susceptibility to external influences and give access to narrow optical transitions, which are not only highly sensitive to possible variations of fundamental constants, but also to non-linearities in isotope shifts. At the Cryogenic Paul Trap Experiment CryPTEx, built at the Max-Planck-Institute for Nuclear Physics, a broad range of HCI can be trapped and sympathetically cooled by laser-cooled Be$^+$ Coulomb crystals, which reduces their temperature by eight orders of magnitude down to 10 mK. Its follow-up experiment CryPTEx II includes a novel, superconducting quadrupole resonator that allows for an ion confinement with extremely stable radio-frequency potentials and for higher storage times and decreased heating rates than now. We have designed an objective covering a 500 micron field of view with a solid angle of 0.379 sr at a working distance of 57 mm to image the trapped ions. Our optics is optimized to transmit wavelengths of 235, 313 and 445 nm. We discuss our design and present first commissioning results.

A 23: Collisions, scattering and correlation phenomena

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

A 23.1 Wed 16:15 S Fobau Physik

Resonant electron scattering in two-center atomic systems — •Alexandra Eckey, Alexander B. Voitkiv, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Electron scattering from an ion in the presence of a neighboring atom is studied theoretically. The incident electron is assumed to be captured by the ion, leading to resonant excitation of the atom which afterwards stabilizes by electron re-emission. We show that the participation of the atom can strongly affect, both quantitatively and qualitatively, the scattering process. Various ion-atom systems and electronic transitions are considered, accounting for quantum interference between the resonant two-center channel and the direct channel of Rutherford scattering from the ion. We show that electron scattering under backward angles may be strongly enhanced, provided the incident electron energy lies very close to the resonance. Due to constructive and destructive interferences, also scattering at intermediate angles can be affected significantly.

[1] A. Eckey, A.Jacob, A. B. Voitkiv and C. Müller, Phys. Rev. A 98, 012710 (2018)

A 23.2 Wed 16:15 S Fobau Physik

Scaling behavior of dielectronic recombination in two-center atomic systems — •Andreas Jacob, Alexander B. Voitkiv, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Dielectronic recombination with an ion in the presence of a neighboring atom is examined by theoretical means. The incident electron is assumed to be captured by the ion, leading to resonant excitation of the atom which afterwards stabilizes by radiative decay. The scaling behavior of this two-center dielectronic recombination with the principal quantum numbers of the participating atomic states is derived, this way extending earlier studies of the process. We show that the participation of the atom can lead to a strong resonant enhancement of electron-ion recombination for internuclear distances up to few nanometers. The enhancement is found to be so enormous that the two-center process can compete with ordinary single-center recombination even after integrating over a rather broad distribution of incident electron energies.

[1] A. Eckey, A. Jacob, A. B. Voitkiv and C. Müller, Phys. Rev. A 98, 012710 (2018)

A 23.3 Wed 16:15 S Fobau Physik

Elastic scattering of twisted electrons by an atomic target: Going beyond the Born approximation — •Valeriia Koshelеva — Helmholtz-Institute Jena, D-07743 Jena, Germany

The elastic scattering of twisted electrons by neutral atoms is studied within the fully relativistic framework. The electron-atom interaction is taken into account in all orders, thus allowing us to explore high-order effects beyond the first Born approximation. To illustrate these effects, detailed calculations of the total and differential cross sections as well as the degree of polarization of scattered electrons are performed. Together with the analysis of the effects beyond the first Born approximation, we discuss the influence of the kinematic parameters of the incident twisted electrons on the angular and polarization properties of the scattered electrons.

A 24: Atomic collisions and ultracold plasmas

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

A 24.1 Wed 16:15 S Fobau Physik

Progress towards an "Intense Pulsed Positron Source" (IPPS) — Matrin Singer[2], •Stephan König[1], Uwe Hergenhahn[2], Gerrit Marx[1], Thomas Sunn Pedersen[2], and Lutz Schweikhard[1] — [1]Institut of physics, University of Greifswald, Felix-Hausdorff-Str.6, 17489 Greifswald — [2]Max Planck Institute for Plasma Physics,Wendelsteinstr. 1, 17491 Greifswald

The development of an Intense Pulsed Positron Source (IPPS) is part of the APEX (A Positron Electron eXperiment) and PAX (Positron Accumulation eXperiment) project [1] with the goal to produce and confine the world's first matter-antimatter pair plasma. The world's brightest positron source, located at FRM2 at Nepomuc (NEutron inducted Positron source MUniCh) in Garching, provides about 10^9 positrons per second. The IPPS project aims at the accumulation and confinement of up to 10^{12} positrons.

In this contribution we present the layout of IPPS and preliminary experimental results. In a first step a Penning-Malmberg trap is built and tested at Greifswald to accumulate, store and control the radial motion of about 10^{10} electrons. In a second step the electrons will be guided into multiple Penning- Malmberg traps on axis and radially spread behind the first trap [2]. After the successful test of the multiple traps, the setup will be moved to NEPOMUC.

[1] T. Sunn Pedersen et al., New J. Phys. 14, 035010 (2011)
[2] J. R. Danielson et al., Phys. Plasmas 13, 123502 (2006)

A 25: Attosecond physics

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

A 25.1 Wed 16:15 S Fobau Physik

Tunneling time in attosecond experiments from time operator prespective — •Ossama Kullie — Institute of Physics, Department of Mathematics and Natural Science, Universitity of Kassel, Germany

Using a semi classical model we found a tunneling time relation [1,2], which successfully calculates the tunneling (tunnel-ionization) time in attosecond experiment for He- and H-atom, with a good agreement with the experiment. The tunneling time in our model is real and can be interpreted as a delay time with respect to the ionization at atomic field strength, which marks the above-threshold ionization regime, where the ionization is classically allowed process. The model exploits the time-energy uncertainty relation without using an explicit time observable or time operator. The existence of such time operator is mathematically proven, however no unambiguous and generally accepted time operator is found so far, especially to calculate the tunneling time in attosecond experiment. In this work we discuss this issue, where our aim is to find a time operator, with which we can calculate the tunneling time given in [1,2] for He- and H-atom. [1] O. Kullie. (open access) Mathematics **6**, 00192 (2018). [2] O. Kullie, Annals of Physics **389** (2018) 333.

A 25.2 Wed 16:15 S Fobau Physik

Mapping laser-driven electron dynamics by a time independent Hamiltonian — •Soumi Dutta, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We study the dynamics of an electron after tunnel ionization in the presence of a strong elliptically polarized laser field. The motion of the electron in the presence of an oscillatory electric field can be described by a smooth trajectory in the Kramers Henneberger (KH) frame. In a series expansion of the time-averaged KH potential the zeroth-order contribution becomes dominant, implying a possible existence of a time independent potential governing the electron*s trajectory. We device a mapping from the KH initial conditions to reference initial conditions of simple Coulomb*s problem.

A 25.3 Wed 16:15 S Fobau Physik

Mapping laser-driven electron dynamics by a time independent Hamiltonian — •Soumi Dutta, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

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A 25.4 Wed 16:15 S Fobau Physik

Mapping laser-driven electron dynamics by a time independent Hamiltonian — •Soumi Dutta, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We study the dynamics of an electron after tunnel ionization in the presence of a strong elliptically polarized laser field. The motion of the electron in the presence of an oscillatory electric field can be described by a smooth trajectory in the Kramers-Henneberger (KH) frame. In a series expansion of the time-averaged KH potential the zeroth-order contribution becomes dominant, implying a possible existence of a time independent potential governing the electron trajectory. We device a mapping from the KH initial conditions to reference initial conditions of simple Coulomb problem.

A 25.5 Wed 16:15 S Fobau Physik

Modeling time-resolved high-order harmonic generation in ZnO — •Christian Hünecke[1], Thomas Lettau[2], Ulf Peschel[2], and Stefanie Gräfe[1] — [1]Institute for Physical Chemistry, Friedrich Schiller University Jena, Germany — [2]Institute for Solid State Theory and Optics, Friedrich Schiller University Jena, Germany

Recent pump-probe experiments with mid-infrared excitations in ZnO have provided evidence for a strong modulation of high-order harmonic spectra by optical phonons [1]. Motivated by these experiments, two approaches to theoretically describe such HHG spectra in the condensed phase are employed, which take into account the strong coupling of the phonons to the electronic degrees of freedom. On the one hand, we use a two-dimensional model system consisting of one electronic and one vibrational spatial degree of freedom, similarly to what is typically done in molecular strong-field physics, however with the difference of periodic boundary conditions for the electron. These results are compared with those obtained with a quasi-particle approach based on a numerical solution of the semiconductor Maxwell-Bloch equations, coupled to an optical phonon mode.

[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.

A 25.6 Wed 16:15 S Fobau Physik

Trajectory control in XUV-initiated high-harmonic generation — •Michael Krüger, Doron Azoury, Barry D. Bruner, and Nirit Dudovich — Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel

A major limitation of high-harmonic generation (HHG) is the fact that the strong driving laser field governs the entire generation process. XUV-initiated HHG replaces the tunnel ionization step in HHG by XUV-driven photoionization, overcoming this limitation [1]. Controlling the delay between an ionizing XUV field and a strong IR laser pulse determines the time instant when electrons are promoted to the continuum and undergo IR-driven recollision. Moreover, an additional second harmonic (SH) field breaks the symmetry of the system, probing the strong-field driven trajectories. In our study, we use the XUV and SH fields to fully control the HHG process, switching between long and short trajectories and achieving frequency tuning of the resulting harmonics. Moreover, we are able to directly observe a new class of trajectories, so-called "downhill" and "uphill" trajectories; here the excess energy of the photoelectron following XUV ionization leads to an extra momentum kick in the direction of the instantaneous IR field force (downhill) or against it (uphill). Our study bears the prospect of increasing the dimensionality of high-harmonic generation spectroscopy for probing complex systems and multi-electron effects.

[1] D. Azoury et al., Nature Communications 8, 1453 (2017).

A 25.7 Wed 16:15 S Fobau Physik

Continuum dynamics of Helium in intense laser fields — •Tobias Heldt, Paul Birk, Gergana D. Borisova, Maximilian Hartmann, Veit Stooss, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

We investigate electron dynamics in strong near-infrared laser fields on an attosecond time scale. Experimentally this is done by attosecond transient-absorption spectroscopy of different targets, e.g. on the benchmark-system helium.

In this work, we analyze which parameters modify observed features in the measured helium absorption spectrum close to and above the single ionization threshold. The helium atom is modelled in the single active electron and the dipole approximation on a discrete 1D grid. Its electron dynamics is examined by solving the time-dependent Schrödinger equation with an ab initio simulation taking into account the Coulomb potential and the laser field. We observe time-dependent electron dynamics below and above the ionization threshold on a subcycle time scale.

A 25.8 Wed 16:15 S Fobau Physik

Effective Nonlinearity of Ionization Harmonics in Amorphous Solids — •Benjamin Liewehr[1], Björn Kruse[1], Christian Peltz[1], Peter Jürgens[2], Anton Husakou[2], Mikhail Ivanov[2], Marc Vrakking[2], Alexandre Mermillod-Blondin[2], and Thomas Fennel[1,2] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, D-18051 Rostock — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2A, D-12489 Berlin

The notion of nonlinear optical phenomena in dielectric solids has been recently complemented by the physics of high-harmonic generation (HHG) [1], associated with interband recombination and Bloch oscillations in strong laser fields [2]. This picture, however, fails to explain recent measurements of the harmonic emission close to the damage threshold of amorphous wide-bandgap materials, as the subfemtosecond ejection dynamics of electrons has not been included so far. Using a rate equation based ionization-radiation model we show that the ionization current as well as the Brunel mechanism, known from gases [3], are also potential sources of low order harmonics in solids. We present an approach to discriminate the harmonics from ionization and Kerr-type contributions, by adapting the concept of nonlinear wave mixing and determine an effective nonlinearity order of the generating process.

[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)

A 25.9 Wed 16:15 S Fobau Physik

Towards High-Harmonic Generation with a High-Repetition Rate laser for kinematically complete experiments — •Farshad Shobeiry, Hemkumar Srinivas, Anne Harth, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, Heidelberg 69117

Attosecond time resolved measurements on atomic and molecular systems require an XUV-IR Pump-Probe scheme. This work involves the design and development of a new setup to generate attosecond pulses through High Harmonic Generation. A high repetition rate NIR laser source delivering pulses at 150 KHz, along with a novel target design is used to generate the XUV light. This beamline is used in combination with a Reaction Microscope (COLTRIMS), to provide a kinematically complete measurement of the atomic processes.

A 26: Atomic systems in external fields

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

A 26.1 Wed 16:15 S Fobau Physik

Influence of nuclear motion on two-center photoionization — •Fiona Grüll, Alexander B. Voitkiv, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Deutschland

Photoionization of an atom A can be strongly enhanced in the presence of a neighboring atom B due to two-center electron correlations. For certain resonant photon energies, atom B can first be excited and afterwards transfer the excitation energy radiationlessly via dipole-dipole interactions to atom A, leading to its ionization. This indirect ionization pathway can dominate over the direct photoionization by several orders of magnitude, as was predicted some years ago assuming a fixed internuclear distance [1]. A related experiment observed enhanced photoionization in heteroatomic dimers, though at substantially reduced scale [2]. In light of this, we analytically study how two-center photoionization is influenced by the nuclear motion in a molecule when considering Li-He dimers as an example. Shifts of the atomic energy levels in the presence of a neighboring atom are calculated as a function of the internuclear distance. Besides, the internuclear motion is accounted for by considering the relevant vibrational states in the molecule.

[1] B. Najjari, A. B. Voitkiv and C. Müller, Phys. Rev. Lett. 105, 153002 (2010)

[2] F. Trinter et al., Phys. Rev. Lett. 111, 233004 (2013)

A 26.2 Wed 16:15 S Fobau Physik

QPROP 3.0: an improved t-SURFF 2.0 algorithm for a trusted Schrödinger solver — •Vasily Tulsky and Dieter Bauer — University of Rostock, Rostock, Germany

Solving the time-dependent Schrödinger equation (TDSE) for an atom in a strong laser field is often a delicate problem and requires numerical methods to obtain accurate results. In the particular case of calculating photoelectron spectra (PES) the t-SURFF method [1] is efficiently applied, allowing to significantly reduce the size of the numerical grid. This poster is devoted to our TDSE solver named QPROP [2-3] and the fresh improvement to its t-SURFF part.

Once the ionizing laser pulse is over, the propagation of the wavefunction is determined by a time-independent Hamiltonian. This allows to analytically obtain the contribution to the surface flux after the pulse [4], covering the infinite time interval in a single step, significantly speeding up the calculation of the PES and allowing to exactly reproduce even its low-energy domain.

[1] L. Tao, A. Scrinzi, New Journal of Physics **14**, 013021 (2012).

[2] D. Bauer, P. Koval, Computer Physics Communications **174**, 396 (2006).

[3] V. Mosert and D. Bauer, Computer Physics Communications **207**, 452 (2016).

[4] F. Morales, T. Bredtmann, S. Patchkovskii, J. Phys. B **49**, 245001 (2016).

A 26.3 Wed 16:15 S Fobau Physik

A rydberg-atom based detector for terahertz radiation — •Lara Torralbo-Campo[1], Manuel Kaiser[1], Raphael Wieland[1], Fabian Rudau[1], Jens Grimmel[1], Xiang Lue[2], Lutz Schrottke[2], Holger Grahn[2], Reinhold Kleiner[1], and Jozsef Fortagh[1] — [1]Universität Tübingen, Physikalisches Institut, Auf der Morgenstelle 14, 72076 Tübingen — [2]Paul-Drude-Institut fuer Festkoerperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V

Rydberg atoms have proven to be an excellent sensitive probe to electromagnetic fields. Here, we present our ongoing development of a Rydberg atom-detector using a four atomic level scheme based on electromagnetically induced transparency (EIT) in a hot atomic vapour. This detector is used to characterize different types of terahertz (THz) source emitters such as superconductors emitters and quantum cascade lasers.

Besides, THz induced single atom transitions and subsequent single atom counting in an ultracold atomic cloud, making the detector suitable for the measurement of photon statistics of the THz emitters.

This detector will enhance the technological development of new THz sources and detectors.

A 26.4 Wed 16:15 S Fobau Physik

A laser system for imaging of rubidium at high magnetic fields — •Jennifer Koch[1], Daniel Adam[1], Quentin Bouton[1], Daniel Mayer[1], Jens Nettersheim[1], Felix Schmidt[1], and Artur Widera[1,2] — [1]Departmet of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany

Impurities in quantum systems are the origin of many fascinating phenomena such as polarons or the Kondo system, for example. Our approach to realize such a system immerses cold single cesium atoms as impurities into an ultracold quantum gas of rubidium. The interaction between the two species can be tuned by magnetic Feshbach resonances at magnetic fields of up to 350 G. In order to characterize our impurity-BEC system, absorption imaging for rubidium and fluorescence imaging for cesium is employed, where resonant light is required in both cases.

In order to allow imaging of or removing the rubidium cloud from the system at high magnetic field, we have constructed a diode-based laser system. At field strengths above 200 G, transition frequencies are shifted by the order of some GHz due to the magnetic field. The stabilization of the linear interference-filter lasers used is based on a flexible frequency offset locking scheme. We present characterization of the system and current status of the project. The system will allow high-field and in-situ imaging of cesium impurities and the rubidium BEC.

A 26.5 Wed 16:15 S Fobau Physik

"Selection rules" for atomic excitation by twisted light — •Yuxiong Duan[1,2], Robert Müller[1,2], and Andrey Surzhykov[1,2] — [1]Physikalisch–Technische Bundesanstalt, D–38116 Braunschweig, Germany — [2]Technische Universität Braunschweig, D–38106 Braunschweig, Germany

Atomic excitation by twisted light has attracted much attention recently [1,2]. Here we present a thorough theoretical analysis of the selection rules for this process. We show that these rules originate from the complex interplay between the structure of the atomic target and of the incident light beam. Since the twisted light has very complex internal structure, where the multipole components of the beam vary significantly within the wave front, the selection rules depend on both the position of the target atom and beam parameters. In order to investigate this dependence, we present detailed calculations for the twisted-light-induced transition $4s\ ^2S_{1/2} \to 3d\ ^2D_{5/2}$ of a Ca^+ ion.

[1]C. T. Schmiegelow et al., Nat. Commun. **7**, 12998 (2016).
[2]A. Afanasev et al., New J. Phys. **20**, 023032 (2018).

A 26.6 Wed 16:15 S Fobau Physik

Mass defect of electronic transitions in atoms and ions — Simon Eilers, •Víctor J. Martínez-Lahuerta, Marius Schulte, and Klemens Hammerer — Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute), Leibniz University Hannover, Appelstrasse 2, 30167 Hannover, Germany

In this work we will 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 and the quadrupole effect caused by external fields, as recently discussed by V. Yudin and A. V. Taichenachev (Laser Phys. Lett. 15, 035703, 2018).

A 26.7 Wed 16:15 S Fobau Physik

Understanding Correlation Effects in Photoelectron Circular Dichroism — •Manel Mondelo-Martell, Christiane Koch, and Daniel Reich — Institüt für Physik, Universität Kassel, Germany

Chirality is a fundamental symmetry breaking, defined by the impossibility to superpose the mirror images of a given object, highly relevant in the fields of AMO and chemistry. Current experimental techniques based on chiral radiation–matter interactions, such as Photoelectron Circular Dichroism (PECD)[1], provide detailed information about such systems, but theoretical models are crucial for its interpretation. Accurate numerical simulation of the photoionization process is limited to ~three electron systems, and studies pursuing a time–resolved solution of the process for larger systems generally need to rely on a simplified *ansatz* to become numerically affordable, which usually leads to a poor description of electronic correlation and thus only qualitative results.

We present a time–resolved simulation of photoelectron spectra in chiral environments using the MCTDHF[2] approach. This algorithm allows for a numerically efficient representation of the wave function through the use of time–dependent basis sets, and includes electronic correlation due to its multiconfigurational character. To study the suitability of this technique for the study of chiral effects in correlated many-electron systems, the photoionization of a He atom embedded in a chiral potential will be simulated. Comparison with the TDHF approach and possible improvements will be discussed.

References [1] I. Powis, in Adv. Chem. Phys. (2008), pp. 267-329. [2] D. Hochstuhl and M. Bonitz, J. Chem. Phys. 134, 084106 (2011).

A 27: Quantum gases (Bosons) (joint session A/Q)

Time: Thursday 10:30–12:00 Location: S HS 1 Physik

A 27.1 Thu 10:30 S HS 1 Physik

Squeezed field path integral description of second sound in Bose-Einstein condensates — •Mir Heliassudin Ilias Seifie[1,2], Vijay Pal Singh[1,2,3], and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Center for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany

We propose a generalization of the Feynman path integral using squeezed coherent states by introducing a squeezing parameter into the path integral. As a result the adaptability of the theoretical model to the physical system is enhanced. 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, which gives an effective low energy description that contains both a coherent field and a squeezing field. We derive the classical trajectory of this action, which constitutes a generalization of the Gross Pitaevskii equation, at linear order. We derive the low energy excitations, which provides a description of second sound in weakly interacting condensates as a squeezing oscillation of the order parameter. This interpretation is also supported by a comparison to a numerical c-field method.

A 27.2 Thu 10:45 S HS 1 Physik

Dimensional crossover for the beyond-mean-field correction in Bose gases — •Tobias Ilg[1], Jan Kumlin[1], Luis Santos[2], Dmitry S. Petrov[3], and Hans Peter Büchler[1] — [1]Institute for Theoretical Physics III and Center for Integrated Quantum Science and

Technology, University of Stuttgart, DE-70550 Stuttgart, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, DE-30167 Hannover, Germany — [3]LPTMS, CNRS, Univ. Paris Sud, Université Paris-Saclay, 91405 Orsay, France

We present a detailed beyond-mean-field analysis of a weakly interacting Bose gas in the crossover from three to low dimensions. We find an analytical solution for the energy and provide a clear qualitative picture of the crossover in the case of a box potential with periodic boundary conditions. We show that the leading contribution of the confinement-induced resonance is of beyond-mean-field order and calculate the leading corrections in the three- and low-dimensional limits. We also characterize the crossover for harmonic potentials in a model system with particularly chosen short- and long-range interactions and show the limitations of the local-density approximation. Our analysis is applicable to Bose-Bose mixtures and gives a starting point for developing the beyond-mean-field theory in inhomogeneous systems with long-range interactions such as dipolar particles or Rydberg-dressed atoms.

A 27.3 Thu 11:00 S HS 1 Physik

Scale-invariant dynamics of an interacting 2D Bose gas — •Raphaël Saint-Jalm, Patricia Christina Marques Castilho, Édouard Le Cerf, Jean-Loup Ville, Brice Bakkali-Hassani, Sylvain Nascimbène, Jean Dalibard, and Jérôme Beugnon — Laboratoire Kastler Brossel, Collège de France, CNRS, ENS-PSL University, Sorbonne Université, 11 place Marcelin Berthelot, 75005 Paris, France

The dynamics of an interacting many-body system is usually difficult to predict fully, but some of its features can be captured if the system has underlying symmetries such as scale invariance. Here we study the dynamics of a 2D cloud of ultracold Rubidium atoms in a harmonic potential. The many-body Hamiltonian of such a system has an exact SO(2,1) symmetry and exhibits scale-invariant properties. We produce an initial cloud strongly out of equilibrium with a uniform density and a tunable shape, and observe this scale-invariant dynamics. Moreover, in the Thomas-Fermi limit where the system can be described by hydrodynamic equations, we demonstrate an additional scale invariance. We also report on the observation of particular shapes whose evolution is periodic, which we attribute to breathers of the 2D Gross-Pitaevskii equation.

A 27.4 Thu 11:15 S HS 1 Physik

Weakly Interacting Bose Gas on a Sphere — •Natália Möller[1], Vanderlei Bagnato[2], and Axel Pelster[1] — [1]Research Center OPTIMAS and Department of Physics, Technische Universität Kaiserslautern, Germany — [2]Institute of Physics of São Paulo, University of São Paulo, São Carlos, Brazil

Here we explore how to describe theoretically a weakly interacting Bose gas on a sphere. In order to derive the corresponding many-body field theory we start with considering a radial harmonic trap, which confines the three-dimensional Bose gas in the vicinity of the surface of a sphere. Following the notion of dimensional reduction as outlined in Ref. [1] we assume a large enough trap frequency so that the radial degree of freedom of the field operator is fixed despite of thermal and quantum fluctuations to the ground state of the radial harmonic trap and can be integrated out. With this we obtain an effective many-body field theory for a Bose-Einstein condensate on a quasi two-dimensional sphere, where the thickness of the cloud is determined self-consistently.

As a first example we determine the critical temperature of a Bose Gas on a sphere, where we recover in the limit of an infinitely large radius the case of a quasi two-dimensional plane with a vanishing critical temperature in accordance with the Mermin-Wagner theorem [2]. Afterwards, we analyze at zero temperature the mean-field physics of a Bose-Einstein condensate on a sphere by deriving the underlying time-dependent Gross-Pitaevskii equation.

[1] L. Salasnich et al., Phys. Rev. A **65**, 043614 (2002)
[2] N. Mermin and H. Wagner, Phys. Rev. Lett. **17**, 1133 (1966)

A 27.5 Thu 11:30 S HS 1 Physik

Quantum walks of two cobosons — •Mama Kabir Njoya Mforifoum[1], Gabriel Dufour[1,2], and Andreas Buchleitner[1] — [1]Institute of Physics, Albert-Ludwigs University of Freiburg, Germany — [2]Freiburg Institute for Advanced Studies, Albert-Ludwigs University of Freiburg, Germany

A quantum walker is a particle evolving coherently over a network of sites and therefore has the ability to interfere with itself, contrary to its classical counterpart. The extension to two-particle quantum walks leads to the introduction of interactions and many-particle interference depending on the particles' statistics (bosonic or fermionic) and their distinguishability. We compare the quantum walk of two interacting cobosons (two pairs of bounded fermions) on a 1D lattice with that of two elementary bosons, and investigate to which extent the composite nature of the cobosons affects their dynamics.

A 27.6 Thu 11:45 S HS 1 Physik

Probing the mott-insulator state in optical lattices with photoassociation collisions — •Hui Sun, Bing Yang, Zhen-sheng Yuan, and Jian-wei Pan — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

The photoassociation collision is a process two colliding atoms form an excited molecular state after absorbing a photon, which can be used to remove doublons in optical lattices. In this work, we present the detection of a bosonic Mott-insulator state in optical lattices via photoassociation collisions. The photoassociation frequency and collision strength in the 0_g^- molecular channel are calibrated in ultracold quantum gases of Rb^{87}. Then we measure the density distributions of two-dimensional Mott-insulator states in optical lattices after illuminated by a photoassociation light, which is 13.6 cm^{-1} red detuned to the D2 line. From the density profiles, we extract the temperatures of the Mott-insulators and demonstrate an improvement of the measurement precision. This new method extends our ability to probe this ultracold strongly correlated systems.

A 28: Interaction with VUV and X-ray light

Time: Thursday 10:30–12:30 Location: S HS 3 Physik

A 28.1 Thu 10:30 S HS 3 Physik

Coherent x-ray-optical control of nuclear excitons with zeptosecond phase-stability — •Kilian P. Heeg[1], Andreas Kaldun[1], Cornelius Strohm[2], Christian Ott[1], Rajagopalan Subramanian[1], Dominik Lendrodt[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

Coherent control of nuclei using near-resonant x-ray fields is an open challenge since it requires a stability of the x-ray light in the few-zeptosecond range. Based on our recent work on spectral narrowing [1], we shape single x-rays delivered by modern x-ray facilities into tunable double pulses and demonstrate control of the relative phase with the desired stability on the few-zeptosecond level [2]. We experimentally exploit this phase control to steer the nuclear dynamics and switch between stimulated emission and enhanced excitation [2]. As application, we discuss strong driving of nuclear transitions [3]. As long-term perspective, we envision time-resolved studies of nuclear out-of-equilibrium dynamics and new prospects in nuclear quantum optics.

[1] K. P. Heeg *et al.*, Science 357, 375 (2017).
[2] K. P. Heeg *et al.*, *submitted.*
[3] K. P. Heeg, C. H. Keitel, J. Evers, arXiv:1607.04116 (2016).

A 28.2 Thu 10:45 S HS 3 Physik

Unexpected Polarization Transfer Echos in Atomic Inner-Shell Two-photon Ionization — •Jiri Hofbrucker[1,2,3], Andrey Volotka[1,3], and Stephan Fritzsche[1,2,3] — [1]Helmholtz-Institute, Jena, Germany — [2]Friedrich-Schiller Universität, Jena, Germany — [3]GSI, Darmstadt, Germany

Unexpected polarization transfer from incident to fluorescence photon is discovered in the case of two-photon inner-shell ionization by circularly polarized light. Beside the expected complete polarization transfer induced at incident photon energy tuned to intermediate resonances, echos of the polarization transfer occur at higher nonresonant incident photon energies due to vanishing of the dominant ionization channel. Measuring the polarization properties of the fluorescence light promises an opportunity to extract ionization properties out of an experiment with an unprecedented accuracy and carry out a critical comparison with available theory.

A 28.3 Thu 11:00 S HS 3 Physik

Photoionoization of low charged silicon ions — •Ticia Buhr[1], Alexander Perry-Sassmannshausen[1], Sebastian Stock[2,3], Jens Buck[4], Simon Reinwardt[5], Michael Martins[5], Sándor Ricz[6], 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]FS-PE, DESY, Hamburg, Germany — [5]Universität Hamburg, Germany — [6]Institute for Nuclear Research, Hungarian Academy of Sciences, Debrecen, Hungary

Single and multiple photoionization of low charged atomic silicon ions (Si^{1+}, Si^{2+} and Si^{3+}) have been investigated in the vicinity of the silicon K-edge using the PIPE setup [1] at the beam line P04 of the synchrotron light source PETRA III (Hamburg, Germany) employing the photon-ion merged-beams technique. Absolute cross sections, precise K-shell ionization resonance parameters (positions, widths and strengths) for these ions and branching ratios for the various production charge states have been determined. The experimental results are compared with theoretical calculations. Such data are of immediate interest for x-ray astrophysics [2].

[1] S. Schippers *et al.*, J. Phys. B **47**, 115602 (2014).
[2] T. Holczer *et al.*, Astrophys. J. **708**, 981 (2010).

A 28.4 Thu 11:15 S HS 3 Physik

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** (2016) 041401(R)
[4] S. Schippers et al., J. Phys. B **47**, 115602 (2014)

A 28.5 Thu 11:30 S HS 3 Physik

Time-resolved XUV refraction using a gas-phase prism — Lorenz Drescher, Oleg Kornilov, Tobias Witting, Jochen Mikosch, Marc Vrakking, and •Bernd Schütte — Max-Born-Institut, Berlin

Recently, we have demonstrated the first refractive lens and the first refractive prism for XUV beams, which are based on the deflection of XUV radiation in an inhomogeneous atomic jet [1]. These results make it possible to transfer techniques that rely on refraction and that are well established in other spectral regions to the XUV domain.

Here we report on the time-resolved investigation of XUV refraction using a gas-phase prism. A broadband XUV pulse induces electric dipoles in a dense He jet that relax via free induction decay, thereby emitting phase-shifted XUV radiation. A time-delayed NIR pulse is used to perturb the free induction decay, leading to a time-dependent suppression of the refracted XUV signal. This allows us to measure the angle-dependent XUV pulse duration, which we find to increase with increasing deflection angle. The XUV pulse duration can be further controlled by varying the gas backing pressure. Our results demonstrate that gas-phase XUV prisms can be used as monochromators for broadband XUV radiation, enabling the generation of ultrashort XUV pulses with bandwidths ranging from the (sub-)meV level to hundreds of meV. In the future, the combination of gas-phase prisms with pump-probe techniques could be exploited to study and control transient refractive index changes in atoms and molecules in the XUV region.

[1] L. Drescher *et al.*, Nature doi.org/10.1038/s41586-018-0737-3

A 28.6 Thu 11:45 S HS 3 Physik

Dispersive soft x-ray absorption fine-structure spectroscopy in graphite with an attosecond pulse — Bárbara Buades[1], •Themistoklis P. H. Sidiropoulos[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 28.7 Thu 12:00 S HS 3 Physik

Relativistic and resonant effects on x-ray multiphoton multiple ionization of heavy atoms — •Sang-Kil Son[1], Koudai Toyota[1], Robin Santra[1,2], Benedikt Rudek[3], Artem Rudenko[4], and Daniel Rolles[4,5] — [1]Center for Free-Electron Laser Science, DESY, Hamburg — [2]Department of Physics, Universität Hamburg, Hamburg — [3]Physikalisch-Technische Bundesanstalt, Braunschweig — [4]J. R. Macdonald Laboratory, Department of Physics, Kansas State University, Manhattan, KS, USA — [5]Deutsches Elektronen-Synchrotron (DESY), Hamburg

An accurate description of the interaction of intense hard x-ray pulses with heavy atoms, which is crucial for many applications of x-ray free-electron lasers (XFELs), represents a hitherto unresolved challenge for theory because of the enormous number of electronic configurations and relativistic effects to be taken into account. Here we present a joint experimental and theoretical study of xenon atoms irradiated by unprecedentedly high-intensity hard x-rays up to 2×10^{19} W/cm^2. Our results show the interplay of relativistic and resonant effects on x-ray multiphoton multiple ionization of heavy atoms and demonstrate the predictive power of the theoretical model, which provides a basis for accurate modeling of radiation damage in XFEL experiments.

A 28.8 Thu 12:15 S HS 3 Physik

Extreme Ultraviolet Core-Exciton Dynamics in Two-dimensional Molybdenum Disulfide — •Michael Zürch[1,8], Hung-Tzu Chang[1], Alexander Guggenmos[1], Diana Y. Qiu[2,3], Romain Geneaux[1], Yen-Chang Chen[4,5], Xuan Wei[5], Chang-Ming Jiang[6,7], Yufeng Liang[4], Felipe H da Jornada[2,3], Adam Schwartzberg[4], David Prendergast[4], Vincent C. Tung[5], Steven G. Louie[2,3], Daniel M. Neumark[1,6], and Stephen R. Leone[1,2,6] — [1]Department of Chemistry, University of California, Berkeley, USA — [2]Department of Physics, University of California, Berkeley, USA — [3]Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, USA — [4]Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, USA — [5]School of Engineering, University of California, Merced, USA — [6]Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, USA — [7]Joint Center of Artificial Photosynthesis, LBNL, Berkeley, USA — [8]Fritz Haber Institute of the Max Planck Society, Berlin, Germany

Novel tightly-bound core-excitons triggered by an XUV attosecond pulse are observed in two-dimensional transition-metal dichalcogenide molybdenum disulfide. State-of-the-art theory calculations confirm the observed features. The dynamics observed in the core-exciton states between the molybdenum 4p and 4d states indicate coherences, and population transfer between different states. The observation of strongly enhanced long-lived core excitons in two-dimensional semiconductors paves the way for further exploration into the properties of core excitons in two-dimensional materials and potential application of these.

A 29: Cluster III (joint session MO/A)

Time: Thursday 10:30–12:30 Location: S HS 001 Biologie

Invited Talk A 29.1 Thu 10:30 S HS 001 Biologie
Optical spectroscopy of small metal clusters: a deeper look at Au_4^+ — •Marko Förstel, Wolfgang Schewe, and Otto Dopfer — TU Berlin, IOAP, Hardenbergstr. 36, 10623 Berlin

The catalytic properties of small metal clusters strongly depend on local structure. This is especially the case for very small clusters, where every new atom changes the physical and thus catalytic properties tremendously. For example, gold clusters show catalytic properties at sizes down to three atoms!

With a new setup we were able to measure the optical absorption spectrum of such small gold clusters in hitherto unavailable quality.[1] These spectra allow for the first time to directly access the structure of the ground and excited state via comparison of the measured vibrational frequencies and Franck-Condon progressions to those from calculated structures. Surprisingly, we find that the optical spectrum cannot be explained by assuming that it stems solely from the rhombic ground state structure of Au_4^+.[2]

[1] M. Förstel, B. K. A. Jaeger, W. Schewe, P. H. A. Sporkhorst, O. Dopfer, Improved tandem mass spectrometer coupled to a laser vaporization cluster ion source Rev. Sci. Instr. 2017, 88, 123110.

[2] M. Förstel, W. Schewe, O. Dopfer, Optical spectroscopy of the Au_4^+ cluster: Resolved vibronic structure indicates an unexpected isomer, *submitted.*

A 29.2 Thu 11:00 S HS 001 Biologie
Activation of Methane by Free Gold Clusters: Ion-Trap Kinetics, IR-Spectroscopy, and Ab Initio Theory — •Thorsten Bernhardt[1], Sandra Lang[1], Joost Bakker[2], Robert Barnett[3], and Uzi Landman[3] — [1]Institute of Surface Chemistry and Catalysis, University of Ulm, 89069 Ulm, Germany — [2]Institute for Molecules and Materials, FELIX Laboratory, 6525 ED Nijmegen, The Netherlands — [3]School of Physics, Georgia Institute of Technology, Atlanta, Georgia 30332-0430, USA

Amongst all the metals gold exhibits the least inclination to undergo chemical reactions with other elements. It is therefore even more surprising that few nanometer sized gold particles and gold clusters consisting of very few atoms display excellent catalytic properties. In order to demonstrate the ability of small gold clusters to activate methane, we previously performed gas phase reaction kinetics experiments in an octopole ion trap. These experimental studies revealed the particular catalytic properties of the gold dimer to activate methane and to convert two methane molecules to ethylene at thermal reaction conditions. These experiments have now been complemented by infrared multi photon dissociation experiments employing the free electron laser FELICE at the University of Nijmegen. These spectroscopy investigations demonstrated that the interaction of methane with small gold cluster cations leads to selective C-H-bond dissociation and the formation of hydrido-methyl complexes.

A 29.3 Thu 11:15 S HS 001 Biologie
Interspecies energy transfer in heterogeneous Ar_2-N_2 clusters quenching predissociation — •Huda Otto, Dana Bloss, Andreas Hans, Xaver Holzapfel, Catmarna Küstner-Wetekam, Christian Ozga, Philipp Schmidt, Arno Ehresmann, and André Knie — Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

Loosely bound systems, like Ar_2, are of technical and biological interest. For example, the Ar dimer (Ar_2) is used as a medium in excimer lamps, and decay processes in such noble gas dimers are showcase examples to explain radiation damage in organic tissues. Ar_2 consists of two *van-der-Waals bound* Ar atoms. This binding type affects the energy transfer between van-der-Waals bound atoms, called clusters. Doping an Ar cluster with a molecule, like N_2, allows to investigate the effect of molecular vibrations on energy transfers in a loosely bound environment. Here, different vibronic states of N_2 in an Ar_2-N_2 cluster were addressed. In gaseous N_2 the resonant excitation of these vibronic states lead to non-radiative predissociation, whereas if the N_2 is van-der-Waals bound on an Ar cluster, the absorbed energy is redistributed within the cluster, resulting in photon emission from perturbed Ar dimers. Thus, an interspecies energy transfer from a N_2 molecule to an Ar dimer must occur. During the talk evidences for the interspecies energy transfer in heterogeneous Ar_2-N_2 clusters will be discussed further.

A 29.4 Thu 11:30 S HS 001 Biologie
Electron and photon interactions with size-selected lead clusters — Steffi Bandelow, •Alexander Jankowski, Stephan König, Gerrit Marx, Lutz Schweikhard, and Markus Wolfram — Institute for Physics, University of Greifswald, Germany

At the ClusterTrap-setup [1], the dissociation pattern of photoexcited lead cluster ions has been of interest in recent studies [2,3]. It was shown that lead transitions from a metallic [4] to a non-metallic fragmentation behavior [2] when approaching smaller cluster sizes. In further investigations, size-selected trapped negatively charged lead clusters are exposed to an electron beam. This leads to electron attachment [5,6] as well as collision-induced dissociation [6]. The resulting product ions reveal first hints of fission processes, where doubly negatively charged clusters break up into two singly charged fragments. The most prominent fragments observed are Pb_{10}^{1-}, and Pb_{n-10}^{1-}, where n is the precursor cluster size. This interpretation is confirmed by photodissociation studies of size- and charge-state selected dianionic lead clusters [7].

[1] F. Martinez *et al., Int. J. Mass Spectrom.* 365-366 (2014) 266.
[2] S. König *et al., J. Phys. Chem. C* 121 (2017) 10858.
[3] M. Wolfram *et al., J. Phys. B: At. Mol. Opt.* 51 (2018) 044005.
[4] P.J. Brucat *et al., J. Chem. Phys.* 84 (1986) 3078.
[5] A. Herlert *et al., Phys. Scripta* T80 (1999) 200.
[6] S. König *et al., Int. J. Mass Spectrom.* 421 (2017) 129.
[7] S. König *et al., Phys. Rev. Lett.* 120 (2018) 163001.

A 29.5 Thu 11:45 S HS 001 Biologie
Photophysics investigation of pyrrole and pyrrole-water$_1$ clusters — •Melby Johny[1], Sebastian Trippel[1,2], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Hamburg — [2]The Hamburg Center for Ultrafast Imaging, Universität Hamburg, Hamburg — [3]Department of Physics, Universität Hamburg, Hamburg

The properties of atoms and molecules are strongly dependent on their local environment and hydrogen bonds are of universal importance in chemistry and biochemistry. Therefore, it is highly desirable to bridge the gap between single, isolated molecules and molecules in solvation.

Here, we show the investigation of the photophysics of pyrrole and the single hydrogen bonded pyrrole-water$_1$ clusters via site-specific x-ray ionisation and strong field ionisation by intense near-infrared laser pulses. The photo-fragmentation owing to core-shell ionisation at nitrogen(N 1s) were analyzed by means of photoelectron photoion-photoion coincidence(PEPIPICO) imaging. A 3D-imaging detector, Timepix3 was used for coincidence detection of strong field ionisation of pyrrole and pyrrole-water$_1$. For pyrrole-water$_1$ clusters, we observed proton or hydrogen atom transfer from pyrrole moiety to the hydrogen bonded water molecule and the fragmentation dynamics is significantly different from bare pyrrole.

A 29.6 Thu 12:00 S HS 001 Biologie
Superelectrophilic Behaviour of closo-Dodecaborate Monoanions — Knut R. Asmis[1], Martin Mayer[1], Jonas Warneke[2], and •Max Grellmann[1] — [1]Wilhelm-Ostwald-Institut

für Physikalische und Theoretische Chemie, Universität Leipzig, Linnestr. 2, 04103 Leipzig (Germany) — [2]Department of Chemistry, Purdue University, West Lafayette, IN 47907 (USA)

Bond formation with an electron-rich system, known as electrophilicity, is commonly observed in electron-deficient molecules. Binding noble gases at room temperature was a marking property predominantly of strong, dicationic systems, therefore termed as *superelectrophiles*. Gas-phase skimmer collision induced dissociation (sCID) lead to the formation of closo-dodecaborate monoanions [B12X11]-, showing a high reactivity towards electron-rich systems for instance dinitrogen, dioxygen and noble gases (Ngs). In particular, the clusters [B12X11]- (X = Cl, CN) have been observed to form spontaneously B-Ng bonds with a substantial degree of covalent interaction, thus showing a superelectrophilic behaviour despite being negatively charged. A significant blue shift of the CO stretching mode when bound with its carbon tail to a closo-dodecaborate monoanion, observed by using infrared photodissociation (IRPD) spectroscopy, verified the suspected electron-deficiency at the binding site of the cluster. Quantum chemical calculations revealed that the anions unite several molecular properties, which lead to a dipole discriminating chemistry, facilitating the addition of Ngs. On this account, small dipole moments of alkanes could be a promising property to introduce the anions into C-H-bond activation.

A 29.7 Thu 12:15 S HS 001 Biologie

Photofragmentation of small bismuth clusters — •Paul Fischer, Gerrit Marx, and Lutz Schweikhard — Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

Bismuth clusters $Bi_n^{+/-}$ in the size range $n = 2$ to 19 have been produced by laser ablation and stored in an electrostatic ion beam trap (EIBT) [1,2]. The trap allows the retention of size-selected ions and their separation from contaminant ions with high resolving powers [3].

Photofragmentation has been performed by use of nanosecond laser pulses ($\lambda = 532$nm). Product patterns include multiple cluster sizes, depending on the selected precursor. To further investigate the fragmentation pathways of the clusters, parameters such as the laser-pulse energy and timing have been varied. In many cases, the preliminary data evaluation suggests pathway competition and only a few sequential decays. The size of the primary neutral fragment being evaporated shifts with increasing precursor cluster size.

[1] H. Wollnik et al., J. Mass Spectrom. Ion Processes 96(3):267-274(1990)
[2] D. Zajfman et al., Phys. Rev. A 55:R1577-R1580(1997)
[3] P. Fischer et al., Rev. Sci. Instrum. 89:015114(2018)

A 30: Atomic Physics, Molecular Physics, and Quantum Optics with X-ray FELs (joint session MO/A)

Time: Thursday 10:30–12:30 Location: S HS 002 Biologie

A 30.1 Thu 10:30 S HS 002 Biologie

Nanodroplet production and characterization for single particle X-ray diffractive imaging — •Amine Gourram[1], Armando Estillore[1], Daniel Horke[1,3], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany — [3]The Hamburg Center for Ultrafast Imaging, University of Hamburg, Hamburg, Germany

X-ray diffractive imaging of single molecules or nanoparticles at free-electron lasers allows the extraction of structural information at sub-nanometer resolution [1]. However, this requires the efficient production and delivery of isolated samples into the x-ray beam. We present our proposed aerosol source for the efficient production of a high-density aerosol of sub-100~nm nanoparticles, based on electrospray aerosolisation. The produced aerosol source will be characterized regarding its efficiency and density for different nanoparticle types and sizes using optical light scattering measurement [2] and differential particle mobility analysers.

[1] Seibert et al., Nature 470, 78-81 (2011) [2] Awel et al., Opt. Express 24, 6507-6521 (2016)

A 30.2 Thu 10:45 S HS 002 Biologie

3D sensitive diffractive imaging of metal cluster shape transitions — •J. Jordan[1], S. Dold[2], I. Barke[3], P. Behrens[1], N. Bernhardt[1], J. Correa[4], S. Düsterer[4], B. Erk[4], L. Hecht[1], A. Heilrath[1], H. Hartmann[3], R. Irsig[3], N. Iwe[3], B. Kruse[3], B. Langbehn[1], B. Manschwetus[4], F. Martinez[3], K. Oldenburg[3], C. Passow[4], C. Peltz[3], F. Seel[1], R. Tanyag[5], R. Treusch[4], A. Ulmer[1], S. Walz[1], K.-H. Meiwes-Broer[3], T. Fennel[3,5], B. v. Issendorff[2], T. Möller[1], and D. Rupp[1,5] — [1]TU Berlin — [2]Univ. Freiburg — [3]Univ.Rostock — [4]FLASH@DESY — [5]MBI Berlin

With their ability to deliver ultra-short X-ray pulses of high brilliance, free-electron lasers (FELs) have opened up new possibilities for natural sciences. In cluster physics, FELs have been used to investigate fundamental light-matter interactions and create scattering images of single clusters in free flight for structure determination. In particular, gas phase metal clusters exhibit a large variety of shapes that are very sensitive to the growth conditions. Their shape can be altered by soft heating, leading to a reordering of the crystal lattice or melting of the surface. In order to image these changes and record their intrinsic timescale, we performed a pump-probe experiment at the FLASH FEL in Hamburg. Silver clusters were produced using a magnetron sputter source and subsequently heated with a picosecond-long, weak optical laser pulse. The temporal evolution of the shapes after excitation was traced by recording wide-angle scattering images that enable a 3D sensitive shape retrieval.

A 30.3 Thu 11:00 S HS 002 Biologie

Neural Networks for Reconstruction of Nanoclusters from Soft X-Ray Scattering Images — •Thomas Stielow, Robin Schmidt, Thomas Fennel, and Stefan Scheel — Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23, 18059 Rostock

Single-shot diffraction imaging by soft X-ray laser pulses is a valuable tool for structural analyses of unsupported and short-lived nanosystems, although inversion of the scattering patterns still prove challenging. Deep learning, on the other hand, is widely used in data sciences for the extraction of information from images and sees more and more application in various sciences. We demonstrate how neural networks can be utilized for full reconstructions of nanoclusters from single-shot wide angle scattering images. Our networks are trained solely on existing physical theories and can be applied to real-world experimental data without limitation to a specific setup due to its robustness. With deep learning, high quality real time evalutation for the next generation FEL systems can finally be implemented.

A 30.4 Thu 11:15 S HS 002 Biologie

Controlling nanoparticles with external fields — •Jannik Lübke[1], Salah Awel[1,4], Armando Estillore[1], Nils Roth[1,2], Amit Samanta[1], Lena Worbs[1], Daniel Horke[1,4], and Jochen Küpper[1,2,3,4] — [1]Center for Free-Electron Laser Science (CFEL), Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Department of Physics, Universität Hamburg, Germany — [3]Department of Chemistry, Universität Hamburg, Germany — [4]The Hamburg Center for Ultrafast Imaging (CUI), Universität Hamburg,

In single-particle coherent x-ray diffraction experiments, diffraction patterns are recorded from individual sample particles. To overcome the inherently small signal-to-noise ratio, large numbers of identical particles need to be controlled and guided subsequently into the small focus of free-electron lasers (FELs). We establish particle control for example *via* electrostatic deflection or optical guiding in tractor beams [1], ultimately aiming at delivering one nanoparticle at a time into successive FEL shots.

[1] Eckerskorn et al., *Proc. SPIE* **9548**, 95480H1-95480H12, 2015

A 30.5 Thu 11:30 S HS 002 Biologie

Detecting ultrafast hole dynamics in water using x-ray transient absorption — •Caroline Arnold[1,2,4], Ludger Inhester[1], Ralph Welsch[1,4], Linda Young[3], and Robin Santra[1,2,4] — [1]Deutsches Elektronensynchrotron DESY, Hamburg — [2]Universität Hamburg — [3]Argonne National Laboratory, USA — [4]Centre for Ul-

trafast Imaging, Hamburg

The dynamics that unfold in aqueous solutions on a molecular time scale are of direct relevance to biological and chemical processes. For example, radiation damage in biological tissues is caused by the photoionization of liquid water. The early steps of radiation damage can be understood by following the electron-hole pair dynamics with femtosecond time-resolution. While the hydrated electron has been addressed in experiments, the dynamics of the residual cation remains elusive. Today's XFEL sources allow to detect the hole by resonant x-ray absorption spectroscopy at the oxygen K-edge with femtosecond time resolution.

We present a theoretical, *ab initio* description of the hole dynamics in ionized water and the resulting x-ray absorption spectra. To this end, we consider excited-state molecular dynamics in liquid water following the removal of an electron from the valence band in a quantum-classical, QM/MM scheme including non-adiabatic transitions. We present first results on time-resolved x-ray absorption spectra in the first 100 femtoseconds following photoionization and discuss their use as a probe for hole dynamics.

A 30.6 Thu 11:45 S HS 002 Biologie

X-ray emission spectroscopy using dispersive spectrometers at Synchrotron and X-ray FEL facilities — •Florian Otte[1,2], Christian Bressler[2], and Metin Tolan[1] — [1]Technische Universität Dortmund, Emil-Figge-Straße 50, 44227 Dortmund, Deutschland — [2]European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld, Deutschland

Crystal spectrometers which enable the energy dispersive detection of X-ray fluorescence during irradiation with intense X-rays have found widespread distribution among X-ray facilities worldwide. Different designs and types exist, but all of them appeal through their ability to track electronic and magnetic properties of samples via characteristic features in X-ray emission signals during the experiment. Which electronic and magnetic properties are accessible specifically, is case and spectrometer dependent. We report on the use of an energy-dispersive von Hamos type spectrometer, which is being used at the FXE instrument at European XFEL GmbH on a regular basis in combination with additional complimentary experimental techniques such as X-ray diffraction for detection of K-edge emission lines on transition metal complexes. A smaller and highly mobile version of this spectrometer type has been successfully used at different beamlines (e.g. P01 at Petra III in Hamburg, Bl9 at DELTA in Dortmund). The highly flexible nature of this spectrometer type is rationalized with experimental results on transition metal complexes. Advantages and disadvantages in comparison with other available spectrometer types are discussed, with special consideration of applications at modern FELs.

A 30.7 Thu 12:00 S HS 002 Biologie

Giant Enhancement of Molecular Ionization at High X-ray Intensity — •Ludger Inhester[1], Yajiang Hao[2], Sang-Kil Son[1], and Robin Santra[1,3] — [1]Center or Free-Electron Laser Science, DESY, Hamburg — [2]Department of Physics, University of Science and Technology Beijing — [3]Department of Physics, Universität Hamburg

The ultraintense and ultrashort x-ray pulses provided by X-ray Free-Electron Lasers (XFELs) sequentially ionize molecular samples many times. We have developed an ab-initio electronic structure toolkit, XMOLECULE[1,2], that models this multiple ionization dynamics. Our calculations show that the rearrangement of charges between different parts of a molecule plays an important role for the ion yield distribution. In this context, we have recently discovered that under intense x-ray radiation the total charge yield of a molecule is enhanced compared to independent atoms[2,3].

We report here on new theoretical results for iodobenzene (C_6H_5I) that show an even stronger ionization enhancement than previously observed for iodomethane (CH_3I)[3]. This finding emphasizes the relevance of the charge-rearrangement-enhanced X-ray ionization of molecules (CREXIM) for the radiation damage in experiments with tightly focused XFEL beams.

[1] Struct. Dyn. 2, 041707 (2015). [2] Phys. Rev. A 94, 023422 (2016) [3] Nature 546, 129-132 (2017)

A 30.8 Thu 12:15 S HS 002 Biologie

The Auger effect in dispersing and absorbing environments — •Janine Franz[1], Stefan Yoshi Buhmann[1,2], and Robert Bennett[1,2] — [1]Institute of Physics, University of Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS), Germany

The Auger effect is the radiationless decay of an inner-shell ionised atom. In this process, the atom relaxes by filling the inner vacancy with an outer shell electron, but instead of releasing the excess energy in form of a photon (spontaneous decay) the energy is reabsorbed by another electron belonging to the same atom. This effect finds many applications: for example in Auger electron spectroscopy, it is used to study material properties of surfaces.

It is well established that dielectric environments can have a significant impact on spontaneous decay (Purcell effect) [1] as well as interatomic energy transfer rates [2]. We present a general expression for the intra-atomic Auger process in the presence of dielectric environments that can be used both as a new starting point for ab initio quantum chemistry, or within the quantum-optical formalism of macroscopic quantum electrodynamics in order to circumvent complex numerics. Within our description, the decay rate can be given in analytical form for some simple environments. We compare Auger decay with a competing process known as interatomic Coulombic decay, focussing on their behaviour in the presence of surfaces.

[1] E. M. Purcell, Proc. Am. Phys. Soc. 69, 674 (1946).

[2] J. L. Hemmerich, R. Bennett and S. Y. Buhmann, Nature Commun. 9, 2934 (2018).

A 31: Quantum gases (Fermions) (joint session A/Q)

Time: Thursday 14:00–16:15 Location: S HS 1 Physik

A 31.1 Thu 14:00 S HS 1 Physik

Dynamical Observation of Spin-Charge Separation in Hubbard Chains — •Jayadev Vijayan[1], Pimonpan Sompet[1], Joannis Koepsell[1], Guillaume Salomon[1], Sarah Hirthe[1], Dominik Bourgund[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Ludwig-Maximilians-Universität, München

Ultracold atoms in optical lattices have emerged as a powerful tool in the quantum simulation of the Fermi-Hubbard model. With access to full spin and density resolution, our quantum gas microscope has enabled the study of the interplay between spin and charge in doped antiferromagnets. In one-dimensinal chains, the phenomenon of spin-charge separation decouples the spin and charge degrees of freedom, encoded in spinons and holons, which propagate at different velocities. We probe this phenomenon by preparing an antiferromagnet and locally quenching it by removing an atom, thereby creating a holon and a spinon. By observing their dynamical evolution, we extract different velocities for these quasi-particles.

A 31.2 Thu 14:15 S HS 1 Physik

Non-Equilibrium Dynamics Induced by Interaction Quenches in Ultra-Cold Fermi Gases — •Andreas Kell[1], Benjamin Rauf[1], Martin Link[1], Kuiyi Gao[1], Alexandra Behrle[1], Timothy Harrison[1], Johannes Kombe[2], Jean-Sebastien Bernier[2], Corinna Kollath[2], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Bonn, Germany — [2]HISKP, University of Bonn, Bonn, Germany

Ultra-cold Fermi gases with tuneable interactions have gathered much interest in the last decade as an excellent tool for the investigation of the BEC-BCS crossover. The Cooper-pairing dynamics and thermalisation in a strongly interacting Fermi gas are not well understood, as the non-equilibrium dynamics upon a quench of the interaction strength 1/kFa are difficult to study both in theory and in experiment. We present our recent measurement results on the dynamics observed in fast changes of the interaction parameter.

A 31.3 Thu 14:30 S HS 1 Physik

Suppression and revival of long-range ferromagnetic order in the multiorbital Fermi-Hubbard model — •Agnieszka Cichy[1], Andrii Sotnikov[2], and Yeimer Zambrano[1] — [1]Adam Mickiewicz University, Poznań, Poland — [2]Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine

The impressive development of experimental techniques in ultracold quantum degenerate gases of alkaline-earth-like (e.g., ^{173}Yb) atoms in recent years has allowed investigation of strongly correlated multiorbital systems. Long-lived metastable electronic states in combination with decoupled nuclear spin give the opportunity to study the Hamiltonians beyond the possibilities of current alkali-based experiments. Motivated by recent experimental progress, by means of dynamical mean-field theory allowing for complete account of SU(2) rotational symmetry of interactions between spin-1/2 particles [1], we observe a strong effect of suppression of ferromagnetic order in the multiorbital Fermi-Hubbard model in comparison with a widely used restriction to density-density interactions. We analyze a connection to the double-exchange model and observe high importance of spin-flip processes there as well. Additional implications on the strongly correlated phases originating from differences between the optical-lattice realizations and interacting electrons in solid state systems are discussed.

[1] A. Sotnikov, A. Cichy, and J. Kuneš, Phys. Rev. B **97**, 235157 (2018).

A 31.4 Thu 14:45 S HS 1 Physik

Exact numerical simulations of periodically-driven one-dimensional extended Hubbard model — •Junichi Okamoto[1], Michael Thoss[1], and Shunske Sato[2] — [1]Institute of Physics, University of Freiburg, Freiburg, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany

Periodically driven many-body systems offer a new route to realize novel model Hamiltonians via Floquet engineering. Notable examples in cold atom systems are: controlling topology of a band structure [1], creating artificial gauge fields [2], and changing tunneling rate [3]. Here, we study a periodically driven one-dimensional extended Hubbard model with an exact time-dependent Schrödinger equation solver. We find that the rapid oscillation of external fields suppresses the tunneling rate, which leads to a metal-insulator transition. We look at the order parameters and transient conductivity to characterize the transition, and show that these quantities do not necessarily correspond to each other as in the equilibrium situations. Further more, two different definitions of transient conductivity give slightly different results. We also show that such a dynamical transition can be well captured by a Floquet effective Hamiltonian when the driving frequency is large enough.

[1] M. Tarnowski et al., Phys. Rev. Lett. 118, 240403 (2017) [2] J. Struck et al., Nature Physics 9, 738 (2013) [3] C. Sias et al., Phys. Rev. Lett. 100, 040404 (2008)

A 31.5 Thu 15:00 S HS 1 Physik

Dynamics in the Dissipative Fermi-Hubbard Model — •Lukas Freystatzky[1,2], Koen Sponsele[1], Benjamin Abeln[1], Marcel Diem[1], Bastian Hundt[1], André Kochanke[1], Thomas Ponath[1], Bodhaditya Santra[1], Klaus Sengstock[1,2,3], Christoph Becker[1,3], and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We study the decay dynamics of metastable ^{173}Yb atoms in a one dimensional lattice realizing a dissipative Fermi-Hubbard model. The dynamics are governed by the coherent evolution due to the Hamiltonian as well as an inelastic scattering process leading to two particle losses. We model the system with a Master equation approach and observe that the system is quickly driven into highly correlated Dicke states, which do not show dissipation any more. We observe a qualitatively similar result in experiment, and study the dependence of the particle number of the steady state on various parameters, motivated by the experimental findings.

The creation of strongly correlated states is a robust phenomenon and the dissipation can potentially be used to drive the system to very specific states, offering interesting opportunities for precision measurements.

A 31.6 Thu 15:15 S HS 1 Physik

Density-wave steady-state phase of dissipative ultracold fermions with nearest-neighbor interactions — Jaromir Panas[1], •Michael Pasek[1], Arya Dhar[1,2], Tao Qin[1], Andreas Geissler[1,3], Mohsen Hafez-Torbati[1], Max Erich Sorantin[4], Irakli Titvinidze[4], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [3]ISIS, University of Strasbourg and CNRS, 67000 Strasbourg, France — [4]Institute of Theoretical and Computational Physics, Graz University of Technology, 8010 Graz, Austria

We investigate the effect of local dissipation on the presence of density-wave ordering in spinful fermions with both local and nearest-neighbor interactions as described by the extended Hubbard model. We find density-wave order to be robust against decoherence effects up to a critical point where the system becomes homogeneous with no spatial ordering. These results should be relevant for future cold-atom experiments using fermions with non-local interactions arising from the dressing by highly-excited Rydberg states, which have finite lifetimes due to spontaneous emission processes.

A 31.7 Thu 15:30 S HS 1 Physik

Easing the sign problem — •Dominik Hangleiter[1], Ingo Roth[1], Daniel Nagaj[2], and Jens Eisert[1] — [1]Freie Universität Berlin, 14195 Berlin — [2]Slovak Academy of Sciences, Bratislava, Slovakia

Quantum Monte Carlo (QMC) methods are the gold standard for studying equilibrium properties of quantum many-body systems – their phase transitions, their ground and thermal state properties. The idea lying at the heart of QMC methods is to sample out expectation values or partition functions by expanding these quantities in a basis. However, such methods face a severe limitation for many quantum systems, in particular so for fermionic systems. This limitation has been dubbed the ‘sign problem’ of QMC, referring to the situation in which the distribution to be sampled from is non-positive. Here, we take a systematic approach towards alleviating the sign problem by local basis changes, realising that it is a basis-dependent property. Going beyond previous work on exactly ‘curing’ the sign problem, we consider the optimization problem of finding the basis in which the sign problem is smallest and refer to this problem as ‘easing’ the sign problem. We then show that easing the sign problem can be a computationally hard task, even in situations in which finding an exact solution or deciding if such a solution exists is easy.

Invited Talk A 31.8 Thu 15:45 S HS 1 Physik

String patterns in the doped Hubbard model — •Daniel Greif — Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Quantum simulation is rapidly emerging as a powerful technique to understand the physics of strongly correlated materials. Quantum gas microscopy is perfectly suited to study the Fermi-Hubbard model, a model widely believed to capture the physics of high-temperature superconductivity. In this talk I will discuss how we search for specific patterns within many individual images of realizations of strongly correlated ultracold fermions in an optical lattice. Upon doping a cold-atom antiferromagnet we find signatures of geometric strings, entities suggested to explain the relationship between hole motion and spin order. We compare both our pattern-based and conventional experimental observables to theoretical predictions, and find very good agreement to a geometric theory of strings, as well as to a pi-flux model of spin liquids. Our results demonstrate the potential for pattern recognition and more advanced computational algorithms including machine learning to provide key insights into cold-atom quantum many-body systems.

A 32: Collisions, scattering and correlation phenomena

Time: Thursday 14:00–16:00 Location: S HS 3 Physik

Invited Talk A 32.1 Thu 14:00 S HS 3 Physik

Time-resolved dynamics of slow photoelectrons in the rescattering regime — •Martin Ranke[1,3], Sophie Walther[1,3], Anastasios Dimitriou[1,3], Mark J. Prandolini[1], Markus Pfau[1,3], Thomas Gebert[2], Marek Wieland[1,3], Markus Drescher[1,3], and Ulrike Frühling[1,3] — [1]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Max-Planck-Institut für Struktur und Dynamik der Materie, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging CUI, Luruper Chaussee 149, 22761 Hamburg, Germany

Acceleration of photoelectrons with intense light fields is an essential process in strong field laser physics. When the momentum change due to the light field acceleration is large, the electrons can be decelerated and scattered from the ionic core. This process is of fundamental importance, for example, in high harmonic generation. Here, we experimentally investigate the dynamics of slow photoelectrons generated by multi-photon ionization of Xe with an infrared (IR) laser pulse using a femtosecond streak camera. The ejected photoelectrons are superimposed with an intense carrier envelope phase stable terahertz (THz) light field strong enough to allow for rescattering. We observed a strong modulation of the photoelectron momentum distribution for different phases between the THz and IR laser fields. The angular momentum distribution is measured using a velocity map imaging (VMI) spectrometer with a novel gas injection design, which provides high target gas densities while preserving its momentum resolution.

A 32.2 Thu 14:30 S HS 3 Physik

The virtual photon approximation for three-body interatomic Coulombic decay — •Robert Bennett[1,2], Petra Votavová[3], Přemysl Kolorenč[3], Tsveta Miteva[4], Nicolas Sisourat[4], and Stefan Yoshi Buhmann[1,2] — [1]Albert Ludwigs University of Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS) — [3]Charles University, Prague, Czech Republic — [4]Sorbonne Université, Paris, France

Interatomic Coulombic decay (ICD) is an ultrafast process by which energy can be exchanged between microscopic systems. Computational quantum chemistry studies of the process usually use a 'virtual photon approximation' to determine the correct long-range asymptote of the ICD rate, which is then used as a consistency check. Using the macroscopic quantum electrodynamics formalism recently presented in [1], we extend the virtual photon approach to the case of three-body ICD [2], inspired by the prediction of a novel superexchange process from ab initio quantum chemistry [3]. The system we study is that in which a passive mediating atom is placed near the donor and acceptor species — the mediator's presence turns out to substantially enhance or suppress the rate. Our approach provides simple analytic formulae for the large-distance limits of three-body ICD, and allows for the inclusion of relativistic retardation. The latter turns out to have a strong effect, causing, for example, spatial oscillations in the ICD rate.

[1] J. L. Hemmerich et al., Nat. Commun. **9**, 2934 (2018). [2] R. Bennett et al., arXiv quant-ph 1811.09489, [3] T. Miteva et al., Phys. Rev. Lett. **119**, 083403 (2017).

A 32.3 Thu 14:45 S HS 3 Physik

Two-center resonant photoionization in slow atomic collisions and strong laser fields — Alexander B. Voitkiv[1], Jacqueline Fedyk[2], Shaofeng Zhang[3], Xinwen Ma[3], and •Carsten Müller[1] — [1]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf — [2]Physikalisch-Chemisches Institut, Ruprecht-Karls-Universität Heidelberg — [3]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China

Photoionization of an atom A by an electromagnetic field can be strongly enhanced in the presence of a neighbouring atom B, if the latter first is resonantly photoexcited and afterwards transfers the excitation energy radiationlessly to atom A. This two-center process is known to be very efficient, when the atoms constitute a bound system and a single photon of sufficient energy is absorbed from the field. In this contribution we show that, surprisingly, two-center photoionization can also dominate in slow collisions between the atoms A and B, even though the average interatomic distance in this situation exceeds the typical size of a bound system by orders of magnitude [1]. Besides we study two-center ionization by multiphoton absorption from bichromatic laser fields. Experimentally accessible parameter domains, where the process represents the dominant ionization mechanism, are identified here as well [2].

[1] A. B. Voitkiv, C. Müller, S. F. Zhang, X. Ma, arXiv:1809.06526
[2] J. Fedyk, A. B. Voitkiv, C. Müller, Phys. Rev. A 98, 033418 (2018)

A 32.4 Thu 15:00 S HS 3 Physik

Resonance strengths for dielectronic recombination of highly charged ions and improved empirical Z-scaling law — •Zoltán Harman[1], Chintan Shah[1], Antonio J. González Martínez[1,2], Ulrich D. Jentschura[1,3], Hiro Tawara[1], Christoph H. Keitel[1], Joachim Ullrich[1,4], and José R. Crespo López-Urrutia[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]Instituto de Instrumentación para Imagen Molecular, Universitat Politècnica de València, Valência, Spain — [3]Department of Physics, Missouri University of Science and Technology, Rolla, USA — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Theoretical and experimental resonance strengths for *KLL* dielectronic recombination (DR) into He-, Li-, Be-, and B-like mercury ions are presented, based on state-resolved DR x-ray spectra recorded at the Heidelberg electron beam ion trap. The DR resonance strengths were experimentally extracted by normalizing them to simultaneously recorded radiative recombination signals. The results are compared to multiconfiguration Dirac-Fock and relativistic configuration interaction calculations that include electron correlation and mixing effects. Combining the present data with other existing ones, we derive an improved semi-empirical scaling law for DR resonance strength as a function of the atomic number Z, taking into account higher-order relativistic corrections, which are especially relevant for heavy highly charged ions. — Z. Harman *et al.,* submitted (2018); arXiv:1807.03366

A 32.5 Thu 15:15 S HS 3 Physik

Progress in Time-Resolved Interatomic Coulomb Electron-Capture by Ba^{2+} near Rb — •Axel Molle[1,2], Oriol Vendrell[3], and Annika Bande[1] — [1]Institute for Methods for Material Development, Helmholtz-Zentrum Berlin — [2]Institute for Chemistry and Biochemistry, Freie Universität Berlin — [3]Physikalisch-Chemisches Institut, Universität Heidelberg

Results of a time-resolved numerical investigation of the Interatomic Coulomb Electron Capture (ICEC) is presented. In the ICEC process, a species A captures a free electron by long-range energy transfer through Coulomb interaction to a bound electron in a neighbouring species B. From a theoretical perspective, ICEC was first predicted for atoms and molecules through scattering theory resulting in an asymptotic approximation [1], and then successfully modelled by electron dynamics in low-dimensional semiconductor systems [2]. We do, however, foresee high relevance for ICEC in the field of ultracold atoms and further the need for a full dynamics description of the process. From the experimental side, techniques for trapping ultracold ions and atom clouds are advancing. Employing MCTDH for fermions, we present progress in the electron dynamics of such an exemplary experiment of a barium(II) cation trapped in a cloud of rubidium atoms at ultracold temperatures. In contrast to the previous theoretical studies, this comprises four continuum dimensions and the Coulomb interaction in its electric dipole-dipole approximation.

[1] Gokhberg, and Cederbaum, Phys. Rev. A **82** (2010).
[2] Pont, Bande, and Cederbaum, J. Phys. Cond. Matter **28** (2016).

A 32.6 Thu 15:30 S HS 3 Physik

Novel and efficient scheme for the optical quenching of metastable helium in the 2^1S_0 state — •Jiwen Guan, Vivien Behrendt, Pinrui Shen, Simon Hofsäss, Jonas Grzesiak, Frank Stienkemeier, and Katrin Dulitz — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str.3, 79104 Freiburg i. Br.

Metastable helium in the 2^3S_1 state is the longest-lived neutral atomic state and the most energetic metastable state of an atomic species. These characteristics make this species an important source of stored energy in ionospheric and discharge plasmas. Such energetic species are excellent candidates for the study of reactive scattering processes. Recently, we have produced a supersonic beam of metastable He in an electron-seeded discharge. However, the atomic beam also contains He in another metastable state, 2^1S_0, which prevents detailed quantum-state-controlled reactive scattering studies.

In this talk, I will describe the experimental characterization of a new optical quenching scheme which makes it possible to fully deplete the population of He(2^1S_0) via optical excitation to the 4^1P_1 state. The scheme is based on simple and inexpensive diode laser technology which can be implemented in many laboratories in a straightforward manner. I will also show preliminary results on the reactive scattering of He(2^3S_1) with a cloud of stationary, ultracold Li atoms.

A 32.7 Thu 15:45 S HS 3 Physik

Ab initio calculation of electron-impact-ionization cross sections for ions in exotic electron configurations — •John Jasper Bekx[1,2], Sang-Kil Son[1,3], Robin Santra[1,2,3], and Beata Ziaja[1,3,4] — [1]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, 22607 Hamburg, Germany — [2]Department of Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [4]Institute of Nuclear Physics, Polish Academy of Sciences, Radzikowskiego 152, 31-342 Kraków, Poland

We provide ab initio calculations of electron impact ionization cross sections for ions in exotic electron configurations, with the purpose of exploring their effect on ionization dynamics triggered by inelastically scattered electrons in plasmas.

A 33: Interaction with strong and short laser pulses

Time: Thursday 16:15–18:15 Location: S Fobau Physik

A 33.1 Thu 16:15 S Fobau Physik

High-Harmonic Generation in a Su-Schrieffer-Heeger Chain — •Christoph Jürss and Dieter Bauer — Institute of Physics, University of Rostock, Germany

High-harmonic spectra for two topological phases of a one-dimensional, linear chain were investigated previously using time dependent density functional theory [1]. A significant difference in the dipole strength between the two topological phases were observed and explained by destructive interferences of emitted light from the electrons in the valence band. We obtain similar results as we couple the tight-binding based Su-Schrieffer-Heeger (SSH) model to an external field. Edge states and spectra in this model are quite robust against random fluctuations of the system. Additionally the bulk-boundary correspondence is investigated by focusing the laser to certain areas of the chain.

[1] D. Bauer and K. K. Hansen, Phys. Rev. Let. **120**, 177401 (2018)

A 33.2 Thu 16:15 S Fobau Physik

Above-threshold ionization beyond dipole approximation in the SFA — •Birger Böning[1,2], Willi Paufler[1,2], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Germany

We theoretically investigate non-dipole effects in the above-threshold ionization (ATI) of atoms using the strong-field approximation (SFA). To this extend, we construct Volkov-like continuum wavefunctions of the photoelectron in laser fields with arbitrary spatial dependence. Based on previous work, we show how to construct these solutions to the Schrödinger equation for an electron in a laser field that can be written as a continuous superposition of plane waves. As an application, we perform detailed computations of ATI spectra within the SFA and discuss contributions due to non-dipole interactions. In particular, the peak shift of the spectra in laser propagation direction for mid-IR fields is shown.

A 33.3 Thu 16:15 S Fobau Physik

Three-dimensional imaging of light induced dynamics in xenon doped 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], 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], 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.

Intense short-wavelength femtosecond light pulses delivered by free-electron laser (FEL) facilities allow to investigate the structure and dynamics of nanometer-sized objects via coherent diffractive imaging (CDI) methods. We studied single helium nanodroplets doped with xenon using extreme ultraviolet (XUV) femtosecond light pulses delivered by the FERMI FEL. When irradiated by a high power infrared (IR) laser pulse, a nanoplasma will be ignited inside the droplets that can be observed in the diffraction pattern from a delayed XUV pulse. The nanoplasma propagation and destruction of the droplets was traced via single-particle imaging from femtoseconds up to hundreds of picoseconds after IR excitation.

A 33.4 Thu 16:15 S Fobau Physik

HILITE - A tool to investigate the interaction of laser light with matter — •Nils Stallkamp[1,2], Stefan Ringleb[2], Markus Kiffer[2], Bela Arndt[3], Sugam Kumar[4], Manuel Vogel[1], Wolfgang Quint[1,5], Gerhard Paulus[2], and Thomas Stöhlker[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [2]Friedrich Schiller Universität Jena — [3]Goethe Universität Frankfurt am Main — [4]Inter University Accelerator Centre Delhi — [5]Ruprecht Karls Universität Heidelberg

The investigation of laser-ion interactions in a detailed way, require well-defined ion targets and detection techniques for high-sensitivity measurements of reaction educts and products. To this end, we have designed and built the HILITE (High-Intensity Laser-Ion Trap Experiment) Penning trap setup, which features various ion-target preparation techniques including selection, cooling, compression and positioning as well as destructive and non-destructive measurement techniques to determine the number of stored ions for all charge states individually and simultaneously. Recently, first commissioning experiments of ion deceleration and dynamic ion capture with highly charged ion bunches from an electron beam ion source (EBIT) have been performed. We have characterised our single-pass non-destructive ion counter in detail and were able to determine the ion velocity as well as the number of ions from the signals acquired. Furthermore, storage times inside the trap in the order of minutes could be achieved. We will present the current status as well as proposed first measurements at laser systems.

A 33.5 Thu 16:15 S Fobau Physik

Towards high-repetition rate laser-driven electron rescattering in the molecular frame. — •Federico Branchi, Mark Merö, Marc J.J. Vrakking, Horst Rottke, and Jochen Mikosch — Max-Born-Institut, Berlin

Laser-induced electron diffraction (LIED) is an extension of classical diffraction with electron beams, where the scattering electron is derived from its own molecule by strong-field ionization and accelerated by the oscillating laser field. Since the electron is strongly confined, high current densities can be achieved in the rescattering process. Due to the short de Broglie wavelength and the phase-locking to the cycle of the driving laser, LIED can achieve Ångstrom spatial and attosecond temporal resolution.

While first applications of LIED to the study of molecular dynamics have been reported [1], fundamental aspects, such as the involvement of multiple continua [2], are still under investigation.

Here, we combine a 100 kHz repetition-rate, mid-IR OPCPA laser system at 1550/3100 nm (signal/idler) [3] with a reaction microscope (REMI) to study LIED of polyatomic molecules in the molecular frame. We present the setup and first experimental results.

[1] Wolter et al., Science 354, 308 (2016)
[2] Schell et al., Science Advances 4, eaap8148 (2018)
[3] Merö et al., Opt. Lett. 43, 5246 (2018)

A 33.6 Thu 16:15 S Fobau Physik

Observation of the Dynamics of a Laser Wakefield us-

ing Few-cycle Laser Pulses at Short-wave Infrared Wavelengths (SWIR) — •Mingzhuo Li[1], Yinyu Zhang[1,2], Carola Zepter[1,2], Philipp Wustelt[1,2], Slawomir Skruszewicz[1,2], A. Max Sayler[1,2], Alexander Sävert[1,2], Malte C. Kaluza[1,2], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantum Electronics, Jena, Germany — [2]Helmholtz Insitute, Jena, Germany

High-energy particles from accelerators are important tools for probing fundamental structure of matter, such as elementary particles, atoms, molecules and cells. Conventional accelerator facilities, limited by the radio-frequency (rf) technology, require space of kilometers and cost over $ 1 billion. Laser wakefield accelerator (LWFA), a table-top accelerator technology, which is based on charged particles propagation through relativistic wakes produced by intense laser beams can accelerate particles to several GeV [1]. In order to control the acceleration process inside the plasma, it is essential to know the dynamics of the wakefield. The direct observation of the dynamics of the laser wakefield is achieved by using the transverse shadowgraphy, which is probed by few-cycle pulses at 810 nm [2]. Increasing the wavelength of probe pulses but keeping the pulse length in few-cycle regime can probe plasmas with lower densities, which will increase the spatial resolution and the sensitivity. Here, we report on the high-resolution observation of the dynamics of a laser wakefield using few-cycle pulses at SWIR (1800 nm). [1] W. P. Leemans, et. al., Nat. Phys. 2, 696-699 (2006). [2] A. Sävert, et. al., Phys. Rev. Lett. 115, 055002 (2015).

A 33.7 Thu 16:15 S Fobau Physik

Photoelectron Momentum Distributions of Potassium from an Ultrashort Intense Laser Pulse — •Lutz Marder, Daniel M. Reich, and Christiane P. Koch — Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel (Germany)

We present ab initio simulation results for the Photoelectron Momentum Distributions (PMDs) in potassium atoms obtained in experiments using highly intense linearly polarized femtosecond laser pulses. To model the potassium atom we use a single-active electron approach with a relativistic effective potential. The electronic wave function is represented by spherical harmonics and a radial spatial grid with a Finite Element Discrete Variable Representation (FE-DVR) using Gauß-Legendre-Lobatto (GLL) points. We compare our simulated PMDs with state-of-the-art experiments investigating interesting features observed in the Photoelectron Angular Distribuations (PADs) of potassium.

A 33.8 Thu 16:15 S Fobau Physik

Nanoscale vacuum-tube-typed electronic devices triggered by few-cycle laser pulses — •Constanze Sturm, Takuya Higuchi, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Electron pulses from a sharp needle tip triggered by ultrashort laser pulses via multiphoton photoemission are extremely confined both in space and time. Employing these electrons as carriers in electronic devices may drastically improve their operational speed.

We present an experiment based on two lithographically fabricated gold tips on top of a fused silica substrate. The two tips facing each other are separated by a fixed distance set between 30 nm and 2 μm. The final tip radius depends on the opening angle chosen for the tips and the dose parameter of the lithography process. Optimizing both results in a minimum tip radius of 15 nm.

In the experiment two tips with different tip radii are illuminated by 6 fs Ti:sapphire laser pulses. Measuring the total current results in a non-vanishing current from the sharper tip to the blunter one. This can be explained by numerical simulations showing a stronger optical near-field enhancement at the sharper tip, resulting in a stronger electron emission. Our goal is to control the electron emission by changing the static field landscape, the incident laser power and the light polarization.

A 33.9 Thu 16:15 S Fobau Physik

Time delay effects 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, Germany

The problem of the electron time delay in the tunnel ionization in strong laser fields has received renewed attention following recent experimental results confirming a non-zero time delay[1]. We investigate aspects of time delay in strong fields by using the strong field approximation for a zero-range potential to calculate the time delay (with respect to the laser field peak) of an ionized electron wavepacket and comparing this to the time delay of a Wigner trajectory for a quasi-static barrier as well as a classically evolved trajectory. Our aim is twofold: to show how the time delay and momentum shift of an ionized electron at the tunnel exit counterbalance[2], creating the asymptotically measurable time delay, and secondly, to find a physical interpretation for the emergence of this asymptotic time delay.

[1] N. Camus, E. Yakaboylu, *et al*, Phys. Rev. Lett. 119:023201, Jul 2017.

[2] M. Klaiber, *et al*, Phys. Rev. Lett. 120:013201 Jan 2018.

A 33.10 Thu 16:15 S Fobau Physik

Setup of a high-intensity XUV beamline based on HHG from sub-10-fs NIR pulses — •Björn Senfftleben[1], Mario Sauppe[1], Martin Kretschmar[1], Johannes Tümmler[1], Ingo Will[1], Marc J. J. Vrakking[1,2], Tamás Nagy[1], Bernd Schütte[1], and Daniela Rupp[1] — [1]Max-Born-Institut Berlin, Deutschland — [2]FU Berlin, Deutschland

Intense extreme ultraviolet (XUV) pulses from high-harmonic generation (HHG) have recently started to compete with short-wavelength free-electron lasers in the sense that high-intensity experiments such as nonlinear ionization or single-shot single-particle coherent diffraction imaging can be carried out in the lab. At the same time, the unique characteristics of laser-based HHG sources, namely the high timing control in pump-probe configurations and sub-femtosecond pulse duration, hold the promise for unprecedented experimental possibilities to study ultrafast nanoscale dynamics.

We are currently setting up a high-intensity XUV beamline using sub-10-fs pulses with up to 30 mJ pulse energy from a newly developed thin-disc-laser based optical parametric chirped-pulse amplification (OPCPA) system. First characterization results of the XUV pulses will be discussed.

A 34: Interaction with VUV and X-ray light

Time: Thursday 16:15–18:15 Location: S Fobau Physik

A 34.1 Thu 16:15 S Fobau Physik

X-ray pulse shaping by mechanical motion of resonant absorber and their applications — •Benedikt Herkommer and Jörg Evers — MPI für Kernphysik Heidelberg

For high-precision spectroscopy with highly energetic radiation as x-ray or gamma-rays it is necessary to have narrow resonances as those of Moessbauer nuclei. Despite the progress of modern x-ray sources it is still quite challenging to coherently control resonant interaction between x-rays and nuclei. In recent works it has been shown that it is possible to shape x-ray pulses in time [1] and frequency [2] domain. Theses works are based on mechanical motion of a resonant absorber.

Based on this methods this poster presents our work how different motion pattern can lead to interference of different frequencies of the the signal. This can lead to quite interesting phenomena which are discussed with regard to their use in spectroscopy applications.

[1] F. Vagizov et al., Nature 508, 80 - 83

[2] K. P. Heeg et al., Science 2017, 357, 375.

A 34.2 Thu 16:15 S Fobau Physik

Spatio- and time dependent Propagation Simulations of hard X-ray FEL radiation through the split-and-delay unit for the HED-instrument at the European XFEL — •Victor Kärcher[1], Sebastian Roling[1], Liubov Samoylova[2], Karen Appel[2], Frank Siewert[3], Ulf Zastrau[2], Frank Wahlert[1], and Helmut Zacharias[1] — [1]Center for Soft Nanoscience, Münster, Germany — [2]European XFEL, Schenefeld, Germany — [3]Helmholtz-Zentrum für Materialien und Energie, Berlin, Germany

For the High Energy Density (HED) instrument at the SASE2 - Undulator at European XFEL an x-ray split-and-delay unit (SDU) is built covering photon energies from $h\nu = 5\,\mathrm{KeV}$ up to $h\nu = 24\,\mathrm{KeV}$. This

SDU will enable time-resolved x-ray pump / x-ray probe experiments as well as sequential diffractive imaging on a femtosecond to picosecond time scale. In order to reach intensities on the order of 10^15 W/cm2 the XFEL pulses will be focused by means of compound refractive lenses (CRL) to a diameter of D = 24 μm. The influence of wavefront disturbances caused by height- and slope-errors of the mirrors inside the SDU on the quality of the two focused partial beams is studied by wavefront propagation simulations using the WPG-framework.

A 34.3 Thu 16:15 S Fobau Physik

An XUV and soft X-ray split-and-delay unit for FLASH II — •Patrick Oelpmann[1], Sebastian Roling[1], Matthias Rollnick[1], Marion Kuhlmann[2], Elke Plönjes[2], Frank Wahlert[1], and Helmut Zacharias[1] — [1]Center for Soft Nanoscience (SoN) der WWU Münster, Busso-Peus Straße 10, 48149 Münster — [2]Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg

An XUV and soft X-ray split-and-delay unit is built that enables time-resolved experiments covering the whole spectral range of FLASH II from $h\nu = 30$ eV up to 2500 eV. With wave front beam splitting and grazing incidence angles a maximum delay of -6 ps $< \Delta t < +18$ ps will be possible with a sub-fs resolution. Two different coatings are required to cover the complete spectral range. Therefore, a design that is based on the three dimensional beam path of the SDU at BL2 at FLASH has been developed which allows choosing the propagation via two sets of mirrors with these coatings. A Ni-coating will allow a total transmission on the order of T = 55 % for photon energies between 30 eV and 600 eV at a grazing angle $\theta = 1.8°$ in the variable delay line. In the fixed delay line the grazing angle is set so $\theta = 1.3°$. With a Pt-coating a transmission of T > 13 % will be possible for photon energies up to 1500 eV.

A 34.4 Thu 16:15 S Fobau Physik

A split-and-delay unit for the European XFEL: Enabling hard x-ray pump/probe experiments at the HED instrument — •Dennis Eckermann[1], Sebastian Roling[1], Karen Appel[2], Matthias Rollnik[1], Frank Wahlert[1], Ulf Zastrau[2], and Helmut Zacharias[1] — [1]Center for Soft Nanoscience (SoN) der WWU Münster, Busso-Peus Straße 10, 48149 Münster — [2]European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld

For the High Energy Density (HED) instrument at the SASE2 - Undulator at the European XFEL an x-ray split-and-delay unit (SDU) is built covering photon energies from hν = 5 keV up to hν = 24 keV. This SDU will enable time-resolved x-ray pump / x-ray probe experiments as well as sequential diffractive imaging on a femtosecond to picosecond time scale. Further, direct measurements of the temporal coherence properties will be possible by making use of a linear autocorrelation. The x-ray FEL pulses are split by a sharp edge of a silicon mirror (BS) coated with Mo/B_4C and W/B_4C multilayers. Both partial beams then pass variable delay lines. For different wavelengths the angle of incidence onto the multilayer mirrors will be adjusted in order to match the Bragg condition. Because of the different incidence angles, the path lengths of the beams will differ as a function of wavelength. Hence, maximum delays between ±1.0 ps at hν = 24 keV and up to ±23 ps at hν = 5 keV are possible.

A 34.5 Thu 16:15 S Fobau Physik

Time-resolved coincidence measurements of interatomic Coulombic decays — •Sophie Walther, Anastasios Dimitriou, Markus Pfau, Mark J. Prandolini, Martin Ranke, and Ulrike Frühling — Universität Hamburg

Interatomic Coulombic Decay (ICD) is an efficient decay channel used by atoms in loosely bound van der Waals noble gas molecules and clusters. Here we present our experimental setup for the investigation of the ICD lifetime in neon dimers using the terahertz (THz)-streaking technique. The neon dimers are ionized with ultrashort extreme ultraviolet laser pulses and superimposed with intense THz fields. The momenta of all generated fragments are measured in coincidence using a Cold Target Recoil Ion Momentum Spectroscopy (COLTRIMS) detector.

A 34.6 Thu 16:15 S Fobau Physik

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

Using the reaction microscope endstation at the free-electron laser (FEL) in Hamburg (FLASH), 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 quadruply charged ions, allows to probe the dissociation. The momentum-resolved data of the coincident fragments of the dissociated molecules will be presented.

A 34.7 Thu 16:15 S Fobau Physik

Two photon double ionization in Neon — •Severin Meister[1], Kirsten Schnorr[2], Sven Augustin[1], Hannes Lindenblatt[1], Florian Trost[1], Yifan Liu[1], Claus-Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik — [2]Paul Scherrer Institut

The angular distribution of electrons, which are emitted in the course of an ionization process, comprises much information about the atom. Double ionization of noble gases has been exclusively achieved by absorbing a single photon with an energy above the double ionization potential. However with the emergence of intense light sources in the extreme ultra violet regime, i.e. Free Electron Lasers, absorbing two photons became feasable. In addition, an adjustable time delay between the two photons allows to investigate time dependent effects. Therefore the presented experiment was carried out at the Free Electron Laser in Hamburg (FLASH2), with a split and delay mirror geometry. The Neon atom absorbes successively two photons, while their delay can be adjusted. In this manner the two electrons are also emitted successively, which discriminates the process from the single photon case. The scheme allows to investigate the dynamics of the two superposed states $^2P_{1/2}, ^2P_{2/3}$ in the intermediate Ne^+ ion by measuring the delay dependent angular distribution of the second electron. Another interesting aspect we are adressing is that the angular distribution of the first electron is predicted to depend on the emission angle of the second one, which stands in contrast to the simple picture of sequential ionization.

A 34.8 Thu 16:15 S Fobau Physik

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

Our group operates a Reaction Microscope as permanent endstation at FLASH2. During the last year, first experiments and several upgrades were performed. Most notably, an XUV split, delay and focusing unit was implemented with gracing incidence mirrors. The installed optics provide a very small focus (~ 5 um) and large delay range (± 2 ps). However, the beam geometry requires to overlap the two focii under an angle proportional to the time delay. Thus, scanning the delay and maintaining spatial overlap becomes complex. In this poster, procedures to handle this will be presented. Furthermore, coincident data of Coulomb-explosion processes is shown demonstrating pump-probe capability over the full delay range.

A 35: Precision Spectroscopy of atoms and ions

Time: Thursday 16:15–18:15 Location: S Fobau Physik

A 35.1 Thu 16:15 S Fobau Physik

Axion-induced Lamb-shift in atomic and muonic hydrogen — •Alina Golub, Selym Villalba-Chávez, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Deutschland

Vacuum polarization effects due to hypothetical axion-like particles, which are predicted in some extensions of the standard model, are considered. The self-energy operator of the electromagnetic field is determined with an accuracy of second-order in the axion-diphoton coupling. The result is utilized for establishing the axion-modified Coulomb potential of a static pointlike charge. In connection, the plausible distortion of the Lamb-shift in hydrogenlike atoms is established and the scopes for searching axion-like particles in high-precision atomic spectroscopy are investigated. Particularly, we show that these hypothetical degrees of freedom are ruled out as plausible candidates for explaining the proton radius anomaly in muonic hydrogen [1].

[1] Axion-modified photon propagator, Coulomb potential, and Lamb-shift; S. Villalba-Chavez, A. Golub, C. Müller accepted for publication in Phys. Rev. D [arXiv:1806.10940v1]

A 35.2 Thu 16:15 S Fobau Physik

Coherent Control of Thermal Atoms with Photonic Crystal Cavities — •Hadiseh Alaeian, Ralf Ritter, Artur Skljarow, Harald Kübler, Tilman Pfau, and Robert Löw — 5.Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany

Unless proper modifications are employed, the atom-photon interaction is an inefficient process in free space. Historically, optical and superconducting cavities have been used successfully to increase the atom-photon interaction probability for the optical and microwave photons, respectively. With recent advancements in nanofabrication, integrated Nano-photonic devices have been used to enhance the quantum optical phenomena in several solid-state based platforms like quantum dots and vacancy centers. In this work, we present our recent theoretical and experimental efforts on the integration of high-Q cavities with thermal atoms beyond the perturbative limit. In particular, we discuss about an optimized cavity in a Si_3N_4 photonic crystal supporting a high-Q mode with small volume at 780nm, i.e. 5S→5P of rubidium. Through a detailed Monte-Carlo calculation incorporating all the device effects, including the Purcell and Casimir-Polder, we demonstrate the feasibility of reaching a strong atom-light coupling down to a single photon.

A 35.3 Thu 16:15 S Fobau Physik

A fresh computational approach to atomic structures, processes and cascades — •Stephan Fritzsche — Helmholtz Institute, Jena, Germany — Friedrich-Schiller University Jena

The recent years have seen an increasing demand for accurate atomic computations. Apart from the traditional fields of astro- and plasma physics, accurate atomic data are needed today in various emerging areas, such as laser spectroscopy, quantum optics and metrology, x-ray lithography, or even in material science, to name just a few. – In this contribution, I present a new (Julia) code for modelling atomic properties and processes. To this end, a high-level toolbox has been designed (and already implemented to a sizable extent) for dealing more efficiently with complex systems. Here, I shall introduce these tools and explain by simple examples how they help provide accurate theoretical predictions and may serve for (requests from) the spectroscopy of atoms and multiply-charged ion and in various fields elsewhere.

A 35.4 Thu 16:15 S Fobau Physik

Two-loop QED diagrams for the bound-electron g factor: radiative corrections to 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 then ionic nucleus. We computed the electric-loop-magnetic-loop diagram, the magnetic-loop-after-loop diagram, and the self-energy-magnetic-loop diagrams, while also shedding light on some other diagrams, which feature a self-energy loop inside the magnetic loop. 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^{-7} 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 35.5 Thu 16:15 S Fobau Physik

Collinear laser spectroscopy with ion trap accuracy - Future perspectives for atomic and nuclear physics — •Kristian König, Phillip Imgram, Jörg Krämer, Tim Ratajczyk, and Wilfried Nörtershäuser — Institut für Kernphysik, TU Darmstadt

At the newly constructed collinear laser spectroscopy apparatus COALA at TU Darmstadt an unprecedented accuracy in the determination of rest-frame transition frequencies was recently demonstrated with stable Ba^{+} ions. To our knowledge, this measurement represents the most-precise collinear laser spectroscopic experiment realized so far and can compete with modern ion trap measurements on dipole-allowed transitions. We will present the results and the future potential for precise and accurate measurements of atomic and nuclear properties at this setup. Required techniques like optical pumping and probing deep-UV transitions as well as a frequency-comb based laser stabilization have already been demonstrated with In^{+} ions, paving the way for collinear spectroscopy on helium-like light ions, which is of great interest from a nuclear structure perspective.

A 35.6 Thu 16:15 S Fobau Physik

Scheme to generate and filter photon pairs from atoms in a hollow-core fibre — •Mark Zentile, Ioannis Caltzidis, Harald Kübler, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

Single photon sources are essential for quantum optics. It has been shown that a heralded source with high-spectral brightness can be achieved using four-wave mixing (4WM) in a thermal-atomic vapour [1]. These systems are particularly useful the photons are to be interfaced with other atomic systems, e.g. quantum memories [2]. However, the schemes used so far require expensive high-power lasers ($\sim$ 1W) to pump the 4WM process. The aim of this project is to develop a source of heralded single photons with a much higher efficiency, thereby allowing the use of a single diode laser as the pump. We will achieve this by using an alkali-vapour contained in a hollow-core micro-structured fibre and exploit the higher efficiency expected [3]. A challenge of this scheme will be to split the photon pairs. Since the wavelengths of the light emerging from the fibre are close to each other, and the beams are overlapped, many common techniques (such as using interference filters and/or spatial filtering) will not work. However, we have identified a scheme using an atomic vapour as a beam splitter for the photon pairs.

[1] MacRae, A. et al., Phys. Rev. Lett. 109, 033601 (2012)
[2] Sprague, M. R. Et al., Nature Photon. 8, 287 (2014)
[3] Londero, P. et al., Phys. Rev. Lett. 103, 043602 (2009)

A 35.7 Thu 16:15 S Fobau Physik

Realistic atomic clock simulations with single to hundreds of atoms — •Marius Schulte[1], Víctor J. Martínez-Lahuerta[1], Piet O. Schmidt[2,3], and Klemens Hammerer[1] — [1]Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute), Leibniz University Hannover — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig — [3]Institute for Quantum Optics, Leibniz University Hannover

Recently, optical atomic clocks have shown great success in achieving systematic fractional frequency uncertainties on the order of 10^{-18} using few hundreds of uncorrelated reference atoms. However the extent to which entanglement can improve such atomic clocks in practice, including realistic local oscillator noise, preparation errors and dead time, has so far been little researched. To answer this question we investigate numerically the long-term stability of optical atomic clocks with entangled atoms. We tackle in particular the exact dynamics of symmetrical systems containing single to few hundred atoms, which lie beyond the validity of Gaussian approximations.

A 35.8 Thu 16:15 S Fobau Physik

Cold Atomic Hydrogen Source @ T-Rex — •Jan Haack, Merten Heppener, Stefan Schmidt, Henrik-Lukas Schumacher, Marcel Willig, Andreas Wieltsch, and Randolf Pohl — Institut f. Physik Johannes Gutenberg-Univertität, Mainz

The Triton-Radius Experiment T-Rex at JGU Mainz aims at a first measurement of the 1S-2S transition in atomic tritium [1]. Such a measurement has the potential to improve the charge radius of the triton nucleus by a factor of 400, with an experimental accuracy of only 1 kHz. This is 100x *less* precise than the current measurements of the 1S-2S transition in H and D, [2,3]. T-Rex will use a cryogenic hydrogen (later tritium) beam and select low atomic velocities by a magnetic quadrupole guide. The slowest atoms will then be stopped using a Li MOT as a cold buffer gas, and trapped in a magnetic minimum trap. We will present the state of the experiment as well as an outlook.
[1] S. Schmidt et al. J. Phys. Conf. Ser. accepted (2018), arXiv 1808.07240
[2] C. Parthey et al. Phys. Rev. Lett. 104 233001 (2010)
[3] C. Parthey et al. Phys. Rev. Lett. 107 203001 (2011)

A 35.9 Thu 16:15 S Fobau Physik

First Measurement Results of the Alphatrap *g*-factor Experiment — •Bingsheng Tu[1], Ioanna Arapoglou[1], José Ramon Crespo López-Urrutia[1], Alexander Egl[1], Martin Höcker[1], Tim Sailer[1], Timo Steinsberger[1,2], Andreas Weigel[1], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg, 69120 Heidelberg

The Alphatrap experiment, situated at the Max Planck Institute for Nuclear Physics in Heidelberg, aims for stringent tests of Bound-State Quantum Electrodynamics (BS-QED) in extremely strong electromagnetic fields via high-precision measurements of the magnetic moment (*g*-factor) of bound electrons in highly charged ions up to hydrogen-like $^{208}Pb^{81+}$. Sub-parts-per-billion precision can be achieved in the double Penning-trap setup which consists of cryogenic 7-electrode and 5-electrode cylindrical Penning traps. The highly charged ions are created in three external ion sources: the Heidelberg EBIT, the room-temperature HC-EBIT and the laser ion source, each for different experimental motivations. Boronlike $^{40}Ar^{13+}$ has already been produced and captured in the Alphatrap setup. Furthermore, a first *g*-factor measurement with a relative uncertainty in the 10^{-9} range has been performed on this system, which exceeds the current calculations by two orders of magnitude. Based on the spin-state detection, laser spectroscopy of the fine structure of boronlike $^{40}Ar^{13+}$ has also been implemented by using a novel technique to detect forbidden transitions. The present status and the future plans of ALPHATRAP will be presented.

A 35.10 Thu 16:15 S Fobau Physik

Simulation of an atomic beam under magneto-optical influence — •Andreas Christian Wieltsch, Jan Haack, Stefan Schmidt, Marcel Willig, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA$^+$, Mainz, Germany

We are developing a simulation software to track the movement of atoms in a laser spectroscopy experiment. In such an experiment atoms are slowed down under magneto-optical influence. The simulation can be used for evaluating different designs of the magnetic field in the slower or optimizing positions and diameters of apertures. This software is build for the Lithium experiment at the University of Mainz.

One way to model the light-atom interaction is using rate equations which are widely used for simulating the movement of atoms in such an experiment. The problem can also be described by the Optical Bloch equations, a set of differential equations describing the transitions between the energy states more precisely. We will present the generic implementation of the simulation program using both approaches, show results of the simulation and compare both methods. Due to the generic implementation, parts of the simulation software can also be used in e.g. the T-REX experiment.

A 35.11 Thu 16:15 S Fobau Physik

Two-loop self-energy corrections 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 calculations of the two-loop self-energy correction to the bound-electron *g*-factor. This correction currently gives rise to the largest uncertainty of theoretical *g*-factor predictions. We have obtained full results for the loop-after-loop diagrams, and partial results for the nested and overlapping loop diagrams, in which we treat the Coulomb interaction in intermediate states to zero and first order.

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

A 35.12 Thu 16:15 S Fobau Physik

Approaching sympathetic cooling of trapped $^{229}Th^{3+}$ ions — •Gregor Zitzer, Johannes Thielking, David-Marcel Meier, Maksim Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

With only a few eV above its nuclear ground state the isomer of ^{229}Th is accessible for direct laser excitation. The isomeric transition may be used as a frequency reference for a new type of optical clocks which is exceptionally insensitive to field-induced frequency shifts.

For the realization of an optical nuclear clock with laser-cooled trapped ions the charge state 3+ of ^{229}Th is preferred, due to its relatively simple and convenient electronic level structure. Direct laser cooling of $^{229}Th^{3+}$ and $^{232}Th^{3+}$ has been demonstrated [1,2].

Due to limitations in the reachable laser cooling power we plan to investigate sympathetic cooling of $^{229}Th^{3+}$ with $^{88}Sr^+$ for experiments with large Coulomb crystals and a future clock operation. In a new setup $^{229}Th^{3+}$ and $^{88}Sr^+$ will be trapped in a linear radiofrequency ion trap. It is planed to extract the $^{229}Th^{3+}$ ions generated by a ^{233}U source via α-decay [3] and guide them to a segmented linear Paul trap. In this trap the laser cooled $^{88}Sr^+$ ions will surround the $^{229}Th^{3+}$ forming a prolate spheroid. Here the concept, design and current status of the experiment on $^{229}Th^{3+}$ will be shown.

[1] C. J. Campbell et al., Phys. Rev. Lett. 102, 233004 (2009)
[2] C. J. Campbell et al., Phys. Rev. Lett. 106, 223001 (2011)
[3] L. v. d. Wense, On the direct detection of ^{229m}Th, Springer International Publ., DOI: 10.1007/978-3-319-70461-6 (2018)

A 35.13 Thu 16:15 S Fobau Physik

Compact Collinear Laser Spectroscopy Setup for Educational Usage — •Philipp Bollinger, Tim Ratajczyk, and Wilfried Nörtershäuser — Institut für Kernphysik, Technische Universität Darmstadt

Collinear laser spectroscopy is widely used to perform highly precise measurements of atomic spectra to extract nuclear properties, namely charge radii, magnetic dipole and electric quadrupole moments [Neugart et al. J. Phys. G. 44 064002 (2017)]. It has also been used to test QED calculation of higher ions [Nörtershäuser et al. PRL 115, 033002 (2015)] and was applied on relativistic beams to test special relativity [Botermann et al. PRL 114, 239902 (2015)] and strong-field bound state QED in heavy ions [Ullmann et al. Nat. Comm. 8, 15484 (2017)]. To give students the possibility to get experienced with this technique, a compact setup for collinear laser spectroscopy is being prepared at TU Darmstadt to be used in the advanced lab classes. The setup uses a specially designed 90° dipole bender to superimpose laser and ion beam which will be tested for its usability in laser spectroscopy. An optical detection region with photomultipliers and a mass spectrometer allow further investigations. We will present the layout and current status of the project.

A 35.14 Thu 16:15 S Fobau Physik

Low emittance laser ablation ion beam source — •Tim Lellinger[1], Tim Ratajczyk[1], Victor Varentsov[2,3], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt — [2]Facility for Antiproton and Ion Research in Europe (FAIR GmbH) — [3]Institute for Theoretical and Experimental Physics, Moscow, Russia

Laser ablation provides access to the production of a wide range of ion beams for various researches and applications. When the laser ablation occurs in a vacuum the high temperature and large angular divergence of the produced plasma plume do not allow the production of high quality ion beams. This can be avoided if the laser ablation is performed in the presence of a He buffer gas, where the ablated ions are stopped and cooled due to collisions with He atoms and then transported by the gas flow through a miniature nozzle into an RF-only funnel. After that the ions are effectively extracted into high vacuum conditions under a combined action of gas dynamic and electric fields. We present the design and first test measurements of such an ion beam source having two RF funnels. This ion source will be able to produce low emittance ion beams in both continuous and pulsed operation mode.

A 35.15 Thu 16:15 S Fobau Physik

Negative Ions Studies in the Frankfurt Low Energy Storage Ring (FLSR) — •Oliver Forstner[1,2,3], Jan Müller[4], Markus Schöffler[4], Lothar Schmidt[4], Thomas Stöhlker[1,2,3], and Kurt Stiebing[4] — [1]Friedrich-Schiller-Universität Jena, Jena — [2]Helmholtz-Institut Jena, Jena — [3]GSI Helmholtzzentrum, Darmstadt — [4]Goethe Universität, Frankfurt

In order to allow for studies of the electronic structure of negative atomic and molecular ions by laser photodetachment, a commercial rf charge exchange ion source for negative ions (Alphatross, National Electrostatic Corporation [1]) has been installed at the injection terminal of the Frankfurt Low Energy Storage Ring (FLSR) facility [2]. First tests with negative ions stored in FLSR at 20 keV have successfully been conducted. So far, the storage times of 50 nA He^-, 260 nA O^- and 110 nA OH^- have been measured. They are in good agreement with the theoretical predicted storage times based on the residual gas pressure ($p_{FLSR} \approx$ 1,0 - 2,0x10^{-10} mbar, corrected for H_2 as residual gas). Also, the measured lifetime of the metastable He^- of about 300 μs is in good agreement with previous measurements [3].

In a next step photodetachment of the stored ions with tunable laser beams in the VIS and NIR range will be performed.

[1] http://www.pelletron.com/products/rf-charge-exchange/ [2] K.E. Stiebing, V. Alexandrov, R. Dörner et al., Nucl. Instr. and Meth. A614, 10 (2010). [3] U.V. Pedersen, M. Hyde, S.P. Møller, T. Andersen, Phys. Rev. A64, 012503 (2001)

A 35.16 Thu 16:15 S Fobau Physik

Laser spectroscopic characterization of the nuclear clock isomer ^{229m}Th — •Johannes Thielking[1], Maksim V. Okhapkin[1], Przemysław Głowacki[1], David-Marcel Meier[1], Lars von der Wense[2], Benedict Seiferle[2], Christoph E. Düllmann[3,4,5], Peter G. Thirolf[2], and Ekkehard Peik[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Ludwig-Maximilians-Universität München, 85748 Garching, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [4]Helmholtz-Institut Mainz, 55099 Mainz, Germany — [5]Johannes Gutenberg-Universität, 55099 Mainz, Germany

An optical clock based on the transition between ground state and low-lying isomer in the nucleus ^{229}Th would be highly immune to field-induced frequency shifts and a sensitive probe of temporal variations of fundamental constants [1]. We recently performed the first measurement of the nuclear magnetic dipole and electric quadrupole moments and the mean square charge radius of the isomer [2]. This was achieved via high-resolution laser spectroscopy of the hyperfine structure of trapped $^{229}Th^{2+}$ ions, loaded from the α decay of ^{233}U. We are now preparing an experiment to investigate the excitation of the nucleus via electronic bridge and NEET processes [3,4] in the energy range from 7.2 to 10.2 eV, using two-step laser excitation in Th^{2+}.

[1] E. Peik, Chr. Tamm, Europhys. Lett. 61, 181 (2003).
[2] J. Thielking et al., Nature 556, 321-325 (2018).
[3] S. G. Porsev et al., Phys. Rev. Lett. 105, 185501 (2010).
[4] F.F. Karpeshin et al., Nucl. Phys. A, 654, 579 (1999).

A 35.17 Thu 16:15 S Fobau Physik

Towards a XUV frequency comb for high resolution spectroscopy on highly charged ions — •Alexander Ackermann, Janko Nauta, Jan Hendrik Oelmann, Julian Stark, Steffen Kühn, José Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany

Highly charged ions (HCI) have been proposed as a candidate for novel frequency standards [1] and for testing of the variation of the fine structure constant [2]. To carry out high resolution spectroscopy on forbidden transitions in HCIs, stable and coherent extreme ultraviolet (XUV) radiation is required. The nonlinear process of high harmonic generation in a gas target in the focus region of a femtosecond enhancement cavity located in a vacuum chamber, is used to convert a near infrared frequency comb into the XUV [3]. A home built chirped pulse amplification system, containing a prism- and grating-based pulse compressor, which enables compensation of second and third order dispersion, is employed to reach 70 W of sub-200 fs pulses at a repetition rate of 100 MHz. Pulses are characterized with a second harmonic frequency-resolved optical gating setup, based on a self developed Echelle grating spectrometer and an autocorrelator.

[1] V.A. Dzuba et al., Phys. Rev. A 86, 054502 (2012)
[2] J.C. Berengut et al., Phys. Rev. Lett. 106, 210802 (2011)
[3] J. Nauta et al., ScienceDirect 408, Pages 285-288 (2017)

A 35.18 Thu 16:15 S Fobau Physik

A proton source for precision experiments in the QLEDS project — •Nicolas Pulido[1], Johannes Mielke[1], Teresa Meiners[1], Malte Niemann[1], Juan M. Cornejo[1], Matthias Borchert[1,3], Jonathan Morgner[1,2], Amado Bautista[1,2], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Ulmer Fundamental Symmetries Laboratory, RIKEN

Penning traps are an essential tool for high precision measurements on the g-factor of protons and antiprotons to perform tests of the CPT theorem [1]. This is the goal pursued by the BASE collaboration. Here we discuss techniques for sympathetic laser cooling and detection to support these tests [2,3]. We present the design of an off-axis proton source that also allows the introduction of an on-axis antiproton beam in the Penning trap system within the BASE collaboration. The source, consisting of an electron gun and a storage trap, will be commissioned in a cryogenic test setup.

The test setup is composed of a 2-stage cryocooler and a Penning trap with permanent magnets. We discuss different methods of non-destructive ion detection for the test setup.

[1] C. Smorra *et al.*, Nature **550**, 371-374 (2017)
[2] C. Smorra *et al.*, EPJ-ST **224**, 3055 (2015)
[3] D. J. Wineland *et al.*, J. Res. NIST **103**, 259-328 (1998)

A 35.19 Thu 16:15 S Fobau Physik

Cold Atomic Hydrogen Source @ T-Rex — •Jan Haack, Merten Heppener, Stefan Schmidt, Henrik-Lukas Schumacher, Marcel Willig, Andreas Wieltsch, and Randolf Pohl — Johannes Gutenberg-Univertität Mainz, QUANTUM, Institut für Physik, Exzellenzcluster PRISMA$^+$

The Triton-Radius Experiment T-Rex at JGU Mainz aims at a first measurement of the 1S-2S transition in atomic tritium [1]. Such a measurement has the potential to improve the charge radius of the triton nucleus by a factor of 400, with an experimental accuracy of only 1 kHz. This is 100x *less* precise than the current measurements of the 1S-2S transition in H and D, [2,3]. T-Rex will use a cryogenic hydrogen (later tritium) beam and select low atomic velocities by a magnetic quadrupole guide. The slowest atoms will then be stopped using a Li MOT as a cold buffer gas, and trapped in a magnetic minimum trap. We will present the state of the experiment as well as an outlook.

[1] S. Schmidt et al. J. Phys. Conf. Ser. accepted (2018), arXiv 1808.07240
[2] C. Parthey et al. Phys. Rev. Lett. 104 233001 (2010)
[3] C. Parthey et al. Phys. Rev. Lett. 107 203001 (2011)

A 35.20 Thu 16:15 S Fobau Physik

A detector for atomic hydrogen — •Hendrik-Lukas Schumacher, Ahmed Ouf, Jan Hack, Stefan Schmidt, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, Institut für Physik, QUANTUM & Exzellenzcluster PRISMA$^+$, Mainz, Germany

Laser spectroscopy of atomic hydrogen and deuterium has yielded the most precise values for the Rydberg constant and, for a long time, of the proton and deuteron charge radii. The biggest obstacle for improved spectroscopy is however the atom's motion and the resulting large systematic uncertainties due to Doppler and time-of-flight broadening. Trapping of atomic hydrogen would solve many of these problems.

To this end, our group plans to trap atomic hydrogen using a cloud of Li atoms in a MOT as a cold buffer gas. This would for the first time also enable high-precision spectroscopy of atomic tritium, eventually leading to a 400fold improved value for the triton charge radius.

Here we report on a simple detector for atomic hydrogen and its isotopes which is based on the heat deposited in a thin (10s of micrometers) metal wire where the 4.5 eV released in the recombination of two H atoms leads to an increase in resistivity. This detector enables measurements of the spatial profile and the flux of atoms from our cryogenic hydrogen beam.

A 35.21 Thu 16:15 S Fobau Physik

Optically transparent solid electrodes for precision Penning traps — Marco Wiesel[1,2,3], Gerhard Birkl[3], Mohammad Sadegh Ebrahimi[1,2], Zhexi Guo[1,2,4], •Kanika Kanika[1,2], Jeffrey Klimes[1,2,4], Alexander Martin[3], Wolfgang Quint[1,2], Nils Stallkamp[1,5], and Manuel Vogel[1,5] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [2]Physikalisches Institut, Universität Heidelberg, 69120 Heidelberg, Germany — [3]Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [4]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [5]Helmholtz-Institut Jena, 07743 Jena, Germany

The concept of an electrically conducting yet optically transparent solid electrode was conceived, and subsequently materialised, tested and implemented in a cryogenic Penning trap. Dedicated to spectroscopy and imaging of confined particles under large solid angles, this trap utilises a 'half-open design' with an open endcap for easy ion ingress and a closed endcap that mainly consists of a glass window coated with a highly transparent conductive indium tin oxide layer. This closed endcap retains the desired trapping capabilities of a conventional endcap electrode and yields flexible access for optical excitation and efficient light collection from the trapping region. With its superior surface quality and its high as well as homogeneous optical transmission, the window electrode is an excellent replacement for partially transmissive electrodes that use holes, slits, metallic meshes, and the like.

A 35.22 Thu 16:15 S Fobau Physik

Atomic computations of Isotope Shift Parameters for Heavy Elements — •Randolf Beerwerth[1,2] and Stephan Fritzsche[1,2] — [1]Helmholtz Institut Jena, 07743 Jena — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena

The isotope shift between two isotopes A and A' of the same element is parametrized in terms of the mass and field-shift parameters. The former arises due to the nuclear recoil, while the latter is caused by the finite extent of the nuclear charge distribution. Generally, only the lowest order in the expansion of the field shift is considered and this allows to extract differential mean squared charge radii $\delta \langle r^2 \rangle^{A,A'}$ from measured isotope shifts using a known value for the field shift factor F. The field shift factor can be computed to good precision from atomic computations without a detailed knowledge of the nuclear parameters.

We present multiconfiguration Dirac–Hartree–Fock (MCDHF) computations of isotope shift parameters for several heavy elements such as bismuth and gold that are provided to support experimental work. In addition, different strategies for evaluating the accuracy of the computed results are discussed.

Instead of describing the field shift by a single parameter F an expansion into higher-order moments can be utilized. Methods for the computation of the corresponding field shift factors are discussed and possibilities for extracting higher order nuclear moments from experimental data are presented.

A 36: Quantum dynamics in tailored waveforms

Time: Friday 10:30–12:15 Location: S HS 3 Physik

Invited Talk A 36.1 Fri 10:30 S HS 3 Physik

Attoclock with tailored polarization — Nicolas Eicke and •Manfred Lein — Institute for Theoretical Physics, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover

The term attoclock refers to the strong-field ionization of an atom and measurement of the resulting photoelectron momentum distribution in order to obtain the (most likely) time of electron departure. Previously, few-cycle circular or elliptical laser fields have been used to achieve a well-defined peak in the momentum distribution, at the price that the ionization timing in linear polarization was not accessible. We propose an attoclock with a bicircular field, i.e. a combination of two counter-rotating circularly polarized fields, tailored such that it mimics linear polarization during three time intervals per optical cycle. For the mapping between electron momentum and ionization time we use a trajectory-free method [N. Eicke, M. Lein, PRA 97, 031402(R) (2018)] based on finding the saddle points of the exact Dyson integral for the momentum-space wave function. From our calculations, we conclude that while ionization is nearly instantaneous for the circular attoclock, the (quasi)linear attoclock has its most likely time of ionization slightly (~10 attoseconds) later than the maximum of the instantaneous field. The momentum-resolved ionization time can alternatively be measured by applying a linearly polarized streaking field parallel or orthogonal to the ionizing field. Parallel streaking yields results in good agreement with the saddle-point times, while orthogonal streaking appears to measure not the true ionization time but a 'Coulomb-free' time, as if the electron were removed from a short-range potential.

Invited Talk A 36.2 Fri 11:00 S HS 3 Physik

Chiral fragmentation of a planar molecule — •Kilian Fehre[1], Sebastian Eckart[1], Maksim Kunitski[1], Martin Pitzer[2], Stefan Zeller[1], Christian Janke[1], Daniel Trabert[1], Jonas Rist[1], Miriam Weller[1], Alexander Hartung[1], Lothar Schmidt[1], Till Jahnke[1], Robert Berger[3], Reinhard Dörner[1], and Markus Schöffler[1] — [1]Institut für Kernphysik Goethe-Universität Frankfurt, Max-von-Laue-Str. 1, 60438 Frankfurt, Germany — [2]Chemical Physics Department Weizmann Institute of Science P.O. Box 26, 76100 Rehovot Israel — [3]Fachbereich Chemie, Philipps-Universität Marburg, Hans-Meerwein-Straße 4, 35032 Marburg, Germany

Most building blocks of living nature are chiral (their mirror image cannot be superimposed with the initial object). We investigate the fully detected five body break-up of formic acid with the COLTRIMS (CoLd Target Recoil Ion Momentum Spectroscopy) technology and discuss two exciting new effects. Firstly, upon n*π^* transition, the initially planar molecule becomes chiral. The observed enantiomer strongly depends on the orientation of the molecule with respect to the light propagation direction and the helicity of the ionizing light. This finding might pave the way for future, purely light-driven control of stereochemistry starting from achiral precursors. Secondly, we observe a very strong (up to 20 %) differential PICD (PhotoIon Circular Dichroism). Like PECD (PhotoElectron Circular Dichroism), PICD shows its self as sensitive probe for the molecular structure.

Invited Talk A 36.3 Fri 11:30 S HS 3 Physik

Simple and robust control of resonant few-photon ionization — •Ulf Saalmann — MPI for the Physics of Complex Systems

It is shown that resonant few-photon ionization can be easily controlled by means of chirped laser pulses. Simply by changing the chirp direction one can switch between excitation and ionization with very high contrast [U Saalmann, S Kumar Giri and J M Rost, PRL 121 (2018) 153203], as calculated paradigmatically for the two-photon ionization of helium. This is a surprising consequence if rapid adiabatic passage is extended to include transitions to the continuum. The chirp phase-locks the linear combination of two resonantly-coupled bound states, whose ionization amplitudes interfere constructively or destructively depending on the chirp direction under suitable conditions. The phenomenon is illustrated by means of a minimal model.

A 36.4 Fri 12:00 S HS 3 Physik

Enhanced Ionization of H_2^+ in Strong Laser Fields — •Philipp Wustelt[1,2], Max Möller[1,2], A. Max Sayler[1,2], Lun Yue[3], Stefanie Gräfe[3], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantum Electronics, Friedrich-Schiller-University Jena, D-07743 Jena, Germany — [2]Helmholtz Institute Jena, D-07743 Jena, Germany — [3]Institute of Physical Chemistry,Friedrich-Schiller University-Jena, Helmholtzweg 4, D-07743 Jena,Germany

Utilizing a benchmark measurement of laser-induced ionization of an H_2^+ molecular ion beam target at infrared wavelength around $2\,\mu$m, we demonstrate that the characteristic two-peak structure predicted for laser-induced enhanced ionization of H_2^+ and diatomic molecules in general [1], is a phenomenon which is confined to a small laser parameter space, where pulse duration and laser intensity are carefully balanced and the interplay between nuclear stretching dynamics and ionization allows for ionization from a broad nuclear wave packet.

Further, we control the effect experimentally and measure its imprint on the electron momentum. We replicate the behavior with simulations, which reproduce the measured kinetic-energy release as well as the correlated electron spectra. Based on this, a model, which both maps out the Goldilocks Zone and illustrates why enhanced ionization has proven so elusive in H_2^+, is derived. This directly address a longstanding debate, explains the elusive nature of enhanced ionization, and serves as a guide for how to manipulate laser parameters to coherently control the phenomenon.

[1] T. Zuo and A. D. Bandrauk, Phys. Rev. A **52**, 2511 (1955)