Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture rooms: BEBEL E34, BEBEL E42, BEBEL E44/46, BEBEL SR140/142 and UDL HS3038; Posters: Spree-Palais)

Invited Talks

A 10.1	Mon	14:00–14:30	BEBEL E44/46	**Coulomb effects and correlation in strong laser-driven quantum dynamics** — •Dieter Bauer
A 18.1	Tue	14:00–14:30	BEBEL E34	**Determination of chiral molecules' handedness** — •Markus Schöffler
A 19.1	Tue	14:00–14:30	BEBEL E42	**The molecular double slit: transition from random to oriented target properties** — •Gregor Hartmann
A 29.1	Wed	14:00–14:30	UDL HS3038	**Single charged impurities inside a Bose-Einstein condensate** — •Sebastian Hofferberth
A 30.1	Wed	14:00–14:30	BEBEL E42	**Stimulated electronic x-ray Raman scattering using x-ray free-electron lasers** — •Nina Rohringer
A 37.1	Thu	10:30–11:00	BEBEL E42	**Electron-impact ionization of highly-charged heavy ions relevant for plasma applications** — •Alexander Borovik
A 38.1	Thu	10:30–11:00	BEBEL E44/46	**Unusual electron dynamics in He clusters induced by intense XUV pulses** — •Yevheniy Ovcharenko
A 41.1	Thu	14:00–14:30	BEBEL E42	**Quantum systems in ultra-strong lasers: from tunnel ionization to spin dynamics** — •Heiko Bauke

Invited talks of the joint symposium SYCS

See SYCS for the full program of the symposium.

SYCS 1.1	Mon	10:30–11:00	Audimax	**Electron dynamics in chiral systems: From structure determination to violation of fundamental symmetries** — •Robert Berger
SYCS 1.2	Mon	11:00–11:30	Audimax	**Electron Scattering in Chiral Photoionization: probing fundamental electron-molecule interactions to chiral molecular recognition** — •Ivan Powis
SYCS 1.3	Mon	11:30–12:00	Audimax	**Enantiomer Identification of Chiral Molecules in Mixtures using Microwave Three-Wave Mixing** — •Melanie Schnell
SYCS 1.4	Mon	12:00–12:30	Audimax	**Mass-selective circular dichroism spectroscopy of chiral molecules** — •Ulrich Boesl

Invited talks of the joint symposium SYQR

See SYQR for the full program of the symposium.

SYQR 2.1	Mon	14:00–14:30	Audimax	**Protocols and prospects for building a quantum repeater** — •Peter van Loock
SYQR 2.2	Mon	14:30–15:00	Audimax	**Quantum teleportation from a telecom-wavelength photon to a solid-state quantum memory** — •Felix Bussieres
SYQR 2.3	Mon	15:00–15:30	Audimax	**Semiconductor quantum light sources for quantum repeaters** — •Peter Michler
SYQR 2.4	Mon	15:30–16:00	Audimax	**Quantum networks based on cavity QED** — •Stephan Ritter

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	10:30–11:00	Audimax	**Rotationally resolved fluorescence spectroscopy - from neurotransmitter to conical intersection** — •Christian Brand
SYAD 1.2	Tue	11:00–11:30	Audimax	**Quantum simulations with ultracold atoms: Beyond standard optical lattices** — •Philipp Hauke
SYAD 1.3	Tue	11:30–12:00	Audimax	**Degenerate quantum gases of alkaline-earth atoms** — •Simon Stellmer
SYAD 1.4	Tue	12:00–12:30	Audimax	**One step beyond entanglement: general quantum correlations and their role in quantum information theory** — •Alexander Streltsov

Invited talks of the joint symposium SYSE

See SYSE for the full program of the symposium.

SYSE 1.1	Wed	14:00–14:30	Audimax	**Addressing open questions of stellar evolution with laboratory experiments** — •Almudena Arcones
SYSE 1.2	Wed	14:30–15:00	Audimax	**Methods and problems of the modern theory of stellar evolution** — •Achim Weiss
SYSE 1.3	Wed	15:00–15:30	Audimax	**Photoabsorption and opacity in the X-ray region: The role of highly charged ions** — •José R. Crespo López-Urrutia
SYSE 1.4	Wed	15:30–16:00	Audimax	**Neutron-rich matter: From cold atoms to neutron stars** — •Achim Schwenk

Prize talks of the joint symposium SYAW

See SYAW for the full program of the symposium.

SYAW 1.1	Wed	14:00–14:30	Kinosaal	**Semicrystalline polymers - pathway of crystallization and deformation properties** — •Gert Strobl
SYAW 1.2	Wed	14:30–15:00	Kinosaal	**A measurement of the evolution of Interatomic Coulombic Decay in the time domain** — •Till Jahnke
SYAW 1.3	Wed	15:00–15:30	Kinosaal	**A one-dimensional liquid of fermions with tunable spin** — •Massimo Inguscio
SYAW 1.4	Wed	15:30–16:00	Kinosaal	**Non-equilibrium: from heat transport to turbulence (to life).** — •David Ruelle
SYAW 2.1	Wed	16:30–17:00	Kinosaal	**Investigation of charge transfer efficiency of CCD image sensors for the scientific small satellite mission "AsteroidFinder"** — •Andrej Krimlowski
SYAW 2.2	Wed	17:00–17:30	Kinosaal	**Metrology of atomic hydrogen: from the Rydberg constant to the size of the proton** — •François Biraben

Invited talks of the joint symposium SYPS

See SYPS for the full program of the symposium.

SYPS 1.1	Thu	14:10–14:40	Audimax	**Oxygen and imaging, a perfect match** — •David Parker
SYPS 1.2	Thu	14:40–15:10	Audimax	**Attosecond imaging** — •Marc Vrakking
SYPS 1.4	Thu	15:25–15:55	Audimax	**Applications of the fast imaging Pixel Imaging Mass Spectrometry camera** — •Mark Brouard
SYPS 2.1	Thu	16:30–17:00	Audimax	**Unraveling the dynamics of state- and conformer selected molecules fixed in space with the VMI** — •Jochen Küpper
SYPS 2.3	Thu	17:15–17:45	Audimax	**Velocity map imaging: from molecules to clusters, nanoparticles and aerosols** — •Michal Farnik
SYPS 2.5	Thu	18:00–18:30	Audimax	**Velocity map imaging studies of quantum state resolved scattering at gas-solid and gas-SAMs surfaces** — •David J. Nesbitt

Invited talks of the joint symposium SYQS

See SYQS for the full program of the symposium.

SYQS 1.1	Fri	10:30–11:15	Audimax	**Tutorial Complex Systems: From Classical to Quantum, from Single to Many Particle Problems** — •Klaus Richter
SYQS 1.2	Fri	11:30–12:00	Audimax	**Multiphoton random walks: Experimental Boson Sampling on a photonic chip** — •Ian Walmsley
SYQS 2.1	Fri	14:00–14:30	Audimax	**Charge transfer and quantum coherence in solar cells and artificial light harvesting systems** — •Christoph Lienau
SYQS 2.6	Fri	15:30–16:00	Audimax	**Feedback control: from Maxwell's demon to quantum phase transitions** — •Tobias Brandes
SYQS 3.4	Fri	17:15–17:45	Audimax	**Multi-photon dynamics in complex integrated structures** — •Fabio Sciarrino
SYQS 3.5	Fri	17:45–18:15	Audimax	**Complexity and many-boson coherence** — •Malte Tichy

Sessions

A 1.1–1.8	Mon	10:30–12:30	BEBEL E34	**Ultra-cold atoms, ions and BEC I (with Q)**
A 2.1–2.8	Mon	10:30–12:30	BEBEL E42	**Precision spectroscopy of atoms and ions I (with Q)**
A 3.1–3.8	Mon	10:30–12:30	BEBEL E44/46	**Interaction with strong or short laser pulses I**
A 4.1–4.4	Mon	10:30–12:30	Audimax	**Electron Dynamics in Chiral Systems SYCS 1 (with MO)**
A 5.1–5.6	Mon	10:30–12:00	DO24 1.101	**Ultracold plasmas and Rydberg systems I (with Q)**
A 6.1–6.8	Mon	10:30–12:30	BEBEL SR144	**Clusters (with MO)**
A 7.1–7.7	Mon	10:30–12:15	UDL HS2002	**Flying/Stationary Qubit Conversion and Entanglement Generation SYQR 1 (with Q)**
A 8.1–8.8	Mon	14:00–16:00	BEBEL E34	**Ultra-cold atoms, ions and BEC II (with Q)**
A 9.1–9.8	Mon	14:00–16:00	BEBEL E42	**Precision spectroscopy of atoms and ions II (with Q)**
A 10.1–10.7	Mon	14:00–16:00	BEBEL E44/46	**Atomic systems in external fields**
A 11.1–11.6	Mon	14:00–16:00	BEBEL HS213	**Electron Dynamics in Chiral Systems SYCS 2 (with MO)**
A 12.1–12.4	Mon	14:00–16:00	Audimax	**Quantum Repeaters SYQR 2 (with Q)**
A 13.1–13.6	Mon	14:00–15:30	DO24 1.101	**Ultracold plasmas and Rydberg systems II (with Q)**
A 14.1–14.28	Mon	16:30–18:30	Spree-Palais	**Poster: Precision spectroscopy of atoms and ions (with Q)**
A 15.1–15.19	Mon	16:30–18:30	Spree-Palais	**Poster: Interaction with strong or short laser pulses**
A 16.1–16.4	Tue	10:30–12:30	Audimax	**Symposium SAMOP Dissertation-Prize 2014 SYAD (with Q, MO, P)**
A 17.1–17.7	Tue	10:30–12:15	Kinosaal	**Quantum Protocols and Gates SYQR 3 (with Q)**
A 18.1–18.7	Tue	14:00–16:00	BEBEL E34	**Interaction with strong or short laser pulses II**
A 19.1–19.7	Tue	14:00–16:00	BEBEL E42	**Photoionization**
A 20.1–20.8	Tue	14:00–16:00	BEBEL E44/46	**Ultra-cold plasmas and Rydberg systems III (with Q)**
A 21.1–21.7	Tue	14:00–15:45	BEBEL SR140/142	**Precision spectroscopy of atoms and ions III (with Q)**
A 22.1–22.7	Tue	14:00–15:45	Kinosaal	**Photon Sources for Quantum Networks SYQR 4 (with Q)**
A 23.1–23.6	Tue	16:30–18:30	Spree-Palais	**Poster: Atomic clusters (with MO)**
A 24.1–24.3	Tue	16:30–18:30	Spree-Palais	**Poster: Atomic systems in external fields**
A 25.1–25.10	Tue	16:30–18:30	Spree-Palais	**Poster: Electron scattering and recombination**
A 26.1–26.6	Tue	16:30–18:30	Spree-Palais	**Poster: Interaction of matter and collisions with ions**
A 27.1–27.12	Tue	16:30–18:30	Spree-Palais	**Poster: Photoionization**
A 28.1–28.9	Tue	16:30–18:30	Spree-Palais	**Poster: Ultra-cold plasmas and Rydberg systems (with Q)**
A 29.1–29.7	Wed	14:00–16:00	UDL HS3038	**Ultra-cold atoms, ions and BEC III (with Q)**
A 30.1–30.7	Wed	14:00–16:00	BEBEL E42	**Interaction with VUV and X-ray light I**
A 31.1–31.4	Wed	14:00–16:00	Audimax	**Fathoming Stellar Evolution with Laboratory Precision SYSE (with MS, Q, MO, EP)**
A 32.1–32.4	Wed	14:00–16:00	Kinosaal	**Awards Symposium I (SYAW 1)**
A 33.1–33.2	Wed	16:30–17:30	Kinosaal	**Awards Symposium II (SYAW 2)**
A 34.1–34.31	Wed	16:30–18:30	Spree-Palais	**Poster: Ultra-cold atoms, ions and BEC (with Q)**
A 35.1–35.16	Wed	16:30–18:30	Spree-Palais	**Poster: Interaction with VUV and X-ray light**
A 36.1–36.8	Thu	10:30–12:30	BEBEL E34	**Ultra-cold atoms, ions and BEC IV (with Q)**
A 37.1–37.7	Thu	10:30–12:30	BEBEL E42	**Electron scattering and recombination**
A 38.1–38.7	Thu	10:30–12:30	BEBEL E44/46	**Atomic clusters (with MO)**

A 39.1–39.8	Thu	10:30–12:30	BEBEL SR140/142	**Precision spectroscopy of atoms and ions IV (with Q)**
A 40.1–40.8	Thu	14:00–16:00	BEBEL E34	**Interaction with strong or short laser pulses III**
A 41.1–41.7	Thu	14:00–16:00	BEBEL E42	**Interaction with VUV and X-ray light II**
A 42.1–42.6	Thu	14:00–15:30	DO26 208	**Ultracold atoms and molecules I (with Q)**
A 43.1–43.4	Thu	14:00–15:55	Audimax	**Velocity map imaging - focusing on intra- and inter-atomic dynamics SYPS 1 (with jDPG)**
A 44.1–44.7	Thu	14:00–16:00	DO24 1.101	**Precision measurements and metrology I (with Q)**
A 45.1–45.5	Thu	16:30–18:30	Audimax	**Velocity map imaging - focusing on intra- and inter-atomic dynamics SYPS 2 (with jDPG)**
A 46.1–46.6	Thu	16:30–18:00	BEBEL E34	**Atomic collisions and ultracold plasmas**
A 47.1–47.8	Thu	16:30–18:30	BEBEL E42	**Attosecond physics**
A 48.1–48.8	Thu	16:30–18:30	BEBEL SR140/142	**Ultra-cold atoms, ions and BEC V (with Q)**
A 49.1–49.6	Thu	16:30–18:30	DO24 1.101	**Precision measurements and metrology II (with Q)**
A 50.1–50.5	Fri	10:30–11:45	BEBEL E34	**Ultra-cold atoms, ions and BEC VI (with Q)**
A 51.1–51.6	Fri	10:30–12:00	BEBEL E42	**Interaction with VUV and X-ray light III**
A 52.1–52.4	Fri	10:30–12:30	Audimax	**Characterization and control of complex quantum systems SYQS 1 (with Q, MO, MS, MP, AGjDPG)**
A 53.1–53.7	Fri	10:30–12:30	DO24 1.101	**Precision measurements and metrology III (with Q)**
A 54.1–54.6	Fri	14:00–15:45	DO24 1.101	**Precision measurements and metrology IV (with Q)**
A 55.1–55.6	Fri	14:00–16:00	Audimax	**Characterization and control of complex quantum systems SYQS 2 (with Q, MO, MS, MP, AGjDPG)**
A 56.1–56.6	Fri	14:00–15:30	DO26 208	**Ultracold atoms and molecules II (with Q)**
A 57.1–57.6	Fri	16:30–18:15	DO24 1.101	**Precision measurements and metrology V (with Q)**
A 58.1–58.5	Fri	16:30–18:30	Audimax	**Characterization and control of complex quantum systems SYQS 3 (with Q, MO, MS, MP, AGjDPG)**

Annual General Meeting of the Atomic Physics Division

Thursday 13:15–14:00 BEBEL E44/46

- Bericht
- Wahl
- Verschiedenes

A 1: Ultra-cold atoms, ions and BEC I (with Q)

Time: Monday 10:30–12:30 Location: BEBEL E34

A 1.1 Mon 10:30 BEBEL E34

Optical Trapping of a Barium Ion — •Thomas Huber, Alexander Lambrecht, Julian Schmidt, Michael Zugenmaier, Leon Karpa, and Tobias Schaetz — Albert-Ludwigs Universität, Freiburg, Deutschland

Trapping ions in optical dipole traps [1] or optical lattices [2] overcomes fundamental limitations for ultracold chemistry experiments set by intrinsic RF driven micromotion [3]. In our former experiments, the lifetime of optically trapped Mg+ ions was limited by recoil heating. We now report the optical trapping of a Ba+ ion in a FORT where the scattering events are substantially suppressed.

We will discuss lifetimes, their limitations, such as the decay into metastable D levels, as well as results on investigating those via efficient repumping schemes. We report about a conceptually new method to compensate electric stray fields necessary to allow high transfer efficiencies between the RF trap (required for initialization) and the FORT. We propose new methods to characterize the dipole force and the related secular frequencies of an ion trapped by the optical dipole trap and the DC potentials.

The progress of a new experiment, mitigating limitations of the current setup will be reported in which the optically trapped ion interacts with atoms from a Magneto Optical Trap.

[1]Nature Photonics 4, 772-775 (2010)
[2]Phys. Rev. Lett. 109, 233004 (2012)
[3]Phys. Rev. Lett. 109, 253201 (2012)

A 1.2 Mon 10:45 BEBEL E34

Generalised Dicke non-equilibrium dynamics in trapped ions — •Sam Genway[1], Weibin Li[1], Cenap Ates[1], Benjamin Lanyon[2,3], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, University of Nottingham, United Kingdom — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [3]Institut für Experimentalphysik, Universität Innsbruck, Austria

We explore trapped ions as a setting to investigate non-equilibrium phases in a generalised Dicke Model of dissipative spins coupled to phonon modes. We find a rich dynamical phase diagram as a function of the spin-phonon coupling and dissipation strength, which includes superradiant-like regimes, dynamical phase-coexistence and phonon-lasing behaviour. A particular advantage of the trapped-ion set-up is that these dynamical phases, and the transitions between them, can be probed in situ via fluorescence measurements. We introduce a minimal model that captures the main physical insights and consider an experimental realisation with Ca^+ ions trapped in a linear Paul trap with a dressing scheme to create effective two-level systems with a tunable dissipation rate [1].

[1] S. Genway, W. Li, C. Ates, B. P. Lanyon and I. Lesanovsky. arXiv:1308.1424 (To appear in Phys. Rev. Lett.)

A 1.3 Mon 11:00 BEBEL E34

Rapid production of a quantum gas of lithium using narrow-line cooling — •Ahmed Omran[1,2], Martin Boll[1,2], Timon Hilker[1,2], Thomas Reimann[1,2], Alexander Keesling[1,2], Konrad Viebahn[1,2], Immanuel Bloch[1,2], and Christian Gross[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str.1, 85748 Garching — [2]Ludwig-Maximilians-Universität München, Fakultät für Physik, Schellingstraße 4, 80799 München

We present an all-optical method for cooling fermionic lithium atoms to degeneracy with a cycle time of 10s. Standard laser cooling of the atomic cloud is followed by a second stage of laser cooling along the narrow $2S_{1/2} \rightarrow 3P_{3/2}$ transition at 323 nm, which yields a lower Doppler temperature [1]. To that end, we built a laser system for producing UV light using two nonlinear frequency conversions, which gives significantly more power than commercial solutions [2].

An optical dipole trap operating near a "magic wavelength", where the UV transition exhibits no light shift, directly captures the atoms from the UV MOT to evaporatively cool them to degeneracy using a Feshbach resonance. This efficient production of fermionic quantum gases is an important step towards our planned study of fermionic many body systems in optical superlattices.

[1] P. M. Duarte et al, Phys. Rev. A 84, 061406(R) [2011]
[2] A. C. Wilson, Appl. Phys. B 105, 741-748 [2011]

A 1.4 Mon 11:15 BEBEL E34

All-optical cooling scheme for a quantum degenerate ^{6}Li-^{133}Cs mixture — •Alda Arias, Rico Pires, Juris Ulmanis, Stephan Häfner, Carmen Renner, Marc Repp, Eva Kuhnle, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg

We have recently measured Feshbach resonances (FRs) in an ultracold ^{6}Li-^{133}Cs mixture with a phase-space density of a factor of 100 below quantum degeneracy [1]. In this talk we will present an all-optical scheme to bring both gases together to quantum degeneracy. After ^{6}Li is loaded and evaporated in a tightly focused crossed-dipole trap (CDT), ^{133}Cs will be loaded into a spatially separated large volume reservoir trap. Subsequently, both traps are spatially overlapped and the CDT serves as a dimple trap [2] for Cs. The difference in trapping potentials, that both species experience due to their different polarizabilities, is compensated by a tune out wavelength trap. With a frequency between the D_1 and D_2 lines of Cs, it only confines the ^{6}Li atoms, while exerting no additional force on Cs. This independent control of the trapping potential of both species, together with the tunability of the interspecies scattering length by means of FRs will allow us to evaporate to double quantum degeneracy, which is an excellent starting point for future experiments on few- and many-body physics.

[1] M. Repp et al., Phys. Rev. A 87, 010701(R) (2013)
[2] T. Weber et al., Science 299, 232 (2003).

A 1.5 Mon 11:30 BEBEL E34

Sympathetic cooling of ions in higher-order rf traps using laser-cooled atoms in a MOT — •Pascal Weckesser, Bastian Höltkemeier, Henry Lopez, Julian Glässel, and Matthias Weidemüller — Physikalisches Institut, Im Neuenheimerfeld 226, 69120 Heidelberg, Germany

Molecular ions are usually caught in a linear Paul trap and cooled sympathetically by He buffer gas. In order to reach lower temperatures for a wide range of molecular ions we investigate replacing He with laser-cooled atoms. Recent theories indicate that cooling in ion traps homogeneously filled with ultracold atoms is limited by the atom-ion mass ratio.

We derive that a localized cloud of ultracold atoms in higher order radio frequency traps overcomes the mentioned mass ratio limitation. A proper description of this local criterion and its features will be introduced.

A 1.6 Mon 11:45 BEBEL E34

Emulating Solid-State Physics with a Hybrid System of Ultracold Ions and Atoms — •Ulf Bissbort[1,2,3], Daniel Cocks[3], Antonio Negretti[4], Zbigniew Idziaszek[5], Tommaso Calarco[6], Ferdinand Schmidt-Kaler[7], Walter Hofstetter[3], and René Gerritsma[7] — [1]MIT, Cambridge, USA — [2]SUTD, Singapore — [3]Johann Wolfgang Goethe-Universität, Frankfurt/Main, Germany — [4]Zentrum für Optische Quantentechnologien, Hamburg, Germany — [5]Faculty of Physics, University of Warsaw, Poland — [6]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [7]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

We propose and theoretically investigate a hybrid system composed of a crystal of trapped ions coupled to a cloud of ultracold fermions. The ions form a periodic lattice and induce a band structure in the atoms. This system combines the advantages of high *delity operations and detection offered by trapped ion systems with ultracold atomic systems. It also features close analogies to natural solid-state systems, as the atomic degrees of freedom couple to phonons of the ion lattice, thereby emulating a solid-state system. Starting from the microscopic many-body Hamiltonian, we derive the low energy Hamiltonian, including the atomic band structure, and give an expression for the atom-phonon coupling. We discuss possible experimental implementations such as a Peierls-like transition into a period-doubled dimerized state.

A 1.7 Mon 12:00 BEBEL E34

Dysprosium atoms in an optical dipole trap — •Holger Kadau, Thomas Maier, Matthias Schmitt, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Strongly dipolar quantum gases enable the observation of many-body phenomena with anisotropic, long-range interaction. Rotonic features, 2D stable solitons and the supersolid state are some of the exotic many-body phenomena predicted for dipolar quantum gases. The element with the strongest magnetic dipole moment is Dysprosium. It is a rare-earth element with a complex energy level structure and several possible cooling transitions. We have prepared samples of dysprosium atoms at $\sim 10\,\mu$K in a magneto-optical trap by laser cooling on a narrow transition at 626 nm. We load several million atoms into an optical dipole trap and transport them to a glass cell with high optical access.

The next goals are evaporative cooling in a crossed optical dipole trap to quantum degeneracy and implementing a high resolution imaging system with the possibility to create nearly arbitrary time-averaged potentials.

A 1.8 Mon 12:15 BEBEL E34

Analogue of Cosmological Particle Creation in an Ion Trap — •Christian Fey[1], Tobias Schaetz[2], and Ralf Schützhold[1] — [1]Universität Duisburg-Essen, Duisburg, Deutschland — [2]Albert-Ludwigs-Universität, Freiburg, Deutschland

We study linear vibrations of ions confined by a trap with a time-dependent potential strength. This system behaves similarly to quantum fields in an expanding or contracting universe, where changes in the metric/curvature produce entangled particles of opposite momenta. For the ions we interpret the strength of the trapping potential as "curvature" and describe the creation of squeezed and entangled phonon-states.

A 2: Precision spectroscopy of atoms and ions I (with Q)

Time: Monday 10:30–12:30 Location: BEBEL E42

A 2.1 Mon 10:30 BEBEL E42

Messung der Zyklotronfrequenz eines einzelnen Protons in einer Penningfalle — •Peter Koss[1], Klaus Blaum[2,3], Sascha Bräuninger[2,3], Holger Kracke[1,4], Clemens Leiteritz[1,4], Andreas Mooser[1,4], Wolfgang Quint[3,5], Stefan Ulmer[6] und Jochen Walz[1,4] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [3]Ruprecht-Karls-Universität, 69047 Heidelberg — [4]Helmholtz Institut Mainz, 55099 Mainz — [5]GSI, 64291 Darmstadt — [6]RIKEN, Wako, Saitama 351-0198, Japan

Ziel des Experiments ist die Bestimmung des g-Faktors eines einzelnen Protons in einem Doppel-Penningfallen-Aufbau. Der g-Faktor kann aus der Messung der freien Zyklotronfrequenz $\nu_c = \frac{q}{m}B$ und der Larmorfrequenz $\nu_L = g\frac{q}{2m}B$ über die Relation $\frac{g}{2} = \frac{\nu_L}{\nu_c}$ bestimmt werden. Die freie Zyklotronfrequenz wird aus den Bewegungsfrequenzen der drei unabhängigen Eigenbewegungen des Protons in der Falle über das Invarianztheorem $\nu_c^2 = \nu_+^2 + \nu_-^2 + \nu_z^2$ bestimmt. Der limitierende Faktor bei der Bestimmung der freien Zyklotronfrequenz ist die Unsicherheit der modifizierten Zyklotronfrequenz, da diese die größte der drei Eigenfrequenzen ist. Die modifizifierte Zyklotronfrequenz muss somit möglichst genau bestimmt werden. Dazu wurden drei Messmethoden zur Bestimmung von ν_+, die kohärente Detektion, die sequentielle Doppel-Dip-Messung und die verzahnte Doppel-Dip-Messung, systematisch untersucht. In diesem Vortrag werden die Methoden zunächst vorgestellt und anschließend verglichen.

A 2.2 Mon 10:45 BEBEL E42

Nachweis von einzelnen Spin-Quantensprüngen eines in einer Penningfalle gespeicherten Protons — •Clemens Leiteritz[1], Andreas Mooser[1,2], Peter Koss[1], Holger Kracke[1,2], Klaus Blaum[3], Wolfgang Quint[4,5], Stefan Ulmer[6] und Jochen Walz[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]Helmholtz Institut Mainz, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [3]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [4]Ruprecht-Karls-Universität, 69047 Heidelberg — [5]GSI Darmstadt, 64291 Darmstadt — [6]RIKEN, Wako, Saitama 351-0198, Japan

Wir berichten über ein Experiment zur Bestimmung des g-Faktors eines einzelnen, in einer Penningfalle gespeicherten Protons. Es wird eine relative Genauigkeit von 10^{-9} angestrebt. Der g-Faktor $g = 2\frac{\omega_L}{\omega_c}$ kann aus der Messung der freien Zyklotronfrequenz $\omega_c = \frac{q}{m}B$ sowie der Larmorfrequenz ω_L im Magnetfeld B bestimmt werden. Hierzu verwenden wir ein Doppel-Penningfallensystem. In der Präzisionsfalle wird die freie Zyklotronfrequenz bestimmt und durch ein angelegtes Hochfrequenz-Feld ein Umklappen des Spins induziert. Durch eine magnetische Inhomogenität im Zentrum der Analysefalle wird der Spin des Protons an die axiale Bewegung entlang des Magnetfelds gekoppelt. Spin-Quantensprünge lassen sich anhand kleiner Änderungen der Axialfrequenz des Teilchens identifizieren. Diese Technik ermöglicht die Messung der Spin-Flip Rate als Funktion der angelegten Hochfrequenz, und somit eine Bestimmung der Larmorfrequenz. Im Vortrag wird der aktuelle Stand des Experiments vorgestellt.

A 2.3 Mon 11:00 BEBEL E42

Theoretical calculations for the determination of the electron mass via measurement of the g-factor of $^{12}C^{5+}$ — •Jacek Zatorski[1], Zoltán Harman[1,2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, Planckstraße 1, 64291 Darmstadt, Germany

We present theoretical results of a recent determination of the electron mass (Ref. [1]) via measurement of the bound electron g-factor in $^{12}C^{5+}$. The electron mass was determined with a relative uncertainty approximately 13 times lower than the established CODATA value (Ref. [2]) by means of comparison of theoretical prediction for $g\left(^{12}C^{5+}\right)$ and the experimental value. In order to reduce an error bar on the theory's side, we, first of all, estimated the unknown two-loop higher-order correction to $g\left(^{12}C^{5+}\right)$, which is the main source of the uncertainty, by extracting this effect from experimental results for $g\left(^{28}Si^{13+}\right)$. In addition, we have improved on the accuracy of certain other physical terms contributing to the g-factor.

[1] S. Sturm, F. Köhler, J. Zatorski, A. Wagner, Z. Harman, G. Werth, W. Quint, C. H. Keitel, and K. Blaum, manuscript submitted.
[2] P. J. Mohr, B. N. Taylor and D. B. Newell, Rev. Mod. Phys. 84, 1527 (2012).

A 2.4 Mon 11:15 BEBEL E42

High-precision QED calculations of the g factor of Li-like ions — •Andrey Volotka[1], Dmitry Glazov[2], Vladimir Shabaev[2], Ilya Tupitsyn[2], and Günter Plunien[1] — [1]Institut für Theoretische Physik, TU Dresden — [2]St. Petersburg State University, Russia

Recent progress in *ab initio* QED calculations of the g factor of Li-like ions will be reported. The one- and two-photon exchange as well as the screened radiative corrections have been rigorously evaluated within an extended Furry picture, which includes a local screening potential in the unperturbed Hamiltonian. In addition, a special scheme, which considerably accelerates the partial-wave expansion convergence, has been employed for the evaluation of the screened radiative corrections. As a result, the theoretical accuracy for the g factor of Li-like ions has been significantly increased for all values of Z.

A 2.5 Mon 11:30 BEBEL E42

Doppler-free broadband two-photon excitation spectroscopy with two optical frequency combs — •Arthur Hipke[1,2], Samuel A. Meek[1], Nathalie Picqué[1,2,3], and Theodor W. Hänsch[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, Fakultät für Physik, Schellingstrasse 4/III, 80799 München, Germany — [3]Institut des Sciences Moléculaires d'Orsay, CNRS, Bâtiment 350, Université Paris-Sud, 91405 Orsay, France

Doppler-free precision measurements of atomic samples are traditionally performed using either a cw laser, or an optical frequency comb for sample interrogation. The limited spectral span where powerful cw lasers are available, however, puts a limit on the optical transitions it can be used for. Using a comb instead considerably complicates data analysis, since multiple transitions can potentially be driven simultaneously, resulting in highly intricate spectra. The limitations of both of these techniques can be overcome by simultaneously interrogating the sample with two combs having slightly detuned repetition rates. We demonstrate this technique's capability for high-resolution (up to 2 MHz) broadband precision spectroscopy by exciting the $5S_{1/2} \rightarrow 5D_{3/2}$ and $5S_{1/2} \rightarrow 5D_{5/2}$ two-photon transitions of atomic Rb vapor at 385 THz (778 nm). Broad two-photon excitation spectra showing well-resolved excited-states Rb hyperfine structure will be presented, clearly paving the way for precision spectroscopy of complex, molecular spectra in any spectral region where optical frequency combs are available.

A 2.6 Mon 11:45 BEBEL E42

Ra^+ ion trapping -Atomic Parity Violation measurement and an optical clock — •Amita Mohanty, Elwin A. Dijck, Mayerlin Nunez Portela, Nivedya Valappol, Oliver Boell, Klaus Jungmann, Cornelis G. G Onderwater, Sophie Schlesser, Rob G. E. Timmermans, Lorenz Wilmann, and Hans W. Wilschut — University of Groningen, FWN, Zernikelaan 25, NL-9747AA Groningen

A single trapped Ra^+ ion has an excellent potential for a precision measurement of the Weinberg mixing angle at low momentum transfer and testing thereby the electroweak running. The absolute frequencies of the transition 7s $^2S_{1/2}$-7d$^2D_{3/2}$ at wavelength 828 nm have been determined in $^{212*214}Ra^+$ to better than 19 MHz with laser spectroscopy on small samples of ions trapped in a linear Paul trap at the online facility TRIμP of KVI. The measurement of the Weinberg angle requires the localization of the ion within a fraction of an optical wavelength. The current experiments are focused on trapping and laser spectroscopy on a single Ba+ as a precursor for Ra^+. Work towards single ion trapping of Ra^+, including the preparation of an offline ^{223}Ra source is in progress. Most elements of the setup for single Ra+ ion parity measurement are also well suited for realizing a most stable optical clock.

A 2.7 Mon 12:00 BEBEL E42

Determination of the level structure of Ir^{17+} featuring transitions extremely sensitive to a variation of the fine-structure constant — •Alexander Windberger[1], Oscar O. Versolato[2], Hendrik Bekker[1], Victor Bock[1], Sebastian Kaul[1], Ruben Schupp[1], Julian Stark[1], Joachim Ullrich[2], Zoltan Harman[1], Natalia Oreshkina[1], Christoph Keitel[1], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Leibniz Universität, Hannover

The Ir^{17+} ion is an ideal system to detect a possible variation of the fine-structure constant and test it in the laboratory, such as the one claimed by Webb and coworkers based on their analysis of quasar absorption spectra at high redshifts. The required sensitivity at the level of 10^{-19} /year can be attained by comparing highly forbidden optical transitions in the Ir^{17+} ion in a clock setup. Since theory reaches only an accuracy of 10^{-1} for those frequencies, an exploration of its electronic structure is needed. We perform electron excitation spectroscopy on Ir^{17+} inside the Heidelberg electron beam ion trap (EBIT) in the optical and vacuum-ultraviolet (VUV) range with an accuracy of 5 ppm and 200 ppm, respectively. To assign transitions to their corresponding levels, different approaches are considered, such as Rydberg-Ritz combinations, determination of g-factors, and use of the characteristic energy scaling of M1 transitions as a function of the atomic number. VUV fluorescence spectroscopy with FLASH-EBIT at BESSY II will be used for improved investigations of key ground state transitions.

A 2.8 Mon 12:15 BEBEL E42

The mass of the electron — •Florian Köhler[1,2,3], Sven Sturm[3], Anke Wagner[3], Günter Werth[4], Wolfgang Quint[1,2], and Klaus Blaum[3] — [1]Fakultät für Physik, Universität Heidelberg — [2]GSI Darmstadt — [3]Max-Planck-Institut für Kernphysik, Heidelberg — [4]Institut für Physik, Johannes Gutenberg-Universität, Mainz

Recently the g-factor experiment for highly charged ions located in Mainz has provided the most stringent bound-state quantum electrodynamics (BS-QED) test [1]. Here, the bound electron g-factor of $^{28}Si^{13+}$ has been determined by the Larmor-to-cyclotron frequency ratio and the ion-to-electron mass ratio. For hydrogenlike ions with small nuclear charge, e.g. Z=6, the g-factor can be calculated with parts-per-trillion precision. Experimental improvements [2] enabled the measurement of the Larmor-to-cyclotron frequency ratio with a relative precision of $3 \cdot 10^{-11}$ for $^{12}C^{5+}$. In combination with theoretical predictions, the atomic mass of the electron has been improved by a factor of 13 with respect to the current CODATA value. This result will directly contribute to ultra-high precision tests of the Standard Model, e.g. the determination of the fine structure constant [3] and future BS-QED tests. In this talk the measurement of the electron mass will be presented and the current status on BS-QED tests will be summarised.

[1] S. Sturm *et al.*, Phys. Rev. Lett. **107**, 023002 (2011)
[2] S. Sturm *et al.*, Phys. Rev. Lett. **107**, 143003 (2011)
[3] R. Bouchendira *et al.*, Phys. Rev. Lett. **106**, 080801 (2011)

A 3: Interaction with strong or short laser pulses I

Time: Monday 10:30–12:30 Location: BEBEL E44/46

A 3.1 Mon 10:30 BEBEL E44/46

Describing the phase of a tunneling electron wave packet by interference with an XUV electron — •Jost Henkel and Manfred Lein — Institut für Theoretische Physik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover Appelstraße 2, 30167 Hannover, Germany

The interference pattern in the photoelectron momentum distribution created by ionization from an IR field and an XUV pulse encodes information about the phases for both ionization processes. Assuming knowledge of the XUV single-photon ionization properties, the interference pattern could provide access to the photoelectron phase in IR ionization. By comparing numerical and analytical solutions of the strong-field approximation (SFA) to numerical solutions of the time-dependent Schrödinger equation (TDSE) for the IR ionization process we can identify additional phase contributions not contained in the SFA. These phase shifts are caused by the core potential or Stark shifting of the ground state during ionization.

A 3.2 Mon 10:45 BEBEL E44/46

Off-axis low-energy structures in above threshold ionization with long wavelength — •Max Möller[1,2], Frank Meyer[1], A. Max Sayler[1,2], Dejan B. Milosevic[3], Wilhelm Becker[4], and Gerhard G. Paulus[1,2] — [1]Institute for Optics and Quantum Electronics, Friedrich Schiller University Jena, Germany — [2]Helmholtz Institute Jena, Germany — [3]Academy of Sciences and Arts of Bosnia and Herzegovina, Bosnia and Herzegovina — [4]Max Born Institute for Nonlinear Optics and Short-Pulse Spectroscopy, Germany

The angle-resolved above-threshold ionization spectra at wavelengths around 2 microns exhibit a characteristic fork-like structure perpendicular to the laser polarization. An extension of the simple-man's model to include angular rescattering and multiple returns reveals the electron trajectories which are responsible for the observed structures.

A 3.3 Mon 11:00 BEBEL E44/46

Laser field induced correlated tunneling of electrons — •Natalya Sheremetyeva, Mara Osswald, and Alejandro Saenz — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin, Germany

Ionization is the central process that controls many phenomena occurring during the interaction of strong laser fields with matter. Often, only the ionization of valence electrons is considered. In reality, more electrons may be involved in the process and their dynamics is correlated. A theoretical description of this dynamics is complicated and in most cases some approximation has to be adopted.

Z. Walters and O. Smirnova proposed a semi-classical model, in which a weakly bound electron escapes from the nuclear potential via tunneling, generating an 'attosecond correlation pulse'. This pulse can excite a more strongly bound electron and can elevate it to the vacated energy level. Consequently, since the electrons are indistinguishable, it appears as if the more strongly bound electron has tunneled directly. Interestingly, it was found in [1] that this particular two-step process has a higher probability than direct tunnel ionization out of the deeper orbital.

We present a quantum-mechanical version of this model. Separate investigations of the influence of the external laser field and the electron interaction on the excitation probability of the more strongly bound electron allows us to search for specific effects due to tunneling. We find no evidence of a tunneling-specific 'attosecond correlation pulse'.

[1] Z. Walters and O. Smirnova, J. Phys. B, 43 (2010), p. 161002

A 3.4 Mon 11:15 BEBEL E44/46

Rydberg state distribution of neutral Helium atoms after frustrated tunneling ionization (FTI) — •Henri Zimmermann, Sebastian Eilzer, and Ulli Eichmann — Max-Born-Institut for Nonlinear Optics und Short Pulse Spectroscopy, Berlin, Germany

Excitation of neutral atoms by short intense laser pulses through the process of frustrated tunneling ionization (FTI) has been found to be one of the four dominant processes in the tunneling regime of strong-field ionization. Several numerical methods ranging from classical to fully correlated quantum mechanical calculations have been used for the prediction of the excited state distribution generated by this process but so far an experimental investigation is still missing. Here, we present the first experimental confirmation of the theoretical predictions for the surviving neutral atoms for Helium. Furthermore we show the presence of laser induced spin dynamics upon excitation as well as the possibility of their modification.

A 3.5 Mon 11:30 BEBEL E44/46

Time delay of laser-induced tunnel-ionization — •Enderalp Yakaboylu, Michael Klaiber, Heiko Bauke, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg,Germany

The tunneling time delay, stemming from Wigner's definition, is investigated for laser-induced tunnel-ionization. First, the concept of Wigner time delay is applied to one-dimensional model configurations of tunneling and it is compared with results obtained from the exact propagator. Then, by adapting Wigner's time delay definition, the tunneling time is investigated in the deep-tunneling and in the near-threshold-tunneling regimes of tunnel-ionization from a Coulomb potential. It is shown that while in the deep-tunneling regime signatures of the tunneling time delay are not measurable at remote distance, it is detectable, however, in the near-threshold-tunneling regime [1,2].

[1] E. Yakaboylu, M. Klaiber, H. Bauke, K. Z. Hatsagortsyan, and C. H. Keitel, preprint arXiv:1309.0610 (to be published in Phys. Rev. A.)

[2] M. Klaiber, E. Yakaboylu, H. Bauke, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Rev. Lett. 110, 053814 (2013)

A 3.6 Mon 11:45 BEBEL E44/46

Real-time tracking of two-electron dynamics in the ionization continuum of Xe — •Mursal Baggash and Horst Rottke — Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Straße 2 A, 12489 Berlin, Germany

We present real-time tracking of atomic 2-electron coherent dynamics in excited autoionizing wavepackets in Xenon using a pump-probe detection scheme. An extreme-ultraviolet (xuv) radiation pulse coherently excites different Fano-resonances simultaneously. The excited resonances are of the type of a single inner-valence-shell and a double valence-shell excitation. The lunched wavepackets' evolution in time is probed with a delayed infrared (ir) laser pulse which further excites one of the electrons to the $(5s)^2(5p)^4 nl\epsilon l'$ ionization continuum where it is detected. We are able to track the oscillatory beating of the formed wavepackets that is imprinted on their decay through autoionization.

A 3.7 Mon 12:00 BEBEL E44/46

Ionization dynamics of atoms anc molecules in sculpted two-color laser fields — •Slawomir Skruszewicz, Robert Irsig, Mohammad Adel Almajid, Dieter Bauer, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Institut für Physik, Universitätsplatz 3, 18051 Rostock, Germany

We present recent results on ionization of atoms and molecules in sculpted two-color laser fields. Technique enables to create electron wavepackets wit sub-fs duration by highly non-linear tunneling process [1] and actively control its dynamics on sub-fs time scale [2]. Consequently, the interference patter between wavepacket propagating in oscillatory laser field can be resolved by means of the angular-resolved photoelectron spectroscopy. Additionally, we identify the ionic Coulomb field influence on propagating electron wavepackets by comparing experimental data with results of strong-field approximation calculations and solving of time-dependent Schrödinger equation.

[1] P. B. Corkum and F.Krausz. Nature Physics 3, 381 (2007) [2] N. Dudovich et. al., Nature 2, 781 (2006)

A 3.8 Mon 12:15 BEBEL E44/46

Strong-field Ionization of Atomic Ions — •P. Wustelt[1,2], M. Möller[1,2], T. Rathje[1,2], S. Trotsenko[2,3], Th. Stöhlker[1,2,3], A.M. Sayler[1,2], and G.G. Paulus[1,2] — [1]Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena, Germany — [2]Helmholtz Institute Jena, Germany — [3]GSI, Darmstadt, Germany

Using a fast ion beam, we investigate the multi-electron strong-field ionization dynamics of atomic ions, in particular in elliptically polarized pulsed laser fields.

In contrast to linear polarization, for elliptically polarized many-cycle pulses, the final ion momentum distribution in single ionization provides direct and complete information on the ionizing field strength as well as the ionization time. Furthermore, we are able to reconstruct the electron momenta from the ion momentum distributions after multiple ionization and, therefore, gain information on the ionization field strength as well as on the release times for subsequent ionization steps.

The results are compared to predictions from classical Monte-Carlo simulations based on quasistatic ionization rates.

In addition, the subtle effects of the Coulomb interaction on the electron trajectory lead to a tilt in the observed momentum distribution. These effects can be used to study the kinematics and the initial conditions of the electron following tunnel ionization.

A 4: Electron Dynamics in Chiral Systems SYCS 1 (with MO)

Time: Monday 10:30–12:30 Location: Audimax

Invited Talk A 4.1 Mon 10:30 Audimax

Electron dynamics in chiral systems: From structure determination to violation of fundamental symmetries — •Robert Berger — Technische Universitaet Darmstadt, Darmstadt, Germany

Chiral systems serve as versatile laboratories for detailed studies on the intriguing interplay between handed objects, be they circularly polarised light, polarised electrons, neutrinos or chiral nuclear arrangements. The study of electron dynamics in such systems allows for instance to determine the specific handedness of a chiral system or even to unravel underlying symmetry principles of the fundamental laws of nature.

In this contribution, the diverse role of electron dynamics in chiral systems will be outlined and recent applications in determination of molecular structure, namely absolute configuration of handed molecules, will be presented. Additionally, fundamental symmetries and detection of their violations in chiral systems will be discussed, ranging from nuclear spin-dependent parity violation in diatomic and polyatomic molecules to parity and time-reversal violating features like the electron electric dipole moment.

Invited Talk A 4.2 Mon 11:00 Audimax

Electron Scattering in Chiral Photoionization: probing fundamental electron-molecule interactions to chiral molecular recognition — •Ivan Powis — University of Nottingham, Nottingham, UK

The photoionization of chiral species by circularly polarized light produces an asymmetric angular distribution of photoelectrons. The forward-backward asymmetries are typically 3-30%, perhaps three orders of magnitude greater than in other chiroptical phenomena. A peculiarity of this phenomenon is a much enhanced sensitivity to scattering phase shifts, and photoelectron Circular Dichroism (PECD) experiments measuring these asymmetries offer fresh generic insights into electronnuclear interactions.

The magnitude of the PECD effect offers a unique sensitivity to probe, in dilute environments, static and dynamic aspects of molecular chirality per se. Absolute molecular configuration (handedness)-

relevant for pharmaceutical, odour, and pesticide production - can be reliably determined by eliminating the common liquid phase interference from induced chiral structure in a solvation shell. More subtle features of molecular conformation (shape) are similarly exposed in this manner. The concept of "shape" is important in many approaches to molecular recognition in e.g. understanding enzyme interaction at receptor sites. Weak, non-bonding molecular interactions drive this recognition. We will conclude by showing how the structure of a prototype self-assembling complex, built by H-bond chiral-recognition between smaller chiral molecules, can be probed in cold molecular beam environments by PECD.

Invited Talk A 4.3 Mon 11:30 Audimax

Enantiomer Identification of Chiral Molecules in Mixtures using Microwave Three-Wave Mixing — •Melanie Schnell — Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Germany

Chiral molecules are fascinating chemists for more than 150 years. The two enantiomers of a chiral molecule can have completely different biological effects. For example, the right-handed enantiomer of carvone smells like spearmint while the left-handed one smells like caraway. In nature, chiral molecules often exist in mixtures with other chiral molecules. Their analysis aiming at identifying the molecular components, determining which enantiomers are present, and measuring the enantiomeric excesses (ee) is still one of the challenging tasks of analytical chemistry, despite its importance for modern drug development.

We present here a new method of differentiating enantiomeric pairs of chiral molecules in the gas phase [1,2] based on broadband rotational spectroscopy. The phase of the acquired signal bares the signature of the enantiomer, as it depends upon the combined quantity of their dipole-moment components, which is of opposite sign for the two enantiomers. The signal amplitude is proportional to the ee. A significant advantage of our technique is its inherent mixture compatibility, and we also present absolute configuration determination.

[1] D. Patterson, M. Schnell, J.M. Doyle, Nature 497 (2013) 475-477.
[2] V.A. Shubert, D. Schmitz, D. Patterson, J.M. Doyle, M. Schnell, Angew. Chem. Int. Ed. (2013) DOI: 10.1002/anie.201306271

Invited Talk A 4.4 Mon 12:00 Audimax

Mass-selective circular dichroism spectroscopy of chiral molecules — •Ulrich Boesl — Technische Universität München, Garching, Germany

The combination of circular dichroism (CD) and mass spectrometry is a young developing research field which promises to become a new analytical tool for mass selective probing of chirality. Such a chiral sensor opens new applications e.g. for studies of chiral catalysis or for analysis of chiral biomolecules brought into the gas phase by laser desorption techniques.This paper deals with a special type of mass selective circular dichroism called REMPI-CD (resonance enhanced multiphoton ionization circular dichroism). REMPI, on the one-hand side, combines optical spectroscopy (first absorption step) with ionization (second absorption step) and thus with mass spectrometry. It has a two-dimensional selectivity with the parameters UV-wavelength and molecular mass. CD, on the other hand, is a frequently used effect to discriminate between the two enantiomers of chiral substances. REMPI-CD then is the small relative difference of ion current induced by left and right circularly polarized laser light. In this paper, measures are presented to enhance the accuracy for these small differences. In addition, REMPI allows for new special effects such as cumulative CD and molecular-ion-CD which are unknown in conventional CD. Finally a strong enhancement of the CD-effect has been observed for cold molecules in supersonic gas beams.

A 5: Ultracold plasmas and Rydberg systems I (with Q)

Time: Monday 10:30–12:00 Location: DO24 1.101

A 5.1 Mon 10:30 DO24 1.101

Full counting statistics of laser excited Rydberg aggregates in a one-dimensional geometry — •Hanna Schempp[1], Georg Günter[1], Martin Robert-de-Saint-Vincent[1], Christoph S. Hofmann[1], David Breyel[2], Andreas Komnik[2], David Schönleber[3], Martin Gärttner[3], Jörg Evers[3], Shannon Whitlock[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [3]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We experimentally study the full counting statistics of few-body Rydberg aggregates excited from a quasi-one-dimensional atomic gas [1]. We measure asymmetric excitation spectra and increased second and third order statistical moments of the Rydberg number distribution, from which we determine the average aggregate size. Estimating rates for different excitation processes we conclude that the aggregates grow sequentially around an initial grain. Direct comparison with numerical simulations confirms this conclusion and reveals the presence of liquid-like spatial correlations. Our findings demonstrate the importance of dephasing in strongly correlated Rydberg gases and introduce a way to study spatial correlations in interacting many-body quantum systems without imaging.

[1] H. Schempp et al., accepted for Phys.Rev.Lett., arXiv:1308.0264 (2013)

A 5.2 Mon 10:45 DO24 1.101

Beyond the Rydberg van-der-Waals Interaction in Thermal Caesium Vapour. — •Alban Urvoy[1], Fabian Ripka[1], David Peter[2], Tilman Pfau[1], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany — [2]Institut für Theoretische Physik III, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany

Rydberg atoms are promising candidates for the realisation of quantum devices, making use of their long-range atom-atom interaction. The presence of van der Waals-type interaction among Rydberg states has recently been demonstrated in thermal rubidium vapour using a pulsed amplifier [1]. We expanded this work to higher atom number density (typ. 10^{12} to 10^{14} cm^{-3}) in caesium vapour and observed two types of atomic response by varying the laser detuning. The border between these two regimes is phase-transition-like. One type of excitation dynamics is consistent with a two-body excitation process, while the other is of many-body nature. We deduce this interpretation from the scaling behaviour of the transition point with Rabi frequency, atom number density and principal quantum number. At such high densities and large excitation bandwidths (≈ 500 MHz), we find that the crossings of the potential of the pair-state of interest with those of neighbouring pair-states become relevant. These modify the pair-state potentials, and allows for direct pair-state excitation at detunings beyond the excitation bandwidth.

[1] T. Baluktsian, B. Huber, et al., PRL **110**, 123001 (2013)

A 5.3 Mon 11:00 DO24 1.101

Excitation dynamics in dissipative many-body Rydberg systems — •David W. Schönleber[1,2], Martin Gärttner[1], and Jörg Evers[1] — [1]Max-Planck-Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg — [2]Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden

Inevitably present in many current experiments with ultracold Rydberg atoms, dissipative effects such as dephasing and decay modify the dynamics of the examined system. To study the effects of these processes on the excitation dynamics, we employ wave function Monte Carlo technique [1]. Starting from the exact many-body Hamiltonian, wave function Monte Carlo technique allows for a treatment of incoherent effects which is equivalent to master equation treatment. Comparing dissipative with quasi-coherent dynamics, we find qualitatively different excitation dynamics arising in off-resonant excitation. In addition, we test the scope of established models such as the rate equation by means of wave function Monte Carlo calculations.

[1] K. Mølmer et al, J. Opt. Soc. Am. B 10, 524-538 (1993)

A 5.4 Mon 11:15 DO24 1.101

Millisecond Dynamics of Mesoscopic Rydberg Samples — •Thomas Niederprüm, Tobias Weber, Torsten Manthey, Oliver Thomas, and Herwig Ott — Research Center Optimas, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

A long standing but not yet fully achieved goal in the field of ultracold atoms consists in establishing longe-range interactions between the atoms. Several proposals have demonstrated that dressing ultracold atoms with highly excited Rydberg states is a promising scheme to tailor such interactions. The timescale for such experiments would be in the millisecond range, where thermal motion, heating, decay, ionization and decoherence phenomena are present. While the short time behavior of cold Rydberg gases, the so called frozen Rydberg gas, has been vastly studied in the past only little work has been done to understand the long time behavior of Rydberg excitations in cold atomic gases. This talk will show how we use the arising ion signal as a continuous probe for the Rydberg population in atomic samples. Furthermore the observed ion signal can reveal temporal correlations in the excited sample. Recent experiments on the excitation dynamics of Rydberg samples of intermediate size are presented and evidence for strongly correlated behaviour of Rydberg excitations will be shown.

A 5.5 Mon 11:30 DO24 1.101

Optical quantum information processing using Rydberg atoms — •David Paredes Barato, Hannes Busche, Simon Ball, David Szwer, Matthew Jones, and Charles Adams — Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, South Road, Durham DH1 3LE, UK

Implementing nontrivial, controllable gates between single photons is a challenge due to the weak nonlinearities present in most materials. When there are strong nonlinearities, such as cross-Kerr nonlinearities, they distort the wavepackets of the photons [1].

Advances in quantum optics with Rydberg atoms have shown that their strong dipole-dipole interactions can be mapped into nonlinearities at the single-photon level [2-4]. The non-local character of these optical nonlinearities at short scales could allow one to circumvent the difficulties in applying other (local) methods to QIP.

Here we present a hybrid optical quantum gate scheme [5] using electromagnetically induced transparency (EIT), dipole blockade and microwave control [4]. This scheme makes use of the spatial properties of the dipole blockade phenomenon to realize a photonic, controlled-z phase gate with fidelities exceding 90%. Current work on the experimental implementation and future developments will be presented.

[1] J.H. Shapiro, Phys Rev. A 73, 062305 (2006).
[2] Y.O. Dudin and A. Kuzmich, Science 18, 887 (2012).
[3] T. Peyronel et al., Nature 488, 57 (2012).
[4] D. Maxwell et al., Phys. Rev. Lett. 110, 103001 (2013).
[5] D. Paredes-Barato and C. S. Adams, Phys. Rev. Lett. *to appear.*

A 5.6 Mon 11:45 DO24 1.101

Single-Photon Switch Based on Rydberg Blockade — •Simon Baur, Daniel Tiarks, Gerhard Rempe, and Stephan Dürr — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching

All-optical switching is a technique in which a gate light pulse changes the transmission of a target light pulse without the detour via electronic signal processing. We take this to the quantum regime, where the incoming gate light pulse contains only one photon on average [1]. The gate pulse is stored as a Rydberg excitation in an ultracold atomic gas using electromagnetically induced transparency. Rydberg blockade suppresses the transmission of the subsequent target pulse. Finally, the stored gate photon can be retrieved. A retrieved photon heralds successful storage. The corresponding postselected subensemble shows an extinction by a factor of 10. The single-photon switch offers many interesting perspectives ranging from quantum communication to quantum information processing.

[1] S. Baur et al., arXiv:1307.3509

A 6: Clusters (with MO)

Time: Monday 10:30–12:30 Location: BEBEL SR144

A 6.1 Mon 10:30 BEBEL SR144

Infrared spectroscopy of doped silicon clusters — •Nguyen Xuan Truong, Marco Savoca, André Fielicke, and Otto Dopfer — Institut für Optik und Atomare Physik, TU Berlin, Germany

Doped Si clusters are investigated with resonant infrared-ultraviolet two-color ionization (IR-UV2CI) combined with global optimization and DFT calculations. Neutral Si_mX_n clusters are irradiated with tunable IR light from a free electron laser before being ionized with UV photons from an F_2 laser. Resonant absorption of IR photons leads to an enhanced ionization efficiency for the neutral clusters and provides the size-specific IR spectra. Structural assignment of the clusters is achieved by comparing the calculated linear absorption spectra of the most stable isomers with experimental data. For Si_mC_n (with $m+n=6$), we found the systematic transition from chain like geometries for C_6 to 3D structures for Si_6 [1]. For further first row doped Si_6X (with X = Be, B, C, N, O) clusters, additional properties have been calculated, such as binding and ionization energies, and natural bond orbitals. All X dopant atoms in Si_6X have a negative net charge suggesting that Si atoms act as electron donors within the clusters. Moreover, the overall structures of Si_6X strongly depend on the nature of the dopant atom (size and valency). While for some of the most stable Si_6X clusters one Si atom in the original Si_7 structure is simply substituted (X = Be, B, C), other cases exhibit a completely different geometry (X = N, O).

[1] M. Savoca, A. Lagutschenkov, J. Langer, Dan J. Harding, A. Fielicke, O. Dopfer, J. Chem. Phys. A **117**, 1158 (2013).

A 6.2 Mon 10:45 BEBEL SR144

Vibrational Spectra and Structres of Silicon Hydride Cluster Cation — •Martin Andreas Robert George, Marco Savoca, Judith Langer und Otto Dopfer — IOAP TU Berlin, Germany

Silanes and their derivatives and ions are fundamental species in a variety of chemical disciplines. IR spectra of silicon hydride cluster cations $Si_xH_y^+$ produced in a supersonic plasma molecular beam expansion of SiH_4, He, and Ar are inferred from photodissociation of cold $Si_xH_y^+$-Ar/Ne complexes obtained in a tandem quadrupole mass spectrometer coupled to an electron impact ionization source and an octopole ion trap. In addition, the clusters are characterized in their ground electronic states by quantum chemical calculations to investigate the effects of ionization and Ar/Ne complexation on their geometric, vibrational, and electronic structure. We present initial results for $Si_2H_6^+$ [1], $Si_2H_7^+$ [2] and $Si_3H_8^+$ [3], which have complex potential energy surfaces, with low-energy isomers featuring unusual three-center two-electron (3c-2e) bonding. The IR spectrum of disilanium, $Si_2H_7{}^+$, a fully H-passivated Si_2 core with a Si-H-Si bridge is described by a 3c-2e bond. The excess proton in the Si-H-Si bridge generates three additional fundamentals, which provide the fingerprint of the 3c-2e bond.

[1] M. Savoca, M.A.R George, J. Langer and O. Dopfer, Phys. Chem. Chem. Phys. **15**, 2774-2781 (2013) [2] M. Savoca, J. Langer and O. Dopfer, Angewandte Chemie **125**, 1376 (2013) [3] M.A.R George, M. Savoca, O. Dopfer, Chem. Eur. J. **19** 45 (2013)

A 6.3 Mon 11:00 BEBEL SR144

Measuring the efficiency of ICD in neon- and in water clusters — •Marko Förstel[1], Tiberiu Arion[2], Lasse Harbo[3], Chao Fan Zhang[4], and Uwe Hergenhahn[1] — [1]Max-Planck-Institute for Plasmaphysics, Greifswald, 17491, Germany — [2]University of Hamburg, CFEL, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Dept. of Physics and Astronomy, Aarhus University, Aarhus, 8000, Denmark — [4]Dept. of Physics and Astronomy, Uppsala University, Uppsala, 75121, Sweden

In our contribution we focus on the measurement of the efficiency of intermolecular coulombic decay (ICD) in neon clusters and in water clusters.

Quite uniquely, our setup allows the quantitative determination of the efficiency of ICD relative to other competing channels. We introduce this technique and discuss the ICD efficiency after inner valence ionization in neon clusters, in water clusters and in clusters of heavy water.

By comparing the ICD efficiency in water and heavy water we can estimate the influence of the dynamics of the two systems on the ICD efficiency. Using these results we can obtain limits on the decay rate of ICD in large systems, i.e. water clusters with a mean size of N = <60>.

A 6.4 Mon 11:15 BEBEL SR144

Microsolvation of the Formanilide Cation (FA^+) in a Non-

polar Solvent: Infrared Spectra of FA^+-L_n clusters (L=Ar, N_2) — •Johanna Klyne[1], Aude Bouchet[1], Matthias Schmies[1], Mitsuhiko Miyazaki[2], Masaaki Fujii[2], and Otto Dopfer[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin — [2]Chemical Resources Laboratory, Tokyo Institute of Technology, Japan

The peptide linkage is an essential component in biochemical regognition processes since its geometry, depending on its local environment, defines the conformation of proteins. Elucidating the sequential microsolvation of peptides is therefore crucial for a full description of their behaviour in biological media. The stepwise microsolvation of cationic formanilide (FA^+-L_n) is characterized by IR spectroscopy of size-selected clusters generated in a molecular beam, combined with density functional calculations. Formanilide is the simplest aromatic molecule containing a peptide linkage (-NH-CO-). The observation of size- and isomer-specific NH stretch frequencies reveals the microsolvation of FA^+ in a nonpolar (L=Ar) and a quadrupolar (L=N_2) solvent. Such aromatic amides exhibit at least two competing binding sites for nucleophilic ligands, namely H-bonding to the acidic N-H group of the amide and π-stacking to the the phenyl ring. The H-bound FA^+-L dimer with L binding to the NH proton of the amide is the most stable isomer. Subsequent ligands are weaklier bound to the aromatic ring (π-stacking). These results demonstrate an ionization-induced change of the preferred binding motif from π-stacking to H-bonding.

A 6.5 Mon 11:30 BEBEL SR144

CO binding to small transition metal alloy clusters — David Yubero Valdivielso[1], Wieland Schöllkopf[2], and •André Fielicke[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

We report on first experiments performed with the new infrared Free Electron Laser at the Fritz-Haber Institute in Berlin. The intense and widely tunable (so far 400–2300 cm^{-1}) IR radiation from the FEL is used to obtain cluster size and composition selective IR spectra of CO complexes of metal alloy clusters via IR multiple photon dissociation. Investigating the binding of carbon monoxide to metal sites via vibrational spectroscopy is frequently used to characterize their electronic and structural properties. The activation of the C-O bond that is probed via the C-O stretching frequency highly depends on the nature of the metal, leading to a transition from molecular to dissociative chemisorption for the earlier transition metals. This is usually related to the rise of the d band center towards the earlier transition metals that allows for a stronger interaction with the CO's $2\pi^*$ orbitals. For pure clusters of many transition metals the binding of CO and the influence of cluster size and charge is well studied. We here aim to obtain an understanding of the effects of alloying on the CO activation, using it as a gauge for the change in the electronic structure in terms of the d band level. Results are presented for small alloy clusters composed from Co and Mn atoms.

A 6.6 Mon 11:45 BEBEL SR144

Gas Phase Vibrational spectroscopy of Messenger-tagged Aluminum Oxide Clusters Anions — •Matias R. Fagiani[1], Xiaowei Song[1], Wieland Schöllkopf[1], Sandy Gewinner[1], Florian A. Bischoff[2], Joachim Sauer[2], and Knut R. Asmis[1,3] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Chemie, Brook-Taylor-Str. 2, D-12489 Berlin, Germany — [3]Lehrstuhlvertretung am Wilhelm-Ostwald-Institut, Universität Leipzig, Linnéstr. 2, D-04103 Leipzig, Germany

Alumina structures of reduced dimensionality are of interest in astrophysics and atmospheric chemistry, as well as in nanostructured ceramic materials and solid catalysts. Little is known, experimentally, concerning the geometric structure of such clusters. Vibrational spectroscopy combined with electronic structure calculations provides more detailed insight into the geometric and electronic structure of these clusters.

Here, we present infrared photodissociation (IRPD) spectra of aluminum oxide cluster anions, focusing mainly on the fully-oxidized, electronic closed-shell clusters. The cluster anions are formed in a sputtering source. Mass-selected anions are trapped, cooled to cryogenic temperatures and messenger-tagged (D_2)in a buffer gas filled ion trap. Photodissociation spectra are measured from 400 to 1200 cm^{-1} with the widely tunable IR radiation of the free electron laser FHI FEL. The spectra are assigned and cluster structures are determined by comparison with the results of density functional calculations.

A 6.7 Mon 12:00 BEBEL SR144

Optical Properties of Supported Size Selected Ag Clusters in the Small Size Limit studied by SHG spectroscopy — Philipp Heister, •Tobias Lünskens, Aras Kartouzian, Martin Tschurl, and Ueli Heiz — Chair of Physical Chemistry, Department of Chemistry and Catalysis Research Center, Technische Universität München, Lichtenbergstraße 4, 85748 Garching, Germany

The optical properties of noble metal nanoparticles have received considerable interest in the past decades due to their Localized Surface Plasmon Resonance (LSPR). These collective oscillations of conduction band electrons can be described classicaly by extensions of Mie theory for particle diameters down to 2 nm. For particles consisting of only a few atoms, this classical description does not hold true anymore. Only a few experimental investigations of this small size limit are reported so far. In those studies the optical properties of metal clusters in the gas phase and metal clusters embedded in rare gas matrices were investigated.

We present Second Harmonic Generation spectra of mono-dispersed silver clusters (Agn, n<55). These clusters were generated by a laser vaporization source, size selected by a Q-MS and soft-landed onto a SiO2 target. Spectra of individual sizes were recorded under UHV conditions. The spectra reveal a clear size dependency, which is discussed by comparison with literature.

A 6.8 Mon 12:15 BEBEL SR144

Surface Scattering of $(CO_2)_n$ off Si(111)/SiO_2 — Bo-Gaun Chen and •Wolfgang Christen — Humboldt-Universität zu Berlin, Brook-Taylor-Straße 2, 12489 Berlin, http://clusterlab.de

Employing a pulsed high-pressure supersonic jet expansion and a dedicated setup for the experimental investigation of chemical processes occurring between neutral, van der Waals bound clusters and a solid surface[1], we report on the angular distribution of large CO_2 clusters scattered off a Si(111)/SiO_2 surface under ultrahigh vacuum conditions. Scattered particles are detected using time resolved mass spectrometry. A translator stage provides the possibility to sample both the incoming beam (target surface retracted) and to determine the angular and velocity distribution of scattered particles. Angular information is obtained by rotating the target surface, the velocity of scattered particles is determined by changing the distance between surface and mass spectrometer.

The presented studies cover a very broad range of cluster sizes, n, $5 \cdot 10^3 < n < 2 \cdot 10^5$ molecules per particle, and focus on the influence of source entropy, realized by accurately setting stagnation pressure and temperature. We observe an interesting dependence of the angular distribution of scattered CO_2 monomers on source conditions, i.e. the scattering angle seems to reflect the expansion path, allowing to distinguish between cluster condensation via expansion on the gaseous or on the liquid side of the critical point, and an intermediate regime where the expansion passes the metastable gas-liquid region.

[1] W. Christen, K. Rademann, *Rev. Sci. Instrum.* **77**, 015109 (2006).

A 7: Flying/Stationary Qubit Conversion and Entanglement Generation SYQR 1 (with Q)

Time: Monday 10:30–12:15 Location: UDL HS2002

A 7.1 Mon 10:30 UDL HS2002

Long distance entanglement of single trapped atoms — •Kai Redeker[1], Daniel Burchardt[1], Norbert Ortegel[1], Markus Rau[1], Julian Hofmann[1], Michael Krug[1], Markus Weber[1], Wenjamin Rosenfeld[1,2], and Harald Weinfurter[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians- Universität München, D-80799 München, Germany — [2]Max-Planck Institut für Quantenoptik, D-85748 Garching, Germany

Entanglement is an essential feature of quantum mechanics. Entanglement of stationary particles like atoms forms the basis of a quantum repeater for efficient long distance quantum communication.

We present an experiment on the generation of entanglement between two separately trapped ^{87}Rb-atoms. In our scheme we use spontaneous emission that provides us with entanglement of the spin of the trapped atoms and polarization of the emitted photon together with entanglement swapping to generate entanglement between the atoms. So far we could demonstrate this scheme over a distance of 20m.[1] Additionally we could show quantum teleportation from a weak laser pulse onto the Zeeman-state of a single ^{87}Rb-atom.

Our current work is on increasing the distance of 400 m and implementing a new fast atomic state measurement with ability to randomly chose the measurement basis on a very fast timescale. Such a System can enable device independent quantum key distribution and as such forms the elementary link of a quantum repeater.

[1]J.Hofmann et al. Science 337, 72 (2012)

A 7.2 Mon 10:45 UDL HS2002

High-fidelity heralded photon-to-atom quantum state transfer — •Christoph Kurz, Michael Schug, Pascal Eich, Jan Huwer, Philipp Müller, and Jürgen Eschner — Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany

A promising platform for implementing a quantum network are atom-based quantum memories and processors, interconnected by photonic quantum channels. A crucial building block in this scenario is the conversion of quantum states between single photons and single atoms through controlled absorption [1, 2] and emission [3].

We present an interface for heralded photon-to-atom quantum state conversion [4], whereby the polarization state of a single photon is mapped onto the spin state of a single absorbing $^{40}Ca^{+}$ ion with >95% average fidelity. A successful state-mapping event is heralded by a single emitted photon. We record >80 s^{-1} events out of 18,000 s^{-1} repetitions.

[1] N. Piro et al., Nat. Phys. **7**, 17 (2011)
[2] J. Huwer et al., New J. Phys. **15**, 025033 (2013)
[3] C. Kurz et al., New J. Phys. **15**, 055005 (2013)
[4] N. Sangouard et al., New J. Phys. **15**, 085004 (2013)

A 7.3 Mon 11:00 UDL HS2002

Interfacing Superconducting Qubits and Optical Photons via a Rare-Earth Doped Crystal — •Nikolai Lauk[1], Christopher O'Brien[1], Susanne Blum[2], Giovanna Morigi[2], and Michael Fleischhauer[1] — [1]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Universität des Saarlandes, Saarbrücken, Germany

Superconducting qubits (SCQ) are promising candidates for scalable quantum computation. However, they are essentially stationary, which makes the transport of quantum information difficult. Telecom-wavelength photons on the other hand, are the best candidates for transporting quantum information, due to the availability of low loss optical fibers.

By interfacing telecom photons with SCQ's one can combine the advantages of both systems to build a quantum network. To this end, we propose and theoretically analyze a scheme for coupling optical photons to a SCQ, mediated by a rare earth doped crystal (REDC). In the first step an optical photon is absorbed in a controlled way into a REDC. This optical excitation is then moved into the spin state using a series of π-pulses and is subsequently transferred to a SCQ through a microwave cavity. Due to intrinsic and engineered inhomogeneous broadening of the optical and spin transitions employed in REDC for the storage of optical photons, we require a special transfer protocol using staggered π-pulses to first move the population into the microwave cavity and then from the cavity to the qubit.

A 7.4 Mon 11:15 UDL HS2002

Remote entanglement generation with parabolic mirrors — •Nils Griebe, József Zsolt Bernád, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany

We develop an entanglement generation scheme which uses parabolic mirrors in a multimode and single photon scenario in order to create an entangled state between two remote material qubits. The qubits are implemented as internal states of trapped ions located in the foci of the two parabolic mirrors [1] which face each other. This configuration which might be used in free space communication causes an interesting dynamics of the two ions and the radiation field. We analyze the dynamics by using semiclassical methods and a photonic path representation of the time evolution operator. In this proposal we use the spontaneous decay as a tool for distant entanglement generation and not as an effect to evade.

[1]Alber,G., Bernád,J.Z., Stobinska,M., Sánchez-Soto,L.L., Leuchs,G.: QED with a parabolic mirror, Phys. Rev. A 88, 023825 (2013).

A 7.5 Mon 11:30 UDL HS2002

Double-heralded single-photon absorption by a single atom — •José Brito, Stephan Kucera, Pascal Eich, Michael Schug, Christoph Kurz, Philipp Müller, Jan Huwer, and Jürgen Eschner — Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany

We present a single-photon single-atom interface experiment, where a heralded single photon generated by Spontaneous Parametric Down Conversion (SPDC) is absorbed by a single atom, generating a single blue (393 nm) photon in an anti-Stokes Raman process [1].

The SPDC photon-pair source [2] is stabilized and tuned to match resonantly the $D_{5/2}$–$P_{3/2}$ atomic transition of $^{40}Ca^{+}$ at 854 nm [3, 4].

A single $^{40}Ca^{+}$ ion is trapped in a linear Paul trap and prepared for the absorption of these photons by coherent excitation from the $S_{1/2}$ ground state to the metastable $D_{5/2}$ state. We correlate the detection of the partner photon that heralds the 854 nm SPDC photon with the blue Raman photon that heralds the absorption event. Furthermore, we explore the subsequent frequency conversion of the SPDC herald to the telecom band.

[1] C. Kurz et al., New J. Phys. **15**, 055005 (2013)
[2] N. Piro et al., J. Phys. B **42**, 114002 (2009)
[3] N. Piro et al., Nat. Phys. **7**, 17 (2011)
[4] J. Huwer et al., New J. Phys. **15**, 025033 (2013)

A 7.6 Mon 11:45 UDL HS2002

Fiber-Cavity Coupled Atomic Ensembles for Photon Storage — •Miguel Martinez-Dorantes, Wolfgang Alt, Jose Gallego, Sutapa Ghosh, Lucie Paulet, Lothar Ratschbacher, Yannik Völzke, and Dieter Meschede — Universität Bonn, Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

Quantum networks have the potential to revolutionize the area of information technology, where the unconditionally secure transmission of information represents a prominent application. The most advanced architectures for realizing long distance quantum links rely on stationary quantum network nodes that are communicating with each other via optical photons. Here, we are experimentally implementing such network node based on small ensembles of neutral atoms coupled to high-finesse optical resonators. The fiber coupled optical cavities are formed by microscopic mirrors that we fabricate at the end facet of optical fibers [1]. Collective interaction of multiple Rubidium atoms in such a small resonator mode can allow atom-photon interface operations with increased bandwidth and fidelities. In order to effective prepare small dense atomic ensembles we start by loading tens of Rubidium atoms from a small magneto optical trap into an optical dipole "conveyor belt". Raman-cooling and adiabatic compression techniques [2] are currently investigated to further compress the atom clouds before they will be transported into a 3D optical lattice created inside an optical resonator [3]. [1] D Hunger et al New J. Phys. 12 065038 (2010) [2] Marshall T. DePue, et al, PRL 82, 11 (1999). [3] Schrader, et al, App. Phys, B 73, 8 (2001)

A 7.7 Mon 12:00 UDL HS2002

Individual addressing of multiple neutral atoms in an optical cavity — •Andreas Neuzner, Matthias Körber, Carolin Hahn, Stephan Ritter und Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Single neutral atoms trapped in a Fabry-Perot-type optical cavity were shown to be a powerful system for the implementation of various quantum-information-processing protocols. This includes the highly efficient creation of single photons and the implementation of an optical quantum memory based on a single ^{87}Rb atom. We present recent progress on the addressing of several atoms trapped in a two-dimensional optical lattice within the resonator by means of a high-numerical-aperture objective. The addressing capability is used to quasi-deterministically load predetermined patterns of atoms and to control the interaction of individual atoms with the resonator mode. Progress towards the realization of a multi-qubit memory for a quantum repeater node will be presented.

A 8: Ultra-cold atoms, ions and BEC II (with Q)

Time: Monday 14:00–16:00 Location: BEBEL E34

A 8.1 Mon 14:00 BEBEL E34

Bose-Einstein condensates in complex $\mathcal{PT}$-symmetric potentials - a finite element approach — •Daniel Haag, Dennis Dast, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

$\mathcal{PT}$-symmetric systems have been intensively studied in optical waveguides where the $\mathcal{PT}$ symmetry is achieved by pumping and absorption processes. In such systems the $\mathcal{PT}$ symmetry leads to a wide range of effects promising technical and scientific applications. By analogy, balanced gain and loss of particles in Bose-Einstein condensates can be described by introducing a $\mathcal{PT}$-symmetric imaginary potential into the Gross-Pitaevskii equation. This equation is solved for various three-dimensional complex potentials using the finite element method.

A 8.2 Mon 14:15 BEBEL E34

Dimensional BCS-BEC Crossover — •Igor Boettcher[1], Jan Martin Pawlowski[1,2], and Christof Wetterich[1] — [1]Institute for Theoretical Physics, Heidelberg University, Germany — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum fuer Schwerionenforschung mbH, Darmstadt, Germany

We investigate how the reduction of spatial dimension influences superfludity of two-component fermions in the BCS-BEC crossover by means of the Functional Renormalization Group. Our approach allows to study the system over the whole parameter space of interaction strength, density, temperature, spin-imbalance, and dimension. The high precision and tunability of recent experiments then allows for a solid benchmarking. We present results on the equation of state and the phase diagram as a function of dimension, and compare with recent measurements.

A 8.3 Mon 14:30 BEBEL E34

Extracting entanglement from identical particles in BECs — •Nathan Killoran, Marcus Cramer, and Martin B. Plenio — Institut für Theoretische Physik, Albert-Einstein-Allee 11, Universität Ulm, D-89069 Ulm, Germany

When identical particles occupy the same spatial mode, such as in BECs, the notion of entanglement must be treated carefully. Because of symmetrization, such systems exhibit strong correlations, which appear as entanglement amongst the particles. But the identical particles are not individually accessible, so it is often assumed that such entanglement is unphysical and cannot be used for typical quantum information tasks. In this talk, we show that any apparent entanglement between identical particles can be faithfully transferred into entanglement between independent modes, which can then be applied to any standard quantum information protocol. We thus clarify and quantify the resource nature of entanglement between identical particles in BECs.

A 8.4 Mon 14:45 BEBEL E34

Collective modes in dipolar bosonic bilayers — •Alexey Filinov[1,2] and Michael Bonitz[1] — [1]Institut für Theoretische Physik und Astrophysik, D-24098 Kiel, Germany — [2]Joint Institute for High Tem- peratures RAS, 125412 Moscow, Russia

Using quantum Monte Carlo method [1] we analyze collective excitations (dynamic structure factor $S(q, \omega)$) in a two-component bosonic system in the bilayer geometry. Dipolar bosons from two layers can differ in their mass, effective scattering length and value of the dipole moment oriented perpendicular to the plane of motion. Motion in the transverse direction is controlled by a confining potential provided by an optical lattice. This leads to a system of two coupled quasi-two dimensional layers dominated either by the intra- or inter-layer interactions.

The dispersion law for the out-of-phase and in-phase collective modes during a crossover from weakly to strongly bound inter-layer dimers is studied in detail and compared with the predictions based on the sum rules formalism [2]

[1] A. Filinov and M. Bonitz, Phys. Rev. A 86, 043628 (2012); [2] K.I. Golden, G.J. Kalman, Phys. Rev. E 88, 033107 (2013).

A 8.5 Mon 15:00 BEBEL E34

Quantum tests of the Weak Equivalence Principle in microgravity — •Naceur Gaaloul, Christian Schubert, Wolfgang Ertmer, and Ernst Rasel — Leibniz University of Hanover, Germany

The high precision of atom interferometer-based sensors makes it nowadays an exquisite tool for performing tests of fundamental theories and for practical applications in inertial navigation, geophysics and timekeeping. One timely challenge is to test the weak equivalence principle, a corner stone of General Relativity, by tracking the trajectories of two different masses in free fall. An unprecedented sensitivity is expected when the interferometry time is reaching several seconds thanks to an operation in microgravity. In the talk we present the current study status of proposed European space missions (Q-WEP and STE-QUEST) aiming for a weak equivalence principle test using a differential atom interferometer with Bose-Einstein condensates as a source. The measurement principle will be presented, an overview of the payload design will be given, and the estimated error budget will be discussed.

A 8.6 Mon 15:15 BEBEL E34

Electromagnetically induced transparency in optical lattices — •Khaled Mohamed Almhdi Alghtus and Alejandro Saenz — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin, Germany

Electromagnetically induced transparency in ultracold atomic gases trapped in optical lattices should be more efficient than in vapour, since collisions and thus dephasing are reduced. In this work the manipulation of electromagnetically induced transparency in optical lattices by a microwave field coupling the two ground states is discussed. The importance of the relative phases of the optical and microwave fields as well as the light shifts due to the optical-lattice forming laser beams is investigated. It is shown how the microwave field can help to control the group velocity and thus the slowing of the light. Furthermore, it is demonstrated analytically how the additional microwave field can be used to compensate for the light shifts (red-detuned case) caused by the additional lattice-forming beam. In addition, various filling patterns of the atoms over the optical lattice are simulated. The coherence and population decay in various filling patterns are discussed. Finally, we have investigated how the concept of neural networks can be used to classify different patterns of the optical lattice and to simulate the coherence decay for different patterns for optimizing the optical lattice and its filling pattern for an optimal effect of electromagnetically induced transparency.

A 8.7 Mon 15:30 BEBEL E34

Quantum many-body physics of interacting photons — •Sebnem Günes Söyler and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We study stationary light of massive photons emerging in a gas of interacting atoms via electromagnetically induced transparency. Path integral Monte Carlo simulations permit an approximation-free determination of the equilibrium phases of the resulting two-component system composed of photons and strongly interacting spin waves. Using this approach we identify a range of interesting quantum phases for varying coupling strengths between the two components, such as photonic superfluids that develop long-range diagonal order for certain parameters. An experimental realization via strongly interacting Rydberg gases will also be discussed.

A 8.8 Mon 15:45 BEBEL E34

Dissipation as a resource for atomic binding and crystallization — •Mikhail Lemeshko[1], Johannes Otterbach[1], and Hendrik Weimer[2] — [1]Harvard University, Cambridge MA, USA — [2]Leibniz Universität Hannover, Germany

The formation of molecules and supramolecular structures results from bonding by conservative forces acting among electrons and nuclei and giving rise to equilibrium configurations defined by minima of the interaction potential. Here we show that bonding can also occur by the non-conservative forces responsible for interaction-induced coherent population trapping. The bound state arises in a dissipative process and manifests itself as a stationary state at a preordained interatomic distance. Remarkably, such a dissipative bonding is present even when the interactions among the atoms are purely repulsive. The dissipative bound states can be created and studied spectroscopically in present-day experiments with ultracold atoms or molecules and can potentially serve for cooling strongly interacting quantum gases [1].

An extension of this technique to a many-particle system (Bose-Einstein Condensate of Rydberg-dressed atoms) allows to observe long-range ordered crystalline structures emerging due to dissipation [2].

[1] M. Lemeshko, H. Weimer, "Dissipative binding of atoms by non-conservative forces" Nature Communications 4, 2230 (2013)

[2] Johannes Otterbach, Mikhail Lemeshko, "Long-Range Order Induced by Dissipation", arXiv:1308.5905

A 9: Precision spectroscopy of atoms and ions II (with Q)

Time: Monday 14:00–16:00 Location: BEBEL E42

A 9.1 Mon 14:00 BEBEL E42

Precision spectroscopy of atomic anions with a view to laser cooling — •Giovanni Cerchiari, Elena Jordan, and Alban Kellerbauer — MPIK, Heidelberg, Germany

We are investigating the electronic structure of negative atomic ions, looking for suitable bound-bound transitions to be used for laser cooling. Cooling of negative ions using electronic transitions has not yet been achieved and could open up the possibility to create negatively charged ensembles at fractions of Kelvin. Most atomic anions show only a single bound state. We are experimentally studying the few exceptions of this rule. Our spectroscopic studies are thus focused on the few atomic species with more than one bound state. We have completed a precise spectroscopic analysis of Os^- and are now probing La^- using similar experimental techniques. Methods of the measurements will be discussed in order to introduce the results achieved on atomic levels as well as transition rates and the energy splitting due to hyperfine and Zeeman effects.

A 9.2 Mon 14:15 BEBEL E42

Progress towards antihydrogen hyperfine spectroscopy in a beam — •Eberhard Widmann — Stefan Meyer Institute for Subatomic Physics, Vienna, Austria, on behalf of the ASACUSA CUSP collaboration

The spectroscopy of antihydrogen promises one of the most precise tests of CPT symmetry. The ASACUSA CUSP collaboration at the Antiproton Decelerator of CERN is preparing an experiment to measure the ground-state hyperfine structure GS-HFS of antihydrogen, since this quantity is one of the most precisely determined transitions in ordinary hydrogen (relative accuracy $\sim 10^{-12}$). The experiment uses a Rabi-type atomic beam apparatus consisting of a source of spin-polarized anthihydrogen (a so-called cusp trap), a microwave cavity to induce a spin flip, a superconducting sextuple magnet for spin analysis, and an antihydrogen detector. In this configuration, a relative accuracy of better than 10^{-6} can be obtained. This precision will already allow to be sensitive to finite size effects of the antiproton, provided its magnetic moment will measured to higher precision, which is in progress by two collaborations at the AD.

The recent progress in producing a beam of antihydrogen atoms and in the development of the apparatus as well as ways to further improve the accuracy by using the Ramsey method of separated oscillatory fields will be presented.

A 9.3 Mon 14:30 BEBEL E42

Measurement of the forbidden 2 ^{3}S$_1$ - 2 ^{1}P$_1$ transition in quantum degenerate helium — •Remy Notermans and Wim Vassen — LaserLaB, Department of Physics and Astronomy, VU University Amsterdam, The Netherlands

There is a longstanding 6.8 (3.0) MHz discrepancy between QED theory and the experimental value of the ionization energy of the 2 ^{1}P$_1$ state in helium. We present the first measurement of the forbidden 887-nm 2 ^{3}S$_1$ - 2 ^{1}P$_1$ transition in a quantum degenerate gas of ^{4}He*, using the experimental setup as used to measure the doubly forbidden 2 ^{3}S$_1$ - 2 ^{1}S$_0$ transition by van Rooij *et al.* (Science **333**, 196 (2011)). The low temperature of the gas ($\sim$1 μK) allows us to observe the transition close to its natural linewidth of 284 MHz.

From our measurements we obtain the transition frequency with a preliminary accuracy of 0.57 MHz, i.e. at 0.2% of its natural linewidth. Our result already deviates $> 3\sigma$ from the current QED theory for the 2 ^{1}P$_1$ ionization energy. Recent measurements by Luo *et al.* of the 2 ^{1}S$_0$ - 2 ^{1}P$_1$ and 2 ^{1}P$_1$ - 3 ^{1}D$_2$ transitions in a RF discharge cell (PRL **111**, 013002 (2013) and PRA **88**, 054501 (2013)) agree with our work, confirming the discrepancy with theory.

A 9.4 Mon 14:45 BEBEL E42

Towards isotope shift and hyperfine structure measurements of the element nobelium — •Premaditya Chhetri[1], Mustapha Laatiaoui[2], Felix Lautenschläger[1], Michael Block[2,3], Werner Lauth[4], Hartmut Backe[4], Thomas Walther[1], Peter Kunz[5], and Fritz-Peter Hessberger[2,3] — [1]Institut für Angewandte Physik, TU Darmstadt, D-64289 Darmstadt — [2]Helmholtz Institut Mainz, D-55099 Mainz — [3]GSI, D-64291 Darmstadt — [4]Institut für Kernphysik, JGU Mainz, D-55122 Mainz — [5]TRIUMF, D-V6T2A3 Vancouver, Canada

Laser spectroscopy on the heaviest elements is of great interest as it allows the study of the evolution of relativistic effects on their atomic structure. In our experiment we exploit the Radiation Detected Resonance Ionization Spectroscopy technique and use excimer-laser pumped dye lasers to search for the first time the $^1P_1$ level in ^{254}No. Etalons will be used in the forthcoming experiments at GSI, Darmstadt, to narrow down the bandwidth of the dye lasers to 0.04 cm^{-1}, for the determination of the isotope shift and hyperfine splitting of ^{253,255}No. In this talk results from preparatory hyperfine structure studies in nat. ytterbium and the perspectives for future experiments of the heaviest elements will be discussed.

A 9.5 Mon 15:00 BEBEL E42

On the 7.8 eV isomer transition in ^{229}Th — •Simon Stellmer[1], Matthias Schreitl[1], Georg Winkler[1], Christoph Tscherne[1], Georgy Kazakov[1], Andreas Fleischmann[2], Loredana Gastaldo[2], Andreas Pabinger[2], Christian Enss[2], and Thorsten Schumm[1] — [1]VCQ and Atominstitut / TU Wien, Vienna, Austria — [2]KIP, University of Heidelberg, Germany

The best atom clocks today employ an optical transition between two electronic states of an atom or ion. It seems tantalizing to utilize a nuclear transition instead, as such a transition would be well-isolated from collisional, electronic, and even chemical perturbations from the environment. In addition, such transitions are expected to be very sensitive probes of drifts in fundamental constants.

The only isotope known to possess an isomer transition in the optical domain is the radioactive element ^{229}Th. Various attempts have been carried out to measure or calculate the transition energy and linewidth. To date, all of these measurements have been refuted, corrected, or at least strongly debated. While a direct evidence of this transition is still pending, its commonly agreed-upon energy is 7.8(5) eV [1].

In this talk, we will present the current status of a novel measurement campaign. In a concerted effort of the Heidelberg and Vienna groups, we use a microcalorimeter to measure the spectrum of gamma photons originating from the decay of excited nuclear states. A double-peaked structure would reveal the existence of the isomer state and allow us to measure its energy with unprecedented precision.

[1] Beck *et. al*, Phys. Rev. Lett. **98**, 142501 (2007)

A 9.6 Mon 15:15 BEBEL E42

Laser spectroscopy of the heaviest elements at SHIPTRAP — •Felix Lautenschläger[1], Mustapha Laatiaoui[2], Premaditya Chhetri[1], Michael Block[2,3], Werner Lauth[4], Hartmut Backe[4], Thomas Walther[1], Peter Kunz[5], and Fritz-Peter Hessberger[2,3] — [1]Institut für Angewandte Physik, TU Darmstadt, D-64289 Darmstadt — [2]Helmholtzinstitut Mainz, D-55128 Mainz — [3]Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt — [4]Institut für Kernphysik, JGU Mainz, D-55128 Mainz — [5]TRIUMF, Vancouver, Canada

The Radiation Detected Resonance Ionization Spectroscopy is a powerful tool for the investigation of the atomic properties of heavy and superheavy elements. For our on-line experiments, we exploit a two-step photoionization process in a buffer-gas filled stopping cell. In the first stage, the ^{1}P$_1$- level of ^{254}No, which can be produced in the complete fusion reaction ^{208}Pb(^{48}Ca,2n)^{254}No, will be sought for using 4 dye lasers delivering the first excitation step and an excimer laser providing the second non-resonant excitation step. Due to the lower ionization efficiency of the non-resonant excitation step, the impact of the excimer laser pulse energy on the ionization efficiency was studied in off-line experiments, using nat. Yb. These results and a general overview of the experimental setup will be presented.

A 9.7 Mon 15:30 BEBEL E42

Prediction of the oscillator strengths for the electric dipole transitions in Th II — •Jerzy Dembczyński[1], Jarosław Ruczkowski[2], and Magdalena Elantkowska[2] — [1]Institute of Control and Information Engineering, Faculty of Electrical Engineering, Poznań University of Technology, Piotrowo 3A, 60-965 Poznań, Poland — [2]Laboratory of Quantum Engineering and Metrology, Faculty of Technical Physics, Poznań University of Technology, Nieszawska 13B, 60-965 Poznań, Poland

In order to parametrize the oscillator strength, the matrix of angular coefficients of the possible transitions in multiconfiguration system were calculated. In the odd and even configuration systems, the fine structure eigenvectors for both parities were obtained, using our semiempirical method, which taken into account also the second order effects, resulting from the excitations from electronic closed shells to open shells and from open shells to empty shell.

The correctness of the fine structure wave functions was verified by the comparison of calculated and experimental hyperfine structure constants for Th II available in the literature. The least square fit to experimental values for some transitions allow to obtain the values of radial parameters and predict the oscillator strengths values for all possible transitions from the levels under consideration.

These calculations are necessary for the design of the nuclear frequency standard based on the thorium ion.

This work was supported by The National Centre for Science under the project N N519 650740

A 9.8 Mon 15:45 BEBEL E42

First experiments with cooled clusters at the Cryogenic Trap for Fast ion beams — •Christian Meyer[1], Klaus Blaum[1], Christian Breitenfeldt[2], Sebastian George[1], Michael Lange[1], Lutz Schweikard[2], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt Universität, 17487 Greifswald, Germany

The Cryogenic Trap for Fast ion beams (CTF) is an electrostatic ion beam trap for the investigation of charged particles in the gas phase located at the "Max-Planck-Institut für Kernphysik" in Heidelberg. It is suited to study thermionic and laser-induced electron emission of anions with complex multi-body structure such as clusters and molecules. They can be stored up to several minutes due to the low pressure of 10^{-14} mbar [1] in an ambient temperature down to 15 K. The experiments were so far hampered by the ion production in a sputter source leading to excited particles with high rovibrational states. In order to be able to investigate the ground state properties of such systems a new supersonic expansion source [2] has been implemented. A laser-induced plasma is expanded into vacuum by short pulses (50 μs) of a helium carrier gas and thereby rovibrationally cooled. First test with metal cluster will be presented and discussed.

[1] M. Lange et al., Rev. Sci. Instr., 81,055105 (2010)
[2] C. Berg et al., J. Chem. Phys. 102, 4870 (1995)

A 10: Atomic systems in external fields

Time: Monday 14:00–16:00 Location: BEBEL E44/46

Invited Talk A 10.1 Mon 14:00 BEBEL E44/46

Coulomb effects and correlation in strong laser-driven quantum dynamics — •Dieter Bauer — Institut für Physik, Universität Rostock

The theoretical treatment of atoms or molecules in strong laser fields is mostly based either on the numerical solution of the time-dependent Schrödinger equation (TDSE) or the strong field approximation (SFA).

The full *ab initio* solution of the TDSE for atoms or molecules in intense, long-wavelength laser fields is limited, in full dimensionality, to, at most, two active electrons. Hence, many-body *ab initio* approaches beyond linear response are badly needed.

The SFA, when expressed in terms of quantum trajectories, provides maximum insight into laser-driven quantum dynamics, as all features in photoelectron or high harmonics spectra can be interpreted in terms of (interfering) quantum trajectories. However, the Coulomb force on the outgoing electron is neglected in the plain SFA, while there have been several effects identified recently that are due to that Coulomb force, examples being holographic side lobes in photoelectron spectra, the low-energy structure, or rotated photoelectron distributions.

In our presentation we will discuss approaches (i) to incorporate Coulomb corrections into the SFA and (ii) to the simulation of many-electron strong-field quantum dynamics without running into the "exponential wall" of solving the many-body TDSE.

A 10.2 Mon 14:30 BEBEL E44/46

Time-resolved Fano spectroscopy and control of laser-coupled doubly-excited states — •Andreas Kaldun, Christian Ott, Alexander Blättermann, Martin Laux, Kristina Meyer, Thomas Ding, Andreas Fischer, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The precise characterization of quantum states is at the heart of atomic and molecular physics. In absorption spectroscopy, different spectral line shapes arise by the interference of the system's dipole response with the incoming light. We here present and experimentally confirm a method to extract dynamical phase- and amplitude modifications of quantum states in laser coupled few-level systems on the example of the lowest doubly-excited states in helium atoms. These states are coherently excited by an attosecond-pulsed extreme-ultraviolet (XUV) field and coupled by a near-visible (VIS) laser pulse. A controlled time delay between the pulses results in small changes in the absorption line shapes of the doubly-excited states, resolved with a home-built high-resolution (20 meV) XUV spectrometer. The observed changes can be understood by considering a coupled four-level system in second order perturbation theory, giving experimental access to the created two-electron wave packet. From the experimental analysis of dipole amplitudes and phases as a function of time delay and intensity, we are able to separate different few-photon transition pathways. We find evidence for a coherent contribution of the N=2 continuum to the two-electron wave packet.

A 10.3 Mon 14:45 BEBEL E44/46

Sub-cycle control of photoelectron emission from metal clusters exposed to intense bichromatic laser pulses — •Dzmitry Komar[1], Johannes Passig[1], Sergei Zherebtsov[2], Robert Irsig[1], Mathias Arbeiter[1], Christian Peltz[1], Frederik Süssmann[2], Slawomir Skruszewicz[1], Matthias Kling[2], Thomas Fennel[1], Josef Tiggesbäumker[1], and Karl-Heinz Meiwes-Broer[1] — [1]Universität Rostock, Universitätsplatz 3, 18051 Rostock — [2]Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Collective electron motion induces strong polarization fields in metal clusters when exposed to intense optical pulses. Highly charged and energetic species are generated by resonant excitation of the cluster plasmon mode via an optimized pump-probe sequence. We conducted pump-probe experiments on nm-sized silver metal clusters applying bichromatic (ω-2ω) pulses of 10^{14} W/cm^2 to probe the nanoplasma. A field-free time of flight spectrometer allows to resolve energetic (up to 100 Up) electron emission in opposite directions along the laser polarization axis. By using the ω-2ω technique, the dependence of the directional emission with respect to phase differences between red and blue spectral parts of the probe pulse has been studied. Strong anisotropies of re-scattered electrons have been obtained allowing to control energetic electron emission on a sub-cycle time scale.

A 10.4 Mon 15:00 BEBEL E44/46

Imaging sub-wavelength optical near-fields of isolated nanosystems — •Lennart Seiffert[1], Frederik Süssmann[2], Sergey Zherebtsov[2], Matthias Kling[2], and Thomas Fennel[1] — [1]Universität Rostock, 18051 Rostock, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

A comprehensive understanding of optical near-field dynamics is key to realizing ultrafast light-wave control of electron motion on the nanoscale. Imaging the near-fields of isolated nanosystems offers fundamental insights into the sub-wavelength spatiotemporal field evolution but requires new, non-invasive metrology. Here we investigate for silica nanospheres to which extend phase-controlled electron backscattering [1] can be used as a probe for localized fields and their particle size-dependent propagation. The electron dynamics is modelled using a quasi-classical trajectory-based mean-field Monte-Carlo approach [2], which is extended to account for propagation effects of the near-fields. We show that characteristic spatial information on the resulting local enhancement of the near-field can be extracted from the angular-resolved photoemission recorded as function of the carrier-envelope-phase of the driving few-cycle laser field [3]. In particular, we study the emergence of sub-wavelength nanofocusing via the size-dependent deformation of the near-field distribution.

[1] S. Zherebtsov et al., Nature Phys. 7:656 (2011)
[2] S. Zherebtsov et al., New J. Phys. 14:075010 (2012)
[3] F. Süßmann et al., submitted (2013)

A 10.5 Mon 15:15 BEBEL E44/46

Solving time-dependent Schrödinger and Schrödinger-like equations on a Graphical Processing Unit — •Yaroslav Lutsyshyn and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Efficient numerical solvers for the time-dependent Schrödinger equation (TDSE) are necessary to simulate the interaction of atoms and molecules with high-intensity laser pulses on an ab-initio level. In fact, current capabilities of TDSE solvers are limited to only two active electrons in full dimensionality, and even to one for long wavelengths or very high intensities. This is because of the exceedingly large numerical grids required to capture the huge electron excursions in strong laser fields. We explore the acceleration of TDSE solvers with the help of graphical processing units (GPU). Propagation algorithms and parallelization schemes that are best suited for GPUs will be discussed. Results obtained in benchmark calculations of high-harmonic spectra and photoelectron spectra will be presented.

A 10.6 Mon 15:30 BEBEL E44/46

Beams made of twisted atoms: A theoretical analysis — •Armen Hayrapetyan[1], Oliver Matula[1,2], Andrey Surzhykov[3], and Stephan Fritzsche[3,4] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, 69120 Heidelberg, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [3]Helmholtz-Institut Jena, 07743 Jena, Germany — [4]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

We have analyzed Bessel beams of two-level atoms that are driven by a linearly polarized laser light. Based on the Schrödinger equation for two-level systems, we first determine the states of two-level atoms in a plane-wave field by taking into account propagation directions both of the atom and the field. For such laser-driven two-level atoms, we construct Bessel beams by going beyond the typical paraxial approximation. In particular, we show that the probability density of these atomic beams exhibits a non-trivial, Bessel-squared-type behavior. The profile of such twisted atoms is affected by atom and laser parameters, such as the nuclear charge, atom velocity, laser frequency, and propagation geometry of the atom and laser beams. Moreover, we spatially and temporally characterize the beam of hydrogen and selected (neutral) alkali-metal atoms that carry non-zero orbital angular momentum (OAM). The proposed spatiotemporal Bessel states (i) are able to describe twisted states of any two-level system which is driven by the radiation field and (ii) have potential applications in atomic and nuclear processes as well as in quantum communication.

A 10.7 Mon 15:45 BEBEL E44/46

Observation of a stability island in the high energy ($E > 0$) region of the hydrogen atom in crossed electric and magnetic fields — •Frank Schweiner, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, 70550 Stuttgart, Germany

The spectra of the crossed fields hydrogen atom at energies slightly above the Stark saddle point are influenced by unstable periodic orbits surrounding the saddle point. Following those periodic orbits to very high energies far above E=0 we demonstrate that different types of bifurcations between the orbits appear. For specific values of the energy and field strengths the orbits become stable, which is related to the formation of a stability island in phase space. The bifurcation scenario is analyzed. The possible existence of narrow resonances obtained by semiclassical quantization of the stable orbits is discussed.

A 11: Electron Dynamics in Chiral Systems SYCS 2 (with MO)

Time: Monday 14:00–16:00 Location: BEBEL HS213

Invited Talk A 11.1 Mon 14:00 BEBEL HS213

Imaging the Absolute Configuration of a Chiral Epoxide in the Gas Phase — •Holger Kreckel[1], Philipp Herwig[1], Kerstin Zawatzky[2], Manfred Grieser[1], Oded Heber[3], Brandon Jordon-Thaden[1], Claude Krantz[1], Oldřich Novotný[1,4], Roland Repnow[1], Volker Schurig[5], Dirk Schwalm[1,3], Zeev Vager[3], Andreas Wolf[1], and Oliver Trapp[2] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Organisch-Chemisches Institut, Ruprecht-Karls-Universität Heidelberg — [3]Weizmann Institute of Science, 76100 Rehovot, Israel — [4]Columbia Astrophysics Laboratory, New York, NY, USA — [5]Institut für Organische Chemie, Eberhard Karls Universität Tübingen

Chiral molecules exist in two different configurations which are non-superimposable mirror images of one another. The respective configurations are referred to as enantiomers. Most methods to distinguish between enantiomers rely on interactions with polarized light. However, to infer the underlying handedness of the molecular structure (the absolute configuration) from spectroscopic measurements is non-trivial. Here we present foil-induced Coulomb Explosion Imaging measurements of isotopically labeled dideuterooxirane ($C_2H_2D_2O$). Our experiments allow for the determination of the handedness of enantioselected samples by direct imaging of individual molecular configurations [1]. Our method requires no quantum-chemical calculations, and it can be applied to small species like epoxides, where the chiral information is carried by light atoms exclusively.

[1] P. Herwig et al., Science 342, 1084 (2013)

A 11.2 Mon 14:30 BEBEL HS213

Enantiomer Identification of Mixtures of Chiral Molecules with Broadband Microwave Spectroscopy — •V. Alvin Shubert[1], David Schmitz[1], David Patterson[2], John M. Doyle[2], and Melanie Schnell[1,3] — [1]Max Planck Institute for the Structure and Dynamics of Matter at the Center for Free-Electron Laser Science, Hamburg, Germany — [2]Department of Physics, Harvard University, Cambridge, MA, USA — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Hamburg, Germany

The phenomenon that biochemical molecules are built almost exclusively from left-handed amino acids and right-handed sugars is known as the "homochirality of life". In nature and as products of chemical syntheses, chiral molecules often exist in mixtures that must be analyzed to identify the molecular components and measure the enantiomeric excesses (ee). We present a new method of differentiating enantiomeric pairs of chiral molecules in the gas phase.[1,2] It is based on broadband rotational spectroscopy and is a sum or difference frequency generation three-wave mixing process. The signal phase differs by pi radians between members of an enantiomeric pair and signal amplitude is proportional to the ee. This technique can also be applied to mixtures of chiral molecules and we present results on the analysis of mixtures of carvone, menthone, and carvomenthenol.

[1] D. Patterson, M. Schnell, J. M. Doyle, Nature 2013, 497, 475-477.
[2] V. A. Shubert, D. Schmitz, D. Patterson, J. M. Doyle, M. Schnell, Angewandte Chemie International Edition 2013, DOI: 10.1002/anie.201306271

A 11.3 Mon 14:45 BEBEL HS213

Measures for Multiphoton Photoelectron Circular Dichroism (PECD) — Christian Lux[1], Cristian Sarpe[1], Thomas Baumert[1], and •Matthias Wollenhaupt[2] — [1]Universität Kassel, Institut für Physik und CINSaT, D-34132 Kassel — [2]Carl von Ossietzky Universität Oldenburg, Institut für Physik, D-26129 Oldenburg, Germany

PECD describes the asymmetry in the photoelectron angular distribution (PAD) after ionization of randomly oriented chiral molecules in the gas phase with circularly polarized light. PECD was observed in one photon ionization using synchrotron radiation. Recently, we have measured PECD by femtosecond REMPI of camphor and fenchone molecules [1]. In our experiments strong contributions of higher-order Legendre polynomials were observed. To apply PECD as a sensitive analytical tool, quantitative measures to evaluate the experimental PECD data are required. For one photon ionization, parameters to characterize the asymmetry of the PAD based on the forward/backward asymmetries have been developed [2]. Although this method can be extended to the multiphoton case, we show that measures based on the forward/backward asymmetry are generally not sufficient to quantify the multiphoton PECD. We suggest a more general measure based on the decomposition of the PAD into their gerade and ungerade part. In addition, a measure to evaluate images from non-cylinder symmetrical PAD is introduced. These measures are evaluated on experimental multiphoton PECD data from camphor molecules.

[1] C. Lux et al., Angew Chem Int Ed 51, 5001 (2012).
[2] L. Nahon et al., J Chem Phys 125, 114309 (2006).

Invited Talk A 11.4 Mon 15:00 BEBEL HS213

Circular Dichroism in Mass Spectrometry: Laser Pulse Induced Electron Wavepacket Dynamics — •Dominik Kröner — Universität Potsdam, Institut für Chemie, D-14476 Potsdam, Germany

The qualitative and quantitative identification of chiral molecules is of central importance in chemical analysis. In mass spectrometry the distinction of enantiomers is achieved by applying circularly polarized laser pulses. The sample is ionized via multiphoton excitation induced by shaped ultrashort laser pulses of opposite helicity, which interact *enantiospecifically* with the chiral molecules according to their handedness. The resulting differences in the ion yields allow to determine a circular dichroism in the mass spectrum. The polarization is, however, not the only pulse parameter which influences the circular dichroism in the ion yields, but also e.g. the pulse duration or the wavelength [1].

We study the fundamental processes, which lead to the distinction of chiral molecules in mass spectrometry, by performing laser driven quantum electron dynamics based on *ab initio* electronic structure calculations, in particular TD-CIS(D). For that purpose, a full treatment of the electric field-electric dipole (and quadrupole) as well as magnetic field-magnetic dipole interactions is required [2]. The influence of different laser pulse parameters on the detected circular dichroism is investigated, in order to explain experimental observations and to allow for predictions of an optimal distinction of enantiomers.

[1] P. Horsch, G. Urbasch, K.-M. Weitzel, D. Kröner, *Phys. Chem. Chem. Phys.* **13**, 2378 (2011).
[2] D. Kröner, *J. Phys. Chem. A* **115**, 14510 (2011).

A 11.5 Mon 15:30 BEBEL HS213

Characterisation and Control of Cold Chiral Compounds — •Chris Medcraft[1,2,3], Thomas Betz[1,2,3], V. Alvin Shubert[1,2,3], David Schmitz[1,2,3], and Melanie Schnell[1,2,3] — [1]Max-Planck-Institut für Struktur und Dynamik der Materie — [2]Center for Free-Electron Laser Science — [3]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

A high-resolution, cavity-based Fourier-transform microwave spectrometer is being commissioned in Hamburg. It is based around the COBRA design (Coaxially Oriented Beam-Resonator Arrangement [1]) and consists of a semi-confocal arrangement of a planar mirror and a spherical curved mirror (diameter=0.6m, R=2m). The high resolution (ca. 3kHz) and larger spectral range (6-40GHz) of this instrument will complement our chirped-pulse FTMW spectrometer [2] (2-8.5GHz), allowing for investigations of nuclear quadrupole hyperfine structure and internal rotation. When combined with a source of cold, slow molecules [3] transit-time and Doppler broadening is reduced and the enhanced resolution may be able to discriminate the parity violating effects in large chiral molecules such as CpReNOCOI. We also present a method [4] that can distinguish between enantiomers by measuring a phase shift in a 3-wave mixing signal that is caused by the opposing signs of the product of the dipole moment components (μa.μb.μc).

[1] Grabow, Rev. Sci. Instrum. 67, 4072 (1996)
[2] Schmitz, Shubert, Betz, Schnell, J. Mol. Spec 280 (2012) 77
[3] Merz, et al, Phys. Rev. A 85, (2012) 063411
[4] Patterson, Schnell & Doyle Nature 497(2013) 475

A 11.6 Mon 15:45 BEBEL HS213

Tracing photoinduced enantiomeric excess by femtosecond accumulative spectroscopy — •Andreas Steinbacher, Patrick Nuernberger, and Tobias Brixner — Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We utilize a fast and sensitive polarimeter [1], specifically designed for applications with femtosecond laser pulses, to follow the asymmetric photochemical conversion of a racemic mixture of 1,1'-binaphthyl-2,2'-diyl hydrogenphosphate. The photoreaction is initiated by circularly polarized UV laser pulses. Depending on the handedness of the polarization, more R- or S-enantiomers are gradually photodissociated, leading to a build-up of enantiomeric excess. Due to the sensitive accumulative detection scheme [1] with an interaction length of 250 μm and the measurement time set to 100 ms for a full determination of the optical activity, we are able to follow the dynamical evolution of this enantiomeric excess. For a specific illumination time, the enantiomeric excess is most pronounced, and decreases again for continued exposure to UV light, as a direct consequence of the different extinction coefficients of the enantiomers. Hence, this detection scheme gives rise to the possibility of employing it in quantum control applications in future experiments.

[1] A. Steinbacher, J. Buback, P. Nuernberger, and T. Brixner, Opt. Express 20, 11838 (2012).

A 12: Quantum Repeaters SYQR 2 (with Q)

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

Invited Talk A 12.1 Mon 14:00 Audimax

Protocols and prospects for building a quantum repeater — •Peter van Loock — Institute of Physics, Johannes Gutenberg Universität Mainz, Germany

An overview will be given of various approaches to implementing a quantum repeater for quantum communication over large distances. This includes a discussion of systems and protocols that are experimentally feasible and thus realizable in the midterm in order to go beyond the current limit of a few hundred km given by direct quantum-state transmissions. At the same time, these schemes should be, in principle, scalable to arbitrary distances. In this context, the influence of various elements and strategies in a quantum repeater protocol on the final fidelities and rates shall be addressed: initial entanglement distribution, Bell measurements, multiplexing, postselection, quantum memories, and quantum error detection/correction. Solely on the hardware side, the differences in using just single quanta or instead employing many quanta for the flying (photons) and the stationary (atoms) qubits will be pointed out.

Invited Talk A 12.2 Mon 14:30 Audimax

Quantum teleportation from a telecom-wavelength photon to a solid-state quantum memory — •Felix Bussieres — Group of Applied Physics, University of Geneva, Switzerland

Quantum teleportation is a cornerstone of quantum information science due to its essential role in several important tasks such as the long-distance transmission of quantum information using quantum repeaters. In this context, a challenge of paramount importance is the distribution of entanglement between remote nodes, and to use this entanglement as a resource for long-distance light-to-matter quantum teleportation. In this talk I will report on the demonstration of quantum teleportation of the polarization state of a telecom-wavelength photon onto the state of a solid-state quantum memory. Entanglement is established between a rare-earth-ion doped crystal storing a single photon that is polarization-entangled with a flying telecom-wavelength photon. The latter is jointly measured with another flying qubit carrying the polarization state to be teleported, which heralds the teleportation. The fidelity of the polarization state of the photon retrieved from the memory is shown to be greater than the maximum fidelity achievable without entanglement, even when the combined distances travelled by the two flying qubits is 25 km of standard optical fibre.

This light-to-matter teleportation channel paves the way towards long-distance implementations of quantum networks with solid-state quantum memories.

Invited Talk A 12.3 Mon 15:00 Audimax
Semiconductor quantum light sources for quantum repeaters — •Peter Michler — Universität Stuttgart, Institut für Halbleiteroptik und Funktionelle Grenzflächen, Germany

Exploiting the quantum properties of light has the potential of enabling many new applications in the field of photonics and quantum information technology, such as secure communication, imaging and lithography techniques beyond the diffraction limit, quantum repeaters as well as photonic quantum computing. Many of these applications require the generation of on demand indistinguishable single photons or entangled photon pairs. Resonantly excited single semiconductor quantum dots are perfectly suited to fulfill these requirements. In my talk, I will discuss the fascinating physic as well as the current status of such resonantly driven semiconductor light sources.

Invited Talk A 12.4 Mon 15:30 Audimax
Quantum networks based on cavity QED — •Stephan Ritter, Joerg Bochmann, Eden Figueroa, Carolin Hahn, Norbert Kalb, Martin Mücke, Andreas Neuzner, Christian Nölleke, Andreas Reiserer, Manuel Uphoff, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

Quantum repeaters require an efficient interface between stationary quantum memories and flying photons. Single atoms in optical cavities are ideally suited as universal quantum network nodes that are capable of sending, storing, retrieving, and even processing quantum information. We demonstrate this by presenting an elementary version of a quantum network based on two identical nodes in remote, independent laboratories. The reversible exchange of quantum information and the creation of remote entanglement are achieved by exchange of a single photon. Quantum teleportation is implemented using a time-resolved photonic Bell-state measurement. Quantum control over all degrees of freedom of the single atom also allows for the nondestructive detection of flying photons and the implementation of a quantum gate between the spin state of the atom and the polarization of a photon upon its reflection from the cavity. Our approach to quantum networking offers a clear perspective for scalability and provides the essential components for the realization of a quantum repeater.

A 13: Ultracold plasmas and Rydberg systems II (with Q)

Time: Monday 14:00–15:30 Location: DO24 1.101

A 13.1 Mon 14:00 DO24 1.101
Critical slow down of a dissipative phase transition in a 2D Rydberg lattice gas — •Michael Höning[1], Wildan Abdussalam[2], Thomas Pohl[2], and Michael Fleischhauer[1] — [1]Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We study two dimensional lattice systems of atoms driven near resonance to strongly interacting Rydberg states. In general dipole blockade gives rise to strong short range correlations of excitations. Dynamical Monte-Carlo simulations of equivalent rate equation models show that for specific driving schemes a phase transition of the steady state to true long range order occurs. The phase diagram is however markedly different from mean-field predictions.

At the phase transition a discrete lattice symmetry is broken and it is found that the system undergoes a critical slow down. The dissipative gap of the system closes in the ordered phase, while in the paramagnetic region relaxation occurs on time scales of single site physics. This behavior is analogous to the formation and dynamics of domain walls in classical Ising models of magnetism. The stationary state of the driven lattice gas is nonetheless protected from local disturbances as they relax on short time scales.

A 13.2 Mon 14:15 DO24 1.101
Rydberg Excitation in Hollow Core Fiber — •Kathrin S. Kleinbach[1], Georg Epple[1,2], Tijmen G. Euser[2], Nicolas Y. Joly[2], Tilman Pfau[1], Philip St.J. Russell[2], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany — [2]Max Planck Institute for the Science of Light, Erlangen, Germany

Rydberg atoms exhibit large polarizabilities, long-range interactions and the Rydberg blockade effect. These special properties can be employed in sensitive electric field sensors or as optical non-linearities down to the single photon level. A promising way to reach applicability in technically feasible devices even at room temperature is the excitation of Rydberg atoms inside hollow core fiber, which can bring together highly excited atomic gases with the features and advantages of optical wave guiding structures. The confinement of the atoms and the light fields results in a perfect atom-light coupling.

We perform coherent three-photon excitation to Rydberg states in a cesium vapor confined in kagomé structured hollow core photonic crystal fiber and capillaries with various core diameters. Spectroscopic signals are detected for main quantum numbers up to n=46 exhibiting sub-Doppler features. The observation of line shifts inside the fiber with respect to a reference cell can be assigned to stray electric fields by comparison with well-known scaling laws of Rydberg states. By increasing the number density, and with this the optical density, inside the fiber we are able to eliminate almost all shifts. A detailed understanding of the origin and the disappearance of the shifts will be essential for the successful development of miniaturized fiber-devices.

A 13.3 Mon 14:30 DO24 1.101
Creation, excitation and ionization of a superatom — •Tobias Weber, Thomas Niederprüm, Torsten Manthey, Oliver Thomas, Vera Guarrera, and Giovanni Barontini — Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We have prepared and studied a single, isolated superatom consisting of a mesoscopic atomic sample with several hundred atoms, coupled to collective Rydberg states. We probe the created excitation blockade by ionizing the superatom. This results in an anti-bunched ion emission which has many similarities to the resonance fluorescence of a single atom. We determine an effective blockade radius for the $51P$-state and demonstrate the collective character of the excitation. The rich internal level structure of the superatom can be further exploited to create pairs of excitations within the superatom. The resulting ion bunching signal shows record values up to $g^{(2)}(0) = 30$. Varying coupling strength and detuning, we observe a significant change in the excitation dynamics, indicating an excitation regime transition. Our results open new possibilities to quantum optical experiments with Rydberg blockaded samples.

A 13.4 Mon 14:45 DO24 1.101
Exploring the phase diagram of a spatially ordered Rydberg gas — •Johannes Zeiher[1], Peter Schauss[1], Sebastian Hild[1], Takeshi Fukuhara[1], Marc Cheneau[2], Manuel Endres[1], Frauke Seesselberg[1], Tommaso Macri[3], Thomas Pohl[3], Christian Gross[1], and Immanuel Bloch[1,4] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Laboratoire Charles Fabry - Institut d'Optique, Palaiseau, France — [3]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [4]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Rydberg gases offer the possibility to study long-range correlated many-body states due to their strong van der Waals interactions. In our setup, we optically excite Rydberg atoms and detect them with submicron resolution, which allows us to measure spatial correlations of resulting ordered states. Starting from a two dimensional array of ground state atoms in an optical lattice, we couple to a Rydberg state in a two-photon excitation scheme. Using numerically optimized pulse shapes for coupling strength and detuning, we deterministically prepare the crystalline state in this long-range interacting many-body system. Control of the spatial configuration of the initial state is of great importance for the investigation of the phase diagram. To achieve this, we developed an experimental scheme based on single site addressing allowing for preparation of initial states with sub-Poisson number fluctuations.

A 13.5 Mon 15:00 DO24 1.101

Observing the dynamics of dipole-mediated energy transport by interaction enhanced imaging — •Georg Günter, Hanna Schempp, Martin Robert-de-Saint-Vincent, Vladislav Gavryusev, Stephan Helmrich, Christoph S. Hofmann, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120, Heidelberg, Germany

Electronically highly excited (Rydberg) atoms experience quantum-state changing interactions similar to Förster processes found in complex molecules, offering a model system to study the nature of dipole-mediated energy transport under the influence of a controlled environment. We demonstrate a non-destructive imaging method to monitor the migration of electronic excitations with high time and spatial resolution using electromagnetically induced transparency on a background gas acting as an amplifier[1]. The many-body dynamics is determined by the continuous spatial projection of the electronic quantum state under observation and features an emergent spatial scale of micrometer size induced by Rydberg-Rydberg interactions[2].

[1] G. Günter et al., Phys. Rev. Lett. 108, 013002 (2012)
[2] G. Günter et al., Science 342, 954 (2013)

A 13.6 Mon 15:15 DO24 1.101

Generating heavy-tailed disorder in Rydberg aggregates — •Sebastian Möbius[1], Sebastiaan M. Vlaming[1], Victor A. Malyshev[2], Jasper Knoester[2], and Alexander Eisfeld[1] — [1]Max Planck Intitute for physics of complex systems, Dresden, Germany — [2]Centre for Theoretical Physics and Zernike Institute for Advanced Materials, University of Groningen, Netherlands

Molecular aggregates exhibit extraordinary absorption properties, depending on their geometrical conformation and inter-monomeric coupling. The narrowing of the absorption band for J-aggregates can be well described by diagonal Gaussian static disorder for individual site energies. Recent studies by Eisfeld et. al [1] have shown, that Levy stable distributions (LSD), a generalization of the Gaussian case, may also lead to a broadening of the absorption band.

Recent developments in generating and trapping highly excited Rydberg atoms, allow for quantum simulations of these molecular aggregates. We show that the interaction of Rydberg atoms with a background gas leads to heavy-tailed disorder in the energy spectrum. Depending on the species of the background gas and the preparation of the system different kinds of heavy-tailed disorder can be observed, including LSD.

[1] A. Eisfeld, S.M. Vlaming, V.A. Malyshev, J. Knoester, PRL 105, 137402 (2010)

A 14: Poster: Precision spectroscopy of atoms and ions (with Q)

Time: Monday 16:30–18:30 Location: Spree-Palais

A 14.1 Mon 16:30 Spree-Palais

Relative frequency comb locked to atomic resonances generated by quantum phase modulation — •Zuoye Liu, Christian Ott, Stefano M. Cavaletto, Kristina Meyer, Zoltán Harman, Christoph M. Keitel, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Recently, a new phase-control mechanism was demonstrated in helium in time-resolved absorption experiments [1]. Here, we theoretically investigate the generation of frequency combs referenced to atomic resonances by extending this phase-control concept to periodic phase manipulations covering the entire evolution of the coherence decay of a two-level system [2]. The comb spectral structure depends on both the atomic and the phase-control properties, which can be cast into closed-form analytical descriptions. As the first envisaged realistic implementation, we perform a simulation for the 1s2*1s2p transition in helium or helium-like beryllium, which agrees excellently with our analytical theory. The mechanism allows to create frequency combs in the x-ray region, providing an opportunity for precision spectroscopy of transitions in highly charged ions [3] in the future. It may thus open the door to fundamental physics applications such as testing the predictions of bound-state QED.

[1] C. Ott et al., Science 340, 716 (2013)
[2] Z. Liu, C. Ott, S. M. Cavaletto, Z. Harman, C. H. Keitel, and T. Pfeifer, ArXiv: 1309. 6335 (2103)
[3] S. Bernitt et al., Nature 492, 225 (2012)

A 14.2 Mon 16:30 Spree-Palais

Towards Laser Cooling of Negative Ions — •Elena Jordan, Giovanni Cerchiari, and Alban Kellerbauer — Max Planck Institut für Kernphysik, Heidelberg

Ultra-cold negative ions could be used in a wide field of applications. We want to demonstrate the first laser cooling of atomic anions. In order to identify suitable negative ions we study them with high-resolution laser spectroscopy. Previously the transition frequencies and transition cross-sections of anions of various Os isotopes have been determined. The hyperfine structure (where applicable) and the isotope shift were resolved, and the Zeeman splitting in a magnetic field was measured. These measurements have shown that laser cooling of Os^- is possible in principle, but at a low cooling transition rate. Therefore we are presently investigating La^- with high-resolution laser spectroscopy, as another potential candidate for anion laser cooling.

A 14.3 Mon 16:30 Spree-Palais

Optical Clock Based on a Single Trapped Ra^+ Ion — •Mayerlin Nunez Portela, Elwin A. Dijck, Amita Mohanty, Nivedya Valappol, Oliver Boell, Klaus Jungmann, Cornelis J. G Onderwater, Sophie Schlesser, Rob G. E. Timmermans, Lorenz Wilmann, and Hans W. Wilschut — University of Groningen, FWN, Zernikelaan 25, NL-9747AA Groningen

Currently single-ion based optical clocks provide the most accurate frequency standards with their stability exceeding that of the latest cesium standards. The ultra-narrow electric quadrupole transitions 7s $^2S_{1/2}$-6d $^2D_{3/2}$ at 828 nm and 7s $^2S_{1/2}$-6d $^2D_{5/2}$ at 728 nm from the ground state to the low lying metastable D-state of Ra^+ are excellently suited for a stable and accurate clock [1]. An important advantage of Ra^+ is that all required optical wavelengths are available from semiconductor diode lasers. This promises a low-cost and compact setup. Fractional frequency uncertainty of 10^{-18} can be reached using a single Ra^+ ion. We note that for radium isotopes with nuclear spin 3/2 the electric quadrupole shift can be largely canceled. We report the status of the project and its integration into a optical fiber linked clock network.

[1] O.O.Versolato et al., Phys. Rev. A 83, 043829 (2011)

A 14.4 Mon 16:30 Spree-Palais

Optical Fiber Link via Telecommunication Networks — •Nivedya Valappol[1], Tjeerd Pinkert[2], Oliver Boll[1], Fred Bosveld[3], Elwin Dijck[1], Kjeld Eikema[2], Klaus Jungmann[1], Jeroen Koelemeij[2], Wim Ubachs[2], and Lorenz Willmann[1] — [1]University of Groningen, Groningen, NL — [2]Vrije Universiteit Amsterdam, Amsterdam, NL — [3]KMNI, De Bilt, NL

Time and frequency distribution over existing communication infrastructure has different applications. A telecommunication channel on a SURFnet fiber link has been established between the VU Amsterdam and Groningen. It is used to transfer stability and accuracy of narrow band lasers (1Hz) in order to compare high precision experiments such as clocks (Al^+, Ra^+) at the two locations. The stability of the 2×317 km underground optical fiber link has been characterized. The long term frequency stability determined with a 3kHz laser linewidth of 2×10^{14} at 5×10^2-5×10^3s can be explained by thermal temperature fluctuations in the ground. This accuracy surpassing, e.g. the satellite based GPS system, can be exploited in superior navigation systems. The full potential with lasers of 1Hz linewidth will permit tests of fundamental physics, such as Atomic Parity Violation measurements, in spatially separated precision experiments.

A 14.5 Mon 16:30 Spree-Palais

Novel technique for precision spectroscopy of fast transitions: photon recoil detection — •Fabian Wolf, Yong Wan, Florian Gebert und Piet O. Schmidt — QUEST Institut, PTB Braunschweig und Universität Hannover

Quantum logic spectroscopy (QLS) has offered the possibility to investigate the electronic structure of many so far inaccessible species, but is limited to transitions involving a long-lived state. Photon recoil spectroscopy (PRS) is an extension of QLS to fast, dipole allowed transitions.

Here we present an absolute frequency measurement of the $S_{1/2} \rightarrow P_{1/2}$ transition of $^{40}Ca^{+}$ using PRS with a co-trapped $^{25}Mg^{+}$ logic ion. The axial mode of the two-ion-crystal is cooled to its motional ground state. Afterwards, the spectroscopy laser induces a detuning-dependent momentum transfer from photon recoil onto the spectroscopy ion that is detected on the logic ion via a red sideband STIRAP-like pulse. This method enables us to resolve the Ca transition to 1/300 of its observed linewidth with high accuracy and short averaging times. This renders PRS a powerful spectroscopic tool for the measurement of broad transitions. Due to its high sensitivity of only 10 absorbed photons for a SNR of 1, PRS is a promising technique for spectroscopy of transition that scatter only few photons.

The next step will be the implementation of a similar scheme for rotational state spectroscopy on a molecular ion. The current status of this experiments and simulations for rotational state preparation are presented as well.

A 14.6 Mon 16:30 Spree-Palais

Towards Bound-Electron *g*-Factor Measurements by Double-Resonance Spectroscopy — •Marco Wiesel[1,2,4], David von Lindenfels[1,2,3], Wolfgang Quint[1,2], Manuel Vogel[1,4], Alexander Martin[4], and Gerhard Birkl[4] — [1]GSI Darmstadt, Germany — [2]Universität Heidelberg, Germany — [3]MPI-K Heidelberg, Germany — [4]TU Darmstadt, Germany

Magnetic moment measurements of electrons bound in highly charged ions provide access to effects of quantum electrodynamics (QED) in the extreme fields close to the ionic nucleus. We report on the cryogenic Penning trap setup ARTEMIS to determine the electronic g-factor of boron-like argon (Ar^{13+}) via the method of double-resonance spectroscopy: A closed cycle between the fine-structure levels $2^2P_{1/2}$ - $2^2P_{3/2}$ is driven by a laser whereas microwaves are tuned to excite transitions between Zeeman-sublevels. With this frequency and the measurement of the ion cyclotron frequency the *g*-factor can be determined with an expected accuracy of 10^{-9} or better.

After these measurements, the setup will be connected to the HITRAP beamline at GSI, so hyperfine structure transitions of hydrogen-like heavy ions can be studied and electronic and nuclear magnetic moments can be measured.

Supported by DFG

A 14.7 Mon 16:30 Spree-Palais

Parity violation effects in the Josephson junction of a *p*-wave superconductor — •Nikolay A. Belov and Zoltan Harman — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

The electroweak theory describes nuclear beta-decay and weak effects in particle physics. One of the most characteristic properties of the electroweak interaction is spatial parity violation (PV). PV was experimentally observed in β decay, however, PV terms of the electroweak interaction also affect the interaction of electrons with the nuclei of the crystal lattice in solid state. Possible solid state systems where one may detect PV are superconductors. The main advantage of the investigation of PV effects with superconductors is the compact size and relatively low price of the experimental apparatus as compared to high-energy experiments. While the electroweak contribution is negligibly low in conventional *s*-wave superconductors, we show that the effect is significantly increased in unconventional *p*-wave ferromagnetic superconductors. We predict values several orders of magnitude higher than for the *s*-wave case, forecasting that the PV effect may be observed in superconductors in future.

A 14.8 Mon 16:30 Spree-Palais

A computer-control system for electron beam ion traps — •Daniel Hollain[1,2], Hendrik Bekker[1], Sven Bernitt[1], and José Ramón Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Ruprecht-Karls-University, Heidelberg, Germany

Modern experiments require computer control and computerized data acquisition systems. This is especially crucial for systematic and repetitive tasks during long runtimes, when many devices and complicated processes run simultaneously. We develop such a system in order to facilitate operations of electron beam ion traps with their attached detectors and power supply units, to reduce operator errors, and to record and evaluate data during beam times as well as at DESY or BESSY. An efficient computer control system reduces the risk of losses of critical experimental data and of operator errors in the laboratory. Automated systems also allow handling larger sets of data and improving the statistics for experiments. Clean programming, uncomplicated maintenance, and complete documentation are important requirements for the software. We develop a framework for the control of devices based on National Instruments I/O cards. We use routines from the PCASPY library from EPICS, the Experimental Physics and Industrial Control System in a client-server model written in Python2. Other system extensions are possible and will be presented. An important advantage is the fact that the recorded data can be directly used for evaluation of the experiment even during runtime.

A 14.9 Mon 16:30 Spree-Palais

Absolute energy determination of He-like Krypton K_α transitions — •René Steinbrügge[1], Sven Bernitt[1], Sascha W. Epp[2], Jan K. Rudolph[1,3], Christian Beilmann[5], Hendrik Bekker[1], Alfred Müller[3], Joachim Ullrich[6], Oscar O. Versolato[1], Hasan Yavaş[4], Hans-Christian Wille[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]MPI für Struktur und Dynamik der Materie, Hamburg — [3]Institut für Atom- und Molekülphysik, Gießen — [4]DESY, Hamburg — [5]Physikalisches Institut, Heidelberg — [6]PTB, Braunschweig

Heliumlike ions serve as an important testing ground for investigations of many-body relativistic and QED effects, which scale with the fourth power of the atomic number Z. We have carried out absolute energy measurements of the w ($^1S_0 \rightarrow {}^1P_1$) and y ($^1S_0 \rightarrow {}^3P_1$) transitions in He-like krypton (Z=36) ions. These were produced and trapped in the transportable electron beam ion trap FLASH-EBIT [1,2], and excited with X-ray photons at PETRA III. The transition energies were measured by scanning a double-crystal monochromator, and detecting fluorescence photons. By using absorption edges for absolute energy calibration we obtain resonance energies of $E(w) = 13114.47(14)$ eV and $E(y) = 13026.15(14)$ eV, which are in excellent agreement with theory, but disagree with earlier, less accurate experiments. Our results largely exclude claims of an anomalous deviation from bound-state QED predictions.

[1] S. W. Epp et al., Phys. Rev. Lett. **98**, 183001 (2007)
[2] S. Bernitt et al., Nature **492**, 225 (2012)

A 14.10 Mon 16:30 Spree-Palais

Z-scaling of M1-transition wavelengths near level crossings for identification of α-sensitive lines in highly charged ions — •Sebastian Kaul[1], Alexander Windberger[1], Oscar O. Versolato[1], Hendrik Bekker[1], Victor Bock[1], Natalia Oreshkina[1], Christoph H. Keitel[1], Zoltan Harman[1,4], Joachim Ullrich[1,2], Piet O. Schmidt[2,3], and José R. Crespo López - Urrutia[1] — [1]Max Planck Institute for Nuclear Physics, D-69117 Heidelberg, Germany — [2]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — [4]Extreme Matter Institute, 64291 Darmstadt, Germany

Optical transitions near level crossings in highly charged ions like Ir^{17+} are of special interest for the search of a possible spatial gradient of the value of α, the fine structure constant due to their high sensitivity to its value. However, wavelength predictions for those transitions are not accurate enough for the application of laser spectroscopy. Therefore, we first perform emission spectroscopy in an electron beam ion trap with a grating spectrometer to record spectra between 200 nm and 700 nm with an absolute accuracy of 10^{-2} nm. In order to identify the observed lines we exploit the Z-scaling laws of the wavelengths of M1 transitions within the isoelectronic sequence Re^{15+}, Os^{16+}, Ir^{17+}, and Pt^{18+}. We also study the electron-density dependence of the signal strength of Ir^{17+} spectra between 5-80mA to determine relative Einstein coefficients for various lines.

A 14.11 Mon 16:30 Spree-Palais

Testing Lorentz Invariance in the Weak Interaction Using Laser-Polarized ^{20}Na — •Elwin A. Dijck, Auke Sytema, Stefan E. Müller, Steven Hoekstra, Klaus Jungmann, Jacob P. Noordmans, Gerco Onderwater, Coen Pijpker, Rob G. E. Timmermans, Lorenz Willmann, and Hans W. Wilschut — University of Groningen, The Netherlands

Lorentz invariance is one of the fundamental principles underlying our current understanding of nature. In models aiming to unify the Standard Model with (quantum) gravity this symmetry may be broken. Few tests of Lorentz invariance in the weak interaction have been made.

We have performed a novel test of rotational invariance by searching for variations in the decay rate of ^{20}Na nuclei depending on the nuclear spin orientation with respect to a possible Lorentz symmetry breaking background field. Using optical pumping, the nuclei were alternately polarized in opposite vertical directions, while the absolute orientation of the spins changed with the rotation of the Earth.

A polarization-dependent Lorentz symmetry violating effect was searched for, putting a 95% confidence limit on the amplitude of sidereal variations in the decay rate asymmetry at $< 3 \times 10^{-3}$. This result was analyzed in the framework of a recently developed theory that assumes a Lorentz symmetry breaking background field of tensor nature.

A 14.12 Mon 16:30 Spree-Palais

An electrodynamic system for highly charged ion transfer to a Paul trap — •Lisa Schmöger[1,2], Baptist Piest[1], Julian Stark[1], Maria Schwarz[1,2], Oscar O. Versolato[1,2], Piet O. Schmidt[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Electron beam ion traps (EBITs) are efficient tools for highly charged ion (HCI) production and spectroscopy. While narrow optical transitions in HCI at rest are of great interest for precision studies of fundamental physics and for realisations of high accuracy frequency standards [1]. However, due to the high ion temperature inside of an EBIT, laser spectroscopy on HCIs is severely constrained by Doppler broadening [2].

For further improvements, our cryogenic linear Paul trap [3] experiment (CryPTEx) in-line with an EBIT will allow for trapping and sympathetic cooling of a wide range of HCIs. A deceleration beamline allows for efficient HCI transfer and their injection at very low kinetic energy into CryPTEx. The deceleration of the ion bunches is performed by means of a novel pulsed buncher tube. We present time-of-flight spectra and measurements with retarding field analysers showing the deceleration and time focussing properties of the setup.

[1] J.C. Berengut et al., Phys. Rev. Lett. 106, 210802 (2011)
[2] V. Mäckel et al., Phys. Rev. Lett. 107 (2011) 143002
[3] M. Schwarz et al., Rev. Sci. Instr. 83, 083115 (2012)

A 14.13 Mon 16:30 Spree-Palais

A Low Energy Ion Beamline for Highly Charged Ions at SpecTrap — •Kristian König[1], Stefan Schmidt[1,2], Zoran Andelkovic[3], Tobias Murböck[4], Manuel Vogel[4], Volker Hannen[5], Jonas Vollbrecht[5], Gerhard Birkl[4], Richard Thompson[6], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt — [2]Institut für Kernchemie, Johannes Gutenberg Universität Mainz — [3]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [4]Institut für Angewandte Physik, TU Darmstadt — [5]Institut für Kernphysik, Westfälische Wilhelms-Universität Münster — [6]Imperial College London, South Kensington Campus London

One of the precision experiments of the HITRAP facility at GSI Darmstadt is SpecTrap, which aims to trap heavy Highly Charged Ions (HCI) in a Penning trap and cool them to cryogenic temperatures. Using laser spectroscopy it is possible to measure their hyperfine structure with an envisaged relative accuracy of the order of 10^{-7} which will serve as a test of strong-field quantum electrodynamics.

This poster will present the current status of the SpecTrap experiment and give an overview of the associated beamline from the Electron Beam Ion Source (EBIS) to the Penning trap. The EBIS can produce HCI up to Xe^{44+} and the beamline is able to transport these ions with small kinetic energy with a few keV to SpecTrap or other experimental setups. Additionally the methods and first experimental results for detecting, cooling and manipulating the ions inside the trap will be shown.

A 14.14 Mon 16:30 Spree-Palais

The Muonic Helium Lamb Shift Experiment — •Johannes Götzfried, Julian Krauth, and The CREMA collaboration — Max-Planck-Institute of Quantum Optics, Garching

Because of its high sensitivity on finite size effects of the nucleus, the measurement of the Lamb shift in exotic atoms has been on the wish-list of atomic and nuclear physics for a long time. Our previous experiment allowed to determine the proton radius with an order of magnitude higher precision compared to spectroscopic measurements of ordinary hydrogen. The successor experiment in muonic helium is currently performed at the Paul-Scherrer-Institute in Switzerland. Using a low energy muon beam line muons are stopped within low pressure helium gas, where exotic atoms are created. Here we measure the 2S-2P transition frequency of muonic helium illuminated by a pulsed TiSa-laser system pumped with a newly developed Yb-YAG thin disk laser. This measurement will ultimately improve the values of the charge radii of 3He+ and 4He+ by an order of magnitude.

A 14.15 Mon 16:30 Spree-Palais

Towards precision laser spectroscopy with cold highly charged ions — •Lisa Schmöger[1,2], Oscar O. Versolato[1,2], Maria Schwarz[1,2], Alexander Windberger[1], Matthias Kohnen[2], Tobias Leopold[2], Joachim Ullrich[2], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, Braunschweig — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover

Highly charged ions (HCI) are promising candidates for bound-state QED studies (g-factor measurements), metrology (optical clocks) and searches for a possible variation of the fine structure constant.

Electron beam ion traps (EBIT) have recently enabled laser spectroscopic studies of trapped HCI. However, large translational temperatures in HCI trapped in an EBIT severely limit resolution. To overcome this, our cryogenic linear Paul trap experiment -CryPTEx- in combination with an EBIT will enable trapping and sympathetic cooling of a wide range of HCI by means of Be^+ ions laser-cooled into Coulomb crystals. The external ion injection capabilities of our Paul trap have been successfully tested and the formation of Be^+ Coulomb crystals is underway.

This new setup opens up a path towards high-precision laser spectroscopy up to optical frequency standards based on narrow transitions in HCI, which are by orders of magnitudes less susceptible to external perturbations than transitions in atoms or singly-charged ions, and which offer fundamental physics test at the highest sensitivities.

A 14.16 Mon 16:30 Spree-Palais

Cooling of highly charged Ions in the HITRAP cooler Penning Trap — •Bernhard Maass[1,2], Zoran Andelkovic[2], Svetlana Fedotova[2], Frank Herfurth[2], Nikita Kotovskiy[2], Claude Krantz[3], Denis Neidherr[2], Wilfried Nörtershäuser[1], Wolfgang Quint[2], and Jochen Steinmann[2] — [1]TU Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]MPI-K Heidelberg

The HITRAP cooler Penning trap will be used for cooling and storing of bunches of up to 10^5 ions as heavy as U^{92+}. The aim is to use both electron cooling and resistive cooling to cool ions down to values below 1 meV. Bunches of 10^{10} electrons can be injected into the trap from an electron source installed downstream. The electrostatic potentials of the trap electrodes will be arranged to form a nested trap to capture both, ions and electrons, simultaneously inside the trap. In the last years, the trap has been investigated by measuring ion and electron storage times. Based on the gained experience from these experiments, the trap is now reassembled with various improvements to further increase the trapping and cooling performance. An installed test ion source provides the opportunity to test and align the renewed setup.

A 14.17 Mon 16:30 Spree-Palais

Metallic Magnetic Calorimeters for High-Resolution X-ray Spectroscopy — •M. Krantz[1], C. Schötz[1], D. Hengstler[1], J. Geist[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], R. Märtin[2], G. Weber[2], Th. Stöhlker[2], and J. Crespo[3] — [1]Kirchhoff-Institut, Universität Heidelberg — [2]Helmholtz-Institut, Jena — [3]Max-Planck-Institute of Nuclear Physics, Heidelberg

We are developing metallic magnetic calorimeters (MMC) for x-ray spectroscopy on highly charged ions in the energy range up to 200 keV. MMCs use a paramagnetic temperature sensor, read-out by a SQUID, to measure the energy deposited by single x-ray photons. Recent prototypes include two linear 8-pixel detector arrays, maXs-20 and maXs-200, as well as a first 2-dimensional 8x8 array, maXs-30, optimized for energies up to 20, 200, and 30 keV, respectively. We discuss the physics of MMCs, design considerations concerning cross talk, the micro-fabrication and the performances of the three prototypes. maXs-200 with its 200 μm thick absorbers made of electro-deposited gold has high stopping power for hard x-rays and achieves an energy resolution of 40 eV (FWHM). maXs-20 with its 5 μm thick absorbers has excellent linearity and a stopping power of 98% for 6 keV photons and presently achieves an instrumental line width of 1.6 eV (FWHM), unsurpassed by any other micro-calorimeter. We have been operating maXs-20 at an EBIT at the MPI-K Heidelberg and prepare maXs-30 for measurements at the ESR (GSI). We will report on first atomic physics measurements as well as the particular challenges to detector operation in both experimental settings.

A 14.18 Mon 16:30 Spree-Palais

Production of highly charged ions and their applications — •Hendrik Bekker[1], Daniel Hollain[1], Nihmal Daya[2], Elias Sideras-Haddad[2], Sergey Eliseev[1], Sven Sturm[1], Klaus Blaum[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik — [2]University of the Witwatersrand

Preparations are under way to bring the Heidelberg electron beam ion trap (HD-EBIT) to higher energy operation, with the aim to reach electron beam energies up to 350 keV at currents up to 500 mA. This will allow us to produce and trap hydrogen-like charge states of all the stable elements. The first goal is the production of hydrogen-like holmium and rhenium, which have a ground-state hyperfine splitting (HFS) in the optical regime. We expect to be able to measure the HFS with a precision at the ppm level, a hundred-fold improvement over previous measurements. An application of extracted ions has been the use of a range of Xe charge states to study the effects of highly charged ions on graphene. The produced defects are expected to generate magnetic defects which should give rise to a measurable Kondo effect. Future plans include the production of high charge states of lead, which will be transported to the Penning traps PENTATRAP and ALPHATRAP for precise measurements of masses and of the bound electron g-factor, from which the 1s electron binding energy and the fine-structure constant can be extracted.

A 14.19 Mon 16:30 Spree-Palais

Towards cavity-based non-destructive readout of a Strontium lattice clock — •Ulrich Eismann, Chunyan Shi, Jean-Luc Robyr, Sébastien Bize, Rodolphe Le Targat, and Jérôme Lodewyck — LNE-SYRTE - Observatoire de Paris, CNRS, UPMC, 61 Avenue de l'Observatoire, 75014 Paris, France.

Recently, the Cesium fountain clocks currently defining the SI second have been superseded in both stability and accuracy by atomic clocks referenced to optical transitions. A way to significantly improve the stability of these clocks is to implement a non-destructive readout of the clock state populations, potentially allowing new applications like relativistic geodesy.

We propose a novel route and demonstrate first results of a doubly-differential non-destructive detection scheme for Strontium atoms inside a high-finesse dual-wavelength cavity. Furthermore, spin squeezing of the coupled atom-cavity system allows pushing of the readout noise below the standard quantum limit.

A 14.20 Mon 16:30 Spree-Palais

High-finesse silicon optical resonators at cryogenic temperatures — •Eugen Wiens, Qun-Feng Chen, Ingo Ernsting, Heiko Luckmann, Alexander Nevsky, and Stephan Schiller — Institut für Experimentalphysik Heinrich-Heine Universität Düsseldorf, Universitätsstr.1, 4ß225 Düsseldorf

Ultra-stable high-finesse optical resonators are widely used in precision experiments for frequency stabilization of the lasers. In our work we investigate a high-finesse silicon optical resonator down to 1.5 K. It is made of a mono-crystalline silicon cylindrical spacer (25 cm long). The silicon high-reflection mirrors are optically contacted to the spacer, forming a high-finesse (> 200 000) resonator at the wavelength of 1560 nm. The resonators are mounted inside a pulse tube cooler cryostat on a vibration-insensitive support. A fiber laser at 1560 nm is locked to the resonator using a Pound-Drever-Hall technique. The frequency stability of the resonator is measured using a femto-second frequency comb, stabilized to an active hydrogen maser and an ultra-stable laser at 1156 nm. Systematic effects such as tilt of the resonator, laser power fluctuations, temperature instability etc. have been evaluated.

A 14.21 Mon 16:30 Spree-Palais

Ultrapure microwave generated from a comb stabilized to a robust reference — •Qunfeng Chen[1], Alexander Nevsky[1], Marco Cardace[1], Uwe Sterr[2], Stephan Schiller[1], and Ingo Erensting[1] — [1]Institut für Experimentalphysik, Heinrich-Heine Universität Düsseldorf — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig

Towards possible use in space for clocks on the ISS or custom satellites, we have developed a microwave-optical local oscillator. It is based on a reference resonator assembly for a Nd:YAG laser consisting of a 10 cm ULE cavity in a special holder allowing movement and tilt of the assembly. The laser instability is 3×10^{-15}. Using a fiber frequency comb stabilized to the cavity-stablized laser, we have produced ultrapure microwaves. The characterization of the system will be presented.

A 14.22 Mon 16:30 Spree-Palais

Active control of the magnetic field in an ion trap — •Matthias Kreis, Stephan Kucera, and Jürgen Eschner — Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany

Experiments using coherent atom–photon interaction require control of the energy splitting of the involved atomic levels and therefore a controlled magnetic field. Magnetic–field noise is caused by electric appliances and current fluctuations in bias field coils but cannot directly be measured at the position of the trapped ions. We present a method for servo control of the magnetic field whereby we calculate the magnetic–field value at the ion's location from values measured with several sensors positioned outside the trap chamber. We demonstrate the compensation of different noise contributions.

A 14.23 Mon 16:30 Spree-Palais

Decoherence-assisted spectroscopy of a single Mg$^+$ ion — •Govinda Clos[1], Martin Enderlein[1], Ulrich Warring[1], Dietrich Leibfried[2], and Tobias Schaetz[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]National Institute of Standards and Technology, 325 Broadway, Boulder, Colorado 80305, USA

Quantum systems that are well isolated from their environments, in particular trapped atoms, offer a high level of control. Several spectroscopic methods have been devised especially for single trapped ions. High-resolution spectroscopy measurements with a precision of better than 10^{-8} are of interest for studying spatial and temporal fine structure variations of the universe. In such experiments, decoherence is typically considered as a source of error. However, here we present a novel and versatile spectroscopy method that is assisted by decoherence: Preparing a superposition of two ground states, the absorption of a single spectroscopy photon and the subsequent spontaneous emission destroy its coherence which can be detected by final state analysis. We experimentally demonstrate the method on trapped and laser-cooled $^{25}Mg^+$ to measure one-, two-, and three-photon transitions from the ground state to the 3P, 3D, and 4P excited states which are relevant for astrophysical data analysis.

A 14.24 Mon 16:30 Spree-Palais

Quantum Logic Enabled Test of Discrete Symmetries — •Malte Niemann[1], Anna-Greta Paschke[1], Kai Voges[1], Stefan Ulmer[2], and Christian Ospelkaus[1,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]RIKEN, Ulmer Initiative Research Unit — [3]PTB Braunschweig

Much progress has been made recently towards a CPT test with baryons based on the (anti-)proton's magnetic moment [1, 2]. A big challenge in any such experiment is the spin state measurement for single (anti-)protons. This requires single particle spectroscopy in strong magnetic gradients at ultra-low background noise and long measuring times.

We describe concepts and simulations for an experiment which will implement single-shot spin state readout using quantum logic operations according to the proposal by Heinzen and Wineland [3]. The spin state will be analysed by coupling the (anti-)proton to a co-trapped $^9Be^+$ ion. Compared to the current techniques much faster experimental cycles are expected, and eventually, a significant boost in precision. We discuss trapping geometries, concepts for single (anti-)proton rf sideband control, and for ground state cooling of the atomic quantum logic ion at a magnetic field of several Tesla in a miniaturized Penning trap stack.

[1] A. Mooser et al., Phys. Let. B 723, 78-81 (2013)
[2] A. Mooser et al., Phys. Rev. Let. 110, 140405(2013)
[3] Heinzen and Wineland, PRA 42, 2977 (1990)

A 14.25 Mon 16:30 Spree-Palais

Towards quantum logic spectroscopy of highly charged ions — •Tobias Leopold[1], Maria Schwarz[1,3], Oscar Versolato[1,3], Matthias Kohnen[1], Alexander Windberger[3], Lisa Schmöger[1,3], Peter Micke[1,3], Joachim Ullrich[1], José Crespo Lopez-Urrutia[3], and Piet Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [3]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Highly charged ions (HCIs) are of special interest in high precision laser spectroscopy. Optical dipole (E1) forbidden transitions offer narrow linewidths perfectly suited for optical clocks. Due to high field strengths in the ions, their energy levels have a low sensitivity to external field shifts. A possible temporal change of the fine structure constant can be probed by spectroscopy of HCIs with unprecedented precision due to highly sensitive transitions.

Electron beam ion traps (EBITs) are an easy way to produce and trap HCIs. However, the trapping potential reaches several kiloelectronvolts so that the temperature of the trapped ions is too high for precision spectroscopy. As direct laser cooling is not applicable in HCIs, we combine an EBIT with a cryogenic linear Paul trap and sympathetically cool with Be^{+} ions.

Our aim is to perform quantum logic spectroscopy with Ir^{17+} as spectroscopy ion. The Be^{+} ion serves as cooling reservoir and readout of the HCI's electronic state. That technique allows to resolve highly forbidden transitions to their natural linewidth.

A 14.26 Mon 16:30 Spree-Palais

Absolute Kα line energies in highly charged Fe ions using X-ray fluorescence spectroscopy — •Jan K. Rudolph[1,2], Sven Bernitt[2], René Steinbrügge[2], Alfred Müller[1], and José R. Crespo López-Urrutia[2] — [1]Institut für Atom- und Molekülphysik, Gießen, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Active galactic nuclei X-ray spectra show prominent features originating from iron Kα transitions. Line emissions of iron ions up to the heliumlike charge state from 6.4 keV to 6.7 keV photon energy provide rich information on the dynamics of X-ray binary stars. To study these transitions we used the Heidelberg transportable electron beam ion trap called FLASH-EBIT [1] to produce a dense target of highly charged iron ions. Kα transitions in this ion cloud were resonantly excited by a monochromatic X-ray beam at the PETRA III synchrotron photon source. Afterwards the fluorescence signal was detected and used to measure line profiles.

We report on absolute line energies with an accuracy of a few ppm for several electric dipole allowed Kα transitions in $Fe^{(17-24)+}$ ions [2]. Also the natural line widths of the investigated fluorescence lines were determined. Well known absorption K-edges were taken as a reference for energy calibration.

This method of measuring absolute line energies combining an EBIT with a high resolved and focused X-ray beam at a synchrotron overcomes classical methods like crystal spectrometer measurements.

A 14.27 Mon 16:30 Spree-Palais

Highly charged ions as new X-ray standard for synchrotrons — •Sven Bernitt[1,2], Thomas Stöhlker[2], and José Ramon Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität, Jena, Germany

Atomic transitions excited by lasers are an established and extremely precise wavelength standard in the optical region. In contrast, work in the X-ray region has to rely on crystallographic standards or K-edge absorption. To overcome the limitations of those methods we aim at establishing transitions in highly charged ions (HCI) as new X-ray standards. To this end we use electron beam ion traps (EBIT) to provide targets of highly charged ions for synchrotron radiation. We present results of precise wavelength measurements of He-like Fe [1] and Kr at the synchrotron PETRA III, as well as a new experimental setup based on a small EBIT with permanent magnets. The latter will provide means of linking transitions in HCI to other wavelength standards, like the ^{57}Fe Mößbauer wavelength, and ultimately a precise calibration of the dynamics beamline P01 at PETRA III.

[1] J. K. Rudolph et al., Phys. Rev. Lett. 111, 103002 (2013).

A 14.28 Mon 16:30 Spree-Palais

X-ray laser spectroscopy with an electron beam ion trap at a free-electron laser — •Sven Bernitt and José Ramon Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Highly charged ions (HCI) of various elements are found in the plasmas of many astrophysical objects. Ions of iron play a particularly important role, often dominating the X-ray spectra. High precision X-ray spectroscopy in the laboratory is necessary to test the underlying theory. With X-ray free-electron lasers now available, the techniques of laser spectroscopy can be applied in the X-ray region. By resonantly exciting transitions with photons it is possible to overcome many of the limitations of conventional spectroscopy with HCI, which used to rely on electron impact excitation. We present the results of experiments carried out at the Linac Coherent Light Source (LCLS) free-electron laser. An electron beam ion trap was used to produce and trap Fe^{13+}, Fe^{14+}, Fe^{15+}, and Fe^{16+} and the fluorescence from resonantly excited transitions between 795 and 830 eV was detected. The relative oscillator strength of two prominent lines in Fe^{16+} provided new insight into a 40 year old enigma [1], and an until then only posulated line of Fe^{15+} was directly observed for the first time.

[1] S. Bernitt, Nature 492, 225 (2012).

A 15: Poster: Interaction with strong or short laser pulses

Time: Monday 16:30–18:30 Location: Spree-Palais

A 15.1 Mon 16:30 Spree-Palais

Time-Dependent Generalized Active Space Configuration Interaction Approach to Ultrafast Dynamics in Atoms and Molecules — •Sebastian Bauch[1,2], Lasse Kragh Sørensen[2], and Lars Bojer Madsen[2] — [1]Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, Leibnizstrasse 15, 24098 Kiel, Deutschland — [2]Institut for Fysik og Astronomi, Aarhus Universitet, Ny Munkegade 120, 8000 Aarhus C, Danmark

The progress in experiments using ultrashort and strong laser pulses demands for the development of theoretical tools for the time-dependent description of multi-electron targets including electron-electron correlations. In this contribution, we address one approach to the time-dependent many-electron problem: the time-dependent generalized active space configuration interaction (TD-GAS-CI) approach [1] within a mixed basis set consisting of a localized bound part and a discretized continuum [2]. We demonstrate the capabilities of the method by comparing to exact solutions of the multi-particle time-dependent Schrödinger equation and address the question of the choice of an appropriate single-particle basis set, in particular Hartree-Fock and natural orbitals. Photoionization cross-sections and higher-harmonic generation in multi-electron model systems are discussed.

[1] T. Fleig et al., J. Chem. Phys. 114, 4775 (2001)
[2] D. Hochstuhl and M. Bonitz, Phys. Rev. A 86, 053424 (2012)

A 15.2 Mon 16:30 Spree-Palais

Time resolved investigation of non-sequential double ionization using two-color laser-pulses — •Nicolas Camus[1], Lutz Fechner[1], Andreas Krupp[1], Joachim Ullrich[1,2], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We present an experiment where two laser pulses (800+400 nm) with controllable time-delay are used to investigate double ionization of atoms. The polarization of the weaker blue field is chosen to be perpendicular to the one of the more intense IR field. Due to the different intensities, ionization is assumed to result from the red component with the blue field causing a streaking of the electrons in the transverse direction. Information about the time the electrons escape can be extracted from the momentum component parallel to the blue field and its variation with the relative phase between the laser pulses. Using a Reaction Microscope, we are able to measure the three-dimensional momentum vectors of all particles in coincidence and determine the streaking traces as a function of the time-delay. Applied to non-sequential double ionization we are able to distinguish and to identify different ionization pathways.

A 15.3 Mon 16:30 Spree-Palais

Orthohelium in laserfields beyond TDDFT: doubly-excited

states made simple using TDRNOT — •Julius Rapp, Martins Brics, and Dieter Bauer — Institut für Physik, Universität Rostock

Time-dependent renormalized natural orbital theory (TDRNOT) is a novel many-particle method [1] to investigate correlated dynamics of quantum systems. We explore the capabilities of TDRNOT and benchmark its performance regarding the application to an exactly solvable one-dimensional helium model atom in both singlet and triplet configuration. Despite being in an early stage of development, TDRNOT outperforms "mature" techniques such as practicable time-dependent density functional theory (TDDFT) concerning the description of highly correlated phenomena such as doubly-excited states, autoionization, and Fano profiles. Moreover, the treatment of, e.g., Rabi oscillations is more intuitive than it is within TDDFT, considering the exotic features of the exact exchange-correlation (XC) functional there such as inital-state dependence, non-locality in time, and similar.

We discuss the result of a recent modification to the TDRNOT scheme [2] which substantially improves the description of the spin-triplet in particular. One remarkable feature compared to TDDFT is the presence of doubly-excited states in the linear response spectrum, whose energies approach the correct values if enough natural orbitals are included in the calculation. As an outlook, we also address dynamics induced by laser fields beyond linear response.

[1] M. Brics, D. Bauer, Phys. Rev. A **88**, 052514 (2013).
[2] J. Rapp, M. Brics, D. Bauer (submitted).

A 15.4 Mon 16:30 Spree-Palais

Line shape modifications of singly-excited Helium states coupled to a ponderomotive continuum — •Veit Stooss, Andreas Kaldun, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

In order to understand and control the dynamics of correlated electron systems as they appear in atoms and molecules it is instructive to study the most fundamental case, namely two interacting electrons bound to an atom. Here, we investigate the special case of singly-excited states in Helium and their laser coupling to a ponderomotive continuum. The line shapes observed in attosecond transient absorption spectra reveal signatures of both bound-to-continuum and bound-to-bound laser coupling. To better understand the full laser coupling dynamics a model simulation was carried out in which the states of the system are excited by an extreme ultraviolet (XUV) laser pulse and coupled by a femtosecond infrared (IR) pulse. The simulation includes the s-, p-, and d-series of singly-excited helium. The completed simulation allows for varying the infrared intensity of the coupling pulse or the relative time delay between XUV- and IR-pulse as control parameters. In addition the coupling between the states as well as the coupling to the continuum can be activated separately to study the relative contributions of the different coupling channels. The results are discussed within the recently developed Fano-phase formalism [1] which shows that resonance line shapes can be used to extract the laser intensity.

[1] C. Ott et al., Science 340, 716 (2013)

A 15.5 Mon 16:30 Spree-Palais

Coulomb effects in two-color atomic ionization and "the phase of the phase" in the photoelectron yield — •Mohammad Adel Almajid and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

The plain strong field approximation (SFA) fails in reproducing *ab initio* spectra obtained by solving the time-dependent Schrödinger equation (TDSE) exactly. There have been various attempts to include Coulomb effects into the direct SFA, one of them being the Coulomb-Volkov approximation (CVA). In our work, we compare TDSE and CVA-SFA photoelectron spectra, in particular for two-color, colinearly polarized pulses, where the relative phase between the two laser fields affects the photoelectron dynamics. A pronounced disagreement between exact TDSE and CVA-SFA results is found for the so-called direct electrons that move towards the detector without hard rescattering at the parent ion. The rescattered electrons instead are well described already by the SFA, extended for the rescattering matrix element. We analyze the photoelectron spectra by Fourier-transforming the momentum-dependent yield as a function of the relative phase between the two pulses, thus obtaining "the phase of the phase". Plotted vs the momenta parallel and perpendicular to the laser polarization direction, this entity tells how the yield of photoelectrons with a certain final momentum is synchronized with respect to changes of the relative phase.

A 15.6 Mon 16:30 Spree-Palais

Ionization of small Argon clusters in intense laser pulses at different wavelengths — •Mehrdad Baghery, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Electrons in clusters, after absorbing energy from a laser field, may not be bound to a specific atom any more, but may still be bound to the cluster as a whole. These electrons may then absorb further energy through inverse Bremsstrahlung and cause other electrons to ionize through collisions. These phenomena make the dynamics of clusters non-trivial.

Since hybrid quantum-classical calculations are usually computationally less expensive than those of a full quantum description, a hybrid quantum-classical model which reproduces quantum predictions may be beneficial to future research. We are presenting such a model for small Argon clusters interacting with intense laser pulses.

A 15.7 Mon 16:30 Spree-Palais

A Two-Color XUV-IR Pump-Probe Scheme for the Study of Xenon Double Ionization — •Alexander Sperl[1], Andreas Fischer[1], Philipp Cörlin[1], Michael Schönwald[1], Arne Senftleben[2], Thomas Pfeifer[1], Joachim Ullrich[3], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Universität Kassel — [3]Physikalisch-Technische Bundesanstalt, Braunschweig

The ionization of rare gas atoms with extreme-ultraviolet (XUV) attosecond laser pulses in the presence of a strong infrared (IR) laser field has been studied frequently and, moreover, it can be used to characterize both the XUV and IR laser fields [1]. Here, we combine a XUV-IR laser system with a reaction microscope and we apply this technique to xenon. With the available XUV-photon energies ranging from 17-40 eV double ionization of xenon (Ip = 33.1 eV) becomes possible and thus enables the investigation of correlated two-electron transitions as a function of the relative phase-shift between the XUV and IR pulses. In the experiment we detect event by event the doubly-charged Xe++ ions in coincidence with the two electrons and we fully reconstruct the three-dimensional momentum vectors and the final kinetic energies of all particles [2]. In the poster we present data on double ionization of Xe in combined XUV and IR laser fields and draw conclusions about the two-electron emission process by analyzing electron angular distributions as well as energy correlation spectra.

[1] H. G. Muller et. al., Appl. Phys. B 74, 2002
[2] O. Guyétand et. al., Appl. Phys. B 41, 065601, 2008

A 15.8 Mon 16:30 Spree-Palais

Imaging collective and uncorrelated electron motion in an FEL-induced nanoplasma — •M Müller[1], J-P Müller[1], M Sauppe[1], L Flückiger[1], A Ulmer[1], B Langbehn[1], T Gorkhover[1,2], C Bostedt[2], I Barke[3], H Hartmann[3], S Toleikis[4], S Düsterer[4], I Rosenow[4], K-H Meiwes-Broer[3], D Rupp[1], and T Möller[1] — [1]TU Berlin — [2]LCLS@SLAC — [3]Uni Rostock — [4]FLASH@DESY

Free-electron lasers (FELs) enable for the first time imaging of single non-crystallizable nanosized particles by elastic light scattering. Due to the high power density involved, the target is almost immediatly strongly ionized. The subsequent formation of a nanoplasma within the sample on the timescale of the pulse implies changes on the scattering picture.

To disentangle the influence of the nanoplasma on the imaging process we performed two-color pump-probe experiments on single large xenon clusters at the FLASH FEL. An intense IR-pulse prepares a highly ionized plasma state with uncorrelated electron motion which is then imaged by an FEL pulse. As a next experimental step, an IR-double pulse can be used to preexpand a cluster to resonant density and drive a collective motion of the quasi-free electrons while a simultaneously incident FEL pulse images the so called Mie plasmon. The experimental setup and preliminary results of this most recently performed experiment will be presented.

A 15.9 Mon 16:30 Spree-Palais

Comparison of split-operator methods for solving the three-dimensional time-dependent Schrödinger equation — •Paul Struszewski, Julius Rapp, and Dieter Bauer — Institut für Physik, Universität Rostock

We study numerical properties of different split-operator methods such as exponential operator splitting (EOS) and alternating direction implicit (ADI) for solving the three-dimensional time-dependent

Schrödinger equation (TDSE) in Cartesian coordinates. The aim is to obtain accurate ab initio results for the interaction of a lithium model system with an intense laser field in order to benchmark methods such as time-dependent density functional theory (TDDFT) in several approximations. The operator splitting allows for a high-order time propagation via the solution of *tridiagonal* linear equations only, which performs very well and can be directly parallelized. In addition, a highly adjusted numerical grid is used to minimize storage space and computing time.

The results provide general indications which operator splitting method is most suitable for solving the TDSE in three dimensions. As expected, the unitary EOS is perfectly norm-conserving, whereas the ADI is not. However, for ADI the variation of norm over time is orders of magnitude smaller in comparison to an explicit scheme. For cases in which ADI is faster than EOS, ADI offers a good compromise between numerical effort and norm-conservation.

A 15.10 Mon 16:30 Spree-Palais

Reconstructing the shape of single nanoclusters imaged with highly intense X-ray pulses — •A. Ulmer[1], L. Flückinger[1], T. Gorkhover[1], B. Langbehn[1], J.P. Müller[1], M. Müller[1], D. Rupp[1], M. Sauppe[1], A. Schreider[1], C. Bostedt[2], I. Barke[3], H. Hartmann[3], K.H. Meiwes-Broer[3], S. Toleikis[4], S. Düsterer[4], R. Treusch[4], and T. Möller[1] — [1]TU Berlin — [2]LCLS@SLAC — [3]Uni Rostock — [4]DESY Hamburg

Free-Electron Lasers (FELs) provide coherent highly intense and short pulses which make it possible for the first time to analyze the morphology of non-periodic or non-crystallizable nanoparticles by elastic light scattering. In addition to shape and structural information the optical properties (dielectric function) and their changes during the light pulse can be imaged.

We recently performed single shot experiments on single large clusters at the Free-Electron LASer Hamburg (FLASH) in a NIR/XUV pump-probe configuration. Reconstruction of the scattering patterns will give insight in both the growth process of the particles as well as the ionization dynamics in the irradiated clusters.

As the phase information is lost due to the imaging process it has to be retrieved using sophisticated techniques [1]. The information in the scattering patterns is limited by experimental constraints such as a necessary center hole and the limited detector size. Possible approaches combining scattering simulations and phase retrieval algorithms will be discussed.

[1] S. Marchesini et. al., Phys. Rev. B 68, 140101 (2003)

A 15.11 Mon 16:30 Spree-Palais

Implementation of Infinite-Range Exterior Complex Scaling in B splines — •Alvaro Magana and Alejandro Saenz — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin, Germany

The traditional box-discretization method for describing atoms and molecules in strong laser fields can lead to an inacurrate description of the system due to unphysical reflections at the finite box boundary. The problem can be cured by choosing a sufficiently large box size to describe correctly all the dynamics of the system, but this in turn demands very large computational efforts. The Infinite-Range Exterior Complex Scaling method (Ir-ECS) [1] has been proposed as a way of solving exactly the time-dependent Schrödinger equation (TDSE) within the physically most relevant region, dramatically reducing the numerical effort. In contrast to previous work in which the inner part of the wavepacket was described with a finite-element approach, we successfully implemented Ir-ECS using a mixed B-spline/Legendre basis in order to solve the TDSE. We report a drastic reduction of the total number of states needed for performing a time propagation using the spectral *ansatz.*

[1] A. Scrinzi, Phys. Rev. A 81, 053845 (2010).

A 15.12 Mon 16:30 Spree-Palais

Contributions from different orbitals to the high-harmonic spectra of N_2 — •Étienne Plésiat[1], Piero Decleva[2], and Alejandro Saenz[1] — [1]AG Modern Optics, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße, 15, 12489 Berlin, Germany — [2]Dipartimento di Scienze Chimiche, Universita' di Trieste, Via L. Giorgieri 1, 34127 Trieste, Italy

In the last decade, high-harmonic generation (HHG) is supposed to become a fantastic tool for obtaining information about the electronic and geometric structure of molecules on the ultrafast time scale. Since the rate of the tunnel ionization depends exponentially on the ionization potential, the HHG spectra were thought to reflect the contribution of the highest occupied molecular orbital (HOMO) only. However, in 2008 the predominance of the HOMO−1 of N_2 in the cut-off region has been observed for the first time [1]. From then on, a particular attention has been payed to the contributions of molecular orbitals with lower binding energies. They have been shown to be responsible for dynamical minima in the plateau region of CO_2 [2]. Theoretical studies generally employ models based on the strong-field approximation (SFA) which are computationally fast but sometimes also inaccurate. In this work, we investigated the multiple-orbital contributions to the HHG spectra of N_2 by solving the TDSE in the single-determinant approximation in a basis of Kohn-Sham orbitals. Accurate results obtained with this method will be presented during the conference.

[1] B. K. McFarland *et al.*, *Science* **322**, 1232 (2008).
[2] O. Smirnova *et al.*, *Nature* **460**, 972, (2009).

A 15.13 Mon 16:30 Spree-Palais

Two-color pump–probe momentum spectroscopy on dissociative photo-ionization of molecular nitrogen. — •Philipp Cörlin[1], Alexander Sperl[1], Andreas Fischer[1], Michael Schönwald[1], Arne Senftleben[2], Thomas Pfeifer[1], Joachim Ullrich[3], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Molecular nitrogen (N_2) has been investigated in an extreme-ultraviolet (XUV)–infrared (IR) pump–probe experiment using attosecond pulse trains with photon energies between 20 eV and 40 eV to ionize N_2 into several binding and anti-binding electronic states. An additional, time delayed 15 fs IR pulse with a center-wavelength of 780 eV is used to modify and probe these states.

The three dimensional momenta of coincident photo-electrons and ions N_2^+ and N^+ are detected over the full solid angle using a Reaction Microscope. This allows to study electron-ion energy-correlations and molecular frame photo-electron angular distributions for dissociative channels and thereby identify the involved N_2^+ states by energy and symmetry. Of particular interest is the ionization into vibrational levels of the bound $C^2\Sigma^+{}_u$ state that for $k \geq 3$ dissociate into $N^+ + N$ via predissociation which has been studied in synchrotron experiments for many years (compare [1] and references therein). In our experiment the energies of these vibrational states have been measured.

[1] L.-E. Berg *et al.*, *Phys. Scr.* **44**, (1991), 131-137

A 15.14 Mon 16:30 Spree-Palais

Krylov subspace methods in relativistic quantum dynamics — •Randolf Beerwerth, Heiko Bauke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik Saupfercheckweg 1, 69117 Heidelberg

The theoretical investigation of relativistic quantum dynamics of electrons, atoms, or ions that interact with strong or short laser pulses often necessitates nonperturbative approaches which rely on numerical methods, e. g., the numerical solution of the time-dependent Dirac equation. Krylov subspace methods, e. g., the Lanczos algorithm, allow to calculate efficiently few approximate eigenvalues and eigenvectors of very large matrices and have become a standard method for solving the nonrelativistic Schrödinger equation. Here we transfer these methods into the domain of relativistic quantum dynamics. Since Krylov subspace methods usually converge to eigenstates with extremal eigenvalues and relativistic Hamiltonians are not bounded it is not self-evident that these methods are applicable in the relativistic domain.

We focus on bound states in relativistic systems and we demonstrate that Krylov subspace methods are well suited to calculate the bound states of the Dirac Hamiltonian. For this purpose, we combine the Lanczos algorithm with the pseudospectral method, where the wave function is expanded into harmonic oscillator eigenfunctions. Due to the exponential convergence of the pseudospectral approach this yields precise results using only a moderate number of basis functions. Time-dependent propagation of Dirac wave functions will also be demonstrated.

A 15.15 Mon 16:30 Spree-Palais

Tunneling theory of H_2 in presence of strong linear and circular polarized fields — •Abdou Mekky Hussien and Alejandro Saenz — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin, Germany

The ratio $\Re$ of the angular ionization probabilities of H_2 between parallel and perpendicular molecular orientations in a linear and a circular polarized fields using a molecular tunneling theory (MO-ADK [1]) is studied. It is found that the ratio $\Re$ for an H_2 molecule in a strong field generally decreases with increases laser intensity, and the pattern of decrease depends on the duration of the laser pulse. A reasonable agreement with the experimental data in [2] is observed. These results invalidate the main result in [3] and corresponding statements in other works, where it is claimed that MO-ADK theory fails to predict the intensity-dependent anisotropy of H_2. Furthermore, the effect of the focal-volume averaging on the anisotropy is studied. Finally, an extention of the MO-ADK model into the barrier-suppression regime is also given. A further improvement of the results at high intensities is found, if this correction is considered.

[1] X. M. Tong *et al.*, *Phys. Rev. A*, **66**, 033402 (2002).
[2] A. Staudte *et al.*, *Phys. Rev. Lett.* **102**, 033004 (2009).
[3] Y.-J. Jin *et al.*, *Phys. Rev. A*, **83**, 063409 (2011).

A 15.16 Mon 16:30 Spree-Palais

Reconstructing scattering patterns of single xenon clusters — •Alexander Schreider[1], Leonie Flückiger[1], Fengling Wang[2], Daniela Rupp[1], and Thomas Möller[1] — [1]TU Berlin — [2]Universität Hamburg

Structure determination of small particles with conventional optical microscopy is significantly limited by diffraction. Coherent Diffraction Imaging (CDI) with short wavelengths brings a solution for imaging such samples by recording diffraction patterns and subsequently reconstructing the lost phase information by iterative algorithms.

We used algorithms based on the Hybrid-Input-Output (HIO) algorithm [1], the Error-Reduction (ER) algorithm [2] and the Shrink-Wrap method [3] to develope a programm for reconstructing measured diffraction patterns of xenon clusters ab initio. This programm was tested and optimized for the particular difficulties of the cluster scattering patterns due to restrictions introduced by the experimental setup. The challenges and possible solutions will be discussed.

[1] J.R. Fienup, Optics Letters 3, 27 (1978), [2] J.R. Fienup, Applied Optics 21, 2758 (1982), [3] S. Marchesini et al., Physical Review B 68, 140101 (2003)

A 15.17 Mon 16:30 Spree-Palais

Influence of the laser waveform of near single-cycle laser pulses on the dissociative ionization of N2O — •Christian Jendrzejewski[1,2], Matthias Kübel[1,2], and Matthias Kling[1,2] — [1]Ludwig-Maximilians-Universität München, Garching, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany

Within the past few years, the development of near-single cycle laser pulses allowed for various studies on electron dynamics in the femto- and attosecond time scale which are fundamental for chemical reactions. In order to investigate the ionization behavior of triatomic molecules in such laser fields laughing gas (N2O) is used as a model system. Thereby, the focus lies on the non sequential double ionization (NSDI) as it is highly important for correlated electron processes. The ionization products of the N2O molecule are temporally and spacially resolved within a reaction microscope. As such photoionization processes are strongly dependent on the laser waveform of the pulse, especially on the carrier-envelope phase (CEP), the CEP is detected for each laser pulse. Combining these two methods, strong dependencies of the ionization yield on the CEP and polarization of the laser pulse are observed.

A 15.18 Mon 16:30 Spree-Palais

Photoelectrons close to threshold — •Elias Diesen, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The 2009 discovery of the low energy structure (LES) [1] of photoionization spectra in the long-wavelength, high-intensity tunneling regime spurred a large experimental and theoretical activity in the last years. The role of classical so-called soft recollisions was investigated in [2,3]. Recent experiments at unprecedented resolution reveal more spectral features [4] above and below threshold, whose explanation is not yet complete. We present theoretical results on the formation of these features that typically appear at energies well below 1 eV.

[1] Blaga et al, Nature Phys., 5, 335 (2009)
[2] Kästner et al, Phys. Rev. Lett. 108, 033201 (2012)
[3] Kästner et al, J. Phys. B 45, 074011 (2012)
[4] Dura et al, Sci. Rep. 3, 2675 (2013)

A 15.19 Mon 16:30 Spree-Palais

Velocity Map Imaging of Trajectory Controlled Above-Threshold Ionization Spectra of Xenon Using the Two-Color Field Technique — •Daniel Würzler, Max Möller, Frank Meyer, Max Sayler, and Gerhard G. Paulus — HIJ IOQ, Max-Wien-Platz 1, 07743 Jena

Recent research shows that adding a weak second harmonic field perpendicular to a strong fundamental beam provides the ability to control high harmonic generation by suppressing recombination of certain electron trajectories. In this study, a collinear interferometer is build in order to combine an ultrashort laser pulse with its second harmonic field in the target area. The setup is used to demonstrate control over electron trajectories of Xenon in above-threshold ionization.

A 16: Symposium SAMOP Dissertation-Prize 2014 SYAD (with Q, MO, P)

Time: Tuesday 10:30–12:30 Location: Audimax

Invited Talk A 16.1 Tue 10:30 Audimax

Rotationally resolved fluorescence spectroscopy - from neurotransmitter to conical intersection — •Christian Brand — Institute for Quantum Optics, Quantum Nanophysics and Quantum Information, University of Vienna, Austria

The combination of rotationally resolved electronic spectroscopy and high level *ab initio* calculations allows a very detailed analysis of molecular structure both in the electronic ground and excited state. Beyond that it contains a wealth of information regarding the excited state photophysics and internal motions, and enables us to look for interactions between electronic states.

In a comprehensive study on the model system indole we observe that the energies of the two lowest excited singlet states vary systematically depending on the nature and the position of a given substituent. This is of major importance as indole is the chromophore of the aromatic amino acid tryptophan and hence is responsible for its emission properties. Depending on whether electron density is donated or withdrawn by the substituent, the energetic gap between the S_1 and S_2 is altered and sometimes even the energetic ordering on the states can be reversed. The photophysical consequences are numerous and will be illustrated for a number of characteristic examples.

Invited Talk A 16.2 Tue 11:00 Audimax

Quantum simulations with ultracold atoms: Beyond standard optical lattices — •Philipp Hauke — Institute of Quantum Optics and Quantum Information, Innsbruck, Austria

Many prominent problems of quantum many-body physics (such as high-Tc superconductivity or quark confinement) remain unsolved, because the exponential growth of Hilbert space prevents numerical treatment of more than a few particles. To solve such models, Feynman proposed thirty years ago to design quantum devices that are governed by the same equations as the abstract model. Ultracold atoms in optical lattices are – thanks to their unprecedented cleanness and control – ideal candidates for such "quantum simulators," and experiments that exceed the capabilities of classical computers are already being performed. In this talk, I present various new avenues that become open by going beyond standard setups, e.g., via exotic geometries, higher orbitals, or spin-dependent lattices. In particular, I discuss the exciting possibilities given by a periodical lattice driving, which allows us to explore frustrated quantum magnetism and which provides an alternative to light-induced synthetic gauge fields. Indeed, experiments along these lines are already being carried out. The proposed systems may realize topological phases, anomalous quantum-Hall states, or spin liquids, thus promising insight into some of the most important problems of condensed-matter and high-energy physics.

Invited Talk A 16.3 Tue 11:30 Audimax

Degenerate quantum gases of alkaline-earth atoms — •Simon Stellmer — Institut für Quantenoptik und Quanteninformation, Innsbruck — Universität Innsbruck — Atominstitut der TU Wien

Alkaline-earth atoms are a well-established and very successful platform for optical clocks, but their introduction into the field of quantum gases occurred only very recently. Atoms of alkaline-earth elements are strikingly different from the widely used alkali atoms with respect to their nuclear, electronic, and scattering properties. Their unique features, such as narrow transitions and metastable states, are at the heart of many novel quantum simulation protocols and related proposals. These fascinating ideas, however, require deeply degenerate samples.

In my talk, I will sketch a robust and efficient scheme that allowed us to reach quantum degeneracy in strontium for the first time. I will then elaborate on an experiment that beautifully combines various favorable properties of strontium: the attainment of Bose-Einstein condensation purely by laser cooling, i.e. without the stage of evaporative cooling. This work holds prospects for the generation of a continuous atom laser.

Invited Talk A 16.4 Tue 12:00 Audimax

One step beyond entanglement: general quantum correlations and their role in quantum information theory — •Alexander Streltsov — ICFO - The Institute of Photonic Sciences, Castelldefels, Spain

Quantum entanglement is by far the most famous kind of quantum correlations and its fundamental role in several tasks in quantum information theory is undeniable. However, recent discoveries suggest that entanglement is not always necessary: a quantum computer can outperform its classical counterpart even without any entanglement. This and related examples demonstrate the limits of the concept of entanglement and suggest the formulation of more general quantum correlations which are more suitable for the tasks under study. Quantum discord is the most famous measure of such general quantum correlations beyond entanglement. In this talk we discuss the role of quantum discord in the quantum measurement process and in the task of entanglement distribution. In particular, we show that quantum discord is the essential resource for this task: the distribution of any finite amount of entanglement requires the transmission of at least the same amount of discord. Our results also reveal optimal distribution protocols even if the exchanged particle exhibits no entanglement with the rest of the system.

A 17: Quantum Protocols and Gates SYQR 3 (with Q)

Time: Tuesday 10:30–12:15 Location: Kinosaal

A 17.1 Tue 10:30 Kinosaal

Quantum key distribution with two-segment quantum repeaters — •Hermann Kampermann, Silvestre Abruzzo, and Dagmar Bruss — Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Germany

Quantum repeaters represent one possible way to achieve long-distance quantum key distribution. One way of improving the repeater rate and decreasing the memory coherence time is the usage of multiplexing. Motivated by the experimental fact that long-range connections are practically demanding, we extend the analysis of the quantum repeater multiplexing protocol to the case of short-range connections. We derive formulas for the repeater rate and we show that short-range connections lead to most of the benefits of a full-range multiplexing protocol [1].

A less demanding QKD-protocol without quantum memories was recently introduced by Lo *et al.* We generalize this measurement-device-independent quantum key Distribution protocol to the scenario where the repeater Station contains also heralded quantum memories. We assume either single-photon sources or weak coherent pulse sources plus decoy states. We show that it is possible to significantly outperform the original proposal, even in presence of decoherence of the quantum memory. We give formulas in terms of device imperfections i.e., the quantum bit error rate and the repeater rate [2].

[1] S. Abruzzo, H. Kampermann, D. Bruß, arXiv:1309.1106v1
[2] S. Abruzzo, H. Kampermann, D. Bruß, arXiv:1306.3095v1

A 17.2 Tue 10:45 Kinosaal

Broadcast Classical-Quantum Capacity Region of Two-Phase Bidirectional Relaying Channels — Holger Boche, Minglai Cai, and •Christian Deppe — Technische Universität München, Fakultät für Elektrotechnik und Informationstechnik, Lehrstuhl für Theoretische Informationstechnik

The transmission of quantum states over long distances is essential for future applications such as quantum networks. The direct transmission is limited by unavoidable losses of the channel. A promising alternative for long distance quantum states distribution is the use of quantum repeaters. We analyze a quantum repeater protocol which takes advantage of bidirectional communication. We consider a three-node quantum network which enables bidirectional communication between two nodes with a half-duplex relay node. The message $m_2 \in M_2$ is located at node 1 and the message $m_1 \in M_1$ is located at node 2, respectively. Our goal is that the message $m_2 \in M_2$ is known at node 2 and the message $m_1 \in M_1$ is known at node 1, respectively. We simplify the problem by assuming an a priori separation of the communication into two phases. The capacity of the first phase (MAC) is known. We determine the capacity region of the second phase (broadcast).

A 17.3 Tue 11:00 Kinosaal

Quantum error correction in a solid-state hybrid spin register — Gerald Waldherr[1], Ya Wang[1], •Sebastian Zaiser[1], Mohammed Jamali[1], Thomas Schulte-Herbrueggen[2], Hiroshi Abe[3], Takeshi Ohshima[3], Junichi Isoya[4], Philipp Neumann[1], and Joerg Wrachtrup[1] — [1]3. Physikalisches Institut , University of Stuttgart — [2]Department of Chemistry, Technical University of Munich — [3]Japan Atomic Energy Agency, Takasaki — [4]Research Center for Knowledge Communities, University of Tsukuba, Tsukuba

Electron spins associated with solid state defects are promising systems for quantum information processing. Exploiting nuclear spins surrounding the defect as a quantum register provides a natural hybrid spin system. Such a system could be used for a fault-tolerant quantum repeater scheme [1] where the spins might be associated to nitrogen-vacancy (NV) centers in diamond. Here, we present a hybrid spin register based on a single NV defect in diamond coupled to three nuclear spins. The electron spin is used for control, and the nuclear spins as a long-lived quantum storage. We achieve high-fidelity initialization and single shot readout of the nuclear spin register. Implementation of a novel non-local gate combined with optimal control enables universal, high-fidelity control. With these techniques, we demonstrate three-qubit entanglement and quantum error correction. These experiments demonstrate the potential of solid state spin systems for quantum computation and communication. [1] L. Childress, et al., Phys. Rev. Lett. 96, 070504 (2006).

A 17.4 Tue 11:15 Kinosaal

A quantum byte with 10^{-4} crosstalk for fault-tolerant quantum computing — •Christian Piltz, Theeraphot Sriarunothai, Andrés Varón, and Christof Wunderlich — Department Physik, Universität Siegen, 57068 Siegen, Germany

A prerequisite for fault-tolerant and thus scalable operation of a quantum computer is the use of quantum error correction protocols. Such protocols come with a maximum tolerable gate error, and there is consensus that an error of order 10^{-4} is an important threshold. This threshold was already breached for single-qubit gates with trapped ions using microwave radiation. However, crosstalk - the error that is induced in qubits within a quantum register, when one qubit (or a subset of qubits) is coherently manipulated, still prevents the realization of a scalable quantum computer. The application of a quantum gate - even if the gate error itself is low - induces errors in other qubits within the quantum register.

We present an experimental study using quantum registers consisting of microwave-driven trapped $^{171}Yb^{+}$ ions in a static magnetic gradient. We demonstrate a quantum register of three qubits with a next-neigbour crosstalk of $6(1) \cdot 10^{-5}$ that for the first time breaches the error correction threshold. Furthermore, we present a quantum register of eight qubits - a quantum byte - with a next-neighbour crosstalk error better than $2.9(4) \cdot 10^{-4}$. Importantly, our results are obtained with thermally excited ions far above the motional ground state.

A 17.5 Tue 11:30 Kinosaal

Strain-induced active tuning of the coherent tunneling in quantum dot molecules — •Eugenio Zallo[1], Rinaldo Trotta[2], Yongheng H. Huo[1], Paola Atkinson[3], Fei Ding[1], Armando Rastelli[2], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany — [2]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Altenbergerstr. 69, A-4040 Linz, Austria — [3]Institut des NanoSciences des Paris, UPMC CNRS UMR 7588,4 Place Jussieu Boite courier 840, Paris 75252 Cedex 05, France

Quantum dot molecules (QDMs) are formed by orbital hybridization of wavefunctions in two closely positioned quantum dots (QDs), and they are important for a coherent manipulation of qubits in quantum information applications. The coupling strength is the key parameter determining the operation rate of quantum gates based on QDMs. Recently, ultrafast optical control of the entangled state of two electron spins interacting through tunneling in a QDM was demonstrated. Despite the extensive efforts in the community, it is a formidable task to actively tune the tunnel coupling in a single QDM obtained by vertical stacking of two semiconductor quantum dots. In this presentation, a novel class of devices that allow large strain and electric fields to be applied to single QD and QDM will be introduced first. Then, the experimental achievement of this active tuning will be demonstrated. By means of externally induced strain fields the coupling strength of holes confined in vertically coupled InGaAs/GaAs QDs was varied by more than 14%.

A 17.6 Tue 11:45 Kinosaal

Harnessing the diamond spin bath — Jan Honert[1], Martin Hohmann[1], Nan Zhao[2], •Helmut Fedder[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut and Research Center SCoPE, University Stuttgart, Germany — [2]Beijing Computational Science Research Center, Beijing, China

^{13}C nuclear spins in diamond are the predominant source of decoherence for electron spin qubits such as the NV center [1] or ST1 [2] defect. At the same time, they are a valuable resource for the implementation of nuclear spin quantum registers [3]. Addressing distant and thus weakly coupled bath spins would enable us to scale up nuclear spin registers to sizes relevant to small scale quantum algorithms such as stabilizer codes that are particularly relevant to quantum repeaters. In here we show that dynamical decoupling techniques can be used to detect a single ^{13}C nuclear spin that is coupled to an NV center with a dipole coupling strength as weak as 400 Hz. We discuss protocols for initializing and coherently controlling such weakly coupled bath spins.

[1] P. Neumann et al. Multipartite entanglement among single spins in diamond. Science 320, 1326 (2008)
[2] S.-Y. Lee et al. Readout and control of a single nuclear spin with a metastable electron spin ancilla. Nature nano. 8, 487 (2013)
[3] G. Waldherr et al. Quantum error correction in a solid-state hybrid spin register. arXiv:1309.6424v2 (2013).

A 17.7 Tue 12:00 Kinosaal

Towards long coherent time quantum memory based on NV center in low temperature — •Sen Yang[1], S. Ali Momenzadeh[1], Thai Hien Tran[1], Ya Wang[1], Naofumi Abe[2], Hideo Kosaka[2], Helmut Fedder[1], Philipp Neumann[1], and Joerg Wrachtrup[1] — [1]3rd Physics Institute, Universitaet Stuttgart, Germany — [2]Research Institute of Electrical Communication, Tohoku University, Japan

The Nitrogen-Vacancy (NV) center in diamond is a promising system for quantum communication/computation. Low temperature gives us not only ultralong spin lifetime but also the ability to address excited states individually. Optically resonant excitation of spin-selective transitions and single shot readout of electron spin in low magnetic field improve initialization and readout fidelity. This opens up the opportunities of making quantum devices based on the fine structure of excited states and photon NV interaction. Long coherence time makes nuclear spin a good choice as quantum memory. $M_s = \pm 1$ ground states and A1 excited state form Λ system which make optical writing possible. Here, we presents recent results of this quantum memory scheme. this quantum memory could be an important component for building quantum repeater based on NV center in diamond.

A 18: Interaction with strong or short laser pulses II

Time: Tuesday 14:00–16:00 Location: BEBEL E34

Invited Talk A 18.1 Tue 14:00 BEBEL E34

Determination of chiral molecules' handedness — •Markus Schöffler[1], Martin Pitzer[1], Maksim Kunitski[1], Allan S. Johnson[1,2], Till Jahnke[1], Hendrik Sann[1], Felix Sturm[1], Lothar Ph. H. Schmidt[1], Horst Schmidt-Böcking[1], Reinhard Dörner[1], Jürgen Stohner[3], Julia Kiedrowski[4], Michael Reggelin[4], Sebastian Marquardt[4], Alexander Schiesser[4], and Robert Berger[4] — [1]Institut für Kernphysik, J. W. Goethe-Universität Frankfurt, Germany — [2]University of Ottawa, ON K1N 6N5, Canada — [3]Institute of Chemistry and Biological Chemistry, Zurich, 8820 Wädenswil, Switzerland — [4]Clemens-Schöpf Institute, TU Darmstadt, Germany

When reaching a certain level of complexity, molecules can have a chiral structure. This is similar to our hands, which also exist in a right and a left version. As the molecules have the same physical properties (density, melting point etc.) determination of the two species poses major challenges even today to chemists. Many indirect methods have been developed therefore with more or less drawbacks. An intense femtosecond laser pulse was used to remove many electrons (>4) from the molecule, resulting in a Coloumb Explosion of the molecules fragments. The COLTRIMS momentum imaging technology COLTRIMS was employed to measure the momentum vector of each emitted fragment (ion and electron) in coincidence. The show case example of racemic CHBrClF will be presented, the fragmentation dynamics discussed and the chiral distinction illustrated. Furthermore the perspectives on larger molecules will be discussed, as well as the challenges using synchrotron radiation

A 18.2 Tue 14:30 BEBEL E34

Photoelectron circular dichroism in above threshold ionization of chiral molecules — •Ingo Dreissigacker and Manfred Lein — Institut für Theoretische Physik, Leibniz Universität Hannover

Motivated by a recent experiment on circular dichroism in the photoelectron momentum distributions of chiral molecules from strong-field ionization [Lux et al., Angew. Chem. Int. Ed. 51, 5001 (2012)], we investigate this effect theoretically. For the first time, we are able to compute the asymmetric response of a sample of randomly oriented chiral molecules to a strong circularly polarized field non-perturbatively and from first principles. The strong-field approximation fails to describe this process due to its plane-wave nature. We therefore apply the Born approximation to the scattering state and use this as a continuum-state correction in the strong-field approximation. In this way, we obtain spectra of the molecules camphor and fenchone and study contributions of individual molecular orientations to the asymmetric photoelectron emission in order to improve the physical understanding of the process.

A 18.3 Tue 14:45 BEBEL E34

Controlling the strong-field dissociation of aligned C_2H_2 ions — •Katharina Doblhoff-Dier[1,2], Xinhua Xie[2], Markus Kitzler[2], and Stefanie Gräfe[1] — [1]Friedrich Schiller Universität, Jena, Deutschland — [2]Technische Universität Wien, Wien, Österreich

Intense, short near infra-red laser sources provide novel tools to control molecular reactions, e.g., via the CE phase[1]. Recently, experimental results have shown the possibility to control fragmentation reactions in acetylene by aligning the molecule relative to the laser polarization direction. In our work, we use these results to gain a better insight into the underlying mechanisms and to obtain an interpretation of the rich experimental results. Simplifying the complex, quantum mechanical dissociation process, we discompose the reaction into several interconnected steps, allowing for their separate modelling and analysis. The complexity of the process, however, requires a wealth of different models. Amongst others, we apply time-dependent density functional theory, molecular tunnelling theory, single orbital electron impact ionization, reduced dimensional quantum dynamics calculations modelling field excitation processes, and both quantum mechanical and (semi-)classical estimates. The comparison and synopsis of all sub-processes allows us to confirm and identify not only multi-orbital contributions but also to investigate the influence of different ionization mechanisms (sequential and non-sequential), relevant for the dissociation process. We hope that the classification of different processes will also help to understand laser aided reactions in more complex molecules.

[1] Xie et al., Phys. Rev. Lett. 109, 243001 (2012)

A 18.4 Tue 15:00 BEBEL E34

Exact TDSE simulations of H_2^+ in intense laser fields — •Volker Mosert and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

We investigate ionization of the hydrogen molecular ion H_2^+ in intense laser fields, in particular the influence of the nuclear motion beyond Ehrenfest dynamics. Simulating molecules in intense laser fields on an *ab initio*-level is in general prohibitive because the time dependent Schrödinger equation (TDSE) for electrons *and* ions has to be solved. However, the problem of H_2^+ in a laser field polarized colinear to the internuclear distance can be reduced to three dimensions when the cylindrical symmetry is exploited. We discretize the problem on a non-equidistant cylindrical grid. A finite difference approximation of the Hamiltonian in conjunction with a Crank-Nicolson time propagator is used to solve the TDSE.

A 18.5 Tue 15:15 BEBEL E34

Multi-channel ionization dynamics of finite systems under intense Xray pulses — •Abraham Camacho Garibay, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS

Xray free-electron lasers sources provide ultra-intense and ultra-short pulses, allowing the study entirely new regimes of light-matter interaction. In particular, a cluster or molecule can absorb many photons, creating a deep Coulombic potential, which depends on the instantaneous charge and instantaneous size of the (expanding) system. This potential modifies energies of photo- and Auger electrons in a characteristic manner. By means of the measurable electron spectra one may uncover the complex electron and ion dynamics in the cluster or molecule.

A 18.6 Tue 15:30 BEBEL E34

Quantum trajectory analysis of clusters and molecules in strong laser fields — •Thomas Keil and Dieter Bauer — Universität Rostock, Institut für Physik

The strong field approximation (SFA) is *the* underlying theory describing the interaction of intense laser light with atoms or molecules. However, it has been noted that several spectral features are not reproduced by the plain SFA because the Coulomb force on the outgoing photoelectron is neglected. It is well-known that photoelectrons generated by strong-field ionization of atoms have a cut-off energy of $2U_p$ if they move directly to the detector (or $10U_p$ if they rescatter once from their parent ion). Electrons emitted from laser-irradiated clusters may have much higher kinetic energies, especially at resonance [1,2]. We apply the methodology developed for the Coulomb-corrected SFA (CCSFA) based on quantum trajectories [3] to a SFA that is corrected for the collective electric field in the cluster. We show that it is this collective field, which arises because of the coherent oscillation of the electron cloud with respect to the ionic background, that generates multi-U_p electrons. This finding comfirms the "surface-plasmon-assisted rescattering in clusters" revealed earlier via classical molecular dynamics simulations [1]. Results from the CCSFA for molecules will be also presented.

[1] Th. Fennel et al., Phys. Rev. Lett. 98, 143401 (2007).
[2] Th. Keil, D. Bauer, J. Phys. B (submitted).
[3] T.-M. Yan et al., Phys. Rev. Lett. 105, 253002 (2010); T.-M. Yan et al., Springer Series in Chemical Physics vol. 104 (2013).

A 18.7 Tue 15:45 BEBEL E34

Field-driven THz-streaking of Nanotip Photoemission — •Georg Herink, Lara Wimmer, Katharina E. Echternkamp, Daniel R. Solli, and Claus Ropers — 4. Physical Institute - University of Göttingen, Göttingen, Germany

We present an ultrafast, nanoscale streaking scheme for field-driven photoemission control using single-cycle THz transients at the apex of a sharp gold tip [1]. The locally enhanced THz-field allows for a high-contrast enhancement or suppression of the near-infrared photoemission yield and a tuning of the photoelectron kinetic energy distribution, both in spectral position and width.

This streaking scheme is unique to nanostructures because of the strong sub-wavelength confinement of the driving field [2]. In particular, the associated electron dynamics are governed by the momentary THz field at the instance of photoemission, rather than by a temporal integral, i.e. the vector potential, as in optical streaking experiments for attosecond spectroscopy [3].

Besides the fundamental interest in the characterization and control of electron trajectories within ultrashort optical near-fields, the approach carries significant potential for pulse compression in ultrafast electron diffraction and microscopy experiments.

[1] Wimmer et al., arXiv: 1307:2581 (2013)
[2] Herink et al., Nature 483, 190-193 (2012)
[3] Corkum, Krausz, Nature Physics 3, 381 - 387 (2007)

A 19: Photoionization

Time: Tuesday 14:00–16:00 Location: BEBEL E42

Invited Talk A 19.1 Tue 14:00 BEBEL E42

The molecular double slit: transition from random to oriented target properties — •Gregor Hartmann[1,2], Markus Braune[3], Jens Viefhaus[3], André Meissner[1], Toralf Lischke[1,2], Axel Reinköster[1], Burkhard Langer[4], Sascha Deinert[3], Leif Glaser[3], Frank Scholz[3], Jörn Seltmann[3], Markus Ilchen[3], André Knie[5], Philipp Schmidt[5], Arno Ehresmann[5], Omar Al-Dossary[6], and Uwe Becker[1,2,6] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle — [3]DESY, Notkestraße 85, 22067 Hamburg — [4]Physikalische Chemie, FU Berlin, Takustr. 3, 14195 Berlin — [5]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [6]Physics Department, King Saud University, Riyadh 11451, Saudi Arabia

The analogy of homonuclear diatomic molecules to the Young type double slit experiment such as Cohen-Fano cross section oscillations has been topic of a large amount of photoionization investigations. Here, the hydrogen molecule's cross section oscillations are analyzed over a large photon energy range (29eV-1200eV) distinguishing between the randomly in space distributed molecule and the 'oriented sample', in which the orientation of the molecular axis to the light polarization vector is detected. Furthermore, a transition effect from random to oriented target properties is detected, when the de Broglie wave length of the photoelectron resolves the internuclear distance. The ion fragment angular distribution is analyzed and found as a reason for the transition.

A 19.2 Tue 14:30 BEBEL E42

Radiative and Auger widths of X-ray K-shell excited few-electron iron ions — •René Steinbrügge[1], Sven Bernitt[1], Sascha W. Epp[2], Jan K. Rudolph[1,3], Christian Beilmann[5], Hendrik Bekker[1], Sita Eberle[1], Alfred Müller[3], Joachim Ullrich[6], Oscar O. Versolato[1], Hasan Yavaş[4], Hans-Christian Wille[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg — [3]Institut für Atom- und Molekülphysik, Gießen — [4]DESY, Hamburg — [5]Physikalisches Institut, Heidelberg — [6]PTB, Braunschweig

The spectrum of highly charged iron ions gives rich information of the dynamics of outflows in X-ray binary stars and active galactic nuclei. Very high X-ray fluxes in the vicinity of such objects produce and drive mainly photoionized plasmas, but up to now it was not possible to investigate the underlying photoionisation processes in the laboratory. We present the first measurement of radiative and Auger rates for K-shell transitions in Li-like, Be-like, and C-like iron ions. These were produced and trapped in the transportable electron beam ion trap FLASH-EBIT and resonantly excited with X-ray photons at PETRA III. We observe photoionization by detecting the changes in the ionic charge state. By taking ratios of the photoionization yield and the simultaneous recorded fluorescence, we suppress setup-dependent uncertainties. Together with the total linewidths [1], this allows us to determine absolute values for the radiative and Auger widths.

[1] J. K. Rudolph et al., Phys. Rev. Lett. **111**, 103002 (2013)

A 19.3 Tue 14:45 BEBEL E42

Angular distribution of photoelectrons emitted from a laser-cooled and polarised lithium target — •Renate Hubele, Johannes Goullon, Elisabeth Brühl, Michael Schuricke, Hannes Lindenblatt, and Daniel Fischer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

With a magneto optical trap (MOT) a polarised atomic target for ionisation experiments can be realised. In the MOT the atoms are cooled to very low temperatures exploiting the principle of Doppler cooling, where the continuous absorption of photons from three pairs of counter-propagating red detuned laser beams is used to slow down the atoms. In our setup, the cooling takes place in a homogeneous magnetic field that leads to an energetic splitting of the atomic states into different Zeeman-sublevels according to their quantum number m. Due to the red-detuning of the cooling laser beams, a predominant population of the $2P_{3/2}, m_L = -1$ (i.e. $m_j = -3/2$) excited state is achieved.

In the experiments presented here, laser light in the UV wavelength range with linear polarisation both parallel and perpendicular to the direction of the external magnetic field is used to ionise the excited lithium atoms and the angular emission pattern of the photoelectrons is recorded with a Reaction Microscope. The emission pattern corresponds to the angular probability densities of the wave function of the final state of the reaction. Due to selection rules, the different polarisations of the UV laser lead to different final states and therefore to distinct electron angular emission patterns.

A 19.4 Tue 15:00 BEBEL E42

Non-monotonic behavior of the ionization probability of model negative ions by high-frequency laser pulses — •Koudai Toyota, Ulf Saalmann, and Jan Michael Rost — Max-Planck-Institute for the Physics of Complex Systems, Noethnitzer Str. 38, 01187, Dresden, Germany

We report on the non-monotonic behavior of the ionization probability of a model negative ion in strong high-frequency laser pulses as a function of pulse durations. Three distinct ionization processes contribute to the behavior and show characteristic features in the photo-electron spectrum. The first mechanism is single-photon absorption which dominates the ionization dynamics for long pulse durations. The second one is non-adiabatic transitions in the adiabatic picture induced by the slow deformation of the electron's effective potential as a function of time. The third mechanism is also a non-adiabatic process, similarly to the shake-off ionization, and can be understood in a sudden picture. This process strongly depends on the carrier-envelope phase of the pulse. The latter two dominate the ionization dynamics for short pulse durations.

A 19.5 Tue 15:15 BEBEL E42

Partial Decay Rates of Driven 1D eZe Helium — •Nicolai Heitz, Klaus Zimmermann, Felix Jörder, Alberto Rodriguez, and Andreas Buchleitner — Physikalisches Institut der Albert-Ludwigs-Universität, Hermann-Herder-Straße 3, D-79104 Freiburg

We study the photoionization process of doubly excited states of 1D helium in the eZe configuration, with full account of the Coulomb singularities as well as of the atomic continuum structure. In order to distinguish pronounced autoionization processes induced by the electron-electron interaction from bona fide photoionization, we implement a variant of complex dilation, which is capable of assessing partial decay channels.

A 19.6 Tue 15:30 BEBEL E42

Molecular hydrogen in strong laser fields: breakdown(s) of the fixed-nuclei approximation — •Johann Förster and Alejandro Saenz — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin, Germany

We investigate the effect of nuclear vibration on the ionization behaviour of molecular hydrogen by a direct solution of the time-dependent Schrödinger equation. For this purpose, our six-dimensional configuration-interaction method to solve the electronic Schrödinger equation of molecular hydrogen in strong laser fields [1, 2] is extended to include molecular vibration. The results obtained within the correlated treatment of electronic and vibrational motion are compared to those stemming from the fixed-nuclei approximation (FNA; i.e. the solution of the electronic Schrödinger equation only for the equilibrium geometry). We show that the FNA breaks down for certain laser parameters in the multiphoton and quasistatic regimes. For example, the total ionization yield can differ from the "full" treatment by several orders of magnitude. The reasons for these complete breakdowns of the FNA are explained and it is shown that other very simple (and "useful") approximations still agree surprisingly well with the "full" treatment.

References

[1] M. Awasthi, Y. V. Vanne and A. Saenz, *J. Phys. B* **38**, 3973 (2005).
[2] Y. V. Vanne and A. Saenz, *Phys. Rev. A* **82**, 011403(R) (2010).

A 19.7 Tue 15:45 BEBEL E42

Optically Excited Graphene - Non - Equilibrium Many Body Theory — •Regine Frank — Institute for Theoretical Physics, Eberhard-Karls University Tübingen, Germany Center for Light-Matter-Interaction, Sensors and Analytics (LISA+) and Center for Complex Quantum Phenomena (CQ)

A generalized non-equilibrium dynamical mean field theory (DMFT) for graphene is presented. The non-equilibrium DMFT derives properties such as electronic density of states (LDOS) and occupation numbers of the optically driven system. It fully characterizes the system in it's time dependent state. It is demonstrated, how such a setup may be employed in order to realize all-optical switching processes. Results for relevant time scales in setups as well as wave-mixing influences are presented.

A 20: Ultra-cold plasmas and Rydberg systems III (with Q)

Time: Tuesday 14:00–16:00 Location: BEBEL E44/46

A 20.1 Tue 14:00 BEBEL E44/46

Many-body physics with Strontium Rydberg lattices — •Laura Gil[1], Rick Mukherjee[1], Elizabeth Bridge[2], Matthew Jones[2], and Thomas Pohl[1] — [1]Max-Planck-Institute for the Physics of Complex Systems, Dresden — [2]Joint Quantum Centre, Durham-Newcastle, UK

We theoretically explore the utility of off-resonant Rydberg state dressing for the creation of tunable long-range interactions between atoms in optical lattices. As an application, here we theoretically demonstrate a viable approach to generate squeezed many-body states in Strontium optical lattice clocks, and discuss prospects for realizing extended Bose-Hubbard models with non-linear tunnelling terms.

A 20.2 Tue 14:15 BEBEL E44/46

Parallel execution of quantum gates in a long linear ion chain via Rydberg mode shaping — •Weibin Li[1], Alexander W. Glaetzle[2], Rejish Nath[2], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, United Kingdom — [2]Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck, Austria

We present a mechanism that permits the parallel execution of multiple quantum gate operations within a single long linear ion chain. Our approach is based on large coherent forces that occur when ions are electronically excited to long-lived Rydberg states. The presence of Rydberg ions drastically affects the vibrational mode structure of the ion crystal, giving rise to modes that are spatially localized on isolated subcrystals which can be individually and independently manipulated. We theoretically discuss this Rydberg mode shaping in an experimentally realistic setup and illustrate its power by analyzing the fidelity of two conditional phase flip gates executed in parallel. The ability to dynamically shape vibrational modes on the single-ion level might find applications in quantum simulators and quantum computation architectures.

A 20.3 Tue 14:30 BEBEL E44/46

Full counting statistics of a dissipative Rydberg gas — Nicola

Malossi[1,2], Maria Valado[1,2], Stefano Scotto[2], Paul Huillery[3], Pierre Pillet[3], Donatella Ciampini[1,2,4], Ennio Arimondo[1,2,4], and •Oliver Morsch[1,2] — [1]INO-CNR, Via G. Moruzzi 1, 56124 Pisa, Italy — [2]Dipartimento di Fisica 'E. Fermi', Universita di Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy — [3]Laboratoire Aime Cotton, CNRS, Univ Paris-Sud 11, ENS-Cachan, Campus d'Orsay Bat. 505, 91405 Orsay, France — [4]CNISM UdR Dipartimento di Fisica, Largo Pontecorvo 3, 56127 Pisa, Italy

Ultra-cold gases excited to strongly interacting Rydberg states are a promising system for quantum simulations of many-body systems [1, 2]. For off-resonant excitation of such systems in the dissipative regime, highly correlated many-body states exhibiting intermittency and multi-modal counting distributions are expected to be created [3-5]. Here we report on the realization of a such a dissipative gas of Rydberg atoms and measure its full counting statistics for both resonant and off-resonant excitation. We find strongly bimodal counting distributions in the off-resonant regime that are compatible with intermittency due to the coexistence of dynamical phases. Moreover, we measure the phase diagram of the system and find good agreement with recent theoretical predictions [3, 5].

[1] F. Verstraete et al., Nat. Phys. 5, 633 (2009). [2] H. Weimer et al., Nat. Phys. 6, 382 (2010). [3] C. Ates et al., Phys. Rev. A 85, 043620 (2012). [4] T.E. Lee et al., Phys. Rev. A 84, 031402(R) (2011). [5] T.E. Lee et al., Phys. Rev. Lett. 108, 023602 (2012).

A 20.4 Tue 14:45 BEBEL E44/46

Investigation of d-state Rydberg molecules — •Alexander Krupp[1], Anita Gaj[1], Jonathan Balewski[1], Philipp Ilzhöfer[1], Markus Kurz[2], Sebastian Hofferberth[1], Robert Löw[1], Tilman Pfau[1], and Peter Schmelcher[2] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany

Rydberg electrons can trap ground state atoms giving rise to the creation of large Rydberg molecules with internuclear distances of several thousands of Bohr radii. Spectroscopic studies already proved the existence of these exotic molecules for Rubidium Rydberg s-states[1].

Recently we studied m_j-dependent d-states where the molecular potential shows a different angular dependency. We prove the existence of these molecules for two different m_j states for principal quantum numbers n from 40-50. By changing the polarization and detuning of our excitation laser we are able to selectively excite specific rovibrational states and thereby generate a specific alignment of these d-state molecules. A full theory, using the Born-Oppenheimer approximation and taking s- and p-wave scattering into account, reproduces our spectroscopy data very well.

[1] V. Bendkowsky et al., *Nature* **458**, 0028–0836 (2009)

A 20.5 Tue 15:00 BEBEL E44/46

Ultra-long-range Rydberg molecules in crossed fields — •Markus Kurz[1] and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — [2]Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Germany

We investigate the impact of crossed external electric and magnetic fields on ultra-long-range Rydberg molecules [1] in the ultracold regime. The theoretical framework of the considered problem is based on the Fermi pseudopotential approximation, where in the electron perturber interaction p-wave contributions are included. This work concludes a number of previous studies where ultra-long-range Rydberg molecules had been exposed to electric and magnetic fields separated [2,3]. The rich topology of the Born-Oppenheimer potential surfaces for several field strengths is studied. Furthermore, we analyze the rovibrational dynamics for different electronically excited states. Finally, we present the electric and magnetic polarizability of field dressed high-ℓ molecular states for various field strengths.

[1] C. H. Greene, A. S. Dickinson, and H. R. Sadeghpour, Phys. Rev. Lett. 85, 2458 (2000).

[2] I. Lesanovsky, H. R. Sadeghpour, and P. Schmelcher, J. Phys. B 39, L69 (2006).

[3] M. Kurz, P. Schmelcher, Phys. Rev. A 88, 022501 (2013)

A 20.6 Tue 15:15 BEBEL E44/46

Patterned Rydberg excitation and ionisation with in-vacuo optical aberration correction — •Rick van Bijnen[1,2], Cornee Ravensbergen[1], Servaas Kokkelmans[1], and Edgar Vredenbregt[1] — [1]Eindhoven University of Technology, P. O. Box 513, 5600 MB Eindhoven, The Netherlands — [2]Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany

We demonstrate the ability to excite atoms at well-defined, programmable locations in a magneto-optical trap, either to the continuum (ionisation), or to a highly excited Rydberg state. To this end, excitation laser light is shaped into arbitrary intensity patterns with a spatial light modulator, such as regular arrays of spots that are spaced several microns apart. Requiring diffraction limited performance, these optical patterns are sensitive to aberrations of the phase of the light field, which occur while traversing the optical beamline. These aberrations are characterised and corrected with the spatial light modulator, without observing the actual light field in the vacuum chamber.

A 20.7 Tue 15:30 BEBEL E44/46

Quantum simulation of correlated solid phases with Rydberg dressed atoms — •Tommaso Macri[1], Fabio Cinti[2], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]National Institute for Theoretical Physics, Stellenbosch, South Africa

The realization and control of long-range interactions in atomic systems at low temperatures opens up a whole new realm of many-body physics that has become a central focus of research. Rydberg gases are suited to achieve this goal, as the van der Waals forces between them are many orders of magnitude larger than for ground state atoms. When the electronic ground state is off-resonantly coupled to a highly excited state with strong binary interactions, the two body interaction is modified into a soft core potential. Importantly, despite the repulsion between the admixed Rydberg states, the dressing of the ground state does not lead to atomic trap-loss, both in free space and in optical lattices. At the many body level these non-local interactions provide an optimal playground for the engineering of exotic many body phases. The ability to control and tune interactions and particle numbers in such systems allows the creation of superfluids, crystalline states as well as the long sought supersolid phase. At high densities the ground state breaks translational invariance and global gauge symmetry creating coherent density waves. For low particle densities, the system is shown to feature a solid phase in which zero-point vacancies emerge spontaneously and give rise to superfluid flow of particles through the crystal, providing the first example of defect-induced supersolidity.

A 20.8 Tue 15:45 BEBEL E44/46

Physics beyond rate equation modeling and the breakdown of universality in Ryberg EIT — •Martin Gärttner and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

For the description of laser driven interacting Rydberg gases and associated nonlinear optical effects, rate equation models have been used extensively recently. We discuss why these models are capable of reproducing collective effects and how they predict a universal relation between Rydberg density and optical susceptibility. By comparing with exact numerical solutions of the many-body master equation, we find regimes in which the rate equation models and the universal relations break down. Most remarkably, for strong coherent driving, an enhancement of Rydberg excitation is found, which cannot be reproduced by rate equation models and thus is a truly coherent effect.

A 21: Precision spectroscopy of atoms and ions III (with Q)

Time: Tuesday 14:00–15:45 Location: BEBEL SR140/142

A 21.1 Tue 14:00 BEBEL SR140/142

The Baryon-Antibaryon Symmetry Experiment (BASE) — •Kurt Franke[1,2], Christian Smorra[2], Andreas Mooser[3], Hiroki Nagahama[2,4], Georg Schneider[2,3], Klaus Blaum[1], Yasuyuki Matsuda[4], Christian Ospelkaus[5], Wolfgang Quint[6], Jochen Walz[3], Yasunori Yamazaki[7], and Stefan Ulmer[2] — [1]MPI-K, Heidelberg, Germany — [2]RIKEN Ulmer IRU, Japan — [3]Universität Mainz, Germany — [4]University of Tokyo, Japan — [5]Universität Hannover, Germany — [6]GSI Darmstadt, Germany — [7]RIKEN APL, Japan

BASE is a multinational collaboration currently building an apparatus at the Antiproton Decelerator (AD) of CERN to make comparison measurements of antiproton and proton magnetic g-factors. Such comparisons are interesting because any measured asymmetry would hint at physics beyond the Standard Model.

The experiment consists of measuring the cyclotron and Larmor frequencies, ν_c and ν_L, of a single trapped (anti)proton, with the g-factor given by $2\nu_L/\nu_c$. Determination of ν_c is by measurement of the three motional eigenfrequencies in the *precision trap,* a Penning trap with highly homogeneous magnetic field. The measurement of ν_L requires tracing out the spin flip resonance curve which further requires a second Penning trap—the so-called *analysis trap*—to measure the spin state. These two Penning traps form the heart of the experiment. Additional subsystems include systems for trapping and storing antiprotons, cryogenics, and low-noise electronics. We will present an overview of the BASE project and the current status.

A 21.2 Tue 14:15 BEBEL SR140/142

The BASE Penning trap system — •Georg Ludwig Schneider[1,3], Christian Smorra[1], Kurt Alan Franke[1,2], Andreas Mooser[3], Hiroki Nagahama[1,4], Klaus Blaum[2], Yasuyuki Matsuda[4], Christian Ospelkaus[5], Wolfgang Quint[6], Jochen Walz[3], Yasunori Yamazaki[7], and Stefan Ulmer[1] — [1]RIKEN Ulmer IRU, Japan — [2]MPI-K Heidelberg, Germany — [3]University of Mainz, Germany — [4]Tokyo University, Japan — [5]University of Hannover, Germany — [6]GSI Darmstadt, Germany — [7]RIKEN APL, Japan

The Baryon Antibaryon Symmetry Experiment (BASE) at CERN aims to measure the g-factor of the antiproton with a precision of one part per billion. This will provide a stringent test of CPT symmetry with baryons.

A single antiproton stored in a cryogenic Penning trap system is used to perform this measurement. The g-factor will be determined by measuring the frequency ratio $\nu_\mathrm{L}/\nu_\mathrm{c}$, where ν_L is the spin precession frequency and ν_c the cyclotron frequency. To achieve this goal an advanced Penning trap system, consisting of four traps was developed. Analysis and precision trap are used to observe single spin flips and obtain the desired frequencies. Cooling and reservoir trap on the other hand allow efficient particle cooling and long-term storage of an antiproton reservoir.

The talk will give an overview on the design, characterization and implementation of this trapping system into the BASE apparatus.

A 21.3 Tue 14:30 BEBEL SR140/142

News from the Muonic Helium Lamb-Shift Experiment — •Marc Diepold and The CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

Our ongoing experiment located at Paul-Scherrer-Institute (Switzerland) recently succeeded to measure the $2S_{1/2} - 2P_{3/2}$ transition in the muonic Helium-4-ion, and will continue to measure the remaining $2S - 2P$ transitions in $\mu 4He^+$ and $\mu 3He^+$ later this summer.

Due to its sensitivity to finite size effects, the Lamb-shift in muonic atoms is an excellent tool to determine nuclear rms charge radii, important input parameters in both nuclear models and atomic theory.

With our result, we will be able to provide a ten times more accurate value for the absolute nuclear charge radius of the alpha particle, together with the respective 3He, 6He and 8He values that can be extracted via already measured isotope shifts.

Furthermore, our data sheds interesting new light on the so-called "proton size puzzle", created by the 7-sigma discrepancy between the muonic hydrogen value of the proton radius and other experiments.

A 21.4 Tue 14:45 BEBEL SR140/142

Charakterisierung des Penningfallen-Massenspektrometers PENTATRAP — •Alexander Rischka[1], Hendrik Bekker[1], Christine Böhm[1,2], José Crespo López-Urrutia[1], Andreas Dörr[1], Sergey Eliseev[1], Mikhail Goncharov[1], Yuri N. Novikov[3], Julia Repp[1], Christian Roux[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, Helmholtz Gemeinschaft, 64291 Darmstadt, Germany — [3]Petersburg Nuclear Physics Institute, 188300 Gatchina, Russia

Das Hochpräzisions-Massenspektrometer PENTATRAP wird zurzeit am Max-Planck-Institut für Kernphysik in Betrieb genommen. Ziel des Experimentes ist es, Massenverhältnisse von mittel- bis hochgeladenen schweren Ionen mit einer relativen Genauigkeit von einigen 10^{-12} zu bestimmen. Dazu steht eine Anordnung von fünf zylindrischen Penningfallen zur Verfügung, die eine in-situ Korrektur der Hochpräzisionsmessungen sowie einen schnellen Ionentransport ermöglicht. Die hochgeladenen Ionen werden von einer DRESDEN-EBIT3 oder der Heidelberg-EBIT bereitgestellt. Geplant ist es Ende 2014 als erste Messung das Massenverhältnis von Re/Os zu messen. Diese Messung wird einen wichtigen Beitrag für Experimente zur Bestimmung der Neutrinomass leisten. Der Vortrag behandelt den aktuellen Stand von PENTATRAP, insbesondere die Charakterisierung des Fallenaufbaus.

A 21.5 Tue 15:00 BEBEL SR140/142

Long storage times for hyperpolarized 129Xe and precise measurement of its absolute polarization — •Maricel Repetto, Stefan Zimmer, Sergei Karpuk, Peter Blümler, and Werner Heil — Johannes Gutenberg Universität, Institut für Physik. Staudingerweg 7 55099, Mainz, Deutschland

Applications of hyperpolarized (HP) 129Xe in medical research and fundamental physics experiments increased significantly in recent years [1, 2]. All uses profit from high degrees of polarization (PXe) which not only needs to be generated but also preserved during transport and storage. PXe is usually determined via comparison of the NMR signals from HP Xe with the NMR signal of thermally polarized H2O or Xe [3]. All these procedures have experimental errors which are hard to eliminate [4]. We present a simple method for the measurement of absolute PXe which best resolution is 0.6 % together with wall storage times > 12 hs using a homebuilt, mobile Xe polarizer.

[1] S. Patz Eur. Jour. Of Rad. 64 (2007) 335-344. [2] K. Tullney Phys Rev. Let. 111, (2013) 100801. [3] G. Schrank. Xenon Polarizer Characterization and Biological Studies. 2009. (Page 27). [4] E.Wilms. Nuc. Ins. And Meth. in Phys Res. A 401 (1997) 491-498.

A 21.6 Tue 15:15 BEBEL SR140/142

Imaging of Relaxation Times and Microwave Field Strength in a Microfabricated Vapor Cell — •Andrew Horsley[1], Guan-Xiang Du[1], Matthieu Pellaton[2], Christoph Affolderbach[2], Gaetano Mileti[2], and Philipp Treutlein[1] — [1]Departement Physik, Universität Basel, Switzerland — [2]Laboratoire Temps-Fréquence, Institut de Physique, Université de Neuchâtel, Switzerland

We present a new characterisation technique for atomic vapor cells [1], combining time-domain measurements with absorption imaging to obtain spatially resolved information on decay times, atomic diffusion and coherent dynamics. The technique is used to characterise a 5 mm diameter, 2 mm thick microfabricated Rb vapor cell, with N_2 buffer gas, placed inside a microwave cavity. Time-domain Franzen and Ramsey measurements are used to produce high-resolution images of the population (T_1) and coherence (T_2) lifetimes in the cell, while Rabi measurements yield images of the σ_-, π and σ_+ components of the applied microwave magnetic field. We observe a 'skin' of reduced T_1 and T_2 times around the edge of the cell due to the depolarisation of Rb after collisions with the silicon cell walls. Our observations suggest that these collisions are far from being 100% depolarising. Our technique is useful for vapor cell characterisation in atomic clocks, atomic sensors, and quantum information experiments.

[1] A. Horsley et al., *Imaging of Relaxation Times and Microwave Field Strength in a Microfabricated Vapor Cell*, accepted to PRA. Arxiv: 1306.1387

A 21.7 Tue 15:30 BEBEL SR140/142

Spin effects and the Pauli principle in semiclassical electron dynamics — Frank Grossmann[1], •Max Buchholz[1], Eli Pollak[2], and Mathias Nest[3] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Chemical Physics Department, Weizmann Institute of Science, 76100, Rehovoth, Israel — [3]Theoretische Chemie, TU München, Lichtenbergstr. 4, 85747 Garching, Germany

We investigate the scattering of two electrons with different semiclassical methods, most importantly Heller's Thawed Gaussian Wavepacket Dynamics [1] and the Herman-Kluk propagator [2].

It has already been shown that fermionic dynamics can be treated semiclassically by including repulsive Pauli potentials or by using antisymmetric trial states [3]. In contrast, we only take initial states with the correct symmetry and unmodified potentials. Propagating either symmetrized or antisymmetrized initial state, we compare the time evolution of the distance between the electrons both from full quantum as well as from semiclassical calculations. The objective is to find out whether the Pauli principle is obeyed by the dynamics under these standard semiclassical propagators, i.e. the fact that two electrons with parallel spins must be in orthogonal states.

[1] E. J. Heller, J. Chem. Phys. 62, 1544 (1975)
[2] M. F. Herman and E. Kluk, Chem. Phys. 91, 27 (1984)
[3] H. Feldmeier, J. Schnack, Rev. Mod. Phys. 72, 655 (2000)

A 22: Photon Sources for Quantum Networks SYQR 4 (with Q)

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

A 22.1 Tue 14:00 Kinosaal

High efficient generation of single mode narrow-band photon pairs — •Michael Förtsch[1,2], Gerhard Schunk[1,2], Josef U. Fürst[1,2], Dmitry Strekalov[1,2], Florian Sedlmeir[1,2], Harald G. L. Schwefel[1,2], Thomas Gerrits[3], Martin J. Stevens[3], Sae Woo Nam[3], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max Planck Institut für die Physik des Lichts, Günther-Scharowsky-Str. 1, Bau 24, 91058, Erlangen, Deutschland — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Staudtstraße 7/B2, 91058, Erlangen, Deutschland — [3]National Institute of Standards and Technology, 325 Broadway, Boulder, CO, 80305, USA

Over the past ten years the interest in resonator assisted spontaneous parametric down-conversion (RA-SPDC) has increased significantly since it offers the possibility to efficiently generate narrow-band heralded single photons, which are directly compatible with atomic transitions. One still remaining challenge with RA-SPDC based systems is the efficient photon generation in exactly one spatiotemporal mode, which up to now is often accompanied with additional lossy filtering. Here we experimentally demonstrate a narrow-band RA-SPDC source based on a crystalline whispering gallery mode resonator, which emits photons in exactly one mode. The unique phase-matching conditions make additional filter cavities unnecessary and results to the best of our knowledge in the highest reported single mode pair-production rate. In combination with the unique wavelength and bandwidth tuning possibilities, our setup is ready to serve as the heralded single photon source in a large variety of proposed quantum-repeater networks.

A 22.2 Tue 14:15 Kinosaal

Electro-mechanical engineering of Non-classical Photon Emissions from Single Quantum Dots — •Bianca Höfer[1], Eugenio Zallo[1], Jiaxiang Zhang[1], Rinaldo Trotta[2], Armando Rastelli[2], Fei Ding[1], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW-Dresden, Helmholtzstrasse 20, D-01069 Dresden, Germany — [2]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Altenbergerstrasse 69, A-4040 Linz, Austria

Indistinguishable photons and entangled photon pairs are the key elements for quantum information applications, for example, building a quantum repeater. Self-assembled semiconductor quantum dots (QDs) are promising candidates for the creation of such non-classical photon emissions, and offer the possibility to be integrated into solid state devices. However, due to the random nature of the self-assembled growth process, post-growth treatments are required to engineer the exciton state in the QDs (e.g. energies, exciton lifetimes, and fine structure splittings). In this work, we study the electro-mechanical engineering of the exciton lifetime, emission energy in the QDs, with the aim to produce single photons with higher indistinguishability. Also we present a recent experimental study on the statistical properties of fine structure splittings in the QD ensemble, in order to gain a deeper understanding of how to generate entangled photon pairs using semiconductor QDs.

A 22.3 Tue 14:30 Kinosaal

Two Photon Interference from Remote Quantum Dots with Inhomogeneously Broadened Linewidths — •Peter Gold[1], Alexander Thoma[1], Sebastian Maier[1], Stephan Reitzenstein[1,2], Sven Höfling[1,3], Christian Schneider[1], and Martin Kamp[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, D-97074, Würzburg, Germany — [2]present address: Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany — [3]present address: SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, KY16 9SS, United Kingdom

The interference of single, indistinguishable photons is at the heart of long distance quantum repeaters. Here, we investigate the influence of non-resonant and quasi-resonant excitation on the interference properties of single photons emitted from semiconductor quantum dots (QDs). For the quasi-resonant excitation scheme, we observe an increase of interference visibility for consecutively emitted photons from the same QD of 69% compared to 12% for non-resonant excitation. In addition, we demonstrate quantum interference of photons emitted from separate QDs simultaneously excited into their p-shell. We can extract a two photon interference visibility as high as (39±2)% for non-postselected coincidences. This value exceeds the predicted value based on coherence and radiative decay times of the quantum dot emission (≈ 25%). We account for this by treating the emission of both quantum dots as inhomogeneously broadened ensembles of Fourier limited photons and observe good congruence between experiment and model.

A 22.4 Tue 14:45 Kinosaal

Interfacing telecommunication and UV wavelengths — •Helge Rütz, Kai-Hong Luo, Hubertus Suche, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

Changing the color of a photonic quantum state by means of coherent frequency conversion allows to interface short-wavelength stationary qubit systems and low-loss photonic channels at telecommunication wavelengths.

Here, we report on such an interface for quantum states of light between trapped ions at 369.5 nm and telecommunication wavelengths around 1310 nm. More specifically, we employ a single-pass quasi-phasematched second-order nonlinear interaction in a periodically poled Potassium Titanyl Phosphate- (KTP-) waveguide in conjunction with a strong cw-pump field at 515 nm.

We present experimental details of our interface, showing bright-light conversion efficiencies of up to 10%. Non-phasematched spontaneous parametric downconversion of pump photons is identified as the major limitation in the achievable signal-to-noise-ratio on the single-photon-level.

Finally, the potential use of our frequency conversion interface in quantum information technology is discussed.

A 22.5 Tue 15:00 Kinosaal

Frequency Conversion of Single Photons from a SPDC Source — •Andreas Lenhard, Stephan Kucera, José Brito, Jürgen Eschner, and Christoph Becher — Universität des Saarlandes, FR 7.2 Experimentalphysik, Campus E2.6, 66123 Saarbrücken

Many quantum repeater schemes rely on the transfer of single photons or entangled states. Thus, long-range transmission in fibers requires photons at low-loss telecommunication wavelengths. We have recently demonstrated the frequency conversion of photons generated by a single quantum emitter in the near-infrared spectral region to the telecom bands via frequency down-conversion in a nonlinear medium [1]. The frequency conversion of an entangled photon is another basic building block to establish quantum networks.

Here we report on the frequency down-conversion of single photons from a photon pair source, resonant with an atomic transition of a quantum repeater node. The pairs are generated by a type-II spontaneous parametric downconversion process in a bulk KTP crystal. One photon of the pair is spectrally filtered to fit a transition of $^{40}Ca^+$-ions at 854 nm and used as a herald [2]. By mixing with a pump field at 2.5 μm in a nonlinear waveguide the partner photon is converted to the telecom O-band at 1313 nm with an over-all efficiency around 10 %. We show that the temporal correlation between the photon pairs is preserved in the conversion process by measuring the photon correlation functions.

1. S. Zaske et al., Phys. Rev. Lett. **109** (2012), 147404
2. N. Piro et al., Nat. Phys. **7** (2011), 17-20

A 22.6 Tue 15:15 Kinosaal

Quantum teleportation and entanglement swapping of matter qubits with multiphoton signals — •Juan Mauricio Torres[1,2], József Zsolt Bernád[1], and Gernot Alber[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Germany — [2]Departamento de Investigación en Física, Universidad de Sonora, Hermosillo, México

We introduce a probabilistic Bell measurement of atomic qubits based on two consecutive photonic field measurements of two single mode cavities with which the atoms interact in two separate stages. To this end, we solve the two-atoms Tavis-Cummings model and exploit the property that the antisymmetric Bell state is insensitive to the interaction with the field. We consider implementations for quantum teleportation and for entanglement swapping protocols both of which can be achieved with 25% success probability and with unit fidelity. We emphasize possible applications for hybrid quantum repeaters where the aforementioned quantum protocols play an essential role.

A 22.7 Tue 15:30 Kinosaal

Rydberg gases at room temperature - pulsed four-wave-mixing down to volumes of a few cubic micrometers — •Andreas Kölle, Bernhard Huber, Fabian Ripka, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Uni Stuttgart

The van-der-Waals interaction between Rydberg-excited atoms provides an interaction range on the micrometer scale. Various experiments in cold atomic clouds demonstrated the feasibility of using Rydberg states for quantum devices like single photon sources. In our experiments, we want to transfer these results to thermal vapor cells of the size of the Rydberg-Rydberg interaction length scale, which are more favorable in terms of scalability and handling. In comparison to an ultra-cold atomic cloud, thermal cells have the disadvantage of thermal atomic motion and the resulting Doppler shift. To overcome this effect we perform our excitation to the Rydberg state on the nanosecond timescale. We present our results of a pulsed four-wave-mixing scheme via a Rydberg state. We observe four-wave-mixed light emission on a nanosecond time scale with a non-trivial temporal evolution which can be described by a coherent interference within the Doppler ensemble. Furthermore we discuss our experimental effort to reduce the excitation volume to a sub micrometer length scale in all 3 dimensions.

A 23: Poster: Atomic clusters (with MO)

Time: Tuesday 16:30–18:30 Location: Spree-Palais

A 23.1 Tue 16:30 Spree-Palais

Untersuchung einer Ringfalle zur Erzeugung von mehrfach negativ geladenen Metallclustern — •Stefan Knauer[1], Gerrit Marx[1], Lutz Schweikhard[1] und Robert Wolf[2] — [1]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald — [2]MPI-K, Saupfercheckweg 1, 69117 Heidelberg

Die Coulombbarrieren und Elektronenbindungsenergien von mehrfach negativ geladenen Metallclustern sind experimentell weitestgehend unerforscht. Da diese in der Natur nicht vorkommen, müssen sie in Laboren erzeugt werden. Dies wird bisher mit einer Kombination aus einer Clusterquelle und Ionenfallen verschiedener Art realisiert [1]. Ein Zugang zur Höhe der Coulombbarrieren ist die Erzeugung von negativen Ladungszuständen bei definierten Elektronenenergien. Dies benötigt ein feldfreies Volumen, das die Wechselwirkung mit Elektronen zulässt, aber gleichzeitig die Speicherung von Clustern ermöglicht. In Greifswald wurde dafür eine Multipol-Ionenfalle, eine sog. Ringfalle [2], aufgebaut. Einfach negativ geladene Cluster werden in einer Magnetronquelle [3] erzeugt, gelangen in das Fallenvolumen und werden anschließend durch Elektronen-Cluster Kollisionen in einen erhöhten Ladungszustand versetzt. Die Reaktionsprodukte können anschließend mittels Flugzeitmassenspektroskopie untersucht werden. In diesem Beitrag werden der Aufbau und die Funktionsweise der Ringfalle vorgestellt.

[1] F. Martinez et al., AIP Conf. Proc. 1521, (2013) 230.
[2] Gerlich et al., Adv. Chem. Phys. 82 (1992) 1.
[3] H. Haberland et al., Z. Phys. D, 20 (1991) 413.

A 23.2 Tue 16:30 Spree-Palais

Setup and characterisation of a THz-radiation source for a field-driven streaking experiment with rare gas clusters — •Jan Lahl[1], Bernd Schütte[2], Tim Oelze[1], Arnaud Rouzée[2], Marc Vrakking[2], and Maria Krikunova[1] — [1]TU Berlin, Institut für Optik und Atomare Physik, Berlin, Germany — [2]Max-Born Institut, Berlin, Germany

Novel light sources like high harmonics generation have triggered a wide range of experiments for studies of light-matter interaction. We are especially interested in electron dynamics in rare gas clusters initiated by extreme-ultraviolet pulses. A field-driven streak camera maps the temporal structure of the electron wave packet into a momentum distribution which can by experimentally measured. For the dynamics on a fs-timescale electric field oscillation periods in sub-ps range (THz frequency) are required. The THz radiation is generated in a LiNbO3 crystal based on optical rectification using near-infrared (NIR) fs-pulses. To meet the phase-matching condition the NIR pulse fronts are tilted by a diffraction grating. Characterisation of the THz is accomplished by electro-optic sampling in a ZnTe crystal. The intensity distribution of a beforehand splitted part of the same NIR beam is analysed with respect to the direction of its polarisation after passing the crystal. Due to its high intensity the THz radiation alters the polarisation of the crystal non-linearly which results in a deviation of the measured intensity distribution. The setup of the THz source will be shown as well as results of the characterisation. An outlook on the intended application in the streaking experiment will be presented.

A 23.3 Tue 16:30 Spree-Palais

Strong scattering in laser-driven rare-gas clusters — •Merten Siegfried, Christian Peltz, and Thomas Fennel — Institute of Physics, University of Rostock

Rare-gas clusters under intense laser pulses are rapidly transformed into finite nanoplasmas. Though main features of the underlying microscopic plasma dynamics can be well described by molecular dynamics (MD) simulations including rate equations for atomic ionization [1], the microscopic treatment of collisions remains a challenge. Electron-atom collisions are often neglected completely though they can be essential to account for the important electron emission processes, such as electron surface backscattering observed at dielectric nanospheres [2]. Also elastic electron-ion scattering is vastly underestimated in MD models using effective soft-core Coulomb potentials as the short-range interaction, primarily responsible for strong collisions, is regularized. We propose a microscopic scheme to re-introduce the missing scattering from the short-range electron-atom/ion interaction as local collisions. A detailed analysis of the impact of elastic electron-atom/ion scattering on the excitation dynamics of medium-sized Argon clusters in intense near-infrared laser fields will be presented.

[1] T. Fennel et al., Rev. Mod. Phys. **82**, 1793 (2010)
[2] S. Zherebtsov et al., Nature Phys. **7**, 656 (2011)

A 23.4 Tue 16:30 Spree-Palais

Microscopic description of single-shot diffractive imaging of clusters via the dyadic Green's function approach — •Katharina Sander, Christian Peltz und Thomas Fennel — Institute of Physics, University of Rostock

The availability of intense femtosecond laser pulses in the XUV and soft X-ray regime from free-electron lasers (FELs) has made it possible to investigate the structure and dynamics of nanosystems via single-shot diffractive imaging experiments, as recently demonstrated with single clusters [1]. However, standard Mie theory is not applicable to model the scattering of non-spherical systems. Therefore, a more general microscopic approach has been developed, that describes light scattering of clusters on an atomic level via dyadic Green's functions. This method can be applied to arbitrary cluster shapes and to strong non-equilibrium states such as internal plasmonic excitation of cluster electrons. As a first application of this model we examine the possibility to image the recently predicted internal plasma waves in clusters induced by a short infrared laser pulse [2]. Our analysis supports, that the ultrafast dynamical movement of the plasma waves can be extracted from the time-resolved scattering pictures. As a second scenario, we investigate the scattering of strongly absorbing silver clusters. For strongly non-spherical geometries the effect of absorption is analyzed by comparing the full Green's function solution to the result of the first Born approximation.

[1] T. Gorkhover *et al.*, Phys. Rev. Lett. **108**, 245005, (2012)
[2] C. Varin *et al.*, Phys. Rev. Lett. **108**, 175007, (2012)

A 23.5 Tue 16:30 Spree-Palais

Electron spectra of size selected rare gas clusters in intense XUV radiation — •Jan P. Müller[1], Leonie Flückiger[1], Bruno Langbehn[1], Maria Müller[1], Daniela Rupp[1], Mario Sauppe[1], Anatoli Ulmer[1], Sven Toleikis[2], Stefan Düsterer[2], and Thomas Möller[1] — [1]Institut für Optik und Atomare Physik, TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22603 Hamburg,Germany

The interaction between rare gas clusters and intense XUV light pulses provided by FEL reveals an complex and ultrafast dynamics. Size selected measurements are able to dinsentangle the dynamics for clusters having different cluster sizes or interacting with different local intensities within the FEL focus (1). Electron spectra are extremely well suited to investigate properties of the nanoplasma building up within the cluster, as well as the change of the binding energies of the core level during interaction. In addition to the ion spectra already investigated, they are signatures for the underlying interaction process. Up to now averaged electron spectra are available (2), size selected measurements are strongly desirable. In this contribution results from a beamtime at FLASH are presented, where xenon clusters were irradiated by FEL pulses with a wavelength of 13.5 nm.

(1) Gorkhover, T. et al. Phys. Rev. Lett., 108 (2012) 245005
(2) Bostedt, C. et al. , Phys. Rev. Lett., 100 (2008) 133401

A 23.6 Tue 16:30 Spree-Palais

Porosity and surface roughness of free SiO_2 nanoparticlesl studied by wide angle X-ray scattering — •Burkhard Langer[1], Christian Goroncy[1], Christopher Raschpichler[1], Thoralf Lischke[2], Bernhard Wassermann[1], Christina Graf[1], and Eckart Rühl[1] — [1]Physikalische Chemie, Freie Universität Berlin — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle

Silica nanoparticles which consist of an amorphous network of SiO_2 containing pores in the nanometer range (1-10) nm are used as a model system to study their porosity and roughness by wide angle X-ray scattering. The particles are prepared with a porous layer of an adjustable thickness between 5 and 50 nm. Dispersions of such nanoparticles are evaporated into a continuous aerodynamically focused free nanoparticle beam crossing a synchrotron radiation beam from BESSY II. The scattered X-ray intensity is detected over a wide angle range by an MCP detector which can be rotated between 10° and 170° around the interaction region [1]. Comparison of the X-ray scattering intensities with model calculations provides novel information on the surface roughness, porosity, and possible contributions of solvent in the pores. While the angle dependent X-ray scattering intensity of nanoparticles with a smooth surface follows clearly the $(qR)^{-4}$ power law given by Mie theory, nanoparticles with a rough surface and core-shell nanoparticles show a different behavior. Deviations from the pure Mie theory will be discussed in terms of the surface roughness compared to the incident X-ray wavelength.

[1] H. Bresch *et al.*, Faraday Discussions, **137**, 389 (2008).

A 24: Poster: Atomic systems in external fields

Time: Tuesday 16:30–18:30 Location: Spree-Palais

A 24.1 Tue 16:30 Spree-Palais

A Penning Trap Experiment at High-Intensity Lasers — •Manuel Vogel[1,2], Wolfgang Quint[2,3], Gerhard Paulus[4,5], and Thomas Stöhlker[2,4,5] — [1]Technische Universität Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung Darmstadt — [3]Ruprecht Karls-Universität Heidelberg — [4]Friedrich-Schiller-Universität Jena — [5]Helmholtz-Institut Jena

We present the HILITE Penning trap experiment dedicated to studies with atomic and molecular ions in extreme laser fields (High-Intensity Laser Ion-Trap Experiment). It is designed to allow the preparation of clean ion targets with well-defined composition, localization, density and shape for irradiation with high-intensity and/or high-energy lasers. Non-destructive detection of reaction products with up to single-ion sensitivity supports advanced studies by maintaining the products for further studies at confinement times of minutes and above. Of particular interest for intial studies are nonlinear processes such as multiphoton ionization of atoms, singly-, and particularly highly charged ions.

A 24.2 Tue 16:30 Spree-Palais

Numerical investigations of tunneling times — •Nicolas Teeny, Heiko Bauke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik Saupfercheckweg 1, 69117 Heidelberg

Tunnel ionization belongs to the fundamental processes of atomic physics and has been investigated in-depth experimentally as well as theoretically. The question, however, how long it takes for an electron to escape from an attractive potential could not yet be answered conclusively. In our contribution, we utilize numerical solutions of the time-dependent Schrödinger and Dirac equations to identify tunneling times [1]. The numerical results are compared with predictions based on theoretical calculations [2].

[1] Proc. of SPIE, **8780**, 87801Q (2013)
[2] Phys. Rev. Lett., **110**, 153004 (2013); E. Yakaboylu et al., arXiv:1309.0610 (to be published in Phys. Rev. A)

A 24.3 Tue 16:30 Spree-Palais

Imaging of Relaxation Times and Microwave Field Strength in Vapor Cells — •Guan-Xiang Du[1], Andrew Horsley[1], Matthieu Pellaton[2], Thejesh Bandi[2], Christoph Affolderbach[2], Gaetano Mileti[2], and Philipp Treutlein[1] — [1]Departement Physik, Universität Basel, Switzerland — [2]Laboratoire Temps-Fréquence, Institut de Physique, Université de Neuchâtel, Switzerland

We present a new characterisation technique for atomic vapor cells [1], combining time-domain measurements with absorption imaging to obtain spatially resolved information on decay times, atomic diffusion and coherent dynamics. The technique has been used to characterise both a microfabricated Rb vapor cell placed inside a microwave cavity, and a larger, high-performance vapor cell atomic clock. Time-domain Franzen and Ramsey measurements are used to produce high-resolution images of the population (T_1) and coherence (T_2) lifetimes in the cell, while Rabi measurements yield images of the σ_-, π and σ_+ components of the applied microwave magnetic field. Images of the microwave magnetic field reveal regions of optimal field homogeneity, and thus coherence. Our technique is useful for vapor cell characterisation in atomic clocks, atomic sensors, and quantum information experiments.

[1] A. Horsley et al., *Imaging of Relaxation Times and Microwave Field Strength in a Microfabricated Vapor Cell*, accepted to PRA. Arxiv: 1306.1387

A 25: Poster: Electron scattering and recombination

Time: Tuesday 16:30–18:30 Location: Spree-Palais

A 25.1 Tue 16:30 Spree-Palais

Hyperfine-induced modifications to the $K\alpha_1$ angular distribution following the radiative electron capture into hydrogen-like ions — •Zhongwen Wu[1], Andrey Surzhykov[1], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, D-07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, D-07743 Jena, Germany

The angular distribution of the $K\alpha_1$ ($1s2p_{3/2}\ ^{1,3}P_{1,2} \rightarrow 1s^2\ ^1S_0$) radiation following the radiative electron capture into initially hydrogen-like ions with nonzero nuclear spin has been studied within the density matrix theory and the multiconfiguration Dirac-Fock method. Emphasis is placed especially upon the hyperfine interaction and how this interaction of the magnetic moment of the nucleus with those of the electrons affects the angular properties of the $K\alpha_1$ emission for isotopes with non-zero nuclear spin $I \neq 0$. As an example, calculations were performed for selected isotopes of helium-like Sn^{48+}, Xe^{52+} and Tl^{79+} ions. A quite sizeable contribution of the hyperfine interaction upon the $K\alpha_1$ angular emission is found for isotopes with nuclear spin $I = 1/2$, while its effect is suppressed for (most) isotopes with larger nuclear spin $I > 1/2$. We therefore expect that accurate measurements of the $K\alpha_1$ angular distributions at ion storage rings can be utilized as a tool for determining the nuclear parameters of rare stable and radioactive isotopes with $I \geq 1/2$.

A 25.2 Tue 16:30 Spree-Palais

High resolution studies of resonant electron-ion recombination processes with an electron beam ion trap — •Stepan Dobrodey[1], Sven Bernitt[1], Chintan Shah[2], Holger Jörg[2], Stanislav Tashenov[2], and José Ramon Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisches Institut, Ruprecht-Karls-Universität, Heidelberg, Germany

Dielectronic recombination (DR) is a resonant electron capture process where a free electron recombines with a highly charged ion (HCI) into an excited intermediate state, transfering its kinetic energy to a bound electron. This state subsequently decays by emission of a photon with a characteristic energy. Electron beam ion traps (EBIT) are convenient devices for investigating this process. They use a monoenergetic electron beam for the production and trapping of HCIs, and at the same time as a source of electrons for recombination. Krypton, with an atomic number of 36, shows a coupling which is intermediate between Russel-Saunders- and jj-Coupling, and therefore challenging for theoretical atomic models. Furthermore in recent years it has become clear that higher order processes, like trielectronic or quadruelectronic recombination, have also to be taken into account [1,2]. We present high resolution measurements of Kr^{28+} up to Kr^{34+} carried out at the FLASH-EBIT.

[1] Beilmann et al., Phys. Rev. Lett. 107, 143201 (2011)
[2] Beilmann et al., Phys. Rev. A 88, 062706 (2013)

A 25.3 Tue 16:30 Spree-Palais

New method of measuring metastable states for electron impact on light targets at all scattering angles — •Marvin Weyland[1,2], Alexander Dorn[1], Hans Rabus[2], Xueguang Ren[1,2], Thomas Pflüger[1,2], and Woon Yong Baek[2] — [1]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

We apply a new method of measuring differential cross sections for metastable atom production by electron impact. A crossed beam setup with a supersonic helium jet and a pulsed electron beam at energies close to the excitation threshold of 19.82 eV is used. Measuring the momentum vectors of the metastable atoms instead of the scattered electrons removes common restrictions to the accessible scattering angles while reaching high detection efficiency. At impact energy of 22.2 eV we can distinguish between excitation of the 2^3S-state and 2^1S- or 2^3P-state. Using a photoemission electron source we reach an impact energy resolution of 200 meV at about 1 μA peak current. Results are compared with simulations of the experiment, using convergent-close-coupling (CCC) and R-matrix-pseudo-state (RMPS) calculations of differential scattering angles. Experimental results agree best with RMPS calculations. Although used here only with helium as a target, the instrument can be used to measure excitation cross sections in many light targets.

A 25.4 Tue 16:30 Spree-Palais

Giant Effect of the Spin-Orbit Interaction in Coulomb Scattering — •Oleksiy Kovtun[1], Stanislav Tashenov[1], Valery Tioukine[2], Andrey Surzhykov[1,3,4] und Vladimir Yerokhin[1,4,5] — [1]Physikalisches Institut der Universität Heidelberg, Germany — [2]Institut für Kernphysik Johannes Gutenberg-Universität Mainz, Germany — [3]Helmholtz-Institut Jena, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [5]Center for Advanced Studies, St. Petersburg State Polytechnical University, Russia

Coulomb scattering of an electron in the field of the nucleus is influenced by the spin-orbit interaction. Due to the orbital momentum precession the electron trajectory is not confined to a single scattering plane as evidenced by the recent bremsstrahlung experiments. In that the angle of bremsstrahlung linear polarization is correlated with the spin direction of the incoming electron [S. Tashenov PRL 107, 173201 (2011), R. Maertin PRL 108, 264801 (2012)]. In the recent experiment we found this effect to be dramatically enhanced at relativistic energies. The scattering plane was turning by as much as several tenth of degrees. The results are in agreement with the full-order relativistic calculations. For this experiment we applied the novel techniques of the pulse shape analysis of the germanium detector signals and gamma-ray Compton imaging. The principles of the Compton imaging were invented in 1973 and our experiment marked their first application in a laboratory physics experiment.

A 25.5 Tue 16:30 Spree-Palais

Polarisation measurement of Dielectronic Recombination transitions into highly charged ions — •Holger Jörg[1], Chintan Shah[1], Sven Bernitt[2], Stepan Dobrodey[2], José R. Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institut der Universität Heidelberg — [2]Max-Planck-Institut für Kernphysik Heidelberg

We report a measurement of hard X-ray linear polarisation produced by dielectronic recombination (DR) of free electrons into highly charged krypton ions. The ions in the He-like through O-like charge states were produced in an electron beam ion trap, FLASH-EBIT. The electron beam energy was adjusted to the maxima of well-resolved K-shell DR resonances. The X rays emitted during radiative stabilization at an energy of 13 keV were registered by a novel Compton polarimeter. This instrument uses an X-ray scattering target and an array of silicon detectors for sampling the azimuthal scattering angular distribution. The preliminary analysis indicates a large degree of linear polarisation of the DR X rays. These results can be used to benchmark atomic calculations, and can also be applied for polarisation diagnostics of hot astrophysical and laboratory fusion plasmas.

A 25.6 Tue 16:30 Spree-Palais

Observation of alignment in Dielectronic and Trielectronic recombination — •Chintan Shah[1], Pedro Amaro[1], René Steinbrügge[2], Sven Bernitt[2], Zoltan Harman[2,3], Stephan Fritzsche[4,5], Andrey Surzhykov[4,5], José Ramón Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institut, Heidelberg, Germany — [2]Max-Planck-Institut für Kernphysik Heidelberg, Germany — [3]ExtreMe Matter Institute, Darmstadt, Germany — [4]Helmholtz-Institut, Jena, Germany — [5]GSI, Darmstadt, Germany

The photon angular distributions in dielectronic and trielectronic recombination with a K-shell excitation were systematically studied with highly charged ions. Fe and Kr ions in the He-like through O-like charge states were produced in an electron beam ion trap, and the electron beam energy was scanned over the dielectronic and trielectronic recombination resonances. Improving on earlier work [1, 2], the photons emitted from the decay of the resonance states were simultaneously recorded by two germanium detectors which were mounted both along and perpendicular to the electron beam axis. The measured anisotropy of photon emission indicates the alignment of the total angular momentum of each resonance state with respect to the beam axis. The results can be used to benchmark atomic calculations, and can be applied for polarization diagnostics of hot laboratory fusion and astrophysical plasmas.

[1] C. Beilmann et al., Phys. Rev. Lett. 107, 143201 (2011)
[2] C. Beilmann et al., Phys. Rev. A 88, 062706 (2013)

A 25.7 Tue 16:30 Spree-Palais

Development of novel Rayleigh and Compton polarimeters — •Stanislav Tashenov — Physikalisches Institut der Universität Heidelberg

To study fundamental processes in atomic collisions and perform polarisation diagnostics of hot fusion and astrophysical plasmas we develop a broad range of polarisation sensitive x-ray detectors. Two detectors are based on Silicon PIN diodes and Silicon Drift Detectors and dedicated to the energy range of 10-30 keV. This is the lowest energy range that was accessed by the Compton and Rayleigh polarimeters. For the energy range of 30 keV - 2 MeV we use a segmented planar germanium detector. It employs a novel technique of Pulse Shape Analysis of the detector signals for a 3D sensitivity to the positions of the x-ray interactions. With this detector we for the first time employed the techniques of Compton Imaging and background reduction in a laboratory physics experiment. It also achieved the polarisation resolution of 0.3 deg which is the record for Compton polarimetry. To improve this further we develop a high resolution polarimeter that is based on a rotationally symmetric annular planar segmented germanium detector.

A 25.8 Tue 16:30 Spree-Palais

Electron impact ionization of ultra-cold lithium — •Michael Schuricke, Elisabeth Brühl, Johannes Goullon, Renate Hubele, Hannes Lindenblatt, Alexander Dorn, and Daniel Fischer — Max Planck Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Collisions of simple atomic systems with photons or charged particles and the correlated motion of the ejected electrons are among the most fundamental yet challenging problems in quantum dynamics. In this regard Li is particularly interesting due to the strongly correlated K-shell electrons and the loosely bound valence electron. Thus, ionization dynamics can be probed for very different regimes of initial-state correlation. As it also marks the next step in complexity compared to He, it is an ideal test case to extend the theoretical methods developed for that system to more complex systems.

To study electron impact ionization of Li an electron gun was implemented in a combination of a magneto-optical trap (MOT) and a Reaction Microscope (ReMi), which records the momenta of all charged particles created over the full solid angle. Despite the incompatible magnetic field geometries of the MOT (quadrupole field) and electron detection in a ReMi (constant field), the MOTReMi allows for coincident detection of ions and electrons with unprecedented resolution.

Here, we will present results on single and double ionization of lithium at an electron energy of 500 eV. In the future the electron energy will be reduced toward the double ionization threshold, where the final state is governed by the correlation of the charged particles.

A 25.9 Tue 16:30 Spree-Palais

A single particle detector for electron-ion collision experiments in the Cryogenic Storage Ring — •Kaija Spruck[1], Claude Krantz[2], Arno Becker[2], Alfred Müller[1], Oldřich Novotný[3], Stephen Vogel[2], Andreas Wolf[2], and Stefan Schippers[1] — [1]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen — [2]Max-Planck-Institut für Kernphysik, Heidelberg — [3]Columbia Astrophysics Laboratory, New York, USA

The study of ion chemistry in the interstellar medium requires, among others, knowledge about cross sections for the recombination of atomic and molecular ions with low temperature ($\sim$ 10 K) electrons. Especially the database on singly charged atomic ions relevant to the chemistry of molecular clouds is incomplete in this respect. The electrostatic Cryogenic Storage Ring (CSR), currently being commissioned at the Max-Planck-Institute for Nuclear Physics in Heidelberg, will allow experiments with atomic, molecular and cluster ions at beam energies up to 300 keV per unit charge in a cryogenic extremely high vacuum (XHV) environment. Collisions of stored atomic ions with electrons provided by an electron cooler will lead to reaction products with charge states that differ from those of the parent particles. The detection of these products will be carried out behind a bending deflector of the storage ring by a high-efficiency movable single-particle detector, based on a secondary electron converter backed by heatable microchannel plates. The designs of the mechanical actuator and the detector are compatible with the cryogenic operating conditions at 10 K and a bakeout temperature of up to 530 K.

A 25.10 Tue 16:30 Spree-Palais

Spin dynamics in photoelectric effect — •Stanislav Tashenov[1], Holger Jörg[1], Darius Banas[2], Heinrich Beier[3], Carsten Brandau[3], Alexandre Gumberidze[3], Siegbert Hagmann[3], Pierre-Michel Hillenbrand[3], Ivan Kojouharov[3], Christophor Kozhuharov[3], Michael Lestinsky[3], Yury Litvinov[3], Shizu Minami[3], Henning Schaffner[3], Uwe Spillmann[3], Thomas Stöhlker[3,4], Andrey Surzhykov[3,4], and Sergiy Trotsenko[3] — [1]Physics Institute, Heidelberg University, Germany — [2]Institute of Physics, Jan Kochanowski University, Kielce, Poland — [3]GSI Helmholtzzentrum, Darmstadt, Germany — [4]Helmholtz-Institut Jena, Jena, Germany

Atomic photoelectric effect is the dominant mechanism in which matter absorbs electromagnetic radiation ranging from visible light up to gamma rays. At relativistic energies its dynamics must be influenced by the spin-orbit interaction – the spin of the photoelectron should precess in the field of the nucleus. However, such spin dynamics was never evidenced in the photoelectric effect. Here we show its first experimental observation. The photo effect was studied in a time-reverse process of Radiative Recombination (RR) of quasi-free electrons into the $2p_{3/2}$ state of H-like uranium ion. The RR x-ray was detected in a coincidence with the Lyα decay x-ray. This is the first observation of the correlated x-rays emitted by a heavy ion. The experiment revealed how the total orbital momentum of the final state is correlated with the directions of the incoming electron and the emitted photon.

A 26: Poster: Interaction of matter and collisions with ions

Time: Tuesday 16:30–18:30 Location: Spree-Palais

A 26.1 Tue 16:30 Spree-Palais

Momentum transfer to a free floating double slit: Realization of a thought experiment from the Einstein-Bohr debates — •Lothar Ph. H. Schmidt, Till Jahnke, Sven Schössler, Markus Schöffler, Adrian Messen, Horst Schmidt-Böcking, and Reinhard Dörner — Goethe-Universität Frankfurt am Main, Germany

In one of the most famous physics debates ever Einstein challenged Bohr and the then new quantum mechanics in 1927 with a thought experiment. He proposed that measuring the momentum transfer to a double slit would unveil through which of the two slits the quantum particle had passed. We translate this experiment finally to experimental reality using an isotope labeled free floating diatomic molecular ion as the double pinhole. The reaction $HD^+ + He \rightarrow H + D + He^+$ was measured in a kinematically complete experiment by using COLTRIMS. We find that the Helium does not only travel delocalized through both slits, but even more counter intuitive and completely opposite to Einstein‘s assumption, it transfers momentum to both slits simultaneously.

A 26.2 Tue 16:30 Spree-Palais

Mean-field description of bare- and dressed-ion collisions with neon atoms — •Gerald Schenk and Tom Kirchner — Department of Physics and Astronomy, York University, Toronto, Ontario, M3J 1P3, Canada

Motivated by the availability of new experimental data [1] we study multiple ionization and charge transfer processes in collisions of neon atoms with doubly- and triply-charged bare and dressed ions at intermediate energies (25 keV/u to 1 MeV/u). In the case of dressed-ion impact, electrons are present on both centres in the initial state. We address this in an independent-particle-model approach, the many-electron system is represented by a single mean field. Electrons of both the target and the projectile are propagated in a common potential using the same basis set to ensure the orbitals remain orthogonal throughout. This allows to represent the combined system in terms of a standard single Slater determinant and to obtain exclusive transition probabilities for all final configurations in a consistent fashion.

The present study expands on recent work for B^{2+}-Ne [2], in which

we examined the role of active projectile electrons for projectile charge state coincident multiple target ionization, in several respects: (i) additional collision channels are considered; (ii) time-dependent response is taken into account; (iii) comparisons with equicharged bare ions are carried out in order to shed more light on the role of the (active and passive) projectile electrons.
[1] W. Wolff et al, Phys. Rev. A **84**, 42704; Ihani et al, J. Phys. B **46**, 115208. [2] G. Schenk et al, Phys. Rev. A **88** 012712.

A 26.3 Tue 16:30 Spree-Palais

Vortices associated with the wavefunction of a single electron emitted in slow ion-atom collisions — •Lothar Ph. H. Schmidt[1], Christoph Goihl[1], Daniel Metz[1], Horst Schmidt-Böcking[1], Reinhard Dörner[1], Serge Yu. Ovchinnikov[2,3], Joseph H. Macek[3], and David R. Schultz[2] — [1]Goethe-Universität Frankfurt am Main — [2]University of North Texas, Denton — [3]University of Tennessee, Knoxville

Using COLTRIMS we measured the momentum distribution of electrons emitted during slow ion-atom collisions He^{2+} + He → He^{+} + He^{2+} + e^{-}. At large scattering angles above 2 mrad it shows rich structures which have not been seen in earlier experiments. They arise from two-electron states absent in an independent electron picture of the transfer ionization process. Our calculations reveal that minima in the measured distributions are zeroes in the electronic probability density resulting from vortices in the electronic current.

A 26.4 Tue 16:30 Spree-Palais

Ion Optics of the HESR Storage Ring at FAIR for Operation with Heavy Ions — •Oleksandr Kovalenko, Oleksiy Dolinskyy, Yuri Litvinov, and Thomas Stoehlker — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

High Energy Storage Ring (HESR) of the FAIR project is primarily designed for internal target experiments with stored and cooled antiprotons, which is the main objective of the PANDA collaboration. However, the HESR storage ring also appears to have remarkable properties to carry out physics experiments with heavy ions. This paper proposes a new ion optical design allowing for the heavy ion operation mode of the HESR. The main goal was to provide an optics which meets the requirements of the future experiments with heavy ion beams. In connection, issues like closed orbit correction, dynamic aperture as well as other characteristics of beam dynamics of the new ion optical setup are under analysis in this study.

A 26.5 Tue 16:30 Spree-Palais

Single differential projectile ionization cross sections for 50 AMeV U28+ in the ESR storage ring — •Siegbert Hagmann[1,2], Pierre-Michel Hillenbrand[1,3], Carsten Brandau[2,4], Alexander Gumberidze[4], Dalong Guo[5,6], Michael Lestinsky[1], Yuri Litvinov[1,7], Alfred Müller[3], Stefan Schippers[3], Uwe Spillmann[1], Sergey Trotsenko[1,8], Thomas Stöhlker[1,8,9], Shahab Sanjari[4], Nicolas Winckler[1], and Weidong Chen[1] — [1]GSI Darmstadt — [2]Inst. f. Kernphysik, Uni Frankfurt — [3]Univ. Giessen — [4]EMMI-GSI-Darmstadt — [5]IMP Lanzhou, China — [6]Univ. Beijing, China — [7]Univ. Heidelberg — [8]Helmholtz Inst. Jena — [9]Univ. Jena

For a thorough understanding of beam loss for low q high Z beams with 2.6AGeV in SIS100 it is imperative that the mechanisms active in projectile ionization be understood quantitatively to provide benchmarks for advanced ab initio theories beyond first order. We have embarked on an experimental investigation of single differential projectile ionization cross sections SDCS $d\sigma/dE_e$ for single and multiple ionization of U28+ in the ESR storage ring by measuring the electron loss to continuum (ELC) cusp at 0 degree with respect to the beam axis employing our imaging forward electron spectrometer. This was motivated by the high relative fraction of multiple ionization estimated by theory to exceed 40%. We report first results for absolute projectile ionization SDCS for U28+. We find a remarkably high asymmetry for the ELC cusp. This is at strong variance with the line shape expected for validity of first order theories.

A 26.6 Tue 16:30 Spree-Palais

Refinement of the Basis for the Solution of the Two-Centre Dirac Equation Employing the Finite Basis Set Approach — •Walter Hahn — Institut für theoretische Physik, Universität Heidelberg, Germany

The solution of the Dirac equation for an electron in the presence of two spatially fixed nuclei is a necessary step for understanding the formation of quasi-molecules in collisions of highly-charged heavy ions and the accompanying creation of lepton pairs. In a previous work, we have shown a numerical solution of this Dirac equation by employing the finite basis set approach together with a basis constructed from B-splines. In this work, we propose two issues for the improvement of the previous results. First, we enlarge the basis by functions found to be essential, which go beyond the B-spline ansatz. We achieve an increase of accuracy, which holds for almost all low-energy bound states and all distances between the two centres, and in some specific cases amounts to several orders of magnitude. Arguments aiming to explain this increase of accuracy are presented. Second, we employ the dual kinetic-balance basis in order to avoid non-physical spurious states. An accurate solution of the problem presented constitutes a cornerstone on the road towards tests of QED in super-critical fields.

A 27: Poster: Photoionization

Time: Tuesday 16:30–18:30 Location: Spree-Palais

A 27.1 Tue 16:30 Spree-Palais

Radiative and Auger widths of X-ray K-shell excited few-electron iron ions — •René Steinbrügge[1], Sven Bernitt[1], Sascha W. Epp[2], Jan K. Rudolph[1,3], Christian Beilmann[5], Hendrik Bekker[1], Sita Eberle[1], Alfred Müller[3], Joachim Ullrich[6], Oscar O. Versolato[1], Hasan Yavaş[4], Hans-Christian Wille[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg — [3]Institut für Atom- und Molekülphysik, Gießen — [4]DESY, Hamburg — [5]Physikalisches Institut, Heidelberg — [6]PTB, Braunschweig

The spectrum of highly charged iron ions gives rich information of the dynamics of outflows in X-ray binary stars and active galactic nuclei. Very high X-ray fluxes in the vicinity of such objects produce and drive mainly photoionized plasmas, but up to now it was not possible to investigate the underlying photoionisation processes in the laboratory. We present the first measurement of radiative and Auger rates for K-shell transitions in Li-like, Be-like, and C-like iron ions. These were produced and trapped in the transportable electron beam ion trap FLASH-EBIT and resonantly excited with X-ray photons at PETRA III. We observe photoionization by detecting the changes in the ionic charge state. By taking ratios of the photoionization yield and the simultaneous recorded fluorescence, we suppress setup-dependent uncertainties. Together with the total linewidths [1], this allows us to determine absolute values for the radiative and Auger widths.

[1] J. K. Rudolph et al., Phys. Rev. Lett. **111**, 103002 (2013)

A 27.2 Tue 16:30 Spree-Palais

Präzisionsspektroskopie an der K-Kante astrophysikalisch relevanter Ionen — •Alfred Müller[1], Alexander Borovik[1], Kristof Holste[1], Jonas Hellhund[1], Dietrich Bernhardt[1], David Kilcoyne[2], Sandor Ricz[3], Stephan Klumpp[4], Michael Martins[4], Jens Viefhaus[5] und Stefan Schippers[1] — [1]Institut für Atom- und Molekülphysik, Universität Giessen — [2]Advanced Light Source, Berkeley, CA, USA — [3]ATOMKI Institute, Debrecen, Ungarn — [4]Institut für Experimentalphysik, Universität Hamburg — [5]FS-PE, DESY, Hamburg

Absolute Wirkungsquerschnitte für die Einfach- und Mehrfach-Ionisation von C^{q+} - Ionen mit q=1,2,3,4 und Ne^{q+}-Ionen mit q=1,2,3 durch einzelne Synchrotronstrahlungs-Photonen wurden an dem neu an PETRA III aufgebauten Photon - Ion Experiment PIPE (Photon - Ion Spectrometer at PETRA III) gemessen. Energieauflösungen der Photonenstrahlen bis herab zu 5 – 10 meV bei 330 eV wurden realisiert. Die abgedeckten Energiebereiche umfassen die niederenergetischsten mit Anregung eines K-Elektrons verknüpften Resonanzen bis hin zu autoionisierenden Zuständen mit Doppelanregung (K- und L-Schale) bei Energien jenseits der eigentlichen Ionisationskante der jeweiligen

K-Schale. Emission von bis zu 3 Elektronen aus Ionen mit einem K-Loch wurde beobachtet. Im Fall von C^{4+} - Ionen wurden intermediäre Hohlatome (hohle Ionen) mit zwei Löchern in der K-Schale spektroskopiert.

A 27.3 Tue 16:30 Spree-Palais

PIPE - Absorption Spectroscopy of Small Molecular Ions — •Stephan Klumpp[1], Karolin Mertens[1], Michael Martins[1], Jonas Hellhund[2], Stefan Schippers[2], and Alfred Müller[2] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]Institut für Atom- und Molekülphysik, Universität Giessen

The Photon-Ion-Spectrometer at PETRA III (PIPE) at the XUV beamline P04, DESY, is a permanent end station dedicated to spectroscopic studies of free ions of various types, as atoms, molecular ions or mass selected clusters.

Using the merged-beams technique the prepared ion beam is collinear overlapped with x-ray photons from the P04 beamline between 250eV and 3000eV. This enables us to perform at PIPE absorption spectroscopy on the absolute scale in the region of the various inner shell absorption edges.

As a first case study for molecular ions the x-ray absorption and fragmentation of the IH^+ molecular ion at the Iodine 3d edge has been investigated. By comparing the IH^+ 3d partial cross section with the corresponding I^+ cross section strong deviations in the ion yield as well as in the shape of the partial cross section is found.

A 27.4 Tue 16:30 Spree-Palais

3d photoionization of ions from the Xe isonuclear sequence — •S Schippers[1], S. Ricz[2], T. Buhr[1,3], A. Borovik Jr.[1], J. Hellhund[1], K. Holste[1], D. Schury[1], S. Klumpp[4], K. Mertens[4], M. Martins[4], R. Flesch[5], G. Ulrich[5], E. Rühl[5], J. Lower[6], T. Jahnke[6], D. Metz[6], L. Ph. H. Schmidt[6], M. Schöffler[6], J. Williams[6], R. Dörner[6], L. Glaser[7], F. Scholz[7], J. Seltmann[7], J. Viefhaus[7], A. Dorn[8], A. Wolf[8], J. Ullrich[3] und A. Müller[1] — [1]IAMP, Univ. Giessen — [2]ATOMKI, Debrecen, Hungary — [3]PTB, Braunschweig — [4]Experimental Physics, Univ. Hamburg — [5]Physical Chemistry, FU Berlin — [6]Atomic Physics, Univ. Frankfurt a. M. — [7]FS-PE, DESY, Hamburg — [8]MPIK, Heidelberg

The photon-ion merged-beams technique has been employed at the new Photon-Ion spectrometer at PETRA III (PIPE) for measuring multiple photoionization of Xe^{q+} (q=1–5) ions. Total ionization cross sections have been obtained on an absolute scale for the dominant ionization reactions of the type $h\nu + Xe^{q+} \rightarrow Xe^{r+} + (q-r)e^-$ with product charge states $q+2 \leq r \leq q+5$. Prominent ionization features have been observed in the photon-energy range 650–800 eV, which are associated with excitation or ionization of an inner-shell $3d$ electron. The well-known collapse of the $4f$ wave function causes dramatic changes in the spectra when going from low to high q. Corresponding single-configuration Dirac-Fock calculations agree quantitatively with the experimental cross sections for non-resonant photoabsorption, but fail to reproduce all details of the measured ionization resonance structures.

A 27.5 Tue 16:30 Spree-Palais

Photoionization and photofragmentation of multiply charged $Lu_3N@C_{80}^{q+}$ ions — •Jonas Hellhund[1], Sándor Ricz[2], Alexander Borovik Jr.[1], Kristof Holste[1], Stephan Klumpp[3], Michael Martins[3], Stefan Schippers[1], and Alfred Müller[1] — [1]I.A.M.P., Univ. Giessen, Germany — [2]Atomki, Debrecen, Hungary — [3]Experimental Physics, Univ. Hamburg, Germany

Photoionization and photofragmentation of $Lu_3N@C_{80}^{q+}$ ($q = 1, 2, 3$) endohedral fullerene ions has been studied using the new Photon-Ion spectrometer at PETRA III (PIPE). Solid endohedral fullerene material was evaporated inside an ECR ion source. The generated ions were mass/charge selected and the ion beam was merged with the photon beam from PETRA III beamline P04. Product-ion yields normalized to ion current and photon flux, i.e., relative cross sections, were measured as a function of photon energy. The experimental photon-energy range was 270–1700 eV. This range comprises the energies for $1s$ ionization of carbon and nitrogen as well as for $3d$-ionization of lutetium.

The measured spectra exhibit clear signatures of carbon K-shell excitation, but no signs of excitation or ionization of encapsulated N or Lu producing vacancies in the $1s$ and $3d$ shells, respectively, have been observed. This is in contrast to recent findings for photofragmentation of $Xe@C_{60}^+$ [1] at energies of 60–150 eV. We speculate that the carbon cage and the encaged Lu_3N molecule completely disintegrate into relatively small fragments after absorption of one energetic photon.

[1] R. A. Phaneuf et al., Phys. Rev. A **88**, 053402 (2013).

A 27.6 Tue 16:30 Spree-Palais

Non-dipole effects in multiphoton ionization of hydrogen atom in short superintense laser fields — •Eric O. Jobunga[1,2] and Alejandro Saenz[1] — [1]AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, D-12489 Berlin, Germany — [2]Department of Mathematics and Physics , Technical University of Mombasa, P. O. Box 90420-80100, Mombasa, Kenya

The development of novel light sources has enabled the realization of high-precision experiments investigating various non-linear processes in the dynamics of atomic, molecular, and ionic systems interacting with high intense laser pulses. At high intensities or short wavelengths, the analysis of these experiments would definitely require a reliable non-perturbative solution of the time-dependent Schrödinger or Dirac equation. These solutions should consider both the temporal and the spatial intensity variations of the laser pulse.We have solved the non-relativistic time dependent Schrödinger equation for a ground state hydrogen atom interacting with short intense spatially and temporally resolved laser fields corresponding to the multiphoton ATI regime for a monochromatic source with $\lambda = 800$ nm. We shall analyse the effects of the A^2 term and the corresponding orders of the multipolar expansion of the transiton matrix.

A 27.7 Tue 16:30 Spree-Palais

Interaction effects on dynamical localization in driven helium — Felix Jörder, Klaus Zimmermann, •Alberto Rodriguez, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

Dynamical localization prevents driven atomic systems from fast fragmentation by hampering the excitation process. We present numerical simulations within a collinear model of microwave-driven helium Rydberg atoms and prove that dynamical localization survives the impact of electron-electron interaction, even for doubly excited states in the presence of fast autoionization. We conclude that the effect of electron-electron repulsion on localization can be described by an appropriate rescaling of the atomic level density and of the external field with the strength of the interaction [1].

[1] F. Jörder, K. Zimmermann, A. Rodriguez, and A. Buchleitner, arXiv:1311.5742

A 27.8 Tue 16:30 Spree-Palais

Dynamical Asymmetries of Electron Emission in CEP stable and two-color fields — •Martin Laux, Marcus Held, Yonghao Mi, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Photoelectron emission asymmetry in strong-field atomic photoionization plays a key role for the understanding of light-matter interaction in general. These asymmetries are caused by the spatial symmetry breaking within the laser pulse, as it happens e.g. in a few-cycle pulse with a fixed carrier-envelope phase (CEP). Another way to create an asymmetric laser field even for longer pulses is the superposition of a pulse with its second harmonic. Tuning the delay between the two colors or varying the CEP affects the asymmetry of photoelectron emission, but in qualitatively different fashions as confirmed by model calculations. A monolithic, robust, and phase-stable setup to create second harmonic light and allowing the continuous adjustment of the relative phase between the fundamental 800 nm and the frequency-doubled 400 nm pulses will be presented. Such dynamical two-color pulses are used for the study of dynamical asymmetry effects in photoionization of atoms and simple molecules with a reaction microscope.

A 27.9 Tue 16:30 Spree-Palais

The $1s^{-1}2s^{-1}, 2p^{-1}$ shake up satellites in Argon — •R. Püttner[1], T. Marchenko[2], R. Guillemin[2], R. K. Kushawaha[2], L. Journel[2], G. Goldsztejn[2], D. W. Lindle[4], M. N. Piancastelli[2,5], J.-P. Rueff[2,3], D. Ceolin[3], and M. Simon[2,3] — [1]Freie Universität Berlin, Germany — [2]CNRS and UPMC, UMR 7614, Paris , France — [3]Synchrotron SOLEIL, Saint-Aubin, France — [4]University of Nevada, Las Vegas, USA — [5]Uppsala University, Sweden

Using a new experimental setup for high-resolution HAXPES in the gas phase, which is mounted at the GALAXIES beamline of SOLEIL, we investigated the $1s^{-1}2s^{-1}, 2p^{-1}$ shake up structures of Argon, The spectrum of the $1s^{-1}2p^{-1}$ shake up satellites is dominated by the np (n=4 to 7) Rydberg series converging towards the ionization thresholds $^1P_1$ and $^3P_{2,1,0}$, which are determined with high accuracy. Below the $1s^{-1}2s^{-1}$ thresholds the spectrum is dominated by the broad $1s^{-1}2s^{-1}(^{1,3}S)4s$ Rydberg states which are split by approximately

16 eV. Moreover, a number of narrow lines are observed above the $1s^{-1}2p^{-1}(^{1,3}P)$ thresholds. Based on their linewidths and splittings these narrow lines are assigned to $1s^{-1}2p^{-1}(^{1,3}P)3p^{-1}n'l'n''l''$ final states populated via double shake processes. In addition, $1s^{-1}2p^{-1}$ the shake up satellites are also observed in molecules (S $1s^{-1}2p^{-1}$ in H_2S, Cl $1s^{-1}2p^{-1}$ in CH_3Cl and CCl_4) showing that this is a rather general effect. This observation opens the exciting new possibility to study single-site double core-hole (SS DCH) states in Si, P, S, and Cl containing molecules using conventional photoelectron spectroscopy at synchrotron radiation facilities.

A 27.10 Tue 16:30 Spree-Palais

Photoionization of the beryllium atom — •Sita Nagina Eberle[1], Oscar O. Versolato[1], Lisa Schmöger[1], Matthias Kohnen[2], Maria Schwarz[1], Piet O. Schmidt[2,3], Joachim Ullrich[1,2], and José R. Crespo López Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany

A source of beryllium photoions was built in order to sympathetically cool highly charged ions in a cryogenic Paul trap with them. A suitable process for this purpose is the two-photon ionization of neutral beryllium atoms that is achieved by a resonant excitation of the $1s^22s^2\ ^1S_0 \to 1s^22s2p\ ^1P_1$ transition at 235 nm of the atom followed by the non-resonant transfer of an electron to the continuum. The laser system used for the excitation and consecutive ionization of the atom is based on frequency doubling twice an amplified diode laser system at 940 nm. Ion and fluorescence spectral lines were measured and compared to simple models that describe the data quite well, at least qualitatively. Regarding the two-photon ionization cross sections, it should be noted that neither our simple estimates nor more sophisticated theoretical models reproduce the present experimental results. Most probably the assumptions underlying those calculations (e.g., weak coupling of the excited state to the continuum) are not realistic for our experimental settings. However, the setup fulfills the required specifications, including beryllium safety measures, and has been implemented in the main experiment CryPTEx.

A 27.11 Tue 16:30 Spree-Palais

Nonlinear photo-ionization dynamics using MCTHDF and Time-dependent RASCI — •Christopher Hinz[1], David Hochstuhl[2], and Michael Bonitz[1] — [1]ITAP, Christian-Albrechts-Universität Kiel, Leibnizstraße 15, 24098 Kiel — [2]d-fine GmbH, Opernplatz 2, D-60313 Frankfurt

As of now, the exact simulation of correlated quantum systems is inherently limited by the exponential growth of the state space with the particle number, and the resulting computational complexity—established as curse of dimensionality. It is therefore necessary to use an adapted approximation to mitigate this barrier, such as by using an ansatz for the many-particle state of the system. To methodically understand the implications of such an ansatz, it is required to strictly quantify its structural properties and their impact on the treated observables. As a first benchmark, we compare the structural properties of atomic states during photo-ionization for the FCI, MCTDHF [1,3] and TD-RASCI [2,3] methods. Particularly, we try to identify the cause of some already known deficiencies of the MCTDHF ansatz [1]. In the end, the detailed insight into the structure of these systems will allow one to guide the development of more advanced approximations.

[1] D. Hochstuhl, and M. Bonitz, J. Chem. Phys **134**(8) (2011)
[2] D. Hochstuhl, and M. Bonitz, JPCS **427**, 012007 (2013)
[3] D. Hochstuhl, C. Hinz and M. Bonitz, EPJ ST in press

A 27.12 Tue 16:30 Spree-Palais

Ionization yield in the resonant C 1s electron excitation range of chiral terpene molecules — •Christian Ozga[1], Benjamin Kambs[1], Kari Jänkälä[2,3], Philipp Schmidt[1], Andreas Hans[1], Philipp Reiss[1], André Knie[1], and Arno Ehresmann[1] — [1]Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology, Universität Kassel, D-34132 Kassel, Germany — [2]Department of Physics, University of Oulu, P.O. Box 3000, 90014 Oulu, Finland — [3]Institute for Experimental Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Inner shell C 1s electrons were excited in different chiral terpene molecules by monochromatized synchrotron radiation with an energy close to the C 1s electron ionization threshold. Undispersed fluorescence excitation within the range between 280 nm and 680 nm and relative ionization yields have been measured. The ionization yield measurements were compared to time dependent density functional theory calculations, revealing the site specificity of the resonant inner shell excitations. This site specificity is discussed as a means for the excitation of individual stereocenters in the investigated chiral molecules.

A 28: Poster: Ultra-cold plasmas and Rydberg systems (with Q)

Time: Tuesday 16:30–18:30 Location: Spree-Palais

A 28.1 Tue 16:30 Spree-Palais

Towards a strongly interacting gas of Strontium Rydberg atoms — •Luc Couturier[1,2], Chang Qiao[1], Valentin Ivannikov[2], Yuhai Jiang[1], and Matthias Weidemüller[1,2] — [1]USTC, Xiupu Road 99, Pudong New Distinct, Shanghai 201315, People Republic of China — [2]Physikalisches Institut, Universität Heidelberg, INF 226 69120 Heidelberg

So far Rydberg atom experiments have mainly focused on alkali metals. However different proposals pointed out the possibility to use alkaline earth metal elements as a two electron Rydberg system allowing trapping of Rydberg atoms and providing thus new schemes for quantum computation [1] as well as interesting applications in many-body quantum physics [2] or for the study ultracold neutral plasma [3]. For these purposes strontium is one of the best candidates, most of the optical spectroscopy and cooling transitions being within reach of commercial lasers, but also exhibiting favorable BEC formation schemes due to the existence of a very narrow transition characteristic of the alkaline earth metals. We present plans for a new experiment on strontium Rydberg atoms being set up at the University of Science and Technology of China.

[1] Mukherjee, R. *et al.* J. Phys. B 44(18), 184010 (2011)
[2] Stellmer, S. *et al.* Phys. Rev. A 87.1 013611 (2013)
[3] Bannasch, G. *et al.* PRL 110(25), 253003.(2013)

A 28.2 Tue 16:30 Spree-Palais

Aggregate formation in off-resonantly driven Rydberg gases — •Martin Gärttner, David Schönleber, and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The dynamics of a cloud of ultra-cold two-level atoms is studied at off-resonant laser driving to a Rydberg state. We find that resonant excitation channels lead to strongly peaked spatial correlations associated with the buildup of asymmetric excitation structures. These aggregates can extend over the entire ensemble volume, but are in general not localized relative to the system boundaries. We identify characteristic features in the spatial excitation density, the Mandel Q parameter, higher statistical moments, and the total number of excitations. Moreover, the influence of decoherence on the aggregate formation mechanism is studied. We conclude that in the presence of strong decoherence the aggregates grow sequentially around an initial grain. In the strongly dissipative regime a rate-equation description can be employed. This allows us to study large ensembles of atoms and to directly compare our findings to recent experimental observations [1].

[1] Schempp *et al.*, arXiv:1308.0264 (2013)

A 28.3 Tue 16:30 Spree-Palais

Measurements and numerical calculations of ^{87}Rb Rydberg Stark Maps — •Jens Grimmel, Markus Mack, Florian Karlewski, Malte Reinschmidt, Florian Jessen, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

Rydberg atoms are extremely sensitive to electric fields and consquently have a rich Stark spectrum. We present high precision frequency measurments of Stark Maps for Rubidium Rydberg atoms with principal quantum numbers between 26 and 75. A two photon measurement scheme creates Rydberg atoms inbetween two electrodes of a capacitor in a glass vapor cell. The exact transition frequency at a given field strength is determined by scanning the coupling laser and observing the apperance of an electromagnetically induced transparency window. The two lasers are phase locked to a frequency comb. The Stark Maps were numerically calculated based on the method of [M. Zimmerman et al., Phys. Rev. A 20, 2251-2275 (1979)], and match the data to within 1MHz.

A 28.4 Tue 16:30 Spree-Palais

Optical control of Rydberg aggregates embedded in a dense atomic gas — •Sebastian Wüster[1], Michael Genkin[1], Alexander Eisfeld[1], and Shannon Whitlock[2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden — [2]Physikalisches Institut, Universität Heidelberg

We find that Rydberg impurities created within a host cold atom cloud realize a system in which excitation transport can be monitored and through the same mechanism continuously tuned between the quantum coherent, classically diffusive and quantum Zeno regimes.

Controllable decoherence and monitoring are both provided by state dependent interactions of the impurities with the background gas, which is electromagnetically rendered transparent [1,2].

We describe the physical process through which the coupling to the background gas de-coheres the quantum excitation transport taking place among the impurities (aggregate), and find that the de-coherence time is naturally reached once enough information is gathered on the excitation location, thus collapsing the wave function. Using an effective description for the aggregate alone, we then investigate how various regimes of transport can be realized.

[1] G. Günter, M. R. de Saint-Vincent, H. Schempp, C. S. Hofmann, S. Whitlock, and M. Weidemüller, Phys. Rev. Lett. 108, 013002 (2012).

[2] B. Olmos, W. Li, S. Hofferberth, and I. Lesanovsky, Phys. Rev. A 84, 041607(R) (2011).

A 28.5 Tue 16:30 Spree-Palais

Time resolved optical detection of Rydberg state population — •Markus Mack[1], Florian Karlewski[1], Nóra Sándor[1,2], Jens Grimmel[1], Florian Jessen[1], Daniel Cano[1], and József Fortágh[1] — [1]Physikalisches Institut der Universität Tübingen, Germany — [2]Wigner Research Center for Physics, Budapest, Hungary

The population of Rydberg states is typically determined by selective field ionization (SFI), which destroys the sample of Rydberg atoms. We have investigated an essentially non-destructive method to probe the excitation of single Rydberg states by time resolved optical absorption measurements without the use of SFI. Numerical predictions for the time-dependent transmission signal under the conditions for electromagnetically induced transparency (EIT) are compared to experimental data.

A 28.6 Tue 16:30 Spree-Palais

Spectroscopy of Rydberg pair states in an ultracold cesium gas — Heiner Sassmannshausen and •Johannes Deiglmayr — ETH Zurich, Laboratory of Physical Chemistry, Zurich, Switzerland

We have recently setup an experiment which allows us to study transitions between Rydberg states by high-resolution millimeter-wave spectroscopy under conditions where the stray electric and magnetic fields are reduced to below 1 mV/cm and 2 mG, respectively. Measurements of the hyperfine-splitting of atomic Rydberg states with principal quantum number beyond n=100, showing transform-limited linewidths of better than 20 kHz, demonstrated the performance of the setup [1].

Recently an optical dipole trap was added to the setup to investigate the Rydberg excitation in denser samples of ultracold atoms. We have observed the excitation of dipole-forbidden pair-states, which we attribute to the formation of so called "macro dimers" [2]. The current status of these experiments will be presented.

[1] H. Sassmannshausen, F. Merkt, J. Deiglmayr, Phys. Rev. A 87, 032519 (2013) [2] S.M. Farooqi, et al., Phys. Rev. Lett. 91, 183002 (2003)

A 28.7 Tue 16:30 Spree-Palais

Interacting Spin-1 chains from multi-level Rydberg atoms — •Rick van Bijnen[1], Rejish Nath[1,2,3], Volckmar Nebendahl[3], Igor Lesanovsky[4], Andreas Laeuchli[3], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany — [2]Indian Institute of Science Education and Research, Pune-411021, India — [3]Institut für Theoretische Physik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria — [4]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Ultracold, highly excited Rydberg atoms exhibit extremely strong and tunable interactions, making them promising candidates for quantum information and quantum simulation purposes. In particular, Rydberg atoms can provide a very close experimental realisation of interacting spin-1/2 systems, represented by the atomic ground- and Rydberg states. So far, most studies involve a single Rydberg S-state, featuring isotropic van der Waals interactions. Here, we consider laser excitation of two distinct Rydberg S-states, representing an interacting spin-1 system. We discuss additional interactions appearing in this system for varying principal quantum numbers and investigate the resulting phase diagram which reveals a range of interesting non-classical ground states, even in the absence of laser driving.

A 28.8 Tue 16:30 Spree-Palais

Second-generation apparatus for Rydberg-atoms in a Bose-Einstein condensate — •Udo Hermann, Huan Nguyen, Michael Schlagmüller, Graham Lochead, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Physikalische Institut, Universität Stuttgart

The giant size and large polarizability of Rydberg-atoms, resulting in strong long-range Rydberg-Rydberg interactions, make them ideal for studying many-body cooperative effects. In particular, the effect of highly excited Rydberg atoms on the density distribution of a Bose-Einstein condensate has opened the door to study Rydberg electron wave functions. In addition, Förster like energy transport in light harvesting complexes can be simulated with this system.

Here we present a new experimental apparatus for the creation and dynamic study of Rydberg-atoms in dense, ultra-cold atomic ensembles. Specific design goals of this new setup are single ion-detection capability, sub-micron optical resolution, precise electric field control and high flexibility in creating both magnetic and optical trapping potentials. We discuss how these different aspects are combined in a single, compact experimental realization and present the first results.

A 28.9 Tue 16:30 Spree-Palais

Dissipative Binding of Lattice Bosons through Distance-Selective Pair Loss — •Benjamin Everest, Michael R. Hush, and Igor Lesanovsky — University of Nottingham, Nottingham, UK

The generation of correlated many body states in cold atomic gases is currently of great interest. In this setting, atoms excited to Rydberg states have proven to be a useful tool as they display strong coherent long-range interactions which can also be used to generate non-local dissipation [1]. Here we explore how such an unusual dissipation mechanism fosters the formation of coherent long lived states for bosons trapped in an optical lattice. This system is modelled with a dissipative master equation with Lindblad jump operators of a form such that two atoms separated by a specific critical distance will be removed. When this dissipation competes with coherent hopping, this can lead to bound complexes of atoms whose internal dynamics is linked directly to their motion. Previously this was shown for hard core bosons and we have now extended this model to bosons with finite interaction strength. This system features a manifold of bound complexes and a more intricate dynamical behaviour.

[1] C. Ates, B. Olmos, W. Li and I. Lesanovsky. Dissipative Binding of Lattice Bosons through Distance-Selective Pair Loss. *Physical Review Letters*, 109(23):233003, December 2012

A 29: Ultra-cold atoms, ions and BEC III (with Q)

Time: Wednesday 14:00–16:00 Location: UDL HS3038

Invited Talk A 29.1 Wed 14:00 UDL HS3038
Single charged impurities inside a Bose-Einstein condensate — •Sebastian Hofferberth[1], Jonathan Balewski[1], Alexander Krupp[1], Anita Gaj[1], David Peter[2], Hanspeter Büchler[2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Phys. Institut, Universität Stuttgart, Germany — [2]Institut für Theoretische Physik III, Universität Stuttgart, Germany

We investigate the interaction of single charged impurtities with a Bose-Einstein condensate (BEC). We produce these impurities by exciting exactly one atom from the BEC to a Rydberg state. Since the ionic core and the Rydberg electron have vastly different mass and interaction range with the surrounding ground state atoms, their effect on the BEC can be observed separately. For low-L Rydberg states, the electron wavefunction is fully immersed in the BEC, and we observe electron-phonon coupling. We show that a single electron excites collective modes of the whole condensate. We also discuss the feasibility of studying the interaction of the ionic core with the BEC, which becomes possible if the electron is excited to a high-L states such that it is moved completely outside of the BEC. In this situation one could study ion-ground state Feshbach resonances at very low temperatures or trap the ion inside the BEC without any external electric fields.

A 29.2 Wed 14:30 UDL HS3038
Field-theoretical Study of the Bose Polaron - Challenges for Quantum Simulation with ultracold Atoms — •Richard Schmidt[1,2] and Steffen Patrick Rath[3] — [1]ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts 02138, USA — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [3]Technische Universitaet Muenchen, James-Franck-Straße, 85748 Garching, Germany

We study the properties of the Bose polaron, an impurity strongly interacting with a Bose-Einstein condensate, using a field-theoretic approach and make predictions for the spectral function and various quasiparticle properties that can be tested in experiment. We find that most of the spectral weight is contained in a coherent attractive and a metastable repulsive polaron branch. We show that the qualitative behavior of the Bose polaron is well described by a T-matrix approximation. We discuss the implications of our results for the attempted quantum simulation of the Froehlich Hamiltonian using ultra cold atoms.

A 29.3 Wed 14:45 UDL HS3038
Bose-Einstein condensation of ultra-cold atoms in a frustrated, triangular optical lattice I. — •Ludwig Mathey[1], Robert Höppner[1], Peter Janzen[1], Julian Struck[1], Malte Weinberg[1], Christoph Ölschläger[1], Patrick Windpassinger[1], Juliette Simonet[1], Klaus Sengstock[1], Philipp Hauke[2], Andre Eckardt[3], and Maciej Lewenstein[4] — [1]Institut für Laserphysik and Zentrum für Optische Quantentechnologien, Universität Hamburg, Hamburg, Germany — [2]IQOQI, Innsbruck, Austria — [3]MPIKS, Dresden, Germany — [4]ICFO and ICREA, Barcelona, Spain

We present a study of Bose-Einstein condensation of ultracold atoms in a triangular optical lattice. As demonstrated in Ref. [1], the tunneling energy between neighboring sites in an optical lattice can be controlled via lattice shaking to be negative or complex-valued. For negative, real-valued tunneling, the system condenses at one of two non-zero quasimomenta, corresponding to classical frustration. Tuning the tunneling energy to complex values corresponds to an artificial gauge field. We demonstrate that the nature of the condensation transition is modified due an additional chiral symmetry that is broken. Furthermore, the artificial gauge field acts as the conjugate external field to the chiral order parameter, which allows to map out magnetization curves of the chirality as a function of the article gauge field. In this talk we give analytical results on the nature of the phase transition, based on an expansion of the free energy in the interaction strength and on a renormalization group approach.

[1] J.Struck, et al., Nature Physics 9, 738 (2013)

A 29.4 Wed 15:00 UDL HS3038
Bose-Einstein condensation of ultra-cold atoms in a frustrated, triangular optical lattice II. — Robert Höppner[1], Julian Struck[1], Malte Weinberg[1], Christoph Ölschläger[1], Patrick Windpassinger[1,3], Juliette Simonet[1], Klaus Sengstock[1], Ludwig Mathey[1], •Philipp Hauke[5], André Eckardt[4], and Maciej Lewenstein[2] — [1]ILP/ZOQ (Hamburg) — [2]ICFO/ICREA — [3]Uni Mainz — [4]MPIPKS — [5]Uni Innsbruck

We study the condensation in frustrated, triangular optical lattices, with emphasis on numerical simulations. We implement the system using a semiclassical version of the Bose-Hubbard model and generate samples of the grand-canonical ensemble using Metropolis Monte-Carlo from which we then calculate the observables. As discussed in Ref. [1], periodic driving of the optical lattice potential generates an effective tunneling energy that becomes complex, thereby creating an artificial gauge-field that acts as a control field of the chiral order that emerges in this system. In analogy to the experimental study, we numerically determine the magnetization curves of the chiral order parameter as function of the artificial gauge field. We demonstrate that the experimentally realized ensemble is not in equilibrium, showing hysteric-like behavior. Beyond the equilibrium system, we therefore also comment on the quench dynamics from the positive tunneling (ferromagnet-like phase) to the negative tunneling, fully frustrated phase.

[1] "Engineering Ising-XY spin-models in a triangular lattice using tunable artificial gauge fields." Nature Physics (2013)

A 29.5 Wed 15:15 UDL HS3038
A novel experiment for coupling a Bose-Einstein condensate with two crossed cavity modes — •Julian Leonard, Moonjoo Lee, Andrea Morales, Thomas Karg, Tilman Esslinger, and Tobias Donner — ETH Zürich, Institute for Quantum Electronics, Zürich, Switzerland

Over the last decade, combining cavity quantum electrodynamics and quantum gases allowed to explore the coupling of quantized light fields to coherent matter waves, leading e.g. to new optomechanical phenomena and the realization of quantum phase transitions. Triggered by the interest to study setups with more complex cavity geometries, we built a novel, highly flexible experimental system for coupling a Bose-Einstein condensate (BEC) with optical cavities, which allows to switch the cavity setups by means of an interchangeable science platform. The BEC is generated from a cloud of laser-cooled 87-Rb atoms which is first loaded into a hybrid trap, formed by a combined magnetic and optical potential, and then optically transported into the cavity setup, where it is cooled down to quantum degeneracy.

At first we aim to explore the coupling of a BEC with two crossed cavity modes. We report on our progress on the implementation of a science setup involving two cavities intersecting under an angle of 60°. The mirrors have been fabricated in order to spatially approach them, thus obtaining maximum single atom coupling rates of several MHz. This setup will allow us to study the coherent interaction of a BEC and the two cavity modes both in internal lambda-level transitions and in spatial self-organization processes in dynamical hexagonal lattices.

A 29.6 Wed 15:30 UDL HS3038
Microscopic description of Bose-Einstein condensates in complex potentials — •Dennis Dast, Daniel Haag, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Bose-Einstein condensates with balanced gain and loss are described in mean-field approximation by a non-Hermitian but $\mathcal{PT}$-symmetric Gross-Pitaevskii equation. To gain a deeper understanding of the non-Hermitian Hamiltonian a microscopic treatment of the incoupling and outcoupling of particles is necessary. We do this by modelling the open system as a subsystem of a closed system. The complete system including the environment is described, on the one hand, by a many-particle Bose-Hubbard Hamiltonian. On the other hand, a Lindblad master equation is used to describe gain and loss in the open quantum system. The behaviour of the Bose-Hubbard Hamiltonian and the Lindblad master equation are compared with the non-Hermitian mean-field description.

A 29.7 Wed 15:45 UDL HS3038
On the Validity of the Truncated Wigner Method for Bosonic Many Body Transport — •Thomas Engl[1], Julien Dujardin[2], Juan Diego Urbina[1], Klaus Richter[1], and Peter Schlagheck[2] — [1]Institut für Theoretische Physik, Universität Regensburg, D-93040

Regensburg, Germany — [2]Département de Physique, Université de Liège, 4000 Liège, Belgium

The Truncated Wigner Method is one of the most frequently used approaches to investigate bosonic many body systems. It is based on the evolution of the Wigner function of the initial state, which is sampled by Gross-Pitaevskii trajectories that are generated by the corresponding mean field Hamiltonian. However, since this is the classical evolution with respect to the quantum Hamiltonian, this method cannot account for interference phenomenons on the many-body quantum level. This concerns in particular coherent backscattering in Fock Space, which arises due to constructive interference of time reversed Gross-Pitaevskii trajectories [1]. Here, we prove the validity of the Truncated Wigner approximation, *i.e.* the cancellation of quantum many-body interference, for bosonic many-body transport in the semiclassical limit, by extending the semiclassical approach developed in our previous work [1].

[1] T. Engl, J. Dujardin, A. Argüelles, P. Schlagheck, K. Richter and J. D. Urbina, arXiv:1306.3169

A 30: Interaction with VUV and X-ray light I

Time: Wednesday 14:00–16:00 Location: BEBEL E42

Invited Talk A 30.1 Wed 14:00 BEBEL E42

Stimulated electronic x-ray Raman scattering using x-ray free-electron lasers — •Nina Rohringer — Max Planck Institute for the Physics of Complex Systems, 01187 Dresden — Center for Free-Electron Laser Science, 22761 Hamburg

X-ray free-electron lasers (XFELs) open the pathway to transfer nonlinear spectroscopic techniques to the x-ray domain, to study the interplay of electronic and vibrational degrees of freedom by time-domain spectroscopy. A promising all x-ray pump probe technique is based on coherent electronic x-ray Raman scattering. I will present the first experimental demonstration of stimulated electronic x-ray Raman scattering. By tuning the relatively broad XFEL pulses to the core-excited Rydberg resonances in the pre K-edge region of neon, resonance scattered photons drive an avalanche of inelastic x-ray scattering events, resulting in exponential amplification of the scattering signal by 6-7 orders of magnitude. Analysis of the line profile of the emitted radiation permits to demonstrate the cross over from amplified spontaneous emission to coherent resonance scattering: In case of coherent scattering, the emitted x-ray radiation shows a pulse-to-pulse fluctuation of the line shape and the spectral peak position, resulting from a stochastic detuning of spectrally structured XFEL pulses from resonance. In combination with statistical covariance mapping, a high-resolution spectrum of the resonant inelastic x-ray scattering process can be obtained, opening the path to coherent stimulated x-ray Raman spectroscopy. An extension of these ideas to molecules will be discussed.

A 30.2 Wed 14:30 BEBEL E42

Time-resolved x-ray imaging of laser-driven hydrogen nanoclusters: a microscopic particle-in-cell analysis — •Christian Peltz[1], Charles Varin[2], Thomas Brabec[2], and Thomas Fennel[1] — [1]Institute of Physics, University of Rostock, Germany — [2]Department of Physics and Centre for Photonics Research,University of Ottawa, Canada

We investigate the time-dependent evolution of laser-heated R = 25 nm solid-density hydrogen clusters via coherent diffractive imaging for an infrared pump/x-ray probe scenario. Our microscopic particle-in-cell analysis provides a full electromagnetic description of both the droplet ionization and expansion induced by the intense few-cycle pump pulse as well as the coherent light scattering by the x-ray probe in the expanding nano-plasma [1]. Unexpectedly, the time-resolved scattering images show Mie-like diffraction pattern with increasing fringe separations as function of delay that indicate a shrinking of the cluster. Our analysis reveals that this effect results from continuous ion ablation on the cluster surface which generates a simple self-similar radial density profile whose evolution can be reconstructed precisely by fitting the time-resolved scattering images using a simplified scattering model in Born approximation. Our findings suggest, that time-resolved diffractive imaging experiments on nano-droplets will provide unprecedented insights into the physics of ion expansion and surface ablation in laser-driven plasmas.

[1] C. Varin, C. Peltz, T. Brabec and T. Fennel , Phys. Rev. Lett. **108**, 175007 (2012)

A 30.3 Wed 14:45 BEBEL E42

Fluorescence as a probe for massive electron impact ionization and excitation in FEL-irradiated xenon clusters — •M Müller[1], L Schroedter[2], T Oelze[1], L Nösel[1], M Adolph[1], F Flückiger[1], T Gorkhover[1], M Krikunova[1], D Rupp[1], M Sauppe[1], A Prystawik[2], A Kickermann[2], S Schorb[1,3], C Bostedt[3], T Laarmann[2], and T Möller[1] — [1]TU Berlin — [2]DESY Hamburg — [3]LCLS@SLAC Stanford

Short-wavelength free-electron lasers allow studying highly excited plasma states far from ground state properties. The nanoplasma dynamics induced in rare-gas clusters by intense XUV pulses from FLASH is complex, evolving on different timescales from fs to ns. Previous experiments on xenon clusters at 90eV photon energy indicate that massive ionization takes place while already early in the pulse direct electron emission becomes frustrated. A dense nanoplasma builds up with electron temperatures of some 10eV with dominant recombination in particular in the slowly expanding cluster core.

The question how the residual electron energy is transferred to enable recombination has been adressed with fluorescence measurements. The fluorescence spectra of xenon clusters irradiated with 90eV photon energy exhibit lines of charge states up to 11+ with photon energies exceeding the excitation energy by up to 25eV. Their behavior is directly connected to the plasma driving parameters, indicating that these energetic photons are products of electron impact ionization and excitation. Plasma calculations allow for tracing the electron temperature in the nanoplasma.

A 30.4 Wed 15:00 BEBEL E42

Ultrafast nanoplasma dynamics in large clusters driven by highly intense laser pulses — •L. Flückiger[1], T. Gorkhover[1], M. Müller[1], M. Krikunova[1], M. Sauppe[1], S. Schorb[2], S. Düsterer[3], M. Harmand[3], H. Redlin[3], R. Treusch[3], C. Bostedt[2], D. Rupp[1], and T. Möller[1] — [1]Technische Universität, Berlin — [2]LCLS, SLAC National Accelerator Laboratory — [3]Deutsches Elektronen-Synchrotron, Hamburg

In a newly developed experimental approach we study the dynamics of individual clusters irradiated with highly intense laser pulses on three different timescales, from femto over pico to nanoseconds. In a two-color pump-probe setup single-shot diffractive imaging with simultaneous ion spectroscopy were performed on single xenon clusters. This technique enables to reveal cluster morphology and energy absorption as well as ionization and fragmentation dynamics of the same target without integration over focal-volume and cluster-size distribution [1].

Highly ionized by a 800 nm Ti:Sa pulse a large cluster transforms into a hot dense nanoplasma expelling surface ions by hydrodynamic forces. Subsequent the fully screened interior of the sample recombines completely. What remains is a cold skinned and neutral core. Its fragmentation evolution is probed directly by imaging snapshots with a 90 eV free-electron-laser pulse. This study helps to shed new light on cluster ionization dynamics and laser induced sample damage.

[1] Gorkhover et al., PRL 108, 245005 (2012)

A 30.5 Wed 15:15 BEBEL E42

Tracing Charge Transfer in Dissociating Multiply Charged Iodine Molecules by XUV Pump-Probe Experiments — •Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Georg Schmid[1], Thomas Pfeifer[1], Artem Rudenko[2], Kristina Meyer[1], Matthias Kübel[3], Matthias Kling[3], Björn Siemer[4], Michael Wöstmann[4], Stefan Düsterer[5], Joachim Ullrich[6], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]J.R. Macdonald Laboratory, Kansas State University — [3]Max-Planck-Institut für Quantenoptik, Garching — [4]Westfälische Wilhelms-Universität, Münster — [5]Deutsches Elektronen-Synchrotron, Hamburg — [6]Physikalisch-Technische Bundesanstalt, Braunschweig

The dynamics of dissociating multiply charged iodine molecules, I_2^{n+}, is induced and probed by intense XUV pulses delivered by the free-electron laser in Hamburg (FLASH). A first pulse multiply ionizes I_2 and thereby triggers the fragmentation of the molecule. During the dissociation a probe pulse further ionizes the fragments after an adjustable time-delay. Depending on their internuclear distance the probe pulse may also initiate charge transfer between the ions. In this way we determine the critical separation and time scales up to which charge transfer along the internuclear axis takes place. These scales are particularly important for understanding the radiation damage occurring in X-ray single-molecule imaging.

A 30.6 Wed 15:30 BEBEL E42

XUV-pump/IR-probe studies of photoionization and dissociation of N_2O — •Michael Schoenwald[1], Philipp Coerlin[1], Andreas Fischer[1], Alexander Sperl[1], Arne Senftleben[1,2], Joachim Ullrich[3], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck Institut fuer Kernphysik, Heidelberg, Deutschland — [2]Institut fuer Physik, Universitaet Kassel, Deutschland — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

Single and double photoionization of nitrous oxide (N_2O) has been investigated by means of kinematically complete XUV-pump/IR-probe experiments using a reaction microscope. A train of attosecond XUV pulses, produced via high harmonic generation in an Ar-filled gas cell, covers the energy range from 20-50 eV. Here, we concentrate on the XUV induced creation of excited cations N_2O^{+*} in a state near the double ionization threashold. Besides stable N_2O^{+*} ions, which can be detected directly, the molecular ions can either dissociate into a charged and a neutral fragment or they autoionize into N_2O^{2+}. The latter leads to Coulomb-explosion into two charged fragments that are detected in coincidence ($N_2O^{2+} \rightarrow N^+ + NO^+$ or $N_2O^{2+} \rightarrow N_2^+ + O^+$). An enhancement of double ionization in the presence of the IR-probe pulse was observed. The strength of the influence of the IR pulse seems to be different for the two different decay channels[1]. First results of our measurements will be presented and discussed.

[1] X.Zhou et al., Nature Physics Vol.8, March 2012

A 30.7 Wed 15:45 BEBEL E42

Multiphoton ionization of Argon in the XUV: Theoretical study of ATI processes seen at FLASH — •Antonia Karamatskou[1,2], Stefan Pabst[1], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, Universität Hamburg, Hamburg, Germany

Recent experiments at the free-electron laser in Hamburg FLASH have succeeded in measuring direct multiphoton ionization and above-threshold ionization (ATI) in the XUV. We present a theoretical description of the phenomena seen in Argon and Xenon in an ab initio approach. Upon solving the time-dependent Schrödinger equation the photoelectron spectrum is calculated. Multiphoton absorption cross sections are derived and employed to quantify the ATI process for different photon energies.

A 31: Fathoming Stellar Evolution with Laboratory Precision SYSE (with MS, Q, MO, EP)

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

Invited Talk A 31.1 Wed 14:00 Audimax

Addressing open questions of stellar evolution with laboratory experiments — •Almudena Arcones — Technische Universität Darmstadt, Institut für Kernphysik, Germany — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany

After several hydrostatic burning stages, massive stars end their life as core-collapse supernova explosions. These high-energy events enrich the interstellar medium with elements formed during the stellar life, produce new heavy elements, and are the birthplace of neutron stars. An exciting stage in the life of neutron stars is the merger with another neutron star or a black hole. Both, core-collapse supernovae and neutron star mergers are sources of heavy elements in the universe. Elements from Sr to Ag can be synthesized in neutrino-driven winds after core-collapse supernovae via charged particle reactions through nuclei relatively close to stability. Heavier elements are produced in rare supernovae and neutron star mergers via the rapid neutron capture process (r-process). In this talk, the role of nuclear masses will be presented showing how further experimental information is highly necessary to constrain the nucleosynthesis and the still uncertain theoretical models. In addition, the r-process can be directly observed after a neutron star merger in the form of a light curve (kilonova) triggered by the radioactive decay of neutron-rich nuclei. In order to obtain the maximum information from such events more atomic data are required to calculate the opacities for r-process ejecta. Therefore, precision experiments are critical to understand supernova, neutron star mergers and their implication in the chemical history of the universe.

Invited Talk A 31.2 Wed 14:30 Audimax

Methods and problems of the modern theory of stellar evolution — •Achim Weiss — Max-Planck-Institut für Astrophysik, Garching

The theory of (hydrostatic) stellar evolution has developed into a mature field of astrophysics. We basically understand the structure and evolution of most stars. The most important input physics is accurate enough to model successfully the nuclear and photometric evolution of stars. I will, in the first part, review this canonical theory, and present a few highlights. A closer look on and into stars, that has become available due to observational progress in the fields of spectroscopy and asteroseismology, reveals, however, that fundamental physical effects, connected mostly with hydrodynamical processes and matter flows, are far from being understood. The second part of this overview will present some of the observational challenges and discuss attempts to improve our theoretical models. The importance of more accurate stellar models for other fields of astrophysics will also be discussed.

Invited Talk A 31.3 Wed 15:00 Audimax

Photoabsorption and opacity in the X-ray region: The role of highly charged ions — •José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Within the radiative zone of stars, the contribution to opacity by highly charged ions is the dominant one. In such a dense and hot environment, X-ray opacity determines radiation transport and radiation pressure. It strongly influences the hydrostatic equilibrium, and thus the structure and dynamic evolution, e. g., oscillations and collapse, of a star. Even minor amounts of iron present there play a key role: They are essential to explain the temperature profile of the Sun and main sequence stars. Highly charged iron ions make the star core almost completely opaque to X-rays, slowing down the energy flux. On the theoretical side, opacity calculations for astrophysics require the use of approximations, and until now very few accurate experimental benchmarks have been reported for them. Recently, with the use of electron beam ion traps at X-ray sources such as free-electron lasers and synchrotron facilities, new methods have been developed for detailed studies of such X-ray photoabsorption process. The results of these experiments test the values of cross sections and resonance energies for ions in charge states which had hitherto been beyond reach, and the experimental results achieve accuracies surpassing that of current theory.

Invited Talk A 31.4 Wed 15:30 Audimax

Neutron-rich matter: From cold atoms to neutron stars — •Achim Schwenk — Institut für Kernphysik - Theoriezentrum, TU Darmstadt — ExtreMe Matter Institute EMMI, GSI, Darmstadt

There are many synergies between neutron matter and ultracold Fermi gases with resonant interactions. This talk will discuss the physics of neutron-rich matter starting from universal properties at low densities to dense matter in neutron stars. We will focus on the similarities of these systems and on the current frontiers in describing neutron-rich systems in the laboratory and in stars.

A 32: Awards Symposium I (SYAW 1)

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

Prize Talk A 32.1 Wed 14:00 Kinosaal

Semicrystalline polymers - pathway of crystallization and deformation properties — •Gert Strobl — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, 79104 Freiburg — Laureate of the Robert-Wichard-Pohl Prize

On cooling a polymer melt, plate-like crystals with thicknesses in the nano-range are nucleated and grow in the two lateral directions. The final structure is semicrystalline and composed of stacks of such crystallites separated by entangled fluid chain sequences. Structure parameters vary with the crystallization temperature which can be chosen far below the equilibrium melting point, down to the transition into the glassy state. The question about the mechanism of polymer crystallization has always been a central issue in polymer physics. Time- and temperature dependent X-ray scattering experiments carried out during the last two decades now led to the establishment of a set of laws which control the structure formation out the entangled melt, recrystallization processes, and the final melting. The laws indicate the participation of an intermediate mesomorphic phase in the crystal formation process. The peculiar deformation behaviour of polymeric materials reflects their semicrystalline structure, including in a coupled fashion both the rubber-like properties of the fluid parts and the elasto-plastic properties of the crystallites.

Prize Talk A 32.2 Wed 14:30 Kinosaal

A measurement of the evolution of Interatomic Coulombic Decay in the time domain — •Till Jahnke — Institut für Kernphysik, Johann Wolfgang Goethe Universität, Frankfurt, Germany — Laureate of the Gustav-Hertz-Prize

Interatomic (or intermolecular) Coulombic Decay (ICD) has become an extensively studied atomic decay process during the last 10 years. In ICD an excited atom or molecule deexcites by transferring its excitation energy to a loosely bound atomic neighbor and leads to the emission of an electron from that neighbor. Originally proposed by Cederbaum et al. [1] it was first experimentally observed by two groups using different techniques [2,3]. Since that time a wealth of experimental and theoretical studies have shown that ICD is a rather common decay path in nature, as it occurs almost everywhere in loosely bound matter.

ICD is predicted to have a highly complex temporal behavior. The efficiency and thus the decay times of ICD depend strongly on the size of the system, i.e. the number of neighboring particles and the distance between them and the excited particle. However, even for most simple model systems consisting of only two atoms the temporal evolution of the decay is non-trivial: as ICD happens on a timescale that is fast compared to relaxation via photon emission, but comparable to the typical times of nuclear motion in the system, the dynamics of the decay is complicated and so far only theoretically explored. Here we present an experimental study resolving ICD in helium dimers (He2) in the time domain [4].

The talk will give a short introduction on ICD and show experimental investigations separating different contributions to the ICD transition matrix element [5]. The final part of the talk will show our time resolved studies of the dynamics of the nuclei of the decaying dimer and give a brief view on possible future applications of ICD [6].

[1] Cederbaum, L. S., Zobeley, J., and Tarantelli, F., Phys. Rev. Lett., 79, 4778 (1997).
[2] Marburger, S., Kugeler, O., Hergenhahn, U., and Möller, T., Phys. Rev. Lett., 93, 203401 (2003).
[3] Jahnke, T., Czasch, A., Schöffler, M. S., Schössler, S., Knapp, A. Käsz, M., Titze, J., Wimmer, C., Kreidi, K., Grisenti, R. E., Staudte, A., Jagutzki, O., Hergenhahn, U., Schmidt-Böcking, H., and Dörner, R., Phys. Rev. Lett., 93, 163401 (2004).
[4] F. Trinter J. B. Williams, M. Weller, M. Waitz, M. Pitzer, J. Voigtsberger, C. Schober, G. Kastirke, C. Müller, C. Goihl, P. Burzynski, F. Wiegandt, T. Bauer, R. Wallauer, H. Sann, A. Kalinin, L. Ph. H. Schmidt, M. Schöffler, N. Sisourat, and T. Jahnke, Phys. Rev. Lett., 111, 093401 (2013)
[5] T. Jahnke, A. Czasch, M. Schöffler, S. Schössler, M. Käsz, J. Titze, K. Kreidi, R. E. Grisenti, A. Staudte, O. Jagutzki, L. Ph. H. Schmidt, Th. Weber, H. Schmidt-Böcking, K. Ueda, and R. Dörner., Phys. Rev. Lett., 99, 153401 (2007)
[6] F. Trinter, M. S. Schöffler, H.-K. Kim, F. Sturm, K. Cole, N. Neumann, A. Vredenborg, J. Williams, I. Bocharova, R. Guillemin, M. Simon, A. Belkacem, A. L. Landers, Th. Weber, H. Schmidt-Böcking, R. Dörner, and T. Jahnke, doi:10.1038/nature12927, Nature (2013)

Prize Talk A 32.3 Wed 15:00 Kinosaal

A one-dimensional liquid of fermions with tunable spin — •Massimo Inguscio — LENS & Dipartimento di Fisica e Astronomia, Università di Firenze, Firenze, Italy — INRIM Istituto Nazionale di Ricerca Metrologica, Torino, Italy — Laureate of the Herbert-Walther-Prize

Ultracold atoms offer an exceptionally rich experimental platform, allowing the most precise metrological measurements and the investigation of fundamental quantum effects in interacting many-body systems [1]. An example is given by ultracold two-electron atoms, which are used to build the most accurate and precise atomic clocks to date. The rich internal structure of these atoms also allows for novel advances in quantum simulation, for instance the investigation of large-spin atomic systems with SU(N) interaction symmetry. We will report on the realization of one-dimensional liquids of fermionic 173Yb with tunable spin, evidencing for the first time intriguing effects arising from the interplay between strong interactions and quantum statistics [2].

[1] M. Inguscio and L. Fallani, Atomic Physics: Precise Measurements and Ultracold Matter, Oxford University Press (2013). [2] G. Pagano et al., A one-dimensional liquid of fermions with tunable spin, Nature Physics (2013, accepted).

Prize Talk A 32.4 Wed 15:30 Kinosaal

Non-equilibrium: from heat transport to turbulence (to life). — •David Ruelle — IHES, 91440 Bures sur Yvette, FRANCE — Laureate of the Max-Planck-Medal

We review some problems in non-equilibrium physics from the point of view of statistical physics and differentiable dynamics. Specifically, we discuss the specific mathematical difficulties which inherently underlie applications to heat transport, to hydrodynamic turbulence, and to the study of life. The microscopic dynamics of transport phenomena (in particular heat transport) is necessarily non hyperbolic, which explains why it is a difficult problem. The 3D turbulent energy cascade can be analyzed formally as a heat flow, and experimental intermittency data indicate that this requires discussing a Hamiltonian system with ~10000 degrees of freedom. Life is a non-equilibrium statistical physics phenomenon which involves chemical reactions and not just transport. Considering life as a problem in non-equilibrium statistical mechanics at least shows how complex and difficult the study of non-equilibrium can be.

A 33: Awards Symposium II (SYAW 2)

Time: Wednesday 16:30–17:30 Location: Kinosaal

Prize Talk A 33.1 Wed 16:30 Kinosaal

Investigation of charge transfer efficiency of CCD image sensors for the scientific small satellite mission "AsteroidFinder" — •Andrej Krimlowski — Deutsches Zentrum für Luft und Raumfahrt — Laureate of the Georg-Simon-Ohm-Prize

Im Rahmen des Projekts AsteriodFinder wurde die Ladungstransporteffizienz von EMCCD-Sensoren des Typs CCD201-20 der Firma e2v technologies PLC vor und nach Bestrahlung mit hochenergetischer Teilchenstrahlung mit einer Dosis von 1,26 10^{10} Protonen/cm^2 bei einer Temperatur von -80°C und einer Bildwiederholungsrate von 5,6 fps gemessen. Insbesondere wurde nach einer Kalibration mit der Fe-55-Methode und einer Photon-Transfer-Kurve der Einfluss einer homogenen Hintergrundbeleuchtung in der Größenordnung des Signallevels von zirka 10 Elektronen auf die durch die Teilchenstrahlung induzierten

Potentialmulden im Gitter des Detektorfestkörpers untersucht, welche die Ladungstransporteffizienz innerhalb von Detektoren erheblich hemmen. Die Messungen zeigten eine signifikante Verbesserung der Transporteffizienz um eine Größenordnung unter Einsatz der Hintergrundbeleuchtung, so dass der bestrahlte Sensor wieder ein vergleichbares Verhalten aufwies wie ein unbestrahlter Sensor gleichen Typs.

Prize Talk A 33.2 Wed 17:00 Kinosaal

Metrology of atomic hydrogen: from the Rydberg constant to the size of the proton — •François Biraben — Laboratoire Kastler Brossel, ENS, CNRS, UPMC, 4 place Jussieu, 75252 Paris Cedex 05, France — Laureate of the Gentner-Kastler-Prize

The hydrogen atom has a central position in the history of 20th-century physics and hydrogen spectroscopy is associated with the successive advances in the understanding of the atomic structure. Thanks to optical frequency measurements and Doppler free techniques, several optical frequencies of hydrogen are now known with a fractional accuracy better than 10-11 and thus it is possible to extract from these data not only the value of the Rydberg constant but also the energy shift due to the finite size of the proton. The value of the proton radius extracted from hydrogen measurements (Rp=0.8764(89)fm [1]) is in agreement with the value deduced from scattering experiments (Rp=0.8791(79) fm [2]). On the contrary these values are in disagreement with the recent result deduced from the measurement of the Lamb shift in muonic hydrogen (Rp=0.84087(39)fm [3]). This discrepancy has renewed the interest in hydrogen spectroscopy. In this lecture, we present the most recent experiments and describe the analysis of the data used to deduce the Rydberg constant, the Lamb shifts and the size of the proton. We report also the recent development of our 1S-3S experiment.

1 P.J. Mohr et al, Rev. Mod. Phys. 84, 1527 (2012).
2 J.C. Bernauer et al, Phys. Rev. Lett. 105, 242001 (2010).
3 A. Antognini et al, Science 339, 417 (2013).

A 34: Poster: Ultra-cold atoms, ions and BEC (with Q)

Time: Wednesday 16:30–18:30 Location: Spree-Palais

A 34.1 Wed 16:30 Spree-Palais

Towards Ultracold Chemistry - Scattering of Ba+ and Rb in an optical dipole trap — •Alexander Lambrecht, Thomas Huber, Michael Zugenmaier, Julian Schmidt, Leon Karpa, and Tobias Schaetz — Albert-Ludwigs-Universität Freiburg

Examining collisions of atoms and ions at extremely low velocities permits to gain information about the corresponding scattering potentials and therefore of quantum effects in chemical reactions. In the last years several experimental groups investigated cold collisions between atoms and ions, leading to better understanding of the atom-ion interaction in many different aspects[1-3]. Our approach to reach the regime of ultracold collisions is to precool a barium+ ion, trapped in a conventional Radio-Frequency (RF) trap, by doppler cooling followed by sympathetic cooling via an ambient rubidium MOT. By spatially overlapping the ion and the atom ensemble within a bichromatic optical dipole trap we overcome the limitations set by heating due to the RF micromotion[4]. We describe the experimental apparatus in its recent stage and the first experiments towards the simultaneous optical trapping of ions and atoms. [1]A.T.Grier, M.Cetina, F.Orucevic and V.Vuletic, Phys.Rev.Lett.102,223201(2009) [2]C.Zipkes, S.Palzer, C.Sias and M.Koehl, nature 464, 388 (2010) [3]W.G.Rellergert, S.T.Sullivan, S.Kotochigova, A.Petrov, K.Chen, S.J.Schowalter and E.R.Hudson, Phys.Ref.Lett. 107,243201 (2011) [4]L.H.Nguyen, A.Kalev, M.D.Barret and B.Engelert, Phys.Rev.A 85,052718 (2012)

A 34.2 Wed 16:30 Spree-Palais

Trapping Ions in a triangular microstructured surface trap — •Henning Kalis, Manuel Mielenz, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs Universität Freiburg

Many quantum systems, that may offer a variety of exotic behaviour are not fully accessible by classical simulations. One approach to overcome this difficulty could be to implement these quantum systems directly and in a well controllable quantum simulator, as proposed by R. Feynman [1]. Geometrical frustration has turned out to be a mechanism for inducing such exotic quantum disordered phases. As a starting point for quantum simulations of these systems we chose the most basic geometry that exhibits frustration, an equilateral triangle. However high-fidelity quantum control of such systems is obligatory and has been demonstrated in linear Paul-Traps (e.g. the quantum simulation of the 1D transverse-field Ising-Model [2,3]). Though high operational fidelity exceeding 99% is currently still restricted to a very limited number of constituents. A promising bottom-up approach for scaling the trapped ion system in size and dimension is based on radiofrequency surface-electrode traps [4], spanning arrays of individual rf-traps with a spacing of 40 micrometer. These surface-electrode traps may thus extend the control to 2D arrays of individual traps (lattices) enabling, in principle, the simulation of 2D Hamiltonians [5]. We will characterize our trapping setup (in collaboration with NIST, Sandia and R.Schmied) and report on the recent experimental results in our triangular trap.

A 34.3 Wed 16:30 Spree-Palais

Towards resolved sideband cooling in an atom-ion hybrid trap — •Joschka Wolf, Artjom Krükow, Arne Härter, Amir Mohammadi, Tobias Schnetzer, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Albert-Einstein Allee 45, 89081 Ulm, Germany

We investigate the properties of a $^{138}Ba^{+}$ ion immersed in a bath of ultracold ^{87} Rb atoms. In the quest for a new level of control of the Ba^{+} ion in our atom-ion apparatus, we want to implement a resolved sideband cooling system. There are some challenges connected to realizing such a system. First a narrow band laser tuned to the $6S_{1/2} \rightarrow 5D_{5/2}$ shelving transition at 1762 nm is needed. To achieve a linewidth much smaller than the typical trapping frequencies of our Paul trap (40 kHz) and a daily frequency drift in the sub kHz regime, we set up a high-Q optical cavity. In order to stabilize the laser to this cavity we need a precise and flexible locking scheme. For this we will use a broadband electro-optical modulator operated in a two-tone configuration [1]. In addition to this shelving laser, we need a second laser resonant to the $5D_{5/2} \rightarrow 6P_{3/2}$ transition in order to deshelve the ion. Employing a sum frequency mixing technique, we will generate the 614 nm light using two high-power lasers at 1064 nm and 1450 nm, respectively. In this poster we show our progress and the capabilities of such a system.

[1] J.I. Thorpe, K.Numata, J.Livas, Opt. Expr. **16** 15980(2008)

A 34.4 Wed 16:30 Spree-Palais

statistical evaluation of ultracold molecular fraction rate — •tomotake yamakoshi[1], shinichi watanabe[1], chen zhang[2,3], and chris greene[2,3] — [1]Department of Engineering Science,University of Electro-Communications, Tokyo, Japan — [2]Department of Physics and JILA, University of Colorado, Colorado, USA — [3]Department of Physics, Purdue University, Indiana, USA

In recent years, various ultracold molecule production experiments have been carried out. Molecules are formed via a field ramp through a Fano-Feshbach resonance (FFR). They are subsequently transferred to the rovibrational ground state by STIRAP with very high efficiency. In this scenario, the final molecule conversion rate is restricted by the FFR fractional conversion. We study the FFR molecular fractional conversion rate using a Monte Carlo simulation based on the stochastic phase space sampling (SPSS) model[1]. The key idea of SPSS is that the phase space volume of atomic pairs does not change during an adiabatic magnetic sweep. We have applied this method to Fermi-Fermi, Bose-Bose, and Bose-Fermi cases, and have compared our SPSS result with that of the equilibrium theory[2]. We have identified some differences between results of the two approaches[3], especially in ultracold regions that have not yet been experimentally realized.

References: [1] E. Hodby et al., Phys. Rev. Lett. 94, 120402 (2005) [2] S. Watabe and T. Nikuni, Phys. Rev. A 77, 013616 (2008). [3] T. Yamakoshi, S. Watanabe, C. Zhang, C. H. Greene, Phys. Rev. A 87, 053604 (2013).

A 34.5 Wed 16:30 Spree-Palais

Quantum breathing frequency of trapped dipolar gases — •Tobias Dornheim, Alexey Filinov, and Michael Bonitz — ITAP, Christian-Albrechts-Universität zu Kiel, Leibnizstraße 15, 24098 Kiel

The quantum breathing mode (BM), i.e. the monopole oscillation of trapped quantum particles, serves as an important method for diagnostics of a variety of finite sized systems [1]. We investigate the BM for harmonically confined bosonic atomic gases with dipole interaction and consider one and two dimensional systems for the whole range of coupling strengths and a variety of particle numbers. We begin our analysis with the ab initio calculation of thermodynamic properties like e.g. energies, superfluid fraction and densities of up to $N \sim 10^3$ trapped particles, using a GPU accelerated realization of the Worm Algorithm Path Integral Monte Carlo scheme [2]. A recently published improved sum rule formalism [3] allows us to obtain an accurate upper bound for the breathing mode frequency. Finally we compare our results to available data for trapped fermions [3] and discuss the influence of Bose- and Fermi-statistics.

[1] C.R. McDonald et al., Phys. Rev. Lett., in press
[2] M. Boninsegni et al., Phys. Rev. E **74**, 036701 (2006)
[3] J.W. Abraham et al., ArXiv e-prints **1311.5371**, (2013)

A 34.6 Wed 16:30 Spree-Palais

Quenching effects in one-dimensional few body ensembles — •Simeon Mistakidis[1], Lushuai Cao[1,2], and Peter Schmelcher[1,2] — [1]Zentrum fur Optische Quantentechnologien, Universitat Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universitat Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Non-equilibrium aspects of few-boson systems in one-dimensional finite lattices are investigated. Starting from the Superfluid regime we drive non-perturbatively the few-body system by sudden interaction quenches. Employing the numerically exact ab-initio Multi-Layer Multi-Configuration time-dependent Hartree method for bosons permits us to realize non-equilibrium simulations. Focussing on the lowlying collective modes of the finite lattice we observe the emergence of tunneling, breathing and dipole processes. In particular the interaction quenches couple the tunneling and dipole modes yielding in this manner resonant phenomena. Finally,complementing the numerical studies an Effective Hamiltonian in terms of the Fock states is derived.

A 34.7 Wed 16:30 Spree-Palais

Classical scattering of charged particles confined on an inhomogeneous helix — •Alexandra Zampetaki[1], Jan Stockhofe[1], Sven Krönke[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

We explore the effects arising due to the coupling of the centre of mass and relative motion of two charged particles confined on an inhomogeneous helix with a locally modified radius. It can be proven that a separation of the centre of mass and the relative motion is provided if and only if the confining manifold represents a homogeneous helix. In this case, bound states of repulsively Coulomb interacting particles occur.

For an inhomogeneous helix, the coupling of the centre of mass and relative motion induces an energy transfer between the collective and relative motion, leading to dissociation of initially bound states in a scattering process. Due to the time reversal symmetry, a binding of the particles out of the scattering continuum is thus equally possible. We identify the regimes of dissociation for different initial conditions and provide an analysis of the underlying phase space via Poincare surfaces of section.

A 34.8 Wed 16:30 Spree-Palais

phase transition of a bosonic binary mixture in state-dependent hexagonal optical lattices — •Lushuai Cao[1,2], Sven Krönke[1], Jan Stockhofe[1], Peter Schmelcher[1,2], Dirk-Sören Lühmann[3], and Ole Jürgensen[3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Institut für Laser-Physik, Universität Hamburg, Hamburg, Germany

We present numerical investigations on the phase transition of a binary bosonic mixture in the state-dependent hexagonal optical lattices, of which the simulations takes into account many-body effects. It has been experimentally [P. S. Panahi, Nat. Phys. 8, 71 (2012)] shown that a binary bosonic mixture possesses a novel phase of Twisted Superfluid, which is characterized by the symmetry breaking in Time-of-Flight measurements. This phase was initially understood with the mean field approximation, by an interband phase difference, while a more extensive mean-field study [S. Choudhury, Phys. Rev. A 87, 033621 (2013)] indicated that there should be no such interband phase difference in the ground state. This work attempts to understand the novel phase with the more exact simulations, taking into account the many-body effects. The many-body simulations are performed via a numerically exact method ML-MCTDHB [S. Krönke, New J. Phys. 15, 063018 (2013), L. Cao, J. Chem. Phys. 139, 134103 (2013)].

A 34.9 Wed 16:30 Spree-Palais

Effects of anisotropy in simple lattice geometries on many-body properties of ultracold fermions in optical lattices — •Anna Golubeva, Andrii Sotnikov, and Walter Hofstetter — Goethe Universität, Frankfurt am Main, Germany

We study the effects of anisotropic hopping amplitudes on quantum phases of ultracold fermions in optical lattices described by the repulsive Fermi-Hubbard model. In particular, using dynamical mean-field theory (DMFT) we investigate the dimensional crossover between the isotropic square and the isotropic cubic lattice.

We analyze the phase transition from the antiferromagnetic to the paramagnetic state and observe a significant change in the critical temperature: Depending on the interaction strength, the anisotropy can lead to both a suppression or increase. We also investigate the localization properties of the system, such as the compressibility and double occupancy.

Using the local density approximation in combination with DMFT we conclude that density profiles can be used to detect the mentioned anisotropy-driven transitions.

A 34.10 Wed 16:30 Spree-Palais

Exotic Quantum Magnetism with cold atoms — •Marie Piraud, Zi Cai, and Ulrich Schollwoeck — Department für Physik, LMU München, Theresienstrasse 37, 80333 München

Strongly interacting ultra-cold atoms in artificial gauge fields can lead to many interesting effects. In the Mott regime for example, effective spin-Hamiltonians can be derived and various magnetic phases appear. In particular, a Dzyaloshinskii-Moriya (DM) Interaction term – which is relevant in the Condensed Matter context – is typically obtained for fermionic or two-component bosonic gases with spin-orbit coupling. We study the spin-Hamiltonians that are obtained in this context using large-scale DMRG simulations in one and two dimensions. The interplay between the exchange and DM interactions lead to ferromagnetic, antiferromagnetic and spiral ordered phases.

A 34.11 Wed 16:30 Spree-Palais

Development of ultrahigh-finesse crossed cavities for a quantum gas experiment — •Moonjoo Lee, Julian Leonard, Andrea Morales, Thomas Karg, Tilman Esslinger, and Tobias Donner — Institute for Quantum Electronics, ETH Zürich, CH-8093 Zürich, Switzerland

Quantum gases coupled to an optical cavity opened a new field for exploring quantum many-body physics with long-range interactions. An additional cavity will provide various possibilities for both the atomic internal and external degrees of freedom based on the interference of two vacuum fields.

We fabricated two independent ultrahigh finesse cavities whose mode axes cross under an angle of 60 degrees. The supermirrors are modified to put them as close as possible in order to obtain the strongest coupling under the given spatial conditions. The machined mirror surfaces have 600 μm width and each cavity has a length of 1.7 mm with 0.5 million finesse. The resulting cavity parameters for a single rubidium atom are $(g, \kappa, \gamma) / 2\pi = (2, 3, 0.15)$ MHz.

We discuss possible future experiments including the measurement of the eigenspectrum of a Bose-Einstein condensate coupled to the two crossed cavities, cavity-vacuum induced transparency, and slow light which might reveal the granular feature of the cavity photons. When the atoms are illuminated by a classical standing wave field, they can self-organize and scatter light from the pump field into both cavities. The emergent dynamical lattice potential will be hexagonal or triangular shape.

A 34.12 Wed 16:30 Spree-Palais

Photoassociation of ultralong-range Rydberg tetramers — •Philipp Ilzhöfer, Anita Gaj, Alexander Krupp, Jonathan Balewski, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

Scattering between a Rydberg electron and ground state atoms can lead to the formation of ultralong-range Rydberg molecules in an ultracold gas. For spherically symmetric Rydberg s-state this was done for principle quantum numbers 35-37 [1]. Here we report on the creation of molecules with higher principle quantum numbers n ranging from 40 to 111 from an ultracold gas of Rb atoms. From the measured binding energies we can precisely determine the electron-atom scattering length. For n=62 and n=71 we observe up to four ground state atoms bound in the Rydberg electron scattering potential. Moreover we can measure Frank Condon factors for the photoassociation of molecular ground and vibrational states. With increasing principle quantum numbers we observe decreasing binding energies, resulting eventually in a broadening and a shift of the spectral lines.

[1] V. Bendkowsky et al., *Nature* **458**, 1005–1008 (2009)

A 34.13 Wed 16:30 Spree-Palais

Curved quantum waveguides: Nonadiabatic couplings and gauge theoretical structure — •Jan Stockhofe[1] and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Germany

We investigate the quantum mechanics of a single particle constrained to move along an arbitrary smooth reference curve by a confinement that is allowed to vary along the waveguide. The Schrödinger equation is evaluated in the adapted coordinate frame and a transverse mode decomposition is performed, taking into account both curvature and torsion effects and the possibility of a cross-section potential that changes along the curve in an arbitrary way. We discuss the adiabatic structure of the problem, and examine nonadiabatic couplings that arise due to the curved geometry, the varying transverse profile and their interplay. The exact multi-mode matrix Hamiltonian is taken as the natural starting point for few-mode approximations. Such approximate equations are provided, and it is worked out how these recover known results for twisting waveguides and can be applied to other types of waveguide designs. The quantum waveguide Hamiltonian is recast into a form that clearly illustrates how it generalizes the Born-Oppenheimer Hamiltonian encountered in molecular physics. In analogy to the latter, we explore the local gauge structure inherent to the quantum waveguide problem and suggest the usefulness of diabatic states, giving an explicit construction of the adiabatic-to-diabatic basis transformation.

A 34.14 Wed 16:30 Spree-Palais

Superfluid atom circuits — •Fred Jendrzejewski, Stephen Eckel, Jeffrey G Lee, Avinash Kumar, Christopher J Lobb, William D Phillips, and Gretchen K Campbell — Joint Quantum Institute, NIST and the University of Maryland

We have created a superfluid atom circuit using a toroidal Bose-Einstein Condensate. Just as a current in a superconducting circuit will flow forever, if a current is created in our superfluid circuit, the flow will not decay as long as the current is below a critical value. A repulsive optical barrier across one side of the torus creates the tunable weak link in the condensate circuit and can be used to control the current around the loop. By rotating the weak link at low rotation rates, we have observed phase slips between well-defined persistent current states. This behavior is analogous to that of a weak link in a superconducting loop. A feature of our system is the ability to dynamically vary the weak link, which in turn varies the critical current, a feature that is difficult to implement in superconducting circuits. For higher rotation rates, we observe a transition to a regime where vortices penetrate the bulk of the condensate. These results demonstrate an important step toward realizing an atomic SQUID analog.

A 34.15 Wed 16:30 Spree-Palais

Measurements of Impurity Coherence in a Fermi Sea by Spin Echo — Marko Cetina[1], •Rianne S. Lous[1,2], Michael Jag[1,2], Florian Schreck[1,3], Rudolf Grimm[1,2], Rasmus S. Christensen[4], and Georg M. Bruun[4] — [1]Insitut für Quantenoptik and Quanteninformation (IQOQI), Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Insitut für Experimental Physik, Universität Innsbruck, Innsbruck, Austria — [3]Institute of Physics, University of Amsterdam, Amsterdam, Netherlands — [4]Department of Physics and Astronomy, University of Aarhus, Aarhus, Denmark

We investigate the decoherence of a fermionic ^{40}K impurity that arises from collisions with a Fermi sea of ^{6}Li using the spin-echo technique. We use a Feshbach resonance to tune the interaction of the impurity with the sea. We measure the decoherence rate of the ^{40}K impurity for various interaction strengths and temperatures. From this, the collision rate of the impurity with the sea can be computed. The results show good agreement with a theory based on the Fermi Liquid picture.

A 34.16 Wed 16:30 Spree-Palais

Towards Creation and Detection of Momentum Entangled Atom Pairs — •Michael Keller[1,2], Mateusz Kotyrba[2], Maximilian Ebner[2], Mario Rusev[2], Johannes Kofler[3], and Anton Zeilinger[1,2] — [1]Institue for Quantum Optics and Quantum Information (IQOQI), Vienna, Austria — [2]University of Vienna, Vienna, Austria — [3]Max-Planck Institute for Quantum Optics, Garching, Germany

We present our work towards the creation and detection of momentum entangled states of metastable helium (He*) atoms.

Starting from a Bose-Einstein condensate (BEC) of metastable helium, stimulated Raman transitions transfer momentum onto the atoms. Subsequent collisions between two counterpropagating matter waves lead to atom pairs that are entangled in their momentum degree of freedom. This state represents a three-dimensional version of the one discussed in the Einstein-Podolsky-Rosen gedankenexperiment.

By using a position resolved micro-channel plate (MCP) detector the high internal energy of the He* atoms of almost 20 eV per atom allows for efficient detection of individual atoms with a high spatial and temporal resolution.

We show that a double double-slit as well as a ghost interference scheme can be used to show the entanglement and that those schemes are feasible with experimental restrictions in our setup. We discuss the main challenges in the experimental realization and present the present status of the experiment.

A 34.17 Wed 16:30 Spree-Palais

The Dynamics of Few-body Dipolar Bosons in the One-dimensional Optical Lattices — •Xiangguo Yin, Lushuai Cao, and Peter Schmelcher — Zentrum für Optische Quantentechnologien, Luruper Chaussee 149, D-22761 Hamburg, Germany

Based on the Multilayer Multi-Configuration Time Dependent Hatree method for bosons, We investigate the dynamics of one-dimensional few-body system composed of bosons with strong dipolar interaction in optical lattices. For the ground state of N bosons in 2N-1 wells, each boson occupies single well without particles in the nearest well, which is like crystal state in solid physics and named crystal-like state. For the ground state of N bosons in 3N-1 wells, each boson occupies two adjacent wells and there is one unoccupied well between each bosons, which is like supersolid state and named supersolid-like state. These two kinds of ground states are set as the initial state and two kinds of local driven potential are taken on one well of optical lattices, including asymmetric tilt potential and symmetric step potential. The vibration, driven by tilt potential, would be transfered from one side to the other side of optical lattices for crystal-like state. While for supersolid-like state, both of driven potential can cause the tunneling of the first particle in two adjacent wells with different amplitude and frequency and the correction induced tunneling of the other particles. However, the frequency of latter tunneling is independent on the shape and amplitude of driven potential.

A 34.18 Wed 16:30 Spree-Palais

Dimensional BCS-BEC Crossover — •Igor Boettcher[1], Jan Martin Pawlowski[1,2], and Christof Wetterich[1] — [1]Institute for Theoretical Physics, Heidelberg University, Germany — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum fuer Schwerionenforschung mbH, Darmstadt, Germany

We investigate how the reduction of spatial dimension influences superfludity of two-component fermion in the BCS-BEC crossover by means of the Functional Renormalization Group. Our approach allows to study the system over the whole parameter space of interaction strength, density, temperature, spin-imbalance, and dimension. The high precision and tunability of recent experiments allows for a solid benchmarking of our description. We present results on the equation of state and the phase diagram as a function of dimension, and compare with recent measurements.

A 34.19 Wed 16:30 Spree-Palais

Trapped-atom interferometry with losses — •Valentin Ivannikov — Swinburne University of Technology, Centre for Atom Optics and Ultrafast Spectroscopy, Australia — Physikalisches Institut, Universität Heidelberg, Germany

An ensemble density matrix model that includes one- and two-body losses is derived for a trapped-atom clock. A trapped-atom clock is mainly affected by one- and two-body losses, generally giving non-exponential decays of populations; nevertheless, three-body recombination is also quantitatively analyzed to demonstrate the boundaries of its practical relevance. The importance of one-body losses is highlighted without which population trapping behaviour would be observed. The model is written with decay constants expressed through experimental parameters. It can complement, e.g., the ISRE (identical spin rotation effect) model to improve its predictions: ISRE dramatically increases the ensemble coherence time, hence it enables one to observe the influence of two-body losses on the interferometry contrast envelope. The presented model is useful for Ramsey interferometry and is ready for immediate experimental verification in existing systems.

In addition, several Ramsey-type interferometry models are presented which include one-body and few-body losses. A way to include ensemble-phase noise to the many-body model due to the rotational property of the Ramsey detection pulse is suggested to avoid the computational complexity of the Markovian simulation.

A 34.20 Wed 16:30 Spree-Palais

Crystallization in dissipative Rydberg lattices — •Wildan Abdussalam[1], Michael Hoenig[2], George Bannasch[1], Michael Fleischhauer[2], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany — [2]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universiteit Kaiserslautern, 67663 Kaiserslautern, Germany

We study two-dimensional lattices of Rydberg atoms with strong van der Waals interactions for configurations in which the competition between coherent laser driving and dissipative processes lead to an inversion of electronic populations. Using Monte Carlo simulations we determine the many-body steady states of this system and identify conditions for the emergence of crystalline phases. Despite the rapid drop of the van der Waals potential the long-range tail of the interaction is shown to qualitatively affect the system behaviour, making simplified nearest-neighbor models inapplicable. Comparisons to previous mean field predictions moreover highlight the importance of classical correlations. Finally, we will discuss different experimental routes to observe the predicted phase transition towards crystalline order.

A 34.21 Wed 16:30 Spree-Palais

Coherently coupled two-component ultracold bosons — •Ulrike Bornheimer, Ivana Vidanovic, and Walter Hofstetter — Goethe Universität, Institut für Theoretische Physik, Max-von-Laue Straße 1, 60438 Frankfurt am Main

We investigate an ultracold, two-component bosonic gas in a cubic optical lattice. In addition to density-density interactions, the atoms are subject to coherent light matter interactions that couple different internal hyperfine states. In the strongly interacting Mott regime, the resulting Bose-Hubbard Model can be mapped onto an effective spin Hamiltonian. We examine the influence of the coherent coupling on the system and its' quantum phases by using Gutzwiller Mean Field as well as Bosonic Dynamical Mean Field Theory.

A 34.22 Wed 16:30 Spree-Palais

Towards atom chips with submicron atom-surface separation — •Amruta Gadge[1], Robert Hollenstein[1,2], Francesco Intravaia[1,3,4], Jessica Maclean[1], Samanta Piano[1], Mark Fromhold[1], Christian Koller[1], and Peter Kruger[1] — [1]Midlands Ultracold Atom Research Centre, School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, UK — [2]Vienna Center for Quantum Science and Technology, TU Wien, Atomistitut, Stadionallee 2 1020 Wien — [3]Institut fuer Physik, Humboldt-Universitaet zu Berlin, Newtonstr. 15, 12489 Berlin, Germany — [4]Max-Born-Institut, 12489 Berlin, Germany

Current atom chip technology enables trapping of atoms at distances of 10-100 microns from the surface. The limitation on the trapping distance arises from distance-dependent effects like surface forces, Johnson noise or fields generated from the adsorbates. Ultra-close trapping of atoms would improve the resolution of cold-atom based surface probes when they are used to map out current distributions and electric and magnetic fields. We are constructing an experimental system to trap atoms very close to the surface, considering relevant effects that can impede trapping at submicron distances. The basis of these experiments is an atom chip incorporating a thin film. We will position an ultracold cloud of Rb87 atoms, above a graphene sheet supported by a TEM grid, which will allow us to control and shift the cloud precisely to specific grid locations. We will compare the losses from the trap when the cloud is above the metal part and the hollow region of the grid. We will show theoretical calculations and experimental progress.

A 34.23 Wed 16:30 Spree-Palais

Artificial gauge fields in a driven optical lattice — •Malte Weinberg[1], Christoph Ölschläger[1], Julian Struck[1], Juliette Simonet[1], Patrick Windpassinger[2], and Klaus Sengstock[1] — [1]Institut für Laserphysik, Universität Hamburg, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany

Atomic quantum gases are neutral, and therefore, not affected by external electromagnetic fields in the way electrons are. This constitutes a central issue towards the quantum simulation of solid state models involving an external magnetic field, e.g. the Quantum Spin Hall Effect. Therefore the experimental realization of artificial gauge fields in ultracold atomic systems shall put through quantum simulators of new kinds of exotic quantum matter.

In this perspective, driven optical lattices constitute a versatile tool, which allows controlling both phase and amplitude of the complex tunneling parameters and, thus, generating artificial gauge potentials [1]. By expanding this concept to a triangular lattice structure, it is possible to realize gauge invariant and fully tunable artificial magnetic fluxes that exhibit a staggered ordering [2].

[1] J. Struck et al., Phys. Rev. Lett. 108, 225304 (2012)
[2] J. Struck et al., Nat. Phys. 9, 738-743 (2013)

A 34.24 Wed 16:30 Spree-Palais

Progress on the Fermi Quantum Microscope — •Timon Hilker[1], Martin Boll[1], Ahmed Omran[1], Thomas Reimann[1], Konrad Viebahn[1], Alexander Keesling[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str.1, 85748 Garching — [2]Ludwig-Maximilians-Universität München, Schellingstr. 4, 80799 München

Ultracold atoms in optical lattices have proven to be a powerful tool for investigating quantum many body systems. Recent experiments have demonstrated the power of single-site resolved detection in optical lattices for the study of strongly correlated bosonic many body systems.

In our experiment we plan to apply similar techniques to fermionic systems. Here, we present our progress towards a fermionic many body system trapped in a 3D optical lattice. Li-6 atoms are cooled to degeneracy using a UV-MOT and a fast optical evaporation. We plan to achieve the imaging of single atoms resolved on individual sites of a 2D plane of the lattice by superimposing an additional small-scale pinning lattice onto the larger-scale physics lattice. This freezes out the distribution of atoms during imaging with a high resolution imaging system, which allows to separate the detector from the physical system under study. Different lattice geometries can thus be studied with single atom sensitivity. In this way we plan to probe the quantum phases of the Fermi-Hubbard Hamiltonian by local measurements, and investigate the underlying phenomena associated with condensed matter systems, e.g. quantum magnetism.

A 34.25 Wed 16:30 Spree-Palais

Stochastic theory of thermal matter fields — •Holger Hauptmann[1], Sigmund Heller[1], Holger Kantz[2], and Walter T. Strunz[1] — [1]Technische Universität Dresden — [2]Max-Planck-Institut für Physik komplexer Systeme

We study quasi one-dimensional ultracold Bose gases with repulsive self interaction. A nonlinear stochastic matter-field equation of generalized Gross-Pitaevskii type will be presented to describe Bose gases in the canonical ensemble (fixed particle number). This might be a more realistic experimental scenario than the grand-canonical approach. Applications of this equation to simulate recent experiments from the Schmiedmayer group [1] will be shown, especially the emergence of correlations in quantum many-body systems. Moreover, results for equilibrium coherence properties of one-dimensional Bose gases will be presented.

[1] Langen et al. Nature Physics 9, 640-643 (2013)

A 34.26 Wed 16:30 Spree-Palais

Nonequilibrium BCS Dynamics of Ultracold Fermi Gases — •Peter Kettmann[1], Simon Hannibal[1], Mihail Croitoru[2], Alexei Vagov[3], Vollrath Martin Axt[3], and Tilmann Kuhn[1] — [1]Institute of Solid State Theory, University of Münster — [2]Condensed Matter Theory, University of Antwerp — [3]Theoretical Physics III, University of Bayreuth

Ultracold Fermi gases are a convenient testbed for complex interacting Fermi systems like, e.g., superconductors. They are on the one hand easily accessible in experiment. On the other hand their interparticle interaction strength can be tuned to pass from a BCS to a BEC state. In this way, many-body effects in strongly correlated Fermi systems like high-Tc superconductors can be tested in a controlled way.

We investigate the BCS phase of an ultracold Fermi gas. In particular we calculate the nonequilibrium dynamics of a confined ^{6}Li gas after a sudden excitation, which can be achieved, e.g., by an abrupt change of an external magnetic field or the system confinement. We show that the dynamics of the BCS gap is given by a collective damped oscillation breaking down after a certain time. Afterwards a rather chaotic oscillation appears. We explain this behavior by expressing the quasiparticle equations of motion in terms of a set of coupled oscillators.

Studying systems with different parameters we see that the dynamics show a more or less pronounced initial part of the oscillation depending on the confinement. This is related to size-dependend superfluid resonances predicted by recent theoretical studies [1] and thus to the BCS-BEC crossover. [1] A. A. Shanenko et al., PRA 86, 033612 (2012)

A 34.27 Wed 16:30 Spree-Palais

Narrow-line laser cooling of dysprosium into an optical dipole trap — •Matthias Schmitt, Thomas Maier, Holger Kadau, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We present our techniques to laser cool dysprosium on a narrow-line transition to achieve suitable conditions to directly load atoms into an optical dipole trap. Dysprosium is the element with the highest magnetic moment and offers a non-spherical symmetric groundstate $^5I_8$. This complex electronic structure leads to several possible cooling and optical pumping transitions. We use a broad cooling transition at 421 nm for Zeeman slowing and capture these atoms in a narrow-line magneto-optical trap using a transition at 626 nm. A transversal cooling stage before the Zeeman slower increases the capture rate by a factor of 4 and atom number by a factor of 3. By using a spectral broadener to increase the capture velocity, we can trap up to $1.2 \cdot 10^8$ atoms and double the capture rate.

To directly load into an optical dipole trap, we compress the magneto optical trap and achieve temperatures of $\sim 10\,\mu$K. We transfer 10 million atoms and subsequently optically transport the cold atom cloud to a glass cell, which offers high optical access. Ongoing work is to increase the phase space density until quantum degeneracy in a crossed optical dipole trap. Future techniques are to implement a high resolution imaging and the possibility to write nearly arbitrary time-averaged potentials with an electro-optical deflector system.

A 34.28 Wed 16:30 Spree-Palais

Single flux quanta observed with ultracold atomic clouds — •Patrizia Weiss, Helge Hattermann, Simon Bernon, Martin Knufinke, Daniel Bothner, Matthias Rudolph, Lörinc Sárkány, Florian Jessen, Petra Vergien, Simon Bell, Reinhold Kleiner, Dieter Koelle, and József Fortágh — Physikalisches Institut and CQ Center for Collective Quantum Phenomena and their Applications, Eberhard-Karls-Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

When superconducting closed loops like a ring are cooled through the superconducting transition ($T_c = 9.2\,$K) in an external field, persistent currents will conserve the magnetic flux inside the ring. This trapped flux is quantized and will be an integer multiple of the magnetic flux quantum $\Phi_0 = 2.067 \times 10^{-15}\,$Tm^2.

We report on the interaction of an atomic cloud with a superconducting ring. We trap atomic clouds of ^{87}Rb in a superconducting magnetic microtrap at 4.2 K and bring the atoms into the vicinity of the ring structure ($R = 10\,\mu$m). The atomic cloud is sensitive to the additional potential generated by the persistent currents in the ring. Changes of single flux quanta Φ_0 can be observed in the atomic density distribution, as well as in the trap shape. The results pave the way towards coupling cold atoms to SQUIDS and the generation of periodic magnetic micropotentials based on persistent currents.

As a further step towards coupling, we will discuss the preparation of cold atomic clouds in a dilution refrigerator [1].

[1] F. Jessen *et. al.*, arXiv:1309.2548

A 34.29 Wed 16:30 Spree-Palais

Towards frustrated systems in a tunable Kagome lattice — •Vincent M. Klinkhamer[1,2], Thomas Barter[2], Claire K. Thomas[2], and Dan M. Stamper-Kurn[2] — [1]Universität Heidelberg, Germany — [2]University of California, Berkeley, USA

We present a revised optical lattice setup and a magnetic field compensation that will improve experimental control of our Kagome lattice experiment. The experiment consists of a ^{87}Rb BEC which is loaded into a tunable optical superlattice. We have studied the geometry-induced phase transition between the superfluid and Mott-insulating phases by continuously varying the lattice from a triangular to a Kagome geometry. Our next goal is to access the third, flat band of the Kagome lattice and study the effects of orbital and spin frustration.

A 34.30 Wed 16:30 Spree-Palais

Towards degenerate Li-Cs mixtures — Sonali Warriar, Asaf Paris Mandoki, Matthew Jones, •Jonathan Nute, Raghavan Kollengode, and Lucia Hackermueller — School of Physics and Astronomy, University of Nottingham, University Park, NG7 2RD, Nottingham, UK

Ultracold mixtures hold the promise of understanding new phases of matter and collisions at very low energies or modelling condensed matter systems. We are setting up an experiment for Bose-Fermi mixtures of lithium and caesium, which are especially well suited to study impurities, transport, solitons or mixtures in optical lattices. These species are appealing because they offer favourable interaction properties and can be manipulated independently of each other due to their different resonance frequencies. Here we present the current status of our experiment. We detail the cooling schemes for the two atomic species and include the development and optimal loading of an optical dipole trap.

A 34.31 Wed 16:30 Spree-Palais

Development of a high power semiconductor based laser source at 493nm for optical trapping of Ba+ ions. — •Tobias Schnetzer, Artjom Krükow, Arne Härter, Amir Mohammadi, Joschka Wolf, and Johannes Hecker Denschlag — Institute for Quantummater, Ulm, Germany

One of the most commonly used tools to trap ions to date are Paul traps. Due to their operating principle trapped particles will undergo a driven micromotion which cannot be cooled. Using optical dipole forces to create a confining potential this micromotion can be circumvented therefore reducing the lower limit of attainable kinetic energies of the trapped ion. In our atom-ion hybrid apparatus we require a common optical trap to confine a single Ba+ together with an ultracold Rb atom cloud at the same time. In this poster we present a home-built semiconductor based laser providing a narrowband multi watt output of near resonant light for the Ba+ ion at 493nm. We discuss our approach to realize a common atom-ion trap where this laser source is key and show our progress.

A 35: Poster: Interaction with VUV and X-ray light

Time: Wednesday 16:30–18:30 Location: Spree-Palais

A 35.1 Wed 16:30 Spree-Palais

Optische Untersuchung ^{229}Th dotierter CaF_2 Kristalle — •Christoph Tscherne, Simon Stellmer, Matthias Schreitl und Thorsten Schumm — Atominstitut, TU Wien, Österreich

Die typischen Energieskalen in der Atomphysik (eV) und Kernphysik (keV-MeV) unterscheiden sich um viele Größenordnungen, sodass eine Vereinbarkeit hinsichtlich der verwendeten Messmethoden nur schwer vorstellbar scheint. Das Isotop Th-229 zeichnet sich jedoch durch einen Isomerzustand aus, der die unter allen Isotopen einzigartig niedrige Anregungsenergie von lediglich 7.8±0.5 eV [1] besitzt. Diese Energie entspricht etwa 160 nm und erlaubt eine Untersuchung des Kernübergangs durch Laserspektroskopie.

Wir nutzen eine hauseigene Kristallzuchtanlage, um Thoriumatome in CaF_2-Kristalle einzubringen. Die dotierten Kristalle werden mit einem Excimer-Laser bei einer Wellenlänge von 157 nm bestrahlt und die UV-induzierten Lumineszenz des Kristalls in ihrem zeitlichen Verhalten und ihrer spektralen Zusammensetzung untersucht. Die gewonnenen Erkenntnisse dienen der weiteren Optimierung des Kristallzüchtungsprozesses und der Charakterisierung von Th:CaF_2-Kristallen als Plattform zukünftiger optischer Uhren.

[1] B. R. Beck et al., Phys. Rev. Lett. 98, 142501 (2007)

A 35.2 Wed 16:30 Spree-Palais

Improving the orientation recovery using diffusion map — •Martin Winter, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme

Upcoming X-ray free electron lasers offer the potential of single-molecule coherent diffractive imaging without prior crystallization of the molecule. Since the molecules are in the gas phase, their orientations vary from shot to shot and the averaging of faint images from similar orientations requires a reliable orientation recovery of each image.

Here we show that such an orientation recovery using diffusion map [1] works only under certain conditions. We diagonalize the Laplace-Beltrami operator, which is approximated by diffusion map, for an ensembles of diffraction patterns from randomly orientated molecules and quantify the breakdown of the orientation recovery. For certain classes of molecules we improve the orientation recovery by hitting the molecule simultaneously from multiple directions or by using more eigenvectors from the diagonalization.

[1] Optics Express, Vol. 20, Issue 12, pp. 12799-12826 (2012)

A 35.3 Wed 16:30 Spree-Palais

Time-domain control of quantum dynamics — •Patrick Reiser, Thomas Pfeifer, and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

A primary tool to investigate structure and dynamics of physical systems is spectroscopy, i.e., the study of light-matter interaction as a function of frequency. Alternatively, the system can be studied in the time domain, and it was shown recently that this complementary view provides a direct avenue to the controlling and interpreting of the underlying quantum dynamics [1]. Here, we present our recent progress in developing novel control techniques in the time domain, which are general and apply to a broad range of target systems across the electromagnetic spectrum. Particular implementations are discussed in attosecond spectroscopy of atomic systems [1] and in x-ray quantum optics with atomic nuclei [2].

[1] C. Ott et al., Science 340, 716 (2013).
[2] K. P. Heeg et al., Phys. Rev. Lett. **111**, 073601 (2013).

A 35.4 Wed 16:30 Spree-Palais

Electron beam ion traps at ultrabrilliant light sources — •Sven Bernitt[1,2], René Steinbrügge[1], Jan Rudolph[1,3], Sascha Epp[4], and José Ramon Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität, Jena, Germany — [3]IAMP, Justus-Liebig-Universität, Gießen, Germany — [4]Max Planck Advanced Study Group, CFEL, Hamburg, Germany

Many plasma properties are determined by the interaction of highly charged ions with photons. In the VUV and X-ray spectral region usually only the time reversed processes were accessible. With the newest generation of ultrabrilliant light sources it is now possible to directly study photonic interactions. We present results obtained with the transportable electron beam ion trap FLASH-EBIT [1], that was used to provide targets of various highly charged ion species for synchrotrons (BESSY II, PETRA III) and free-electron lasers (FLASH, LCLS). By resonantly exciting VUV and X-ray transitions and detecting fluorescence as well as changes in charge state it was possible to precicely measure transition energies, natural line widths, and properties of resonant photoionization. This provides valuable data for astrophysics and allows to test general atomic theory [2,3].

[1] S. W. Epp et al., Phys. Rev. Lett. 98, 183001 (2007). [2] S. Bernitt et al., Nature 492, 225 (2012). [3] J. K. Rudolph et al., Phys. Rev. Lett. 111, 103002 (2013).

A 35.5 Wed 16:30 Spree-Palais

Mössbauer meets Fano at x-ray energies: Controlled line shapes in cooperative emission from nuclei — •Kilian P. Heeg[1], Christian Ott[1], Daniel Schumacher[2], Hans-Christian Wille[2], 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

Control of spectroscopic line shapes at hard x-ray energies is demonstrated in the reflectance of a thin film cavity with embedded Moessbauer nuclei. Tunable Fano interference between a spectrally broad cavity response and a narrow bound state nuclear contribution enables us to switch between Lorentz- and Fano-profiles [1, 2]. Spectroscopic signatures such as the cooperative Lamb shift and superradiant line broadening are extracted from the recorded asymmetric line shapes with high precision and agree excellently with our theoretical model [3]. Our results advance spectroscopy and precision metrology in the hard x-ray domain, and provide access to a multitude of applications linked to Fano interference.

[1] U. Fano, Phys. Rev. **124**, 1866–1878 (1961)
[2] C. Ott et al, Science **340**, 716–720 (2013)
[3] K. P. Heeg, and J. Evers, Phys. Rev. A **88**, 043828 (2013)

A 35.6 Wed 16:30 Spree-Palais

A nuclear polariton with two entangled counter-propagating branches — Wen-Te Liao, •Fabian Lauble, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Recent developments of x-ray optics lay the foundation for controlling the quantum behavior of single x-ray photons. Apart from their potential in the field of quantum information, the probing proficiency of single x-ray quanta would be an appreciated counterpart to traditional imaging techniques with intense x-ray beams. Here we present a setup for generating the special superposition of a simultaneously forward- and backward-propagating collective excitation in a nuclear sample [1]. This can be achieved by actively manipulating the scattering channels of single x-ray quanta with the help of a normal incidence x-ray mirror to create a nuclear polariton which propagates in two opposite directions. The two counter-propagating polariton branches are entangled by a single x-ray photon, while their phase relation can be controlled by the hyperfine magnetic field in the sample either by coherent storage [2] or by magnetic field rotations [3]. The quantum nature of the polariton entanglement gives rise to a sub-Ångstrom wavelength standing wave excitation pattern [1] that can be used as a flexible tool to dynamically probe matter on the atomic scale.

[1] W.-T. Liao and A. Pálffy, arXiv:1308.3121 (2013).
[2] W.-T. Liao, A. Pálffy and C. H. Keitel, Phys. Rev. Lett 109, 197403 (2012).
[3] Y. V. Shvyd'ko et al., Phys. Rev. Lett. 77, 3232 (1996).

A 35.7 Wed 16:30 Spree-Palais

Determination of atomic fundamental parameters for quantitative X-ray fluorescence analysis — •Philipp Hönicke, Martin Gerlach, Michael Kolbe, Matthias Müller, Beatrix Pollakowski, Rainer Unterumsberger, and Burkhard Beckhoff — Physikalisch-Technische Bundesanstalt, Abbestr. 2-12, 10587 Berlin

For a reliable quantitative X-ray fluorescence analysis (XRF) exact knowledge of involved atomic fundamental parameters is essential. These parameters include the mass absorption coefficients and photo ionization cross sections, fluorescence yields, Coster-Kronig transition probabilities and others. In this work, fundamental parameters for several chemical elements have been experimentally determined using the radiometrically calibrated XRF instrumentation of the Physikalisch-Technische Bundesanstalt (PTB). In addition, the dependence of selected fundamental parameters on the chemical species of an element of interest was analyzed using high resolution X-ray emission spectrometry. The experiments were carried out at both the laboratory of the PTB at the electron storage ring BESSY II, where monochromatized synchrotron radiation of high spectral purity up to 10 keV is available and at a wavelength shifter beamline (BAMline) at BESSY where higher photon energies are available. The determination of atomic fundamental parameters with low experimental uncertainties leads to significant improvements in quantitative XRF analysis.

A 35.8 Wed 16:30 Spree-Palais

Single-shot single-cluster measurements of large He nanodroplets irradiated by strong XUV laser pulses — •Bruno Langbehn, Leonie Flückiger, Jan P. Müller, Maria Müller, Yevheniy Ovcharenko, Daniela Rupp, Mario Sauppe, Anatoli Ulmer, and Thomas Möller — TU Berlin

With the advent of novel XUV light sources such as free electron lasers (FELs) imaging of non-periodic objects (nanoparticles, viruses and macromolecules) and studying their ultrafast ionization dynamics has become possible. Therefore a fundamental understanding of the interaction of short wavelength light pulses with matter can be obtained. In particular He clusters and nanodroplets can serve as model systems for studying ionization processes and plasma dynamics due to their simple electronic structure. When irradiated by intense FEL light, highly excited plasma states (far from ground state properties) will be generated and novel ionization channels can be explored.

In order to obtain single shot single cluster data, a He cluster beam will be set up using a pulsed Even-Lavie valve operating at temperatures down to 6 K with repetition rates up to 500 Hz. Large He nanodroplets ($\langle N \rangle \geq 10^6$) will be generated using extreme nozzle geometries to record high quality scattering patterns as well as ion and electron spectra simultaneously in experiments at XUV-FELs such as FERMI and FLASH.

A 35.9 Wed 16:30 Spree-Palais

Soft X-ray emission spectrometry of titanium oxide nanonlayers with an efficient wavelength dispersive spectrometer
— •Rainer Unterumsberger, Matthias Müller, and Burkhard Beckhoff — Physikalisch-Technische Bundesanstalt, Abbestr. 2-12, 10587 Berlin

In this work the sensitivity of a calibrated grating spectrometer [1] was improved to analyze nanolayers of different titanium oxides with soft X-ray Emission Spectrometry (XES). The improvement up to a factor of 5 was achieved by a single bounce monocapillary, which is focusing monochromatized soft X-ray undulator radiation down to the micrometer range [2]. Using this set-up, the chemical species was successfully obtained for different titanium compounds by XES. In addition, the transition probabilities of the L-fluorescence lines after an ionization of the L3 subshell were determined. The measurements were carried out at the plane-grating monochromator beamline in the PTB laboratory at BESSY II using monochromatized undulator radiation and calibrated instrumentation [3].

References

[1] M. Müller et al., Phys. Rev. A 79, 032503 (2009)

[2] R. Unterumsberger et al., Spectrochimica Acta Part B 78 (2012) 37-41

[3] B. Beckhoff, J. Anal. At. Spectrom. 23, 845 (2008)

A 35.10 Wed 16:30 Spree-Palais

DESC: A multilayer based delay stage for CAMP at the FEL FLASH enables time-resolved experiments from fs to 100 ps range.
— •Mario Sauppe[1], Jan P. Müller[1], Daniel Rolles[2], Rolf Treusch[2], Authors as in[3], Daniela Rupp[1], and Thomas Möller[1] — [1]IOAP, TU Berlin — [2]DESY — [3][1]

Brilliant light pulses from short wavelength free-electron lasers allow the investigation of nanosized particles with a very high temporal and spatial resolution. Radiation damage leads to fast destruction of the investigated objects. Ionization processes which dramatically change the electronic structure of the target objects take place on the fs timescale. Ionic motion, on the other hand, may start during the interaction with the pulse but can reach into a 100 ps range. In order to investigate the complex dynamics of radiation damage in nanosized particles on all relevant time scales, the **DE**lay **S**tage for **C**AMP *DESC* will be set up at the free-electron laser FLASH.

For splitting and delaying the light pulses, DESC will be based on highly reflective multilayer plane mirrors, e.g. for 13.5 nm but also other wavelengths are possible. Delays will be available from about 0 fs up to 600 ps with a femtosecond resolution due to high precision closed loop stages. After DESC, the double pulse can be focused by a Kirkpatrick-Baez optic, leading to extremely intense light pulses in a micrometer spot in the **C**FEL-**A**SG **M**ulti **P**urpose chamber *CAMP* [1]. The poster gives an overview of DESC and introduces challenges in the design.

[1] L. Strüder et al., Nucl. Instr. Meth. Phys. Res. A **614** (2010) 483.

A 35.11 Wed 16:30 Spree-Palais

CAMP - a Permanent User Endstation for X-Ray Imaging and Pump-Probe Experiments at FLASH
— •Daniel Rolles[1], Benjamin Erk[1], Robert Moshammer[2], Jan P. Müller[3], Thomas Möller[3], and the CAMP collaboration[1,2,3] — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany — [3]Technische Universität Berlin, Berlin, Germany

CAMP is a multi-purpose instrument optimized for imaging and pump-probe experiments with Free-Electron Lasers (FELs) that was developed in the Max Planck Advanced Study Group at the Center for Free-Electron Laser Science (CFEL) in Hamburg [1] and that was employed at the LCLS, FLASH, and SACLA FELs for the last four years. It offers a choice of large-area, single-photon counting X-ray pnCCD imaging detectors as well as various charged particle spectrometers for electron and ion imaging and coincidence experiments. CAMP is now being installed at FLASH BL1, which is being equipped with new micro-focusing KB optics, to become a permanent endstation available to all users. Here we present an overview of the layout and capabilities of this new endstation.

[1] L. Strüder et al., Nucl. Instr. Meth. Phys. Res. A. 614, 483 (2010)

A 35.12 Wed 16:30 Spree-Palais

Measuring Molecular-Frame Photoelectron Angular Distributions at High Kinetic Energies.
— •Evgeny Savelyev[1], Cedric Bomme[1], Denis Anielski[1,2], Benjamin Erk[1], Rebecca Boll[1,2], and Daniel Rolles[1] — [1]Deutsches Elektronen-Synchrotron(DESY), Hamburg, Germany. — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany.

We have built a new double-sided velocity map imaging (VMI) spectrometer optimized for electron-ion coincidence measurements to determine molecular-frame photoelectron angular distributions (MFPADs) for photoelectrons with kinetic energies up to 300 eV. It was employed for the first time at the gas-phase beamline P04 at PETRA to record the MFPADs after inner-shell photoionization of several halogenated carbon compounds. We will present and discuss the results of these measurements along with describing the design of the new spectrometer.

A 35.13 Wed 16:30 Spree-Palais

Direct excitation of s-p E1 transitions in Ir^{17+}
— •Alexander Windberger[1], Oscar O. Versolato[2], Hendrik Bekker[1], Sven Bernitt[1], Stepan Dobrodey[1], Rene Steinbrügge[1], Lisa Schmöger[2], Joachim Ullrich[2], Zoltan Harman[1], Natalia Oreshkina[1], Christoph Keitel[1], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Leibniz Universität, Hannover

Due to its electronic configuration displaying near degeneracies of 4f and 5s levels, the Ir^{17+} ion offers a quantum system of particular interest for the study of a possible variation of the fine structure constant at the highest sensitivity. It offers transitions in the optical domain that appear to be excellently suited for high-precision metrology. Disentangling its complex structure is beyond current theoretical capabilities, and therefore spectroscopy in the optical and VUV regime using electron impact excitation is a first step toward those goals. We carry out such measurements at 5 ppm (200 ppm) accuracy in the optical (VUV) regime with an electron beam ion trap (EBIT), and complement them with direct excitation of E1 allowed s-p transitions of both ground state configurations using photonic excitation by means of VUV synchrotron radiation. A campaign at BESSY II with FLASH-EBIT will allow for spectroscopy in the relevant 30-100 eV range that will improve accuracy by at least a factor of 10 and identify the ground state transitions. The experimental requirements for fluorescence detection in the VUV range under magnetic trapping conditions will be presented.

A 35.14 Wed 16:30 Spree-Palais

Multi-photon ionization processes in rare gases
— •Sadegh Bakhtiarzadeh[1,2], Tommaso Mazza[1], Markus Ilchen[1], and Michael Meyer[1] — [1]European XFEL GmbH, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany

Interaction of photons with matter has been subject to studies for a long time. Recently, it has entered a new area with the availability of intense VUV or X-ray Free Electron Lasers (FEL), where the short wavelength radiation can couple efficiently to inner electronic shells of the atoms. In this regards, we have performed a series of experiments on rare gases, especially Ar and Xe, using three different photon energies (105, 123 and 140 eV) from FLASH, Hamburg, Germany. Using a multilayer mirror the FEL beam was focused to a spot size of 5 μm diameter, i.e. intensities in the order of 10^{14} W/cm^2 could be reached. Under such high intensities, different ionization processes can happen, of which the most important are the two-photon sequential as well as the two-photon direct ionization. The relative importance of the individual channels has been investigated by energy-resolved electron spectroscopy. As additional proof for the non-linearity of the process the intensity dependence of the electron emission was monitored. For the expected quadratic dependence of the two-photon processes, an exponent smaller than 2 was generally observed. This can be explained by the extended acceptance angle in the experiment requiring proper volume integration, i.e. a careful consideration of regions with different intensities.

A 35.15 Wed 16:30 Spree-Palais

Time-resolved Measurement of Interatomic Coulombic Decay in Ne_2 at FLASH — •Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Artem Rudenko[2], Lutz Foucar[3], Georg Schmid[1], Thomas Pfeifer[1], Kristina Meyer[1], Denis Anielski[1], Rebecca Boll[1], Daniel Rolles[4], Matthias Kübel[5], Matthias Kling[2,5], Simona Scheit[6], Vitaly Averbukh[7], Joachim Ullrich[8], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]MPI für Kernphysik, Heidelberg — [2]J.R. Macdonald Laboratory, Kansas — [3]MPI für medizinische Forschung, Heidelberg — [4]DESY, Hamburg — [5]MPI für Quantenoptik, Garching — [6]Goethe-Universität, Frankfurt — [7]Imperial College, London — [8]PTB, Braunschweig

Interatomic Coulombic Decay (ICD) is a radiationless decay mechanism in weakly bound systems, where an excited atom relaxes via an energy transfer to a van-der-Waals–bound neighbour, which then emits an electron. The process has been theoretically predicted and experimentally confirmed in clusters and molecules. The lifetime of ICD is a crucial parameter for understanding the underlying mechanism. Here, we present the first direct time-resolved measurement of an ICD lifetime, applying an XUV pump-probe scheme to the neon dimer Ne_2. A 58 eV pump pulse of approximately 60 fs length creates a $2s$ hole, initiating the decay process, which is probed after an adjustable time delay by an exact copy of the first pulse. Whether or not ICD has happened by the time the probe pulse impinges, leads to the population of different energy levels. The resulting fragmentation channels are separated by means of a Reaction Microscope.

A 35.16 Wed 16:30 Spree-Palais

VUV Studies on Doped Helium Nanodroplets — •Raphael Katzy[1], Aaron LaForge[1], Michele Alagia[6], Lorenzo Avaldi[2], Carlo Callegari[3], Marcello Coreno[2], Michele Devetta[4], Marcel Drabbels[5], Antti Kivimaki[2], Viktor Lyamayev[7], Tommaso Mazza[7], Thomas Möller[8], Marcel Mudrich[1], Yevheniy Ovcharenko[8], Paolo Piseri[4], Kevin Prince[3], Robert Richter[3], Frank Stienkemeier[1], Stefano Stranges[9], and Michele DiFraia[10] — [1]Universität Freiburg, Germany — [2]CNR-IMIP Rome, Italy — [3]Sincrotrone Trieste, Italy — [4]Univerity of Milan, Italy — [5]EPFL Lausanne, Switzerland — [6]CNR-IOM Trieste, Italy — [7]European XFEL GmbH, Germany — [8]Technische Universität Berlin, Germany — [9]University of Rome "Sapienza", Italy — [10]University of Trieste

We performed measurements on doped helium nanodroplets by VUV-seeded FEL FERMI@Elettra.

In the strong field of the FEL clusters gain large amounts of enegy leading to highly excited and ionized states. Nanoplasma is formed and finally leads to a Coulomb explosion of the cluster. Going to short wavelengths in the XUV range the the plasma formation is not uniform anymore. Utilizing doped clusters we observe strong ionization at the surface while in the center of the cluster plasma formation is reduced due to recombination.

A 36: Ultra-cold atoms, ions and BEC IV (with Q)

Time: Thursday 10:30–12:30 Location: BEBEL E34

A 36.1 Thu 10:30 BEBEL E34

Manipulation and Coherence of Ultracold Atoms in Superconducting Coplanar Resonator — •Helge Hattermann, Simon Bernon, Patrizia Weiss, Martin Knufinke, Daniel Bothner, Matthias Rudolph, Reinhold Kleiner, Dieter Koelle, and József Fortágh — Physikalisches Institut and CQ Center for Collective Quantum Phenomena and their Applications, Eberhard-Karls-Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

Superconducting circuits in the microwave regime are promising candidates for quantum information processing. However, their coherence times are still limited to 100 μs. A possible solution is to create a hybrid quantum system, in which the quantum information is processed by superconducting circuits and the information is coherently transferred and stored in a second quantum system. Due to their long coherence times, ultracold atoms coupled to a superconducting resonator are suitable for such a quantum memory.

Here we report on the preparation and coherence of atomic ensembles in a superconducting coplanar resonator on an atom chip based on niobium thin films at 4.2 K. Atoms are trapped by persistent currents in the resonator ground planes. The coherence of atomic superposition states is investigated by means of Ramsey interferometry. We find atomic coherence times on the order of several seconds. We report on progress towards coupling of the atoms to the mode of a cavity.

S. Bernon *et. al.*, Nat. Commun. **4**, 2380 (2013)

A 36.2 Thu 10:45 BEBEL E34

Measuring the resistive flow above the critical current in an atomic superfluid — •Fred Jendrzejewski, Stephen Eckel, Christopher J. Lobb, William D. Phillips, and Gretchen K. Campbell — Joint Quantum Institute, NIST and the University of Maryland

A superfluid current between two reservoirs, i.e. a source and drain, is persistent even without an external chemical potential difference between the reservoirs. However, above a critical current the superfluid flow becomes unstable and excitations are created, leading to resistive flow. To sustain such a dissipative current, an external chemical potential difference between the source and the drain must be applied.

In this presentation we report on the direct observation of both superfluid and resistive flow through a weak link in a weakly interacting atomic BEC. In our superfluid system, two weak links are used to divide a ring-shaped trap into two regions. Moving the weak links at a constant rate, allows for the creation of controlled flow between the source and the drain. Above a critical value of the weak link velocity, we observe a chemical potential difference between the distinct reservoirs which increases as a function of time. The observed time evolution can be well described in terms of a phenomenological theory incorporating explicitly the creation of excitations in form of phase slips. Such transport measurements will allow for a study of the microscopic origin of the dissipation and paves the way for more complex atomtronic devices like atomic DC squids.

A 36.3 Thu 11:00 BEBEL E34

Field ionization of rubidium atoms near nanotips — •Markus Stecker, Peter Federsel, Hannah Schefzyk, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

Detection of correlations in ultracold quantum gases requires a well suited local single atom detection scheme. For this purpose, we investigate the possibility of using charged nanotips. Due to the strong field enhancement at the tip apex, low voltages are sufficient to field ionize nearby rubidium atoms. As the ionization volume is on the length scale of the tip radius and the ions are detected with single particle resolution, this scheme should allow for local, in-situ investigation of ultracold atomic clouds.

We present the first steps towards this new detection scheme. Using a pulsed electrochemical etching technique, we produce sharp tungsten tips with variable length and nanometer sized tip radii. The field enhancement of the tip is characterized by electron field emission measurements. We demonstrate field ionization of rubidium at a single charged nanotip and investigate adsorption effects. As a next step, cold magneto-optically trapped atoms are ionized close to a tungsten nanotip.

A 36.4 Thu 11:15 BEBEL E34

Towards Graphene Atom Chips — •Christian Koller[1], Amruta Gadge[1], Robert Hollenstein[1,2], Samanta Piana[1], Jessica Maclean[1], Francesco Intravaia[1,3,4], Mark Fromhold[1], and Peter Krueger[1] — [1]MIdlands Ultracold Atom Research Center, UNiversity of Nottingham, NG7 2RD, Nottingham, UK — [2]Vienna Center for Quantum Science and Technology, TU Wien, Atominstitut, Stadionallee 2, 1020 Wie — [3]Max-Born-Institut, 12489 Berlin, Germany — [4]Institut fuer Physik, Humboldt-Universitaet zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

Current atom chip technology enables trapping of atoms at distances of 10-100 microns from the surface. The limitation on the trapping distance arises from distance-dependent effects like surface forces, Johnson noise or fields generated from the adsorbates. Ultra-close trapping of atoms would improve the resolution of cold-atom based surface probes when they are used to map out current distributions and electric and magnetic fields. We are constructing an experimental system to trap atoms very close to the surface, considering relevant effects that can impede trapping at submicron distances. The basis of these experiments is an atom chip incorporating a thin film. We will position an ultracold cloud of Rb87 atoms, above a graphene sheet supported by a TEM grid, which will allow us to control and shift the cloud precisely to specific grid locations. We will compare the losses from the trap when the cloud is above the metal part and the hollow region of the grid. We will show theoretical calculations and experimental progress.

A 36.5 Thu 11:30 BEBEL E34

Excited-state quantum phase transitions in Dicke superradiance models — •Tobias Brandes — TU Berlin

We derive analytical results [1] for various quantities related to the excited-state quantum phase transitions in a class of Dicke superradiance models in the semiclassical limit. Based on a calculation of a partition sum restricted to Dicke states, we discuss the singular behavior of the derivative of the density of states and find observables such as the mean (atomic) inversion and the boson (photon) number and its fluctuations at arbitrary energies. Criticality depends on energy and a parameter that quantifies the relative weight of rotating versus counterrotating terms, and we find a close analogy to the logarithmic and jump-type nonanalyticities known from the Lipkin-Meshkov-Glick model.

[1] T. Brandes, Phys. Rev. E 88, 032133 (2013).

A 36.6 Thu 11:45 BEBEL E34

Observation of atom-ion charge transfer beyond the Langevin regime — •Amir Mohammadi, Artjom Krükow, Arne Härter, Tobias Schnetzer, Joschka Wolf, and Johannes Hecker Denschlag — Universität Ulm, Institut für Quantenmaterie, Albert-Einstein-Allee 45, D-89069 Ulm, Deutschland

We investigate the interaction of a laser-cooled trapped ion ($^{138}Ba^+$ or $^{87}Rb^+$) with an ultracold cloud of optically confined ^{87}Rb atoms. The ion is held in a linear Paul trap and is immersed in the center of the cold atomic cloud. Due to the interaction potential $\frac{1}{r^4}$ charge transfer collisions usually occur at an energy independent rate [1]. This leads to an energy independent charge transfer rate which has been confirmed experimentally [2, 3]. In our experiments we observe a deviation from this behavior as we find strong energy dependence in the charge transfer rate at kinetic energies in the sub-mK range. At these very low kinetic energies an additional charge transfer channel opens up due to the increasing importance of three-body atom-atom-ion recombination [4]. We present first experimental findings of this novel charge transfer mechanism.

[1] P. Langevin, Ann. Chim. Phys. **5**, 245 (1905)
[2] Andrew T. Grier *et al.*, Phys. Rev. Lett. **102**, 223201 (2009)
[3] Felix H. J. Hall *et al.*, Phys. Rev. Lett. **107**, 243202 (2011)
[4] Arne Härter *et al.*, Phys. Rev. Lett. **109**, 123201 (2012)

A 36.7 Thu 12:00 BEBEL E34

Excited state quantum phase transition in the kicked top — •Victor M. Bastidas[1], Pedro Perez-Fernandez[2], Malte Vogl[1], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Departamento de Fisica Aplicada III, Escuela Superior de Ingenieros, Universidad de Sevilla, Camino de los Descubrimientos s/n, ES-41092 Sevilla, Spain

Our aim in this talk is to describe the excited state quantum phase transition in the quasienergy spectrum of the kicked top. Using a semiclassical approach, we analytically obtain a logarithmic divergence in the density of states, which is a hallmark of a continuous excited state quantum phase transition. We propose a protocol to observe signatures of the phase transition close to the critical quasienergy.

A 36.8 Thu 12:15 BEBEL E34

Noise driven transition in nonlinear lattices — •Alexandru Nicolin and Mihaela Carina Raportaru — Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Reactorului 30, Magurele, Romania

The classical Fermi-Pasta-Ulam problem is considered in the context of stochastic stability to show that spatially periodic states that are Lyapunov stable are unstable with respect to stochastic perturbations. We present detailed numerical simulations to show the collapse of the periodic states onto the fundamental states due to stochastic perturbations. Our results are directly relevant for Bose-Einstein condensates loaded into optical lattices where such periodic states have already been realised experimentally and their stability with respect to the interaction with the thermal cloud is yet uncharted territory.

A 37: Electron scattering and recombination

Time: Thursday 10:30–12:30 Location: BEBEL E42

Invited Talk A 37.1 Thu 10:30 BEBEL E42

Electron-impact ionization of highly-charged heavy ions relevant for plasma applications — •Alexander Borovik — Institut für Atom- und Molekülphysik, Universität Giessen

Accurate data on atomic processes are of crucial importance for the correct description and understanding of ionized-matter environments. The need for the huge amount of data on electron-impact ionization cross sections and plasma rate coefficients required for plasma modeling can only be met by theoretical calculations. However, for many-electron systems like heavy ions, an extremely complicated pattern of atomic processes makes the task to correctly predict the cross-sections and plasma-rate-coefficients challenging. An experimental approach, on the other hand, can give accurate data but only with a limited coverage of the required data amount and also has inherent limitations. We present a detailed study of electron-impact ionization cross-sections for highly-charged heavy ions involving both the measured results obtained from crossed-beam experiments and theoretical data calculated with the configuration-averaged distorted wave method. The combination of theory and experiment allows us to infer accurate plasma rate coefficients for plasma physics applications.

A 37.2 Thu 11:00 BEBEL E42

First systematic measurement of the photon emission anisotropy following resonant recombination into highly charged ions — •Chintan Shah[1], Pedro Amaro[1], René Steinbrügge[2], Sven Bernitt[2], Zoltan Harman[2,3], Stephan Fritzsche[4,5], Andrey Surzhykov[4,5], José Ramón Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institut, Heidelberg, Germany — [2]Max-Planck-Institut für Kernphysik Heidelberg, Germany — [3]ExtreMe Matter Institute, Darmstadt, Germany — [4]Helmholtz-Institut, Jena, Germany — [5]GSI, Darmstadt, Germany

We report the first systematic measurement of the photon angular distribution in the inter-shell dielectronic and higher-order resonant electron recombination into highly charged ions. Iron and krypton ions in the He-like through O-like charge states were produced in an electron beam ion trap, and the electron beam energy was scanned over the K-shell dielectronic and higher-order recombination resonances. Improving on earlier work [1, 2], the photons emitted in the decay of the resonance states were simultaneously recorded by two germanium detectors which were mounted both along and perpendicular to the electron beam propagation direction. The measured photon emission asymmetries indicate the alignment of the total angular momentum of each resonance state with respect to the beam axis. The results can be used to benchmark atomic calculations, and can be applied for polarization diagnostics of hot astrophysical and laboratory fusion plasmas. [1] C. Beilmann et al., Phys. Rev. Lett. 107, 143201(2011) [2] C.Beilmann et al., Phys. Rev. A 88, 062706(2013)

A 37.3 Thu 11:15 BEBEL E42

Polarization of bremsstrahlung photons in coincidence

(e, e', γ) **studies** — •Robert A. Müller[1,2], Vladimir A. Yerokhin[3], and Andrey Surzhykov[1] — [1]Helmholtz-Institut Jena — [2]Universität Jena — [3]St. Petersburg State Polytechnical University

In atomic bremsstrahlung the scattering of an electron by an atomic field is accompanied by the emission of a photon. The polarization of this photon has been studied in detail both in theory and experiment during the last years [1,2]. In most of these studies, however, the scattered electron remained unobserved. Owing to recent experimental advances, a new generation of studies becomes feasible in which the photon polarization is detected in coincidence with the electron scattering angle. First steps towards these coincidence experiments have been done for low- and medium-Z targets [3]. Moreover experiments are planned for the high-Z domain. Therefore we present in this contribution the theoretical study of the polarization of bremsstrahlung photons observed together with the scattered electrons. We applied the density matrix approach and pertubation theory to perform calculations for electrons with an energy of 100keV up to 500keV scattered by gold targets. The electron scattering angle shows a strong influence on the polarization properties of the photon, especially in comparison to the case when the scattered electron is not observed.

[1] R. Märtin et al., Phys. Rev. Lett. **108**, 264801 (2012)
[2] V. A. Yerokhin and A. Surzhykov, Phys. Rev. A **82**, 062702 (2010)
[3] W. Nakel, Radiat. Phys. Chem. **75**, 1164 (2006)

A 37.4 Thu 11:30 BEBEL E42

Giant Effect of the Spin-Orbit Interaction in Coulomb Scattering — •Oleksiy Kovtun[1], Stanislav Tashenov[1], Valery Tioukine[2], Andrey Surzhykov[1,3,4], and Vladimir Yerokhin[1,4,5] — [1]Physikalisches Institut der Universität Heidelberg, Germany — [2]Institut für Kernphysik Johannes Gutenberg-Universität Mainz, Germany — [3]Helmholtz-Institut Jena, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [5]Center for Advanced Studies, St. Petersburg State Polytechnical University, Russia

Coulomb scattering of an electron in the field of the nucleus is influenced by the spin-orbit interaction. Due to the orbital momentum precession the electron trajectory is not confined to a single scattering plane as evidenced by the recent bremsstrahlung experiments. In that the angle of bremsstrahlung linear polarization is correlated with the spin direction of the incoming electron [S. Tashenov PRL 107, 173201 (2011), R. Maertin PRL 108, 264801 (2012)]. In the recent experiment we found this effect to be dramatically enhanced at relativistic energies. The scattering plane was turning by as much as several tenth of degrees. The results are in agreement with the full-order relativistic calculations. For this experiment we applied the novel techniques of the pulse shape analysis of the germanium detector signals and gammaray Compton imaging. The principles of the Compton imaging were invented in 1973 and our experiment marked their first application in a laboratory physics experiment.

A 37.5 Thu 11:45 BEBEL E42

Pair production and annihilation via nuclear resonances in atoms and ions — •Nikolay A. Belov and Zoltan Harman — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Processes connected with pair production and annihilation in atoms and ions are theoretically investigated. These include nuclear excitation by resonance positron annihilation (NERPA) and nuclear-resonant e^-e^+ pair creation in heavy ion collisions. Possible experimental schemes are put forward for the observation of these reactions. NERPA is an alternative channel of positron-matter interaction, with potential relevance in cosmic ray studies, medical positron emission tomography research, in experimental investigations of nuclear chain reactions, and in star evolution simulations. It also constitutes a novel means for the energy-selective excitation of nuclei. In heavy ion collisions, the Coulomb-excited nucleus may decay by a creation of a free-free or bound-free e^-e^+ pair. Thus, it is an additional, resonant channel of pair creation in nucleus-nucleus collisions, an experimental investigation of which is projected at the FAIR facility.

A 37.6 Thu 12:00 BEBEL E42

Spin-dependent Kapitza-Dirac diffraction in a two-color laser field — •Matthias Maximilian Dellweg and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

The Kapitza-Dirac effect [1] is the diffraction of an electron beam on the periodic potential generated by a standing light wave. An experimental verification of the effect, as originally proposed, was accomplished only recently [2]. Spin effects due to 3-photon interaction have been predicted for X-ray photons [3].

We study a generalization of the Kapitza-Dirac effect to the case of a bifrequent light field, which allows 3-photon interactions to occur even in the nonrelativistic regime. To this end, we solve the Pauli equation numerically for the relevant momentum eigenstates, and compare the results with fourth order perturbation theory.

[1] P. L. Kapitza, P. A. M. Dirac, Proc. Cambridge Philos. Soc. **29**, 297-300 (1933)
[2] D. L. Freimund, K. Aflatooni, H. Batelaan, Nature **413**, 142-143 (2001)
[3] S. Ahrens, H. Bauke, C. H. Keitel, C. Müller, Phys. Rev. Lett. **109**, 043601 (2012)

A 37.7 Thu 12:15 BEBEL E42

Interaction of relativistic electron vortex beams with few-cycle laser pulses — •Armen Hayrapetyan[1,2], Oliver Matula[1,3], Andrea Aiello[2,4], Andrey Surzhykov[5], and Stephan Fritzsche[5,6] — [1]Universität Heidelberg, 69120 Heidelberg, Germany — [2]Max-Planck-Institut für die Physik des Lichts, 91058 Erlangen, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [4]Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [5]Helmholtz-Institut Jena, 07743 Jena, Germany — [6]Universität Jena, 07743 Jena, Germany

We have studied the interaction of relativistic electron vortex beams (EVBs) with laser light. Exact analytical solutions for this problem are obtained by employing the Dirac-Volkov wave-functions to describe the (monoenergetic) distribution of the electrons in vortex beams with well-defined orbital angular momentum (OAM). Our new solutions explicitly show that the OAM components of the laser field couple to the total angular momentum of the electrons. When the field is switched off, it is shown that the laser-driven EVB coincides with the field-free EVB as reported by Bliokh et al. [Phys. Rev. Lett. 107, 174802 (2011)]. Moreover, we calculate the probability density for finding an electron in the beam profile and demonstrate that the center of the beam is shifted with respect to the center of the field-free EVB. This shift is unavoidably accompanied with an azimuthal dependence of the electronic probability density distribution and can be an important observable that manifests itself in the interaction of the twisted electrons with laser pulses.

A 38: Atomic clusters (with MO)

Time: Thursday 10:30–12:30 Location: BEBEL E44/46

Invited Talk A 38.1 Thu 10:30 BEBEL E44/46

Unusual electron dynamics in He clusters induced by intense XUV pulses — •Yevheniy Ovcharenko[1], Aaron LaForge[2], Victor Lyamayev[3], Raphael Katzy[2], Patrick O'Keeffe[4], Oksana Plekan[5], Paola Finetti[5], Robert Richter[5], Kevin Prince[5], Marcel Drabbels[6], Carlo Callegari[5], Frank Stienkemeier[2], and Thomas Möller[1] — [1]IOAP, TU-Berlin, Germany — [2]Physikalisches Institut, Universität Freiburg, Germany — [3]European XFEL, Hamburg, Germany — [4]CNR IMIP, Monterotondo Scalo, Italy — [5]Elettra-Sincrotrone Trieste, Basovizza, Italy — [6]EPFL, Lausanne, Switzerland

The investigation of complex atomic and molecular systems in intense IR and XUV pulses has attracted considerable attention during the last decade, since it leads to a better understanding of light matter interaction. Recently, the first seeded Free Electron Laser FERMI became available for users and now offers unique possibility to perform detailed investigations in such systems due to the narrow bandwidth, fine energy tunability and high intensity in XUV energy range. By using this new source the ionization dynamics in He clusters has been explored with electron spectroscopy in a wide energy range. In addition to the conventional sequential multi-step ionization with a photon energy well above the first ionization potential (IP) a novel ionization process following resonant excitation below IP was observed. It is due to autoionization of two or more electronically excited cluster atoms as predicted recently [1]. The process is very efficient and can exceed the rate of direct photoionization above IP.[1] A.I. Kuleff et al., PRL 105, 043004 (2010)

A 38.2 Thu 11:00 BEBEL E44/46

Detecting interatomic Coulombic decay in neon clusters by photon measurement — •Andreas Hans[1], A. Knie[1], M. Förstel[2], P. Schmidt[1], P. Reiss[1], T. Jahnke[3], R. Dörner[3], A. I. Kuleff[4], L. S. Cederbaum[4], P. V. Demekhin[1], U. Hergenhahn[2], and A. Ehresmann[1] — [1]Institut f. Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [2]Max-Planck-Institut f. Plasmaphysik, c/o HZB-Bessy II, Albert-Einstein Str. 15, 12489 Berlin — [3]Institut f. Kernphysik, Goethe Universität, Max-von-Laue-Str. 1, 60438 Frankfurt — [4]Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg

The role of interatomic Coulombic decay (ICD) in biological context is currently discussed due to anticipated genotoxic effects of low energy electrons typically produced in non-local autoionization processes. All unambiguous experimental observations of ICD so far relied on the detection of charged decay products. The further investigation of the biological relevance by this methods is constrained, since the mean free travel path of charged particles in dense media (e.g. biological samples) usually is very short. A complementary detection method for ICD, applicable to dense media, is therefore required. Here, we report the first unequivocal proof of ICD by measurements of fluorescence emission from neon clusters. In a proof of principle experiment, photon and electron emission of a supersonic neon cluster jet were measured simultaneously. Furthermore it is shown that the photon signal of clusters can easily be discriminated from the monomer's signal by its characteristic resonant excitation energies and lifetime measurements.

A 38.3 Thu 11:15 BEBEL E44/46

Electron re-localization dynamics in Xenon clusters under intense XUV pump-probe excitation — •M. Arbeiter, Ch. Peltz, and Th. Fennel — Institute of Physics, University of Rostock

Intense and temporally structured light fields from free-electron lasers enable the time-resolved investigation of ionization dynamics in finite systems at shortwavelength, as demonstrated in a recent femtosecond XUV pump-probe experiment on Xenon clusters [1] at FLASH. Subpicosecond relaxation dynamics in the XUV driven cluster nanoplasma are revealed via the delay dependent charge states of emitted atomic ions. Our semiclassical molecular dynamics study reveals that the process of electron re-localization in the ionized cluster is key to understand the delay-dependent ion charge states [2]. We show that nanoplasma expansion cooling rapidly diminishes three-body-recombinations within a few picoseconds leading to a bimodal electron energy distribution of strongly bound electrons (re-localized) and weakly bound (quasifree, Rydberg-like). A suitable criterion to account for electron re-localization is found by microscopic analysis of the local quasi continuum between neighboring atoms, leading to an appropriate definition of effective ion charge states. A systematic pump-probe analysis reveals that electron re-localization provides a fingerprint of electron cooling and nanoplasma rarefaction through cluster expansion and yield a good qualitative agreement with the observed experimental findings [1].

[1] M. Krikunova et al. J. Phys. B 45, 105101 (2012)
[2] M. Arbeiter, Ch. Peltz, Th. Fennel, to be submitted

A 38.4 Thu 11:30 BEBEL E44/46

Explosion of heteronuclear clusters irradiated by strong X-ray pulses — •Pierfrancesco Di Cintio, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany

By means of N-body simulations we study the ion and electron dynamics in molecular first-row hydride clusters when exposed to intense and short X-ray pulses [1]. We find that, for a particular range of X-ray intensities, fast protons are ejected from the system on a considerably shorter time scale than that of the screened core. As a consequence, the structure of heavy atoms is kept "intact", which may be relevant in the context of X-ray based molecular imaging. Moreover the final charge states of the heavy ions are considerably lower than those of the ions in pristine atomic clusters exposed to the same laser pulses, which is in agreement with recent measurement of CH_4 cluster at the LCLS in Stanford.

[1] P. Di Cintio, U. Saalmann & J.M. Rost, Phys. Rev. Lett. 111, 3401 (2013)

A 38.5 Thu 11:45 BEBEL E44/46

THz field streaking implemented to studies of rare gas clusters — •T Oelze[1], B Schütte[2], M Müller[1], J P Müller[1], M Sauppe[1], L Flückiger[1], D Rupp[1], M Wieland[3], U Frühling[3], A Al-Shemmary[4], N Stojanovic[4], T Möller[1], M Drescher[3], and M Krikunova[1] — [1]IOAP TU Berlin — [2]MBI — [3]IEXP Uni Hamburg — [4]HASYLAB@DESY

Coherent, ultrashort and high flux photon pulses in the short-wavelength regime from free-electron lasers enable a wide range of experiments to study the interaction between light and matter with high spacial and temporal resolution. In our experiment at FLASH rare gas clusters were used as size-scalable model systems and were irradiated by XUV pulses at 92 eV in the presence of a THz field. At the beginning of the FEL pulse photoionized electrons escape the cluster leaving a positive charge behind. As a result further electron emission becomes frustrated and an electron nanoplasma is formed. Field-driven streaking camera allows to study how the temporal structure of the electron photoemission is altered by the cluster environment. In this approach the momentum of emitted electrons is changed according to the phase of the electric field of the THz radiation. Photoelectron spectra taken at different phases of the THz field are then used to create streaking spectrograms. From these spectrograms the temporal structure of the electron photoemission can be reconstructed providing insight into the nanoplasma formation.

A 38.6 Thu 12:00 BEBEL E44/46

Laser-induced delayed electron emission of metal cluster anions — •Christian Breitenfeldt[1], Klaus Blaum[2], Sebastian George[2], Michael Lange[2], Sebastian Menk[2], Christian Meyer[2], Lutz Schweikhard[1], and Andreas Wolf[2] — [1]Institut für Physik, Ernst-Moritz-Arndt Universität, 17487 Greifswald, Germany — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Radiative cooling is a fundamental process that determines the internal temperature of vibrationally excited ions as a function of time, eventually bringing them into thermal equilibrium with their environment. We have investigated the cooling of Cu_n^- (n=4,5,6,7) and Co_n^- (n=3,4) anions in a crygenic electrostatic trap. The cluster ions were produced in a Cs sputter ion source, with a vibrational excitation corresponding to temperatures of several thousand Kelvins. They were then size-selected and transferred to the Cryogenic Trap for Fast ion beams CTF located at the Max-Planck-Institut fr Kernphysik within 120 μs. They were stored at a kinetic energy of 6 keV. This electrostatic ion beam trap can be operated at a temperature below 15 K by a closed-cycle helium refrigeration system. The extremely low pressure (few 10^{-12}mbar) achieved by cryopumping resulted in a very low background of collision-induced ion loss and thus a beam lifetime of several minutes. We have studied vibrational autodetachment (also called delayed detachment) by recording the rate of neutral particles escaping from the trap as a function of the delay after the pulses from a laser emitting at wavelengths of 600 to 1300 nm.

A 38.7 Thu 12:15 BEBEL E44/46

Real-time observation of recombination in clusters exposed to intense HHG pulses — •Bernd Schütte[1], Mathias Arbeiter[2], Thomas Fennel[2], Filippo Campi[3], Marc J. J. Vrakking[1], and Arnaud Rouzée[1] — [1]Max-Born-Institut, Berlin, Germany — [2]Universität Rostock, Germany — [3]Lund University, Sweden

High-order harmonic generation (HHG) sources provide light pulses in the extreme-ultraviolet (XUV) spectral range with unique properties including a large wavelength tunability, extremely short pulses down to the attosecond range and a straightforward manner in which pump-probe measurements can be performed. Here we demonstrate that the advantageous features of HHG in combination with the velocity map imaging (VMI) technique lead to a significant improvement in the understanding of cluster dynamics.

The observation of very low kinetic energy electrons from rare-gas clusters exposed to intense HHG pulses is attributed to electron-ion recombination processes to Rydberg states in the expanding nanoplasma. Their subsequent reionization with the DC detector electric field known as frustrated recombination is observed experimentally for the first time. Moreover, using a time-delayed visible or infrared pulse, we investigate the recombination dynamics of quasifree electrons to atomic excited states during the nanoplasma expansion, a method termed reionization of excited atoms from recombination (REAR). In addition, we show that REAR can be used as a sensitive probe for tracing the cluster expansion up to the nanosecond range.

A 39: Precision spectroscopy of atoms and ions IV (with Q)

Time: Thursday 10:30–12:30 Location: BEBEL SR140/142

A 39.1 Thu 10:30 BEBEL SR140/142

Highly-sensitive image-current detection systems for BASE — •Christian Smorra[1], Kurt Alan Franke[1,2], Andreas Mooser[3], Hiroki Nagahama[1,4], Georg Ludwig Schneider[1,3], Klaus Blaum[2], Yasuyuki Matsuda[4], Christian Ospelkaus[5], Wolfgang Quint[6], Jochen Walz[3], Yasunori Yamazaki[7], and Stefan Ulmer[1] — [1]RIKEN, Ulmer IRU, Japan — [2]MPI-K Heidelberg, Germany — [3]University of Mainz, Germany — [4]Tokyo University, Japan — [5]University of Hannover, Germany — [6]GSI Darmstadt, Germany — [7]RIKEN, APL, Japan

The BASE collaboration aims for a ppb measurement of the antiproton magnetic moment by using the so-called double Penning-trap technique. Key components for this measurement are superconducting single-particle image-current detection systems for the determination of the antiproton's motional eigenfrequencies. BASE focused on improving the state-of-the-art detection systems in order to achieve a better signal-to-noise ratio for the axial detection systems and shorter resistive cooling time constants for the cyclotron detectors. Benefits are a higher spin-state detection fidelity, shorter measurement times, faster cooling cycles and lower effective particle temperatures.

The talk gives an overview on the design and characterization of our recenty developed detection systems. Compared to previously used detectors, a factor of five higher signal-to-noise ratio was achieved and the cyclotron cooling times were significantly reduced.

A 39.2 Thu 10:45 BEBEL SR140/142

Kryogene Detektionselektronik für das ALPHATRAP Experiment — •Andreas Weigel[1,2], Marko Turkalj Oreskovic[1,2], Christian Roux[1], Robert Wolf[1], Sven Sturm[1] und Klaus Blaum[1,2] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Fakultät für Physik, Universität Heidelberg, 69120 Heidelberg, Germany

Das ALPHATRAP-Projekt ist ein neues g-Faktor Penningfallenexperiment, das sich derzeit am Max-Planck-Institut für Kernphysik Heidelberg in der Aufbauphase befindet. Es ist der Nachfolger des Mainzer g-Faktor-Experiments, mit dem kürzlich der bisher empfindlichste Test der Quantenelektrodynamik an wasserstoffähnlichem ^{28}Si durchgeführt wurde. Ziel von ALPHATRAP sind g-Faktor-Messungen an den schwersten hochgeladenen Ionen, bis hin zu wasserstoffähnlichem Blei, bei einer gleichzeitig verbesserten Messgenauigkeit. Dies soll dazu beitragen, die Grenzen der Gültigkeit der QED gebundener Zustände noch weiter auszuloten.

Die Bestimmung des g-Faktors basiert auf der nichtdestruktiven Bestimmung des Quantenzustandes des Elektronenspins mittels des kontinuierlichen Stern-Gerlach Effektes in einer magnetischen Flasche. Dazu muss die Axialfrequenz des Ions über die Detektion von Spiegelströmen, die das Teilchen in den Fallenelektroden induziert, gemessen werden. Diese Ströme liegen typischerweise im Bereich von einigen fA, weshalb es einer sehr rauscharmen kryogenen Detektionselektronik bedarf. Design und Test der kryogenen Detektionselektronik werden vorgestellt.

A 39.3 Thu 11:00 BEBEL SR140/142

Development of cryogenic components for the ALPHATRAP experiment — •Marko Turkalj Oreskovic, Andreas Weigel, Christian Roux, Robert Wolf, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, Heidelberg

At the Max-Planck-Institute for Nuclear Physics, Heidelberg, a Penning trap experiment for the determination of the g-factor of the bound electron in heavy highly-charged ions is under construction.

ALPHATRAP will be connected to an EBIT via a room temperature beam-line. Since trapping of highly-charged ions requires extremely good vacuum, in excess of 10-15 mbar, the external flow of the background gas from the room-temperature beam-line has to be reduced significantly. Therefore, a cryogenic vacuum valve was developed, which enables adequate storage times. The valve can reduce the rest-gas pressure by a factor of at least 400, is manually actuated, and operates at cryogenic temperatures as well as in strong magnetic fields.

Furthermore, for the image-current detection electronics a cryogenic electromechanical switch and a variable capacitor are developed. Advantages compared to solid state devices are negligible leakage currents for the switch being in open position and negligible dielectric losses. The switch is designed as a single pole single throw switch and has a residual resistance of only 11 mOhm.

The designs and first test results of the devices will be presented.

A 39.4 Thu 11:15 BEBEL SR140/142

Systematic laser-spectroscopic investigations of the La spectrum — •Tobias Binder[1], Bettina Gamper[1], Jerzey Dembczynski[2], and Laurentius Windholz[1] — [1]Institut für Experimentalphysk, TU Graz, Petersgasse 16, A-8010 Graz, Österreich — [2]Chair of Quantum Engineering and Metrology, TU Poznan, Pl-60-965 Poznan, Polan

While performing laser excitation of transitions within the spectrum of Lanthanum atoms, we quite often realized that excitation is possible even at wavelengths for that no emission lines are known. Thus we made a continuous laser scan over a wide spectral range: from 5833 to 5650 Å. Within this region we found, using optogalvanic detection, several hundreds of transitions, most of them up to now unknown combinations between already known energy levels. Moreover, several lines could not be interpreted and did lead to the discovery of new, up to now unknown energy levels. In several cases we had to correct existing levels in their J-value. The final goal of the investigations is a semi-empirical interpretation of the La levels in order to find their designations and wave-function compositions.

A 39.5 Thu 11:30 BEBEL SR140/142

EUV spectroscopy of Re, Os, Ir, and Pt near the $4f-5s$ level crossing — •Hendrik Bekker[1], Oscar O. Versolato[2], Alexander Windberger[1], Ruben Schupp[1], Zoltan Harman[1], Natalya Oreshkina[1], Piet O. Schmidt[2,3], Joachim Ullrich[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik — [2]Physikalisch-Technische Bundesanstalt — [3]Leibniz Universität Hannover

Understanding the electronic level structure of the $4f-5s$ crossing in highly charged ions is a challenging goal for both atomic theory and experiment. Complex electron correlations make calculations cumbersome, producing results with an accuracy which is not sufficient for unambiguous identification of the plethora of observed transitions. We employ an electron beam ion trap to prepare Re, Os, Ir, and Pt ions in charge states 13+ to 20+. Transitions in the extreme-ultra-violet (EUV) range are studied with a grating spectrometer. The first identification step is to determine the charge state to which the transitions belong. For that we apply two independent methods, yielding agreeing values. We then tentatively match observed transitions to atomic theory predictions. The results provide a benchmark for atomic theory in the area of highly correlated systems. A better understanding of the Ir^{17+} level structure is required for future laser spectroscopy studies of a possible variation of the fine-structure constant. Photon excitation measurements on the thus far observed transitions are planned at BESSY II.

A 39.6 Thu 11:45 BEBEL SR140/142

New even and odd energy levels of the La atom — Bettina Gamper[1], Tobias Binder[1], Feyza Güzelcimen[2], Gönül Basar[2], Sophie Kröger[3], and •Laurentius Windholz[1] — [1]Institut für Experimentalphysk, TU Graz, Petersgasse 16, A-8010 Graz, Österreich — [2]Istanbul University, Faculty of Science, Physics Department, Tr-34134 Vezneciler, Istanbul, Turkey — [3]Hochschule für Technik und Wissenschaft Berlin, Fachbereich 1, Wilhelminenhofstr. 75A, D-12459 Berlin, Deutschland

The investigation of structures in the optogalvanic spectrum of La, which can not be interpreted as transitions between known energy levels, may lead to the discovery of up to now unknown energy levels. Usually, the lowering of the fluorescence intensity of a strong La line marks the lower level of the excited transition, and the new upper level energy can be calculated using the centre of gravity excitation wave number. However, to be sure that the level really exists, some additional excitations from other known lower levels are necessary. Levels found in Graz, performing excitation in the wavelength range 690-560 nm, are confirmed in Istanbul by means of a Ti:Sa laser system (720-950 nm).

A 39.7 Thu 12:00 BEBEL SR140/142

Metallic Magnetic Calorimeters for High-Resolution X-ray Spectroscopy — •D. Hengstler[1], C. Schötz[1], M. Krantz[1], J. Geist[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], R. Märtin[2], G. Weber[2], T. Gassner[2], and Th. Stöhlker[2] — [1]Kirchhoff-Institut, Uni Heidelberg — [2]Helmholtz-Institut, Jena

We are presently commissioning maXs, an 8x8 detector array of metallic magnetic calorimeters for high resolution X-ray spectroscopy. The detector is operated at T = 20 mK and is attached to the tip of a 400 mm long and 80 mm wide cold finger of a cryogen-free ^{3}He/^{4}He-dilution refrigerator. Metallic magnetic calorimeters are particle detectors that convert the energy of a single incoming photon into a temperature rise, leading to a change of magnetization in an attached paramagnetic temperature sensor that is inductively read out by a SQUID magnetometer. Three different arrays, maXs-20, maXs-30 and maXs-200, optimized for X-rays with energies up to 20, 30 and 200 keV respectively, will be available. The cryogenic platform will also allow to operate polar-maXs, a novel high resolution Compton polarimeter which comprises active low-Z Compton scatterer surrounded by a belt of about 60 maXs-type detector pixels with high stopping power. In the ongoing commissioning phase single channel maXs-20 detectors achieved an energy resolution of 1.6 eV (FWHM) for 6 keV photons, which is unsurpassed by any other micro-calorimeter. The combination with the fast signal rise-time, the large dynamic range and the excellent linearity up to tens of keV of photon energy, will make maXs to a powerful spectrometer for a number of challenging experiments.

A 39.8 Thu 12:15 BEBEL SR140/142

An absolute, high-precision ^{3}He / Cs combined magnetometer — •Hans-Christian Koch[1,2], Antoine Weis[1], and Werner Heil[2] — [1]Université de Fribourg, Département de Physique, Chemin du musée 3, 1700 Fribourg (Switzerland) — [2]Johannes Gutenberg Universität Mainz, Institut für Physik, Staudingerweg 7, 55128 Mainz (Germany)

Many experiments in fundamental science, such as the search for the neutron electric dipole moment (nEDM) at PSI, Switzerland, demand precise measurement and control of an applied magnetic field. Here, we report on a combined ^{3}He-Cs magnetometer for absolute measurement of a μT magnetic field with a precision of better than 10^{-6}. The measurement principle relies on detection of the precession frequency of polarized ^{3}He atoms by optically pumped double-resonance Mx-Cesium magnetometers. Measurements at the magnetically shielded room of PTB, Berlin, have been conducted to investigate the performance and intrinsic sensitivity of the combined device.

A 40: Interaction with strong or short laser pulses III

Time: Thursday 14:00–16:00 Location: BEBEL E34

A 40.1 Thu 14:00 BEBEL E34

Time-dependent renormalized natural orbital theory applied to correlated two-electron dynamics — •Martins Brics, Julius Rapp, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

Time-dependent density functional theory (TDDFT) with practicable exchange-correlation functionals fails in capturing highly correlated electron dynamics. In particular, the description of doubly-excited states requires exchange-correlation functionals with memory, which are both unknown and numerically unfavorable. Time-dependent renormalized natural orbital theory (TDRNOT) [1] is a promising approach to circumvent this problem while still overcoming the so-called “exponential wall”. In TDRNOT, the renormalized eigenfunctions of the one-body reduced density matrix, natural orbitals, are the basic variables (instead of the single-particle density, as in TDDFT).

The laser-driven two-electron spin-singlet system is known to be the “worst case” testing ground for TDDFT. Therefore we employ the widely used, numerically exactly solvable, one-dimensional helium model atom (in a laser field) to benchmark the TDRNOT approach. The method is almost as inexpensive numerically as adiabatic TDDFT, but is capable of describing correlated phenomena such as doubly excited states, autoionization, Fano profiles in the photoelectron spectra, and resonant processes such as Rabi oscillations.

[1] M. Brics, D. Bauer, Phys. Rev. A **88**, 052514 (2013).

A 40.2 Thu 14:15 BEBEL E34

Challenges in the application of time-dependent renormalized natural orbital theory (TDRNOT) — •Julius Rapp, Martins Brics, and Dieter Bauer — Institut für Physik, Universität Rostock

Time-dependent renormalized natural orbital theory (TDRNOT) is a promising approach to describe correlated electron quantum dynamics, even beyond linear response. It has been shown that it captures phenomena [1] utterly unaccessible by time-dependent density functional theory (TDDFT) using practicable and known exchange-correlation functionals.

After an introduction to TDRNOT, we address current challenges in the numerical solution of the TDRNOT equations of motion for the renormalized natural orbitals. In particular, we investigate the effect of (1) the truncation to a finite number of orbitals and (2) the splitting of the time propagator. Despite these two major issues, TDRNOT results for the widely-used one-dimensional helium model (in both singlet and triplet configuration) are clearly superior to those obtained by any practicable TDDFT approach [2].

[1] M. Brics, D. Bauer, Phys. Rev. A **88**, 052514 (2013).
[2] J. Rapp, M. Brics, D. Bauer (submitted).

A 40.3 Thu 14:30 BEBEL E34

Strong-field Kapitza-Dirac Scattering of Neutral Atoms — •Sebastian Eilzer, Henri Zimmermann, and Ulli Eichmann — Max-Born-Institut for Nonlinear Optics und Short Pulse Spectroscopy, Berlin, Germany

Laser induced strong-field phenomena in atoms and molecules on the femtosecond time scale have been almost exclusively investigated with traveling wave fields. Most observed phenomena are well explained in the dipole approximation which, however, reduces the field to a purely electric field oscillating in time. Spatially dependent electromagnetic fields, e.g., in a standing light wave, allow for strong energy and momentum transfer. We report a strong-field version of the Kapitza-Dirac effect for neutral atoms where we scatter neutral He atoms in an intense short pulse standing light wave with femtosecond duration and intensities well in the strong-field tunneling regime. We observe substantial longitudinal momentum transfer concomitant with an unprecedented atomic photon scattering rate greater than $10^{16}s^{-1}$.

A 40.4 Thu 14:45 BEBEL E34

On the transient optical response of atomic gases — •Michael Hofmann and Carsten Bree — Weierstrass Institute, Berlin, Germany

Femtosecond filaments are strings of intense laser light and dilute plasma in transparent dielectrics. They maintain high intensities and small beamwaists along several times the Rayleigh length, making them powerful tools for remote spectroscopy, supercontinuum generation, or femtosecond LIDAR. In 2009, an experiment [1] challenged our understanding of the physics underlying filamentation, leading to a still unresolved debate about the very nature of the optical nonlinearities that maintain filamentation.

It has recently been indicated that the main shortcomings of the standard model of filamentation are related to the perturbative, purely phenomenological treatment of the optical nonlinearities. Therefore, the controversy can only be settled by a fully quantum mechanical treatment of the atomic optical response. Here, we present a numerical method enabling us to compute the transient optical response of hydrogen-like atoms subject to strong laser fields, based on numerically solving the time dependent Schrödinger equation. This method allows us to calculate transient absorption spectra, and the impact of

Autler-Townes and dynamical AC-Stark atomic level splitting therein. In particular, we discuss the contribution of laser-dressed atomic states [2] to the optical response.

[1] Loriot et al. 2009 Optics Express 17, pp. 13429-13434
[2] Richter et al. 2013 New J. Phys. 15 083012

A 40.5 Thu 15:00 BEBEL E34

Compton scattering of X-ray photons assisted by a strong laser pulse — •Daniel Seipt[1,2] and Burkhard Kämpfer[2,3] — [1]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden — [3]TU Dresden, Institut für Theoretische Physik, 01062 Dresden

The presence of a strong optical laser pulse modifies the spectral distribution and polarization properties of hard X-ray photons scattered off free electrons. We discuss this process of laser assisted Compton scattering, taking into account the finite pulse length of both the high-intensity laser and the X-rays. Side-bands emerge in the energy spectrum via non-linear frequency mixing and multi-photon effects are amplified by the large frequency ratio. Up to 1000 laser photons can be scattered together with an X-ray photon—the side-bands form a broad plateau of several keV width—for laser intensities of 10^{18} W/cm^2. The photons in the side-bands experience a polarization rotation due to the non-linear mixing of X-ray and laser photons.

A 40.6 Thu 15:15 BEBEL E34

Strong-field gas excitation and EUV light generation in plasmonic nanostructures — •Murat Sivis, Frederik Busse, and Claus Ropers — IV. Physical Institute, University of Göttingen, Göttingen, Germany

Spatial confinement of electromagnetic fields in tailored plasmonic nanostructures allows for the enhancement of a variety of high-order nonlinear optical phenomena using low-energy laser pulses at MHz repetition rates. Here, we present a detailed study of extreme-ultraviolet (EUV) light generation in noble gases employing bowtie-antennas and tapered hollow waveguides for field-enhancement. In contrast to former expectations [1], we do not observe any signature of coherent high harmonic generation. Instead, we identify atomic and ionic fluorescence induced by multiphoton or strong-fieldgas excitation and ionization as the predominant mechanisms of EUV light generation in such plasmon-assisted scenarios [2,3]. Furthermore, we discuss novel nonlinear effects such as the formation of a waveguide nanoplasma exhibiting a strong bistability, manifest as a pronounced intensity- and pressure-dependent hysteresis in the fluorescence signal. These observations lead to a deeper understanding of nanostructure-enhanced gas excitations and EUV light generation, representing an intriguing link between strong-field physics, plasma dynamics and ultrafast nano-optics.

[1] S. Kim *et al.*, Nature **453**, 757 (2008).
[2] M. Sivis *et al.*, Nature **485**, E1 (2012).
[3] M. Sivis and C. Ropers, Phys. Rev. Lett. **111**, 085001 (2013).

A 40.7 Thu 15:30 BEBEL E34

Signatures of minicharged particles and paraphotons in a high-intensity laser field — •Selym Villalba Chavez and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

Polarimetric experiments in the field of a high-intensity laser wave are illuminating scenarios from which the low energy frontiers of the standard model can be investigated. Particularly, the occurrence of extra $U(1)$ symmetries implies the existence of both hidden-photons called paraphotons and light minicharged particles. We show how the absorption and dispersion of probe photons in the vacuum polarized by a high-intensity circularly polarized laser field are modified due to the coupling between the visible electromagnetic sector and these hypothetical degrees of freedom. The result of this analysis reveals that – in such a background – only the regime close to the two-photon reaction can be a sensitive probe of these hidden particles. Parameters of modern laser systems are used to impose stringent constraints on the respective coupling constants in regions where experiments driven by dipole magnets are less constricted.

[1] S. Villalba-Chavez and C. Müller, Ann. Phys. **339**, 460 (2013).

A 40.8 Thu 15:45 BEBEL E34

Strongly enhanced pair production in combined high- and low-frequency laser fields — •Martin J.A. Jansen and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Creation of electron-positron pairs resulting from the decay of high-energy probe photons traveling in high-intensity laser fields is investigated [1]. The rate of the strong-field Breit-Wheeler process is shown to be strongly enhanced by the application of an additional laser mode with high-frequency but low amplitude, which effectively lowers the energetic barrier of the process. Our calculations are carried out non-perturbatively in an experimentally accessible regime.

[1] M.J.A. Jansen and C. Müller, Phys. Rev. A 88, 052125 (2013)

A 41: Interaction with VUV and X-ray light II

Time: Thursday 14:00–16:00 Location: BEBEL E42

Invited Talk A 41.1 Thu 14:00 BEBEL E42

Quantum systems in ultra-strong lasers: from tunnel ionization to spin dynamics — •Heiko Bauke[1], Sven Ahrens[1], Michael Klaiber[1], Enderalp Yakaboylu[1], Karen Z. Hatsagortsyan[1], Carsten Müller[1,2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

We extend the well-known tunneling picture of a scalar tunneling barrier into the relativistic domain, that is where the laser's magnetic field becomes non-negligible and, therefore, requiring a non-zero vector potential. Going beyond the quasistatic WKB approximation and employing numerical methods allows us to identify two time scales of relativistic tunneling, the typical time that characterizes the probability density's decay of the ionizing electron under the barrier (Keldysh time) and the time interval which the electron spends inside the barrier (Eisenbud-Wigner-Smith tunneling time) [1]. Finally, we will consider spin effects in tunnel ionization [2] and demonstrate distinct spin dynamics in the relativistic Kapitza-Dirac effect [3] and for electrons moving in strong circularly polarized laser fields.

[1] Phys. Rev. Lett., **110**, 153004 (2013); E. Yakaboylu et al., arXiv:1309.0610; Proc. of SPIE, **8780**, 87801Q (2013)

[2] M. Klaiber et al., arXiv:1305.5379

[3] Phys. Rev. Lett. **109**, 043601 (2012); Phys. Rev. A, **88**, 012115 (2013).

A 41.2 Thu 14:30 BEBEL E42

Time-resolved spectroscopy and coherent control of autoionizing states in neon — •Thomas Ding, Christian Ott, Andreas Kaldun, Alexander Blättermann, Kristina Meyer, Martin Laux, Veit Stooss, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The understanding of few- or many-electron dynamics represents a central topic of modern quantum mechanics. Information about the concerted motion of two or more bound electrons in atoms is encoded in the spectral resonance line shapes. In the experiment presented here we achieved coherent control of short-lived (femtosecond-domain) auto-ionizing wave-packet dynamics in neon (Z=10). Our transient absorption scheme involves a two-color two-photon pump step to coherently populate both spectroscopically bright (odd parity) and dark states (even parity) at the same time. This makes use of weak broadband atto-second-pulsed light in the extreme ultraviolet (XUV) energy range to excite the system into various doubly- and inner-valence-excited states lying ~ 45 eV above the even-parity ground state. Moderately strong few-cycle near-infrared (NIR) pulses simultaneously facilitate the one-photon population transfer from those excited bright states to dark states. We study the initiated wave-packet oscillation under the influence of a time-delay-controlled and intensity-controlled replica of the NIR pump pulse inducing transient bright/dark level-couplings. This provides the opportunity to perform spectroscopy on dipole-forbidden states. Also, the method in principle allows to extract the coupling strength (dipole-matrix element) between quantum states.

A 41.3 Thu 14:45 BEBEL E42

Inelastic X-ray Scattering in Single Molecule Imaging with Free-Electron Lasers — •Jan Malte Slowik[1,2,3], Gopal Dixit[1,3], Sang-Kil Son[1,3], and Robin Santra[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 Centre for Ultrafast Imaging, Hamburg, Germany

Imaging of the structure of bio-macromolecules with atomic resolution is essential to comprehend their function. Because many proteins do not form crystals, it would be enormously beneficial to be able to image single molecules. Free-electron lasers (FEL) offer an ideal tool to image nanocrystals and single-molecules with atomic resolution. The structural information is contained in the elastic x-ray scattering signal. However, in contrast to crystallography, in single molecule imaging there are no Bragg reflections, which means the elastic scattering is not enhanced. Because the usual scattering detectors cannot distinguish between elastically or inelastically scattered photons, the quality of the signal is attenuated by inelastic scattering. Here, we present a study of inelastic x-ray scattering under typical single molecule imaging conditions. We show the scattering spectrum as well as elastic and inelastic scattering probabilities, using the example of a carbon atom. Furthermore, we include the radiation damage caused by the highly intense FEL x-ray pulse by solving a rate equation model. In this way we obtain the elastic and inelastic scattering patterns of a carbon atom for different pulse durations and fluences.

A 41.4 Thu 15:00 BEBEL E42

Dominant secondary nuclear photoexcitation with the XFEL — •Jonas Gunst[1], Yuri A. Litvinov[2], Christoph H. Keitel[1], and Adriana Pálffy[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]GSI Helmholtzzentrum, Darmstadt

The highly brilliant photon beams provided by x–ray free electron lasers (XFEL) are expected to strongly advance the resonant driving of nuclei embedded in solid–state targets. Concurrently, the high electric field intensities may also generate new states of matter like cold, high density plasmas [1] where secondary nuclear excitation processes via the coupling to the atomic shell are rendered possible. Here, we investigate at the example of ^{93m}Mo isomer triggering the nuclear excitation by electron capture (NEEC) as secondary process in an XFEL scenario explicitly designed for direct photoexcitation.

In ^{93m}Mo triggering the isomeric energy of 2.4 MeV could be released via a 4.85 keV transition to an above lying level connected to freely radiating states. Our results prove that the triggering via NEEC is orders of magnitude higher than via direct photoexcitation mainly due to a higher cross section and an increased interaction time [2]. Moreover, due to the broad electron distribution in the plasma, the NEEC isomer activation is more robust against the fulfillment of the resonance condition. The latter can be essential for an experimental realization due to the present uncertainty of 80 eV in the ^{93m}Mo triggering transition.

[1] S. M. Vinko *et al.*, Nature **482**, 59 (2012)
[2] J. Gunst *et al.*, arXiv:1309.5835 (2013)

A 41.5 Thu 15:15 BEBEL E42

Small group velocities at large frequencies — •Kilian P. Heeg[1], Ralf Röhlsberger[2], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

We study the properties of x rays reflected from a thin-film cavity with embedded Moessbauer nuclei [1, 2] in the time domain. For a suitably chosen nuclear target, the phase imprinted on the field results in sub- or superluminal propagation of the x-ray light. The group delay can be controlled with external parameters such as the tilting angle of the cavity and its magnetization. Our calculations predict that temporal shifts of the pulses of order of several 10 ns are possible. We further propose a setup to measure this group delay based on existing instrumentation, and discuss a possible experimental implementation at a synchrotron light source.

[1] R. Röhlsberger et al, Science **328**, 1248–1251 (2010)
[2] K. P. Heeg et al, Phys. Rev. Lett. **111**, 073601 (2013)

A 41.6 Thu 15:30 BEBEL E42

Mössbauer meets Fano at x-ray energies: Controlled line shapes in cooperative emission from nuclei — Kilian P. Heeg[1], Christian Ott[1], Daniel Schumacher[2], Hans-Christian Wille[2], 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

Control of spectroscopic line shapes at hard x-ray energies is demonstrated in the reflectance of a thin film cavity with embedded Moessbauer nuclei. Tunable Fano interference between a spectrally broad cavity response and a narrow bound state nuclear contribution enables us to switch between Lorentz- and Fano-profiles [1, 2]. Spectroscopic signatures such as the cooperative Lamb shift and superradiant line broadening are extracted from the recorded asymmetric line shapes with high precision and agree excellently with our theoretical model [3]. Our results advance spectroscopy and precision metrology in the hard x-ray domain, and provide access to a multitude of applications linked to Fano interference.

[1] U. Fano, Phys. Rev. **124**, 1866–1878 (1961)
[2] C. Ott et al, Science **340**, 716–720 (2013)
[3] K. P. Heeg, and J. Evers, Phys. Rev. A **88**, 043828 (2013)

A 41.7 Thu 15:45 BEBEL E42

Polarization correlations in the Rayleigh scattering — •A. Surzhykov[1], V. Yerokhin[2], T. Jahrsetz[1], Th. Stöhlker[1,3,4], and S. Fritzsche[1,5] — [1]Helmholtz-Institut Jena, — [2]St. Petersburg State Polytechnical University — [3]GSI Helmholtzzentrum für Schwerionenforschung — [4]Institut für Optik und Quantenelektronik, Universität Jena — [5]Theoretisch-Physikalisches Institut, Universität Jena

Studies on the elastic Rayleigh scattering of photons by bound atomic electrons have a long tradition. Over the last decades, for example, a number of experimental and theoretical works have dealt with the total as well angle-differential cross sections. More recent investigations are focused on the linear polarization of the scattered photons. Of particular interest is the question of how this polarization is affected if the incident light is itself (linearly) polarized. In order to better understand such a *polarization transfer* between the incoming and outgoing photons, theoretical analysis has been performed by us based on the second-order perturbation approach [1]. Detailed calculations were carried out for Ne, Xe and U targets, and for photon energies up to ten times the 1*s* ionization threshold. Based on these calculations we found that the (degree) of linear polarization of scattered x-rays is generally significantly reduced comparing to the polarization of the incident light. Such a "depolarization" is mainly caused by the relativistic effects and non-dipole contributions to the electron-photon interaction and becomes most pronounced for the backward x-ray scattering.

[1] A. Surzhykov *et al.*, submitted to PRA.

A 42: Ultracold atoms and molecules I (with Q)

Time: Thursday 14:00–15:30 Location: DO26 208

A 42.1 Thu 14:00 DO26 208

Nonlinear spectroscopy of trapped ions — •Manuel Gessner[1,2], Frank Schlawin[1,3], Hartmut Häffner[2], Shaul Mukamel[3], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, University of California, Berkeley, California 94720, USA — [3]Department of Chemistry, University of California, Irvine, California 92697, USA

Nonlinear multidimensional spectroscopy is a powerful tool to probe non-equilibrium phenomena of complex quantum systems. It has been successfully implemented in systems ranging from nuclear magnetic resonance to molecular aggregates. In this talk we present experimentally feasible methods to obtain multidimensional spectra for the electronic and vibrational degree of freedom of trapped ion systems. The ability to address single ions provides unprecedented possibilities for the design of multidimensional signals. The obtained spectra can be used to study quantum transport and different environmental effects.

A 42.2 Thu 14:15 DO26 208

Atom-light Quantum Interface Based on Nanofiber Traps — •Eva Bookjans, Jean-Baptiste Béguin, Stefan L. Christensen, Heidi L. Sørensen, Jörg H. Müller, Jürgen Appel, and Eugene S. Polzik — Niels Bohr Institute, Copenhagen University, Denmark

We report on our experimental progress towards coupling ultra-cold atoms to a tapered optical nanofiber with a subwavelength diameter. The strong coupling between the guided light mode of a tapered optical nanofiber and atoms close to the fiber surface make it an ideal system not only for trapping, manipulating, probing, and detecting atoms but also for interfacing distant quantum systems. Laser-cooled Cesium atoms are trapped in a one-dimensional optical lattice potential along the fiber, which is created by the evanescent field of a far red-detuned standing wave (1064 nm) and far blue-detuned (780 nm) light [1]. We will present a dispersive dual-color interferometric probing scheme, which we will implement in order to perform projection noise limited quantum-non demolition (QND) measurements of the quantum state of the trapped Cesium atoms [2,3]. The ultimate objective of the presented research is to take advantage of the unique properties of an atom-nanofiber trap and to engineer and characterize nontrivial quantum states in few atom ensembles using QND coupling to light and photon counting measurements.

[1] E. Vetsch *et al.*, Phys. Rev. Lett. **104**, 203603 (2010)
[2] J. Appel *et al.*, PNAS **106**, 10960 (2009)
[3] J. Lodewyck *et al.*, Phys. Rev. A **79**, 061401 (2009)

A 42.3 Thu 14:30 DO26 208

3D Imaging of Cavity Vacuum with Single Atoms Localized by a Nanohole Aperture — •Moonjoo Lee[1,2], Junki Kim[2], Wontaek Seo[2], Hyun-Gue Hong[2], Younghoon Song[2], Ramachandra Dasari[3], and Kyungwon An[2] — [1]Institute for Quantum Electronics, ETH Zürich, CH-8093 Zürich, Switzerland — [2]Department of Physics and Astronomy, Seoul National University, Seoul 151-747, Korea — [3]G. R. Harrison Spectroscopy Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139, U.S.A.

P. A. M. Dirac first introduced zero-point electromagnetic fields in order to explain the origin of atomic spontaneous emission. Vacuum fluctuations associated with the zero-point energy in cavities are now utilized in quantum devices such as single-photon sources, quantum memories, switches and network nodes. Here we present 3D imaging of vacuum fluctuations in a high-Q cavity based on the measurement of position-dependent emission of single atoms. Atomic position localization is achieved by using a nanoscale atomic beam aperture scannable in front of the cavity mode. The 3D structure of the cavity vacuum is reconstructed from the cavity output. The rms amplitude of the vacuum field at the antinode is also measured to be 0.92 ± 0.07 V/cm. The present work utilizing a single atom as a probe for sub-wavelength imaging demonstrates the utility of nanometer-scale technology in cavity quantum electrodynamics.

A 42.4 Thu 14:45 DO26 208

Quantum simulation of nuclear matter with ultracold molecules — •Jordi Mur-Petit — Instituto de Estructura de la Materia IEM-CSIC, Madrid, Spanien

Cold polar molecules have attracted attention in the last years as systems potentially capable of realizing a variety of strongly-correlated phases of condensed matter, from quantum magnetism models [1] to superconductivity [2] and topological phases [3]. In these and similar proposals, attention has been driven to the use of vibrational and rotational degrees of freedom to encode and manipulate quantum information. Here, we propose to use ultracold molecules to quantum-simulate nuclear matter. We discuss how to harness a manifold of rotational and hyperfine states of polar molecules to encode the degrees of freedom required to quantum-simulate nuclear matter, spin and isospin. Then, we consider the use of external fields to control the intermolecular interactions [4] in order to model known properties of the nucleon-nucleon interaction at low energies. This work is a first step in the study of open problems in nuclear physics, from the equation of state of nuclear matter, to the determination of magic numbers of highly asymmetric nuclei [5]. [1] R. Barnett et al., PRL 96, 190401, 2006. [2] A. Gorkov et al., PRL 107, 115301, 2011. [3] J. Levinsen et al., PRA 013603, 2011; S. Manmana et al., PRB 87, 081106R, 2013. [4] A. Micheli et al., Nat. Phys. 2, 341, 2006; T.V. Tscherbul and R.V. Krems, ch. 4 in "Cold Molecules", edited by R. Krems, W. Stwalley and B. Friedrich, CRC Press, 2010; M. Lemeshko et al., Mol. Phys. 111, 1648, 2013. [6] J. Dobaczewski (ed.), J. Phys. G 37, special issue no. 6, 2010.

A 42.5 Thu 15:00 DO26 208

Towards optical Feshbach resonances with ^{40}Ca — •Evgenij Pachomow[1], Max Kahmann[1], Uwe Sterr[1], Fritz Riehle[1], and Eberhard Tiemann[2] — [1]Physikalisch Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig — [2]Institut für Quantenoptik, Welfengarten 1, 30167 Hannover

Alkaline earth metals find applications in various fields of research and technology. Especially due to the narrow singlet-triplet intercombination line, photoassociation (PA) and optical Feshbach resonance (OFR) experiments have been the subject of research in the last decade. Compared to the other alkaline earth metals like strontium and ytterbium, where PA and OFR have already been performed, calcium offers an even narrower intercombination line of $\Gamma/2\pi \approx 374$ Hz, which is supposed to solve loss problems at OFRs. We recently produced a quantum degenerate ^{40}Ca gas using a two stage magneto-optical trap and subsequent forced evaporation cooling in an optical dipole trap. The interaction in the gas depends on the scattering length, which we plan to tune using the OFR. As a first step in the two molecular potentials c ($\Omega = 0+$) and a ($\Omega = 1$) correlating to the ^{3}P+^{1}S asymptote the six weakest bound photoassociation resonances were measured. Based on this data set these molecular potentials were fitted using a coupled channel model. On the basis of the experimentally observed spectra and the coupled channel model we investigate the feasibility of OFRs and their corresponding losses.

This work is funded by DFG through QUEST and RTG 1729.

A 42.6 Thu 15:15 DO26 208

En route to quantum many-body physics with ultracold polar molecules - 23Na40K Feshbach molecules and beyond. — •Nikolaus Buchheim, Zhenkai Lu, Tobias Schneider, Immanuel Bloch, and Christoph Gohle — Max-Planck-Institut für Quantenoptik, Garching, Germany

Ultra cold quantum gases with long-range dipolar interaction promise exciting new possibilities for quantum simulation of strongly interacting many-body systems. New classes of many-body phases (like super solids and stripe phases) are on the horizon and ferroelectric phases of highly polarizable systems are expected [1, 2].

The known route for creating polar molecules from laser-cooled alkaline atoms [3] involves the association of pairs of unbound atoms to weakly bound molecules (Feshbach molecules) using a magnetic field controlled Feshbach type scattering resonance. This is followed by a stimulated Raman adiabatic passage (STIRAP) to the rovibrational groundstate. We report on spectroscopic studies on a near-degenerate 23Na40K mixture along the lines of and expanding on [4].

[1] G. Pupillo et al. arXiv: 0805.1896 (2008).
[2] M. Iskin et al. Phys. Rev. Lett. 99, 110402 (2007).
[3] K.-K. Ni et al. Science 322, 231 (2008).
[4] C.-H. Wu et al. Phys. Rev. Lett. 109, 085301 (2012).

A 43: Velocity map imaging - focusing on intra- and interatomic dynamics SYPS 1 (with jDPG)

Time: Thursday 14:00–15:55 Location: Audimax

Welcome and introduction

Invited Talk A 43.1 Thu 14:10 Audimax

Oxygen and imaging, a perfect match — •David Parker — Radboud University, Department of Physics, FNWI-IMM-MLF, NIjmegen, The Netherlands

Molecular oxygen, O_2, is fascinating molecule. Despite this, a full understanding of the photodynamics of molecular oxygen is lacking due to the complex electronic structure and the forbidden nature of almost all optical transitions of O_2. Over the past decade our group has been able to reveal many new aspects of O_2 photodynamics due in part to the development and application of the velocity map imaging technique. In this talk I will highlight our past work on the photodissociation of: O_2 super-excited states , the Herzberg continuum6 of O_2, singlet oxygen b-state, the Schumann-Runge continuum, and O_2-isoprene clusters. I will mainly describe new work on the photodissociation of the singlet oxygen a $^1\Delta_g$ -state. Velocity map imaging will be shown to be particularly well-matched to the study of O_2 photodynamics.

Invited Talk A 43.2 Thu 14:40 Audimax

Attosecond imaging — •Marc Vrakking — Max Born Institute (MBI), Berlin

The natural timescale for electron dynamics reaches down to the attosecond domain. Following the discovery of attosecond laser pulses, about a decade ago, attosecond science has developed into a vibrant, new research field, where the motion of single or multiple electrons and, in molecules, the coupling of electronic and nuclear motion, can be investigated, on attosecond to few-femtosecond timescales. Attosecond experiments require suitable observables. In my talk I will describe how "attosecond imaging", basing itself on kinetic energy and angle-resolved detection of photoelectrons and fragment ions using a velocity map imaging (VMI) spectrometer, has been exploited in a number of pump-probe experiments. The use of a VMI spectrometer in attosecond experiments has allowed the characterization of attosecond pulse trains and isolated attosecond pulses, the elucidation of continuum electron dynamics and wave packet interferometry in atomic photoionization and the observation of electron localization in dissociative molecular photoionization.

A 43.3 Thu 15:10 Audimax

Insight in chemical dynamics by three-dimensional momentum imaging — •Robert Siemering[1], Eric Wells[2], Itzik Ben-Itzhak[3], Matthias Kling[4], and Regina de Vivie-Riedle[1] — [1]Ludwig-Maximilians-Universität, München, Germany — [2]Augustana College, Sioux Falls, USA — [3]Kansas State University, Manhattan, USA — [4]Max Planck Institute of Quantum Optics, Garching, Germany

The description of laser pulse interaction with molecules have different constrains for theory and experiment. While adaptive feedback in experiments can manipulate dynamics in molecular systems, the finding of the underlying mechanism or the forming of an appropriate theoretical model is difficult. This is especially the case when the feedback is limited to a single observable. By rapidly inverting velocity map images of ions to recover the three-dimensional photofragment momentum distribution and incorporating that feedback into the control loop, the specificity of the control objective is dramatically increased. As an example in the isomerization of acetylene ($C_2H_2^{2+} \rightarrow CH_2^+ + C^+$) the angle-resolved ratio of CH^+/CH_2^+ was controlled in the experiment[1]. With the experimentally obtained pulses on-the-fly-trajectories were performed to unveils the underlying barrier suppression mechanism. The theoretical model can explain the observed shift to lower kinetic energy release values for the CH_2^+ fragments.

[1] Wells, E., *et al.*, Adaptive Strong-field Control of Chemical Dynamics Guided by Three-dimensional Momentum Imaging, *Nature Communications*, DOI:10.1038/ncomms3895

Invited Talk A 43.4 Thu 15:25 Audimax

Applications of the fast imaging Pixel Imaging Mass Spectrometry camera — •Mark Brouard — Department of Chemistry, University of Oxford

Recent work on the development of a fast imaging camera, known as the Pixel Imaging Mass Spectrometer (or PImMS) camera will be described [1,2]. The talk will focus on example applications of the PImMS camera. These range from studies of molecular photofragmentation [3] using correlation imaging techniques, progress towards three-dimensional velocity map ion imaging, through to imaging mass spectrometry of surfaces [4]. Future potential developments and applications will also be discussed.

[1] A. Nomerotski, M. Brouard, E. Campbell, A. Clark, J. Crooks, J. Fopma, J.J. John, A.J. Johnsen, C.S. Slater, R. Turchetta, C. Vallance, E. Wilman and W.H. Yuen, JINST 5, C07007, (2010). [2] J J John, M Brouard, A Clark, J Crooks, E Halford, L Hill, J W L Lee, A Nomerotski, R Pisarczyk, I Sedgwick, C S Slater, R Turchetta, C Vallance, E Wilman, B Winter and W H Yuen, JINST 7, C08001, (2012). [3] A. T. Clark, J. P. Crooks, I. Sedgwick, R. Turchetta, J. W. L. Lee, J. J. John, E. S. Wilman, L. Hill, E. Halford, C. S. Slater, B. Winter, W.H. Yuen, S. H. Gardiner, M. L. Lipciuc, M. Brouard, A. Nomerotski, and C. Vallance, J. Phys. Chem. A 116, 10897, (2012). [4] M. Brouard, E. Halford, A. Lauer, C. S. Slater, B. Winter, W. H. Yuen, J. J. John, L. Hill, A. Nomerotski, A. Clark, J. Crooks, I. Sedgwick, R. Turchetta, J. W. L. Lee, C. Vallance, and E. Wilman, Rev. Sci. Instrum. 83, 114101, (2012).

A 44: Precision measurements and metrology I (with Q)

Time: Thursday 14:00–16:00 Location: DO24 1.101

Group Report A 44.1 Thu 14:00 DO24 1.101

Technology development in Hannover for the space-based gravitational wave detector LISA — •Michael Tröbs, Simon Barke, Iouri Bykov, Oliver Gerberding, Jan-Simon Hennig, Katharina Isleif, Maike Lieser, Jens Reiche, Sönke Schuster, Gerhard Heinzel, and Karsten Danzmann — AEI Hannover

The Laser Interferometer Space Antenna (LISA) is a future space-based gravitational wave detector consisting of three satellites. LISA shall act as a Michelson interferometer and measure distance variations between free-floating test masses inside the satellites.

We give a brief overview on programmatics and report on work performed in Hannover on the main optical instrument (the optical bench) comprising the interferometers, the electronic device to read out the phase changes (the phasemeter) and the phase reference between two optical benches on a spacecraft (backlink).

A 44.2 Thu 14:30 DO24 1.101

Vorschlag für die Messung der Erdbeschleunigung mit Antiwasserstoff — •Sebastian Wolf und Ferdinand Schmidt-Kaler — Johannes Gutenberg-Universität, Mainz, Deutschland

Die Symmetrie von Materie und Antimaterie ist eine der aktuellsten Fragen in der Physik. Experimentell weitgehend ungeklärt ist die gravitative Wechselwirkung von Antimaterie. Bei geladenen Teilchen wird jeglicher Einfluss der Gravitation durch weit stärkere Coulombkräfte überdeckt, andererseits lassen sich ungeladene Antimaterie Teilchen für Fall-Experimente nicht ausreichend kühlen [1]. In der GBAR-Kollaboration [2] arbeiten wir an einem Fall-Experiment mit Antiwasserstoff. Im ersten Schritt werden am ELENA/AD-Ring (CERN) positiv geladene Antiwasserstoffionen ($\bar{H}^+$) erzeugt, in einer Paulfalle gefangen und mitfühlend mit $^9Be^+$- Ionen in den Grundzustand der Bewegung gekühlt. Das Laser-induzierte Abtrennen des Positrons startet das Fall-Experiment bei dem die Gravitationsbeschleunigung auf 1 % genau gemessen werden soll [3,4]. Wir berichten über den Stand des experimentellen Aufbaus.

[1] The ALPHA Collaboration, Nat. Comm. **4**, 1785 (2013).
[2] http://gbar.in2p3.fr/
[2] Dufour et al, to be published
[3] Pérez et al, Class.Quantum Grav. **29**, 184008 (2012).

A 44.3 Thu 14:45 DO24 1.101

Testing the breadboard model of the LISA Phasemeter — •Oliver Gerberding, Simon Barke, Nils Brause, Ioury Bykov, Karsten Danzmann, Gerhard Heinzel, Joachim Kullmann, Jens Reiche, and Thomas Schwarze — Max-Planck Institut für Gravitationsphysik (Albert Einstein Institut) und Institut für Gravitationsphysik der Leibniz Universität Hannover

The planned space-born gravitational wave detector LISA will allow to detect gravitational waves at frequencies between 0.1 mHz and 1 Hz. It uses precision heterodyne laser interferometry as main measurement technology. A breadboard model for the phase readout system of these interferometers (Phasemeter) has been developed in the scope of an ESA technology development project by a collaboration between the Albert-Einstein Institute, the Technical University of Denmark and the Danish industry partner Axcon Aps. The breadboard is designed to demonstrate all functions for operating a complete LISA-like metrology system, to meet all performance requirements for a future mission and to study the effort of bringing the design to space qualification. Here we will present a system overview and the results of a comprehensive testing campaign. This includes phase readout of signals between 2 and

25 MHz with 1 microcycle/sqrt(Hz) performance, clock noise transfer, inter-satellite ranging and communication, laser frequency control and acquisition. In addition we present an optical non-linearity test that we use to validate the performance of the full metrology chain by aiming to demonstrate the for LISA necessary dynamic range of 10 orders of magnitude at low frequencies.

A 44.4 Thu 15:00 DO24 1.101

Gravimetric atom interferometer (GAIN): towards mobile absolute gravity measurements — •Christian Freier, Matthias Hauth, Vladimir Schkolnik, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile atom gravimeter, based on interfering ensembles of laser cooled 87Rb atoms in an atomic fountain configuration. It is specifically designed to show the potential of atom interferometry for mobile gravity measurements in the context of geodesy and geophysics.

We report on recent measurements comparing our atom gravimeter with a state-of-the-art falling corner cube gravimeter and with a super-conducting relative gravimeter. The latter was conducted at the geodetic observatory in Wettzell, demonstrating the mobility and robustness of our set-up.

We achieved a sensitivity of 1×10^{-8}g/shot with no observable instrumental drift. The derived absolute value of g agrees with the expected number up to a level of 10^{-8}g. A thorough analysis and/or elimination of systematic effects is currently underway to significantly improve the absolute accuracy in the near future.

A 44.5 Thu 15:15 DO24 1.101

Simulation and Optimisation of Laser Interferometers — •Christoph Mahrdt, Evgenia Kochkina, Vitali Müller, Sönke Schuster, Benjamin Sheard, Gudrun Wanner, and Gerhard Heinzel — Max-Planck-Institut für Gravitationsphysik, Hannover

In this talk the main work on interferometer design will be presented which is carried out at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) in Hannover for the space missions such as the Laser Interferometer Space Antenna (LISA), LISA Pathfinder and a planned successor to the Gravity Recovery and Climate Experiment (GRACE) called GRACE Follow-On. Simulations for the laser interferometers of the aforementioned projects are used to investigate noise coupling mechanisms such as tilt-to-length coupling and to study the dependence of their coupling coefficients on misalignments of optical components. Furthermore, simulations are performed to optimise the interferometer design by developing imaging optics that mitigate tilt-to-length coupling or minimise the effect of stray light. The main tool for these simulations is IfoCad (www.geo600.uni-hannover.de/ifocad/), a software library that is being developed at the Albert Einstein Institute in Hannover since 2008. IfoCad includes routines for Gaussian beam tracing in 3D optical systems, photodiode signal computation, sophisticated optimisation routines and various beam types such as general astigmatic Gaussian beams or higher-order Gaussian modes. The current development focuses on including polarisation and diffraction effects. In this talk IfoCad will be introduced and results for important applications will be presented.

A 44.6 Thu 15:30 DO24 1.101

Precision measurements with Gaussian and non-Gaussian states — •Daniel Braun[1,2], Claude Fabre[3], Pu Jian[3], Olivier Pinel[4], and Nicolas Treps[3] — [1]Laboratoire de Physique Théorique, Universit *e Paul Sabatier and CNRS, 31062 Toulouse, France — [2]Institut für theoretische Physik, Universität Tübingen, 72076 Tübingen, Germany — [3]Laboratoire Kastler Brossel, Université Pierre et Marie Curie-Paris 6, ENS, CNRS, 75252 Paris, France — [4]Centre for Quantum Computation and Communication Technology, Department of Quantum Science, The Australian National University, Canberra, ACT 0200, Australia

We calculate the quantum Cramér-Rao bound for the sensitivity with which parameters encoded in general single-mode (possibly mixed) Gaussian states, or non-Gaussian states obtained by photon-addition or -subtraction can be measured. We apply the formula for the Gaussian state to the problems of estimating phase, purity, loss, amplitude, and squeezing and provide the full quantum Fisher information (QFI) matrix for simultaneous measurement of several parameters. Our results unify previously known partial results and constitute a complete solution of the problem. For the photon-subtracted state, we show that the QFI diverges in the limit of no squeezing and almost no photons, which enable in principle arbitrarily precise measurements with essentially no light. However, this divergence is cancelled by the decaying success probability of the preparation scheme. In the limit of large photon numbers N, the non-classicality of the light only leads to a relative correction of order $1/N$.

A 44.7 Thu 15:45 DO24 1.101

Cryogenic Sapphire Optical Cavities — •Moritz Nagel, Klaus Döringshoff, Sylvia Schikora, Evgeny V. Kovalchuk, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

We present the status of our work on an ultra-stable cryogenically cooled sapphire optical cavity system, with a prospective thermal noise limited frequency stability better than $3 \cdot 10^{-17}$. These cavities will be used in a high-precision experiment, which will test Lorentz invariance within the 10^{-20} regime.

A 45: Velocity map imaging - focusing on intra- and interatomic dynamics SYPS 2 (with jDPG)

Time: Thursday 16:30–18:30 Location: Audimax

Invited Talk A 45.1 Thu 16:30 Audimax

Unraveling the dynamics of state- and conformer selected molecules fixed in space with the VMI — •Jochen Küpper — Center for Free-Electron Laser Science, DESY, Hamburg — Department of Physics, University of Hamburg — The Hamburg Center for Ultrafast Imaging, Hamburg

Velocity-map imaging (VMI) provides a powerful detection scheme for the dynamics of complex molecules. In this tutorial, I will introduce the methods to spatially separate different species present in molecular beams, to fix these molecules in space, and to investigate their structures and dynamics using VMI.

Inhomogeneous electric fields enable the spatial separation of conformers (structural isomers), nuclear spin isomers, and individual quantum states. These experiments exploite the neutral-molecule analogues of the electric bender, the ion guide, and the linear accelerator. The created state-selected molecular samples provide unprecedented options to fix molecules in space. The VMI spectrometer allows to unravel the resulting rotational dynamics of molecules in the applied electric and laser fields of vastly different strength and duration. The detailed analysis of these rotational dynamics and the prepared pendular states is an instructive example of quantum control.

VMI is also used to image photoelectron angular distributions (PAD). Utilizing the described controlled samples one can observe molecular frame (MF) PADs that provide direct images of electronic and geometric structures of molecules, potentially with femtosecond time resolution.

A 45.2 Thu 17:00 Audimax

Quantification of the Photoelectron Circular Dichroism from Multiphoton Ionization with Femtosecond Laser Pulses — •Christian Lux[1], Stefanie Züllighoven[1], Cristian Sarpe[1], Matthias Wollenhaupt[2], and Thomas Baumert[1] — [1]Universität Kassel, Institut für Physik und CINSaT, D–34132 Kassel, Germany — [2]Carl von Ossietzky Universität Oldenburg, Institut für Physik, D–26129 Oldenburg, Germany

The asymmetry of photoelectron angular distributions from randomly oriented enantiomers of chiral molecules in the ionization with circularly polarized light arises in forward/backward direction with respect to the light propagation. This effect was termed Photoelectron Circular Dichroism (PECD) and so far investigated using synchrotron radiation [1]. In our recent publication [2] we have demonstrated that PECD is accessible via a Resonance Enhanced Multi-Photon Ionization (REMPI) using femtosecond laser pulses. We observed highly structured asymmetries in the range of ± 10%. Attributed to the MPI high order odd Legendre polynomials appear in the measured PECD.

In this talk we show our recent findings on the bicyclic Ketones Camphor, Fenchone and Norcamphor. In order to quantify this data we want to introduce quantitative measures. These measures will be used to distinguish the three bicyclic Ketones and to quantify ellipticity dependences on Camphor as well as the enantiomeric excess in mixtures of R- and S-Fenchone.

[1] I. Powis in S. A. Rice (Ed.): Adv. Chem. Phys. **138**, 267-329 (2008)
[2] C. Lux et al., Angew. Chem. Int. Ed. **51**, 5001-5005 (2012)

Invited Talk A 45.3 Thu 17:15 Audimax

Velocity map imaging: from molecules to clusters, nanoparticles and aerosols — •Michal Farnik, Viktoriya Poterya, Jozef Lengyel, Andriy Pysanenko, Pavla Svrckova, and Jaroslav Kocisek — J. Heyrovsky Institute of Physical Chemistry, ASCR, Dolejskova 3, 18223 Prague 8

We will present several experiments with large clusters and nanoparticles performed with our cluster beam (CLUB) apparatus which has recently been upgraded with velocity map imaging (VMI) system. The unique and versatile apparatus allows for various experiments besides VMI including, e.g., high resolution mass spectrometry, particle cross section measurements etc. Combination of these experiments can lead to unprecedented detailed information about the dynamics of photochemistry and photophysics even in large clusters. This will be illustrated for systems of atmospheric relevance such as hydrogen halides and freons on/in ice nanoparticles.

A 45.4 Thu 17:45 Audimax

Imaging Cold Molecules on a Chip — •Silvio Marx[1], David Adu Smith[1], Mark Abel[1], Thomas Zehentbauer[1], Gerard Meijer[1,2], and Gabriele Santambrogio[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [2]Radboud University of Nijmegen, Nijmegen, The Netherlands

We recently reported the manipulation of the external and internal degrees of freedom of cold molecules using a chip-based Stark decelerator. This comprised the trapping, guiding and deceleration of packets of polar molecules as well as the excitation of the molecules' rotational and vibrational degrees of freedom while they were on the chip. Now we present the final crucial component for a fully integrated molecule chip: on-chip detection.[1] By means of resonance-enhanced multiphoton ionization (REMPI) and ion optics we image the molecules in the microtraps of our chip and use this resolution to analyze the phase space distribution of the molecules. This is done by taking time-resolved snapshots of the molecules' ballistic expansion after release from their traps, in a similar fashion as for the time-of-flight imaging of atomic ensembles on atom chips. Moreover, with this detection method we investigate the effect of a phase-space manipulation sequence applied to the trapped molecules.

[1] S. Marx et al., Phys. Rev. Lett. 111, 243007 (2013)

Invited Talk A 45.5 Thu 18:00 Audimax

Velocity map imaging studies of quantum state resolved scattering at gas-solid and gas-SAMs surfaces — •David J. Nesbitt[1], Monika Gruetter[3], J. Robert Roscioli[2], Carl Hoffman[1], and Daniel J. Nelson[1] — [1]JILA/University of Colorado, Boulder, CO, USA — [2]Aerodyne Research Inc., 45 Manning Road, Billerica, MA, USA — [3]University of Goettingen, Goettingen, Germany

This talk describes results from a novel surface-scattering technique which combines resonance enhanced multiphoton ionization (REMPI) with velocity-map imaging (VMI) to yield quantum-state and 2D velocity component resolved distributions in the scattered molecular flux. We will discuss work in hyperthermal scattering (Einc = 21(5) kcal/mol) of jet cooled HCl from i) Au(111) on flat mica surfaces and ii) -CH3 terminated self-assembled monolayers (SAM). These first data establish an exciting new class of experimental tools for exploring energy transfer and reactive scattering events on SAMs, liquid, and metal interfaces with quantum state resolved information on correlated internal and translational distributions.

A 46: Atomic collisions and ultracold plasmas

Time: Thursday 16:30–18:00 Location: BEBEL E34

A 46.1 Thu 16:30 BEBEL E34

Electron spectroscopy at the high-energy endpoint of electron-nucleus bremsstrahlung — •Pierre-Michel Hillenbrand[1,2], Siegbert Hagmann[1,3], Dariusz Banas[4], Carsten Brandau[5,2], Reinhard Dörner[3], Enrico De Filippo[8], Alexandre Gumberidze[5], Dalong Guo[9,10], Doris Jakubassa-Amundsen[11], Michael Lestinsky[1], Yuri Litvinov[1,12], Alfred Müller[2], Hermann Rothard[13], Stefan Schippers[2], Uwe Spillmann[1], Andrey Surzhykov[6], Sergey Trotsenko[1,6], Alexander Voitkiv[14], Vladimir Yerokhin[15], and Thomas Stöhlker[1,6,7] — [1]GSI Darmstadt — [2]Univ. Giessen — [3]Univ. Frankfurt — [4]Univ. Kielce, Poland — [5]Extreme Matter Institute Darmstadt — [6]Helmholtz-Institut Jena — [7]Univ. Jena — [8]INFN Catania, Italy — [9]IMP Lanzhou, China — [10]Univ. Beijing, China — [11]Univ. München — [12]Univ. Heidelberg — [13]CIRIL GANIL Caen, France — [14]MPI-K Heidelberg — [15]Petersburg State Univ., Russia

The high-energy endpoint of electron-nucleus bremsstrahlung has been studied in inverse kinematics: For collisions $U^{88+} + N_2 \rightarrow U^{88+} + [N_2^+]^* + e^- + \gamma$ the energy distribution of electrons scattered under $\vartheta_e^{lab} = 0°$ with $v_e \approx v_{proj}$ was measured coincident with the bremsstrahlung photons emitted under various angles ϑ_γ^{lab}. The triple-differential cross sections provide a stringent test for the fully relativistic theory of electron-nucleus bremsstrahlung. Furthermore the studied process, also termed radiative electron capture to continuum RECC, was compared to the competing processes of non-radiative electron capture to continuum ECC and the electron loss to continuum ELC.

A 46.2 Thu 16:45 BEBEL E34

Röntgenpolarimetrie angewandt zur Untersuchung der Wechselwirkung von energiereichen Teilchen- und Photonenstrahlen mit Materie — •Renate Märtin[1,2], Karl-Heinz Blumenhagen[1,3], Sebastian Hess[2], Max Schwemlein[2,4], Uwe Spillmann[2], Günter Weber[1,2] und Thomas Stöhlker[1,2,3] — [1]HI-Jena, Jena — [2]GSI, Darmstadt — [3]IOQ, Universität Jena — [4]EMMI, Darmstadt

Die Messung der linearen Polarisation von harter Röntgenstrahlung, die in Stößen von energiereichen Teilchen und Photonen mit Materie entsteht, ermöglicht Einblick sowohl in die Dynamik der Wechselwirkung als auch in die Struktur von atomaren hochgeladenen Systemen. Darüber hinaus kann die Polarisationsmessung der Röntgenstrahlung in Stoßprozessen zur Diagnose der Spinpolarisation von Elektronen- und Ionenstrahlen dienen. Frühere Messungen der linearen Polarisation waren aufgrund des Fehlens effizienter Polarisationsdetektoren fast ausschließlich auf die Messung der Spektral- und Winkelverteilung beschränkt. Durch die Entwicklung von orts-, zeit- und energieempfindliche Röntgendetektoren, die als Compton-Polarimeter eingesetzt werden können, besteht seit einiger Zeit die Möglichkeit die lineare Polarisation von Photonen im Energiebereich von ca. 60 keV bis einige hundert keV effizient zu untersuchen. Wir präsentieren verschiedene Experimente zur Studie der linearen Polarisation, die an den unterschiedlichsten Strahlplätzen durchgeführt wurden. Dazu gehören Messungen am ESR-Speicherring, der polarisierten Elektronenquelle SPIN in Darmstadt und der PETRAIII-Synchrotronanlage in Hamburg.

A 46.3 Thu 17:00 BEBEL E34

Observation of the Double resonant coherent excitation of highly charged ions crystals — •Alena Ananyeva[1,2], Toshiyuki Azuma[3,4], Harald Bräuning[2], Angela Bräuning-Demian[2], Yasuyuki Kanai[4], Yuji Nakano[3,4], and Yasunori Yamazaki[4,5] — [1]Goethe-Universität, Frankfurt-am-Main, Germany — [2]GSI, Darmstadt, Germany — [3]Tokyo Metropolitan University, Japan — [4]RIKEN, Tokyo, Japan — [5]University of Tokyo, Japan

An ion passing through a crystal feels the periodic Coulomb potential of the target like a fast oscillating electromagnetic field with frequencies in the x-ray range. If the field frequency matches the energy difference between two electronic states a resonant excitation of the ion became possible. The onset of the process can be steered by tuning the relative orientation of the incoming ion velocity and the crystallographic orientation. If the crystal orientation permits simultaneously the frequencies for two different electronic transitions, a double resonant excitation process became possible. This contribution present experimental evidence of the double excitation process in relativistic H-like and He-like Ar ions observed by means of resonance coherent excitation in a Si target. The experiment was performed by using beams of Ar ions at few hundreds MeV/u and a 1 μm thick crystal. The double resonance was detected by measuring the charge state distribution of the ions after the interaction with the crystal and the yield of the x-rays emitted during the decay of the excited states as function of the relative orientation of the target to the beam direction. Resonance spectra for transitions from n=1 to n=3,4,5 levels were obtained.

A 46.4 Thu 17:15 BEBEL E34

Switching exciton pulses through conical intersections — •Karsten Leonhardt, Sebastian Wüster, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems

Exciton pulses transport excitation and entanglement adiabatically through Rydberg aggregates [1], assemblies of highly excited light atoms, which are set into directed motion by resonant dipole-dipole interaction [1-4]. Here, we demonstrate the coherent splitting of such pulses as well as the spatial segregation of electronic excitation and atomic motion [5]. Both mechanisms exploit local non-adiabatic effects at a conical intersection, turning them from a decoherence source into an asset. The intersection provides a sensitive knob controlling the propagation direction and coherence properties of exciton pulses.

References

[1] C. Ates, A. Eisfeld, J-M. Rost, *New. J. Phys.* **10**, 045030 (2008).
[2] S. Wüster, C. Ates, A. Eisfeld, J-M. Rost, *Phys. Rev. Lett.* **105**, 195392 (2010).
[3] S. Möbius, S. Wüster, C. Ates, A. Eisfeld, J-M. Rost, *J. Phys. B.* **44**, 184011 (2011).
[4] S. Wüster, A. Eisfeld, J-M. Rost, *Phys. Rev. Lett.* **106**, 153002 (2011).
[5] K. Leonhardt, S. Wüster, J.-M. Rost, *ArXiv e-prints* **1310**, 6975 (2013).

A 46.5 Thu 17:30 BEBEL E34

Cooling Relativistic Ion Beams of initially large Momentum Spread with a fast scanning cw Laser System — •Michael Bussmann[1], Danyal Winters[2], Weiqiang Wen[3], Christina Dimopoulou[2], Tino Giacomini[2], Christophor Kozhuharov[2], Thomas Kühl[2,4,5], Yuri Litvinov[2], Matthias Lochmann[2,4], Wilfried Nörtershäuser[2,6], Fritz Nolden[2], Rodolfo Sánchez[2,6], Shahab Sanjari[2], Markus Steck[2], Thomas Stöhlker[2,5,7], Johannes Ullmann[2,6], Tobias Beck[6], Gerhard Birkl[6], Benjamin Rein[6], Sascha Tichelmann[6], Thomas Walther[6], Xinwen Ma[3], Dacheng Zhang[3], Markus Löser[1], Michael Seltmann[1], Matthias Siebold[1], and Ulrich Schramm[1,8] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]GSI Darmstadt — [3]Institute of Modern Physics, Chinese Academy of Science, Lanzhou — [4]Uni Mainz — [5]HI Jena — [6]TU Darmstadt — [7]Uni Jena — [8]TU Dresden

We present new results from a recent experiment on laser cooling of relativistic bunched ion beams at the Experimental Storage Ring at GSI. Our results show laser cooling with a single solid-state cw laser system with a laser frequency scanning range larger than the bucket acceptance. This technique is of great importance for future storage ring facilities such as FAIR and HIAF, as it allows for all-optical beam cooling of initially hot ion beams without the need for pre-electron cooling or stochastic cooling.

A 46.6 Thu 17:45 BEBEL E34

Quantum phases of quadrupolar Fermi gases on a quasi one-dimensional system — •Wen-Min Huang[1,2], Martin Lahrz[1], and Ludwig Mathey[1,2] — [1]Center for Optical Quantum Technologies and Institute for Laser Physics University of Hamburg, 22761 Hamburg, Germany — [2]Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany

In this work, we study quantum phases diagrams of polar fermions with a pure interquadrapolar interaction on two one-dimensional tubes. In the framework of Tomonaga-Luttinger-liquid theory, we map out the phases diagrams with reasonable experimental parameters versus the distance of two tubes and the angle between the direction of the tubes and quadrupolar moments. The latter can be controlled by an external field in experiments. We show that there are two magic angles from 0 to $\pi/2$, where intratube quadrupolar interactions vanish and change signs. Between two magic angles, a two gapless Tomonaga-Luttinger liquids exhibit under a dominated intratube attraction. By further computing various correlation functions, we show that a polarized triplet superfluid and a planer (pseudo-)spin-density wave compete each other. Outside of the regime, both intratube and intertube interactions are repulsive. Under the renormalization-group transformation in weak couplings, a flow to strong coupling of the backward scattering between two tubes lead to a pseudo-spin-gapped state with an axial-(pseudo-)spin-density-wave correlation in low-energy limit.

A 47: Attosecond physics

Time: Thursday 16:30–18:30 Location: BEBEL E42

A 47.1 Thu 16:30 BEBEL E42

A new twist in photoionization time delay — •Gopal Dixit[1], Himadri Chakraborty[2], Mohamed Madjet[3], and Misha Ivanov[1,4] — [1]max Born Institute, Max-Born-Strasse 2A, 12489 Berlin, Germany — [2]Department of Natural Sciences, Northwest Missouri State University, Missouri USA — [3]Qatar Environment and Energy Research Institute, Qatar Foundation Doha, Qatar — [4]Laboratory, Imperial College London, London SW7 2AZ, United Kingdom

A series of provocative experiments and theoretical studies have brought the question of photoionization time delay to the forefront and the issue is still unresolved. In this talk, I will discuss the effects of electron-electron correlations on the valence photoionization time delay in Ar atom and will present our calculated results, which are in excellent agreement with the Lund group experimental results.

After establishing the delayed response of the outgoing electron to the photon as a result of electron correlations in the photoionization of atoms, I will go beyond the prototypical examples, namely the rare gas atoms, and to consider a more interesting and complex system. I will show effects of confinement and electron correlations on the relative time delay between the 3s and 3p photoionization of Ar confined endohedrally inside C60. Particular nuances of the delay process near a resonance and a Cooper minimum have been recognized. Interesting aspects of the time behavior of atomic emissions, when the atom is taken hostage inside a material confinement, will be discussed. In this context, emissions at the spectral region of the confiner*s plasmonic response are of particular interest.

A 47.2 Thu 16:45 BEBEL E42

2D spectral interpretation of time-dependent absorption spectra of transiently-coupled excited atomic states — •Alexander Blättermann, Christian Ott, Andreas Kaldun, Thomas Ding, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We demonstrate a two-dimensional time-domain spectroscopy method to extract amplitude and phase modifications of excited atomic states caused by the interaction with ultrashort laser pulses. The technique is based on the Fourier analysis of the absorption spectrum of perturbed polarization decay [1,2]. The analytical framework of the method reveals how amplitude and phase information can be obtained from measurements, and how interaction pathways can be separated in the two-dimensional spectral representation. We apply the method experimentally to the helium atom, which is excited by attosecond-pulsed extreme ultraviolet light [3,4], to characterize laser-induced couplings of doubly-excited states [5-7].

References:

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A 47.3 Thu 17:00 BEBEL E42

High-Order Harmonic Spectroscopy with Water Droplets —

•Heiko G. Kurz[1,2], Martin Kretschmar[1,2], Tamas Nagy[1], Detlev Ristau[1,2,3], Manfred Lein[2,4], Uwe Morgner[1,2,3], and Milutin Kovacev[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, Hannover — [2]QUEST, Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, Hannover — [3]Laser Zentrum Hannover e.V., Hollerithallee 8, Hannover — [4]Leibniz Universität Hannover, Institut für theoretische Physik, Appelstrasse 2, Hannover

We report on high-order harmonic generation (HHG) from dense water droplets, where two intense femtosecond laser pulses interact with a micrometer-sized liquid water droplet under vacuum conditions. The first pulse expands the droplet, which performs a transition from the liquid phase into the gas phase. The second pulse is used for HHG, where different density states become accessible by controlling the delay between the two pulses. Information about the density evolution of the target is probed in-situ with the harmonic radiation, and two density regimes can be determined. The first at low density, where the harmonic yield develops according to the phase-matching conditions and a second, where the density of the target is too high and the electronic trajectories are perturbed during their excursion in the continuum by neighboring particles. By controlling the density of the target via the delay, the transition between these two density regimes is observed.

A 47.4 Thu 17:15 BEBEL E42

Signatures of isolated attosecond pulses spanning the water window by few-cycle driven HHG —

•Stephan M. Teichmann[1], Francisco Silva[1], Seth L. Cousin[1], Michaël Hemmer[1], and Jens Biegert[1,2] — [1]ICFO, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]Institució Catalana de Recerca i Estudis Avanats, 08010 Barcelona, Spain

Excellent transmission contrast in the water window between 280 eV and 530 eV can be exploited for high resolution biological imaging. High order harmonic generation (HHG) has been demonstrated as a table-top source for fully coherent X-ray radiation. While isolated attosecond pulses, useful for pump-probe experiments on the time scale of subatomic motion, have been produced with this technique, they have thus far not been generated in the desirable water window.

Here, we present results from ponderomotively scaled HHG using 1.6 cycle, 1.8 μm wavelength pulses at a repetition rate of 1 kHz with stable carrier envelope phase (CEP). We generate harmonic spectra up to 550 eV in helium, thus spanning the entire water window with fully coherent X-rays. Moreover, control over the CEP allows us to drive the HHG process with a well-defined electric field which in turn leads to the production of half-cycle cutoffs. Simulations confirm, for the first time, the production of isolated attosecond transients across the water window up to 530 eV.

A 47.5 Thu 17:30 BEBEL E42

Noncollinear Optical Gating —

•Christoph M. Heyl[1], Fernando Brizuela[1], Linnea Rading[1], Piotr Rudawski[1], Byunghoon Kim[1], Samuel Bengtsson[1], Stefanos Carlström[1], Amélie Jarnac[2], Aurelien Houard[2], André Mysyrowicz[2], Per Johnsson[1], Johan Mauritsson[1], Cord L. Arnold[1], and Anne L'Huillier[1] — [1]Department of Physics, Lund University, Sweden — [2]Laboratoire d'Optique Appliquée, École Polytechnique, France

The generation of isolated attosecond pulses via high-order harmonic generation (HHG), a key issue in attosecond science, requires CEP-stable few-cycle laser pulses and advanced gating techniques. Commonly used gating schemes rely on manipulating the driving field in order to confine the extreme ultraviolet (XUV) emission to a single half cycle. Here, a different approach is presented, based on driving HHG in a noncollinear geometry. A noncollinear generation scheme can be used to angularly streak the generated attosecond pulse train, a method, recently introduced in a conceptually different approach by Vincenti *et al.* [1]. The streaking effect gives access to multiple isolated attosecond pulses and can therefore be used to monitor generation dynamics. Our approach constitutes the first gating scheme which allows a direct separation of the generated XUV radiation from the fundamental field and does not require any manipulation of the driving field [2]. It is therefore ideally suited for pump-probe studies in the XUV regime and promises new advances for intra-cavity high-order harmonic generation.

[1] H. Vincenti *et al.*, Phys. Rev. Lett. **108**, 113904 (2012)
[2] C. M. Heyl *et al.*, to be published

A 47.6 Thu 17:45 BEBEL E42

Non-Equilibrium Dynamics Manifested by Fluctuations in a Quantum Many-Body System: Giant Dipole Resonance of Atomic Xenon —

•Yi-Jen Chen[1,2], Stefan Pabst[1], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany

For a quantum many-body system driven out of equilibrium, the dynamics of the system is typically characterized by the expectation value of a suitable observable. The purpose of this work is to evaluate the information inaccessible by the dynamics of the average yet contained in the dynamics of the uncertainty. To this end, many-electron atomic xenon is chosen as the model system. Using ultrashort XUV pulses, we excite the Xe giant dipole resonance, a well-known example among atomic systems where the collective excitation of the electrons in the 4d shell plays a prominent role. The system is numerically propagated with the ab-initio time-dependent configuration-interaction singles method. We calculate the expectation value of a one-body operator, here the total dipole momentum, and the corresponding uncertainty. We point out the new information extracted from the dynamics of the uncertainty, with special attention to electronic correlation and the coherence between different configurations. By turning on and off the interchannel coupling in the simulation, the sensitivity of the uncertainty as a probe for many-body effects is also discussed.

A 47.7 Thu 18:00 BEBEL E42

Ultrafast resonant X-Ray scattering from electron wave packets —

•Daria Popova[1,2] and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Notkestrasse 85, D-22607 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, D-22761 Hamburg, Germany

X-ray free electron laser sources enable ultrafast structural studies of matter with angstrom space and (sub-)femtosecond time resolutions. This makes them a promising tool for imaging of electron wave packet dynamics, which usually takes place on time scales ranging attoseconds to femtoseconds. X-ray resonant scattering is an advantageous technique that is an element-specific probe for charge and spin spatial modulations. We concentrate our study on diffraction of resonant hard X-ray radiation from dynamical electron systems. We examine its basic properties by providing several examples of scattering patterns calculated from different types of electronic wave packets. It has been discussed in the literature that a quantum electrodynamics (QED) treatment is necessary for a correct description of non-resonant scattering of ultrashort X-ray pulses from a dynamical electron system. Therefore, we also apply a QED description to treat resonant X-ray scattering, which allows us to take into account both elastic and inelastic processes. We find that scattering patterns also in the resonant case cannot be interpreted in terms of an instantaneous electron density.

A 47.8 Thu 18:15 BEBEL E42

Role of higher order return trajectories in continuum-continuum harmonic generation —

•Hossein Ebadi — Structural dynamics of (bio)chemical Systems, MPI-BPC, Am Fassberg 11, 37077 Goettingen, Germany

High harmonic generation has been numerically analyzed. A clear contribution of those quantum orbits with higher order return to the target potential has been observed in the continuum-continuum harmonic generation [1]. This occurs via interference of their associated wave-packets. In the barrier suppression ionization regime, the role of the trajectories with return order higher than one can be dominant at certain intensity. An empirical method [2] has been introduced to estimate the impact of different return order trajectories at certain emission time. [1] M.C. Kohler, C. Ott, P. Raith, R. Heck, I. Schlegel, C.H. Keitel, T. Pfeifer, Phys. Rev. Lett., 105, 203902 (2010). [2] D. Bauer, P. Mulser Phys. Rev. A, 59 , 569 (1999).

A 48: Ultra-cold atoms, ions and BEC V (with Q)

Time: Thursday 16:30–18:30 Location: BEBEL SR140/142

A 48.1 Thu 16:30 BEBEL SR140/142

Beating the flux limits: An ultra-bright atom lasers based on adiabatic potentials — •Wolf von Klitzing[1], V. Bolpasi[1], N.K. Efremidis[2], M.J. Morrissey[3], P. Condylis[4], and D. Sahagun[5] — [1]FORTH- IESL — [2]Vassilika Vouton, P.O. Box 1527 — [3]Vassilika Vouton, P.O. Box 1527 — [4]FORTH- IESL , Vassilika Vouton, P.O. Box 1527 — [5]FORTH- IESL , Vassilika Vouton, P.O. Box 1527

I will present a novel, ultra-bright atom-laser and ultra-cold thermal atom beam. Using rf-radiation we strongly couple the magnetic hyperfine levels of ^{87}Rb atoms in a trapped Bose-Einstein condensate. The resulting time-dependent adiabatic potentials forms a trap, which at low rf-frequencies opens up just below the condensate and thus allows an extremely bright well-collimated atom laser to emerge. As opposed to traditional atom lasers based on weak coupling of the magnetic hyperfine levels, this technique allows us to outcouple atoms at an arbitrarily large rate. We achieve a flux of 4×10^7 atoms per second, a seven fold increase compared to the brightest atom lasers to date. Furthermore, we demonstrate by two orders of magnitude the coldest thermal atom beam (200 nK).

A 48.2 Thu 16:45 BEBEL SR140/142

Realizing non-hermicity with ultra-cold atoms and hermitian multi-well potentials — •Manuel Kreibich, Jörg Main, and Günter Wunner — Institut für Theoretische Physik 1, Universität Stuttgart, 70550 Stuttgart, Germany

We discuss the possibility of realizing a *non-hermitian*, i. e. an *open* two-well system of ultra-cold atoms by enclosing it with additional wells that serve as particle reservoirs. With the appropriate design of the additional wells almost arbitrary currents can be induced to and from the inner wells, including the important class of $\mathcal{PT}$-symmetric currents, which support stable solutions.

We show that interaction in the mean-field limit does not destroy this property, it even allows for simple analytic expressions in the Thomas-Fermi limit. We finally discuss the implications of our results on the stability of atomic transport in optical lattices.

A 48.3 Thu 17:00 BEBEL SR140/142

Non-equilibrium dynamics of ultra-cold atoms — •Fernando Gallego-Marcos[1], Christian Nietner[2], Gloria Platero[1], and Tobias Brandes[2] — [1]Instituto de Ciencia de Materiales, CSIC, Cantoblanco, 28049 Madrid, Spain — [2]Institut für Theoretische Physik, Technische Universität, 10623 Berlin, Germany

We study the dynamics between two ultra-cold atomic reservoirs, in the grand canonical ensemble, which initially have different temperatures and/or particle densities. These reservoirs are modeled as ideal quantum gases which are coupled to a quantum system with several discrete transition frequencies. We calculate the time dependent particle- and energy currents through the quantum system using a Born-Markov-Secular master equation approach in correspondance with Ref. [1]. Additionally, assuming a linear relation between the energy current and the change of the reservoir temperatures, we are able to model the equilibration of the reservoirs. Our numerically obtained results for fermionic particle transport are in accordance with recent experimental observations [2]. Moreover, we find a strong dependence of the equilibration on the energy structure of the quantum system. Consequently, we use a linear response approximation to analytically investigate this dependence in more detail.

References

[1] Nietner, C., Schaller, G., & Brandes, T. 2013, arXiv:1309.3488

[2] Brantut, J.-P., Grenier, C., Meineke, J., et al., Science 342, 713 (2013)

A 48.4 Thu 17:15 BEBEL SR140/142

Cold atom sources for integrated quantum sensors — •Fedja Oručević, Anton Piccardo-Selg, Tom Barrett, Gal Aviv, Thomas Fernholz, and Peter Krüger — Midlands Ultracold Atom Research Centre, School of Physics and Astronomy, University of Nottingham, UK

The progress in trapping and manipulation of cold atoms achieved over the past decade and their intrinsic quantum nature make them ideally suited for quantum sensor applications. However, the complexity of typical cold atom setups is such that they largely remain confined to the laboratory. Recent efforts therefore focus on miniaturising and integrating different components to form truly portable devices.

At the heart of such a system is a source of cold atoms, for example based on atom chip technology. We present a new low-power design that does not require the use of external coils. With a 45°-tilted magnetic field quadrupole we trap $> 10^8$ rubidium atoms in a mirror magneto-optical trap using less than 5 W of electrical power.

A 48.5 Thu 17:30 BEBEL SR140/142

Finite size effects stabilize inhomogeneous structures — •Florian Cartarius[1,2], Anna Minguzzi[1], and Giovanna Morigi[2] — [1]Université Grenoble 1/CNRS, Laboratoire de Physique et de Modélisation des Milieux Condensés (UMR 5493), B.P. 166, 38042 Grenoble, France — [2]Fachrichtung 7.1: Theoretische Physik, Universität des Saarlandes, D 66123 Saarbrücken, Germany

We consider classical dipolar particles in a planar geometry confined by a harmonic ring trap. Using a Basin-Hopping Monte Carlo method and analytical calculations we study the minimal energy configurations. We find that close to the linear to zigzag transition [1], the energy is minimized by inhomogeneous soliton-like configurations originating from the short-range character of dipolar interactions. We develop a long-wavelength model that takes into account the coupling between radial and axial modes and show that its solutions well account for the inhomogeneous structures. They generically emerge for power law interactions with $1/r^{\alpha}$, when $\alpha > 1$. The inhomogeneous structures are due to finite size effects, but are still present for systems with very large number of particles and are thus experimentally relevant.

[1] G. Birkl, S. Kassner, and H. Walther, *Nature* **357**, 310 (1992)

A 48.6 Thu 17:45 BEBEL SR140/142

Heat transport through the isotropic Lipkin-Meshkov-Glick model — •Georg Engelhardt, Victor Manuel Bastidas, and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

The Lipkin-Meshkov-Glick (LMG) model is a paradigmatic instance for a system exhibiting a quantum phase transition. We consider the isotropic LMG model coupled to two heat baths at different temperatures. We analytically calculate the heat current and the heat conductivity through the system using the master equation in Born-Markov-secular approximation. In the thermodynamic limit, we find that the heat conductivity vanishes in the symmetric phase while it is finite in the symmetry-broken phase.

A 48.7 Thu 18:00 BEBEL SR140/142

Broken Integrability Trace on Stationary Correlation Properties — •Ioannis Brouzos[1], Angela Foerster[2], and Tommaso Calarco[1] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm — [2]Instituto de Fisica da UFRGS, Av. Bento Gonccalves

We show that the breaking of integrability in the fundamental one-dimensional model of bosons with contact interactions leaves its trace on the stationary correlation properties of the system. We calculate energies and correlation functions of the integrable Lieb-Liniger case where all pairs of atoms interact with the same strength, comparing the Bethe with a corresponding Jastrow ansatz which are the basic constructions of correlated wave-functions in many-body quantum physics. Then we examine the non-integrable case of different interaction strengths between each pair of atoms by means of a modified (and variationally optimized) Jastrow ansatz which we propose as a very good approximation for this case. We show that properties of the integrable state are more stable (persist if the integrability is not extremely broken) close to the infinitely strong interacting Tonks-Girardeau regime than for week interactions. All energies and correlation functions are given in terms of explicit analytical expressions which the Jastrow ansatz makes possible. We finally compare the correlations of the integrable and non-integrable case and show that appart from symmetry breaking the behavior changes dramatically, with additional and more pronounced maxima and minima (interference peaks) appearing.

A 48.8 Thu 18:15 BEBEL SR140/142

A Thermoelectric Heat Engine with Ultracold Atoms — •Sebastian Krinner[1], Jean-Philippe Brantut[1], Charles

Grenier[1], Jakob Meineke[1], David Stadler[1], Dominik Husmann[1], Corinna Kollath[2], Tilman Esslinger[1], and Antoine Georges[3,4,5] — [1]Institute for Quantum Electronics, ETH Zürich, CH-8093 Zürich, Switzerland — [2]Universität Bonn, D-53115 Bonn, Germany — [3]Centre de Physique Théorique, École Polytechnique, CNRS, 91128 Palaiseau cedex, France — [4]Collège de France, 11 place Marcelin Berthelot, 75005 Paris, France — [5]Université de Genève, CH-1211 Genève, Switzerland

Thermoelectric effects, such as the generation of a particle current by a temperature gradient, have their origin in a reversible coupling between heat and particle flows. These effects are fundamental probes for materials and have applications to cooling and power generation. Here, we demonstrate thermoelectricity in a fermionic cold atoms channel in the ballistic and diffusive regimes, connected to two reservoirs. We show that the magnitude of the effect and the efficiency of energy conversion can be optimized by controlling the geometry or disorder strength. Our observations are in quantitative agreement with a theoretical model based on the Landauer-Büttiker formalism. Our device provides a controllable model system to explore mechanisms of energy conversion and realizes a cold atom-based heat engine.

A 49: Precision measurements and metrology II (with Q)

Time: Thursday 16:30–18:30 Location: DO24 1.101

Group Report A 49.1 Thu 16:30 DO24 1.101
Phase-predictable tuning of single-frequency optical synthesizers — •Felix Rohde[1], Erik Benkler[1], Thomas Puppe[2], Reinhard Unterreitmayer[2], Armin Zach[2], Christoph Raab[2], and Harald R. Telle[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, Braunschweig D-38116 — [2]TOPTICA Photonics AG, Lochhamer Schlag 19, D-82155 Graefelfing

Single-frequency optical synthesizers (SFOS) provide an optical field with arbitrarily adjustable frequency and phase which is phase-coherently linked to a reference signal. Ideally, they combine the spectral resolution of narrow linewidth frequency stabilized lasers with the broad spectral coverage of frequency combs in a tunable fashion. In current state-of-the-art SFOSs, a dedicated comb line order switching was used to enable tunability over carrier frequency intervals wider than the repetition frequency of the employed mode-locked laser. This imposes technical overhead, leads to forbidden frequency gaps and limits the tuning agility of the SFOS. Here, we present the first characterization of a novel type of SFOS which relies on serrodyne-shifting the carrier frequency of the employed frequency comb. We investigate the tuning behavior of two identical SFOSs, sharing a common reference, by comparing the phases of their output signals. We achieve phase-stable and cycle slip free frequency tuning over 500 comb lines (28.1 GHz) with a maximum differential phase error of 62 mrad. The tuning range in this approach can be extended to the full bandwidth of the frequency comb.

Group Report A 49.2 Thu 17:00 DO24 1.101
Optimally designed magnetic field sensing with nitrogen-vacancy centers — Tobias Nöbauer[1], •Björn Bartels[2], Andreas Angerer[1], Florian Mintert[2,3], and Johannes Majer[1] — [1]Atominstitut, TU Wien & Vienna Center for Quantum Science and Technology, Stadionallee 2, 1020 Wien, Austria — [2]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Albertstr. 19, 79104 Freiburg, Germany — [3]Department of Physics, South Kensington Campus, Imperial College, London, SW7 2AZ, UK

Sensing of small magnetic fields on the nano-scale can be achieved with the help of nitrogen-vacancy (NV) centers. We experimentally demonstrate an enhancement of sensitivity in a spin-echo-based sensing scheme by using shaped microwave pulses. The pulses are the result of optimization in frequency space, which permits us to find narrow-band pulses that achieve robustness against imperfections, such as ensemble broadening. We verify this robustness experimentally with quantum gates on individual NV centers and use these gates for sensing with macroscopic ensembles of NV centers. The potential of the present framework for applications beyond sensing is demonstrated theoretically with the control of entanglement dynamics and the realization of time-optimal gates.

A 49.3 Thu 17:30 DO24 1.101
X-ray frequency combs via optical quantum control — •S. M. Cavaletto, Z. Harman, Z. Liu, C. Ott, C. Buth, T. Pfeifer, and C. H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Optical frequency combs had a revolutionary impact on precision spectroscopy and metrology. The spectrum of a frequency comb, consisting of evenly spaced lines, is the result of an infinite train of femtosecond pulses produced in a mode-locked ultrafast laser. Recently, frequency-comb technology was extended to the extreme-ultraviolet spectral regime via high-harmonic generation (HHG) in a femtosecond-enhancement cavity [1]. We propose optical schemes to transfer the coherence of a driving, optical frequency comb to the radiation emitted by transitions of higher frequencies [2,3,4]. The comb structure we predict in the x-ray emission or absorption spectra might eventually represent an alternative scheme for x-ray frequency-comb generation, able to overcome the frequency limitations of present HHG-based methods. – [1] A. Cingöz *et al.*, Nature **482**, 68 (2012). [2] S. M. Cavaletto *et al.*, Phys. Rev. A **88**, 063402 (2013). [3] Z. Liu *et al.*, submitted (2013); arXiv:1309.6335. [4] S. M. Cavaletto *et al.*, submitted (2013).

A 49.4 Thu 17:45 DO24 1.101
Optical Frequency Transfer over a 1840-km Fiber Link with superior Stability — •Stefan Droste[1], Thomas Udem[1], Theodor Hänsch[1], Ronald Holzwarth[1], Filip Ozimek[2], Harald Schnatz[2], and Gesine Grosche[2] — [1]Max-Planck-Institut für Quantenoptik — [2]Physikalisch-Technische Bundesanstalt

The comparison of the latest generation of atomic frequency standards calls for new methods of transferring highly stable optical frequencies. Well established satellite-based frequency dissemination techniques do not reach the required stability set by state-of-the-art frequency standards. Recently, a lot of work has been put into investigating fiber links as a possible medium for transferring optical frequencies.

We established a fiber connection between the two institutes Max Planck Institute of Quantum Optics (MPQ) in Garching and the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig. In a loop configuration we transferred an optical carrier frequency at 194 THz over a 1840 km long fiber link. By investigating the underlying noise structure we found an, until now, unconsidered noise type that leads to a tau^{-2} dependency in the modified Allan deviation. The instability of the transferred frequency drops below 10^{-18} after only 70 s and we found no systematic offset between the sent and transferred frequency within an uncertainty of about 3×10^{-19}.

A 49.5 Thu 18:00 DO24 1.101
Optical feedback frequency stabilized cavity ring-down spectroscopy — •Johannes Burkart and Samir Kassi — Université Joseph Fourier (Grenoble 1) / CNRS, LIPhy UMR 5588, F-38041 Grenoble, France

Metrological applications of molecular spectroscopy such as a determination of the Boltzmann constant necessitate highly linear absorption and frequency axes. These issues are addressed by our novel optical feedback frequency stabilized cavity ring-down spectrometer (OFFS-CRDS) which combines arbitrary resolution down to the kilohertz level with a shot-noise limited absorption detectivity of a few $10^{-13}\,\text{cm}^{-1}$ over one second averaging time. Its unprecedented performance is based on a single-sideband-tuned distributed-feedback diode laser that is optical-feedback locked to a highly stable V-shaped reference cavity [1]. The frequency stability of this source is transferred to a linear ring-down cavity by means of an all-fibered Pound-Drever-Hall locking scheme, which maximizes cavity transmission and yields several hundred ring-down events per second. We characterize the performance of the OFFS-CRDS spectrometer experimentally and present results from first applications to absorption line shape studies and Doppler thermometry.

[1] J. Burkart, D. Romanini, and S. Kassi, Opt. Lett. **38**, 2062-2064 (2013).

A 49.6 Thu 18:15 DO24 1.101
Towards VUV frequency comb based high-precision spectroscopy of an optical nuclear transition of Thorium-229 —

•Georg Winkler[1], Enikoe Seres[1,2], Josef Seres[1], and Thorsten Schumm[1,2] — [1]Insitute of Atomic and Subatomic Physics, Vienna University of Technology, Stadionallee 2, 1020 Vienna, Austria — [2]Wolfgang Pauli Institute, CNRS UMI 2842, Nordbergstrasse 15, 1090 Vienna, Austria

The radio isotope Thorium-229 is predicted to possess a unique extremely low-energy excited state of the nucleus in the range of $7.6 \pm 0.5\,eV$ [1], promising the chance to coherently manipulate a nucleus by UV laser light for the first time. Apart from exciting fundamental research questions this well-shielded narrow-linewidth transition opens up the possibility to realize a compact solid-state optical time standard surpassing the precision of existing systems by orders of magnitude.

Here we report about the ongoing project to build a UV frequency comb suited to interrogate and characterize the nuclear transition in its solid-state environment when embedded into a host crystal. In particular, precise comparison to established radio-frequency clock transitions should be made possible with this modern research tool.

[1] B. R. Beck et al., Phys. Rev. Lett., 98, 142501 (2007).

A 50: Ultra-cold atoms, ions and BEC VI (with Q)

Time: Friday 10:30–11:45 Location: BEBEL E34

A 50.1 Fri 10:30 BEBEL E34

Pairing of few Fermi atoms in one dimension — •Pino D'Amico and Massimo Rontani — CNR-NANO S3, Via Campi 213A, 41125 Modena, Italy

Experimental advances allow us to confine a chosen number of few quantum degenerate Li6 atoms in a trap with unit precision down to the empty-trap limit. The Heidelberg group recently observed an even-odd oscillation of the "ionization" energy required to subtract an atom from a one-dimensional trap in the presence of moderate attractive interactions, which was attributed to pairing [PRL 111, 175302 (2013)]. Naively, one would expect pairing to be strongly suppressed in one dimension, due to the lack of orbital degeneracies. Here we address theoretically the pairing behavior of a few Fermi atoms in a one-dimensional harmonic trap through the exact diagonalization of the fully interacting Hamiltonian. From the analysis of exact ground- and excited-state energies and wave functions we extract both the pairing gap and the Cooper pair size, reproducing the observed even-odd behavior. Our results demonstrate that pairing in one dimension is a strongly cooperative effect that significantly deviates from the behavior predicted by perturbation theory at interaction strengths within experimental reach.

A 50.2 Fri 10:45 BEBEL E34

Universal spin dynamics in two-dimensional Fermi gases — •Marco Koschorreck[1,2], Daniel Pertot[1,2], Enrico Vogt[1], and Michael Köhl[1,2] — [1]University of Cambridge — [2]Universität Bonn

Spin transport has unique properties, setting it aside from charge transport: first, the transport of spin polarization is not protected by momentum conservation and is greatly affected by scattering. Therefore, the question arises: what is the limiting case of the spin transport coefficients when interactions reach the maximum value allowed by quantum mechanics? Second, unlike charge currents (which lead to charge separation and the buildup of an electrical field, counteracting the current), spin accumulation does not induce a counteracting force.

Fermionic quantum gases allow the study of spin transport from first principles because interactions can be precisely tailored and the dynamics is on directly observable timescales. In particular, at unitarity, spin transport is dictated by diffusion and the spin diffusivity is expected to reach a universal, quantum-limited value on the order of the reduced Planck constant divided by the particle mass. Here, we study a two-dimensional Fermi gas after a quench into a metastable, transversely polarized state [1]. Using the spin-echo technique, for strong interactions, we measure the lowest transverse spin diffusion constant of 0.0063(8) $\hbar$/m so far. For weak interactions, we observe a collective transverse spin-wave mode that exhibits mode softening when approaching the strongly interacting regime.

[1] Koschorreck, M., Pertot, D., Vogt, E. & Köhl, M. Nature Physics 9, 405-409 (2013).

A 50.3 Fri 11:00 BEBEL E34

Magnetic ordering in three-component ultracold fermionic mixtures in optical lattices — •Andrii Sotnikov and Walter Hofstetter — Goethe Universität, Frankfurt am Main, Germany

We study finite-temperature magnetic phases of three-component mixtures of ultracold fermions with repulsive interactions in optical lattices by means of dynamical mean-field theory (DMFT). We focus on the case of one particle per site (1/3 band filling) at moderate interaction strength, where we observe a transition between different sublattice orderings by means of the unrestricted real-space generalization of DMFT.

Our simulations show that long-range ordering in three-component mixtures should be observable at temperatures comparable to those in two-component mixtures. We analyse different types of antiferromagnetic order (2- and 3-sublattice color-density waves, color-selective antiferromagnetism) and determine the critical temperatures for transitions between different phases. We also discuss the effect of the asymmetry in interspecies interactions on these magnetic phases and the corresponding critical temperatures.

A 50.4 Fri 11:15 BEBEL E34

Energy dependent ℓ-wave Confinement-Induced Resonances — •Benjamin Hess[1], Panagiotis Giannakeas[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

The universal aspects of two-body collisions in the presence of a harmonic confinement are investigated for both particle exchange symmetries. The main focus of this study are the confinement-induced resonances (CIR) which are attrtibuted to different angular momentum states ℓ and we explicity show that in alkaline collisions emerge only four universal ℓ-wave CIRs. Going beyond the single mode regime the energy dependence of ℓ-wave CIRs is studied. In particular we show that all the ℓ-wave CIRs may emerge even when the two-body potential cannot support any bound state. Even more, we observe that the intricate dependence on energy yields resonant features where the colliding system within the confining potential experiences an effective free-space scattering. Our analysis is done within the framework of the generalized K-matrix theory and the relevant analytical calculations are in good agreement with the corresponding ab initio numerical simulations

A 50.5 Fri 11:30 BEBEL E34

Transport with ultra-cold atoms at constant density — •Christian Nietner — Institut für Theoretische Physik, TU Berlin, Germany

We investigate the transport through a few-level quantum system described by a Markovian master equation with temperature- and particle-density dependent chemical potentials. From the corresponding Onsager relations we extract linear response transport coefficients in analogy to the electronic conductance, thermal conductance and thermopower. Considering ideal Fermi and Bose gas reservoirs we observe steady-state currents against the thermal bias as a result of the non-linearities introduced by the constraint of a constant particle density in the reservoirs. Most importantly, we find signatures of the on-set of Bose-Einstein condensation in the transport coefficients.

A 51: Interaction with VUV and X-ray light III

Time: Friday 10:30–12:00 Location: BEBEL E42

A 51.1 Fri 10:30 BEBEL E42

Electron beam ion traps at ultrabrilliant light sources — •Sven Bernitt[1,2], René Steinbrügge[1], Jan Rudolph[1,3], Sascha Epp[4], and José Ramon Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität, Jena, Germany — [3]IAMP, Justus-Liebig-Universität, Gießen, Germany — [4]Max Planck Advanced Study Group, CFEL, Hamburg, Germany

Many plasma properties are determined by the interaction of highly charged ions with photons. In the VUV and X-ray spectral region usually only the time reversed processes were accessible. With the newest generation of ultrabrilliant light sources it is now possible to directly study photonic interactions. Results obtained with the transportable electron beam ion trap FLASH-EBIT [1] will be presented. It was used to provide targets of various highly charged ion species for synchrotrons (BESSY II, PETRA III) and free-electron lasers (FLASH, LCLS). By resonantly exciting VUV and X-ray transitions and detecting subsequent fluorescence as well as changes in the ion charge state it was possible to precisely measure transition energies, line widths, and properties of resonant photoionization. Our experiments provide valuable data for astrophysics and test general atomic theory [2,3].

[1] S. W. Epp et al., Phys. Rev. Lett. 98, 183001 (2007). [2] S. Bernitt et al., Nature 492, 225 (2012). [3] J. K. Rudolph et al., Phys Rev. Lett. 111, 103002 (2013).

A 51.2 Fri 10:45 BEBEL E42

Raman scattering of x-rays by heavy hydrogen-like ions — Thorsten Jahrsetz[1,2], Stephan Fritzsche[3,4], and •Andrey Surzhykov[4] — [1]Physikalisches Institut, Universität Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]Theoretisch-Physikalisches Institut, Universität Jena — [4]Helmholtz-Institut Jena

The scattering of photons on atoms, ions or molecules may lead to an excitation of the target. In atomic physics, this so-called Raman scattering was studied mainly for light neutral atoms. Advances in electron beam ion traps (EBITs), brilliant x-ray sources, and x-ray detector technology, allow nowadays an experimental investigation of inelastic x-ray scattering by heavy highly-charged ions. In such experiments relativistic, higher-multipole and even QED effects can be examined in detail. To support these future studies, we performed a theoretical analysis of Raman scattering of x-ray photons by heavy hydrogen-like ions [1].

We used second-order perturbation theory and a relativistic Greens function approach to evaluate the (total) scattering cross-section, the angular distribution of the photons, and the polarization of the ion after the scattering process. Special attention was paid to inelastic scattering involving the $1s_{1/2} \rightarrow 2s_{1/2}$, the $1s_{1/2} \rightarrow 2p_{1/2}$, and the $1s_{1/2} \rightarrow 2p_{3/2}$ transitions in H, Xe^{53+}, and U^{91+} targets.

[1] T. Jahrsetz et. al. in preparation

A 51.3 Fri 11:00 BEBEL E42

Lyman emission after Core Excitation of Water vapor — •LTAIEF BEN LTAIEF, ANDREAS HANS, PHILIPP SCHMIDT, PHILIPP REISS, ANDRE KNIE, and ARNO EHRESMANN — Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology, Universität Kassel, Heinrich-Plett Straße 40, D-34132 Kassel, Germany

The deexcitation channels of neutral hydrogen atoms after core excitation of gaseous water molecules by synchrotron radiation were studied using dispersed VUV fluorescence spectroscopy. The ionization yield and the intensity of several Lyman emission lines were measured as a function of exciting photon energy in the region of O1s excitations of water (532 eV - 542 eV). The population of the Lyman series (n≥3 as initial state) mirrors the excitation of different Rydberg states in the molecule.

A 51.4 Fri 11:15 BEBEL E42

Photon-photon coincidence in the EUV regime for very large gas pressures after dissociation of hydrogen molecules in superexcited states into neutral fragments — •Philipp Schmidt[1], Philipp Reiss[1], André Knie[1], Arno Ehresmann[1], Kouichi Hosaka[2], Yuko Nakanishi[2], Ken-ichi Shiino[2], and Noriyuki Kouchi[2] — [1]Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Department of Chemistry, Tokyo Institute of Technology, Meguro-ku, Tokyo 152, Japan

The time dependent fluorescence intensity in the EUV regime of molecular hydrogen after photoexcitation with an energy of 33.66 eV has been measured with a photon-photon coincidence setup starting at 2 Pa up to very high pressures of 150 Pa. At this energy, the resonant excitation of the superexcited Q_2 $^1\Pi$ (1) state leads to neutral dissociation into hydrogen atoms, where both atoms can be excited with principal quantum numbers of $n = 2$ and $n = 3$. The angular correlation function, coincidence time spectra as well as individual detector intensity has been analysed in this large pressure region with respect to possible entanglement effects between the neutral fragments by using the $2p$-$1s$ decay by Ly-α emission.

A 51.5 Fri 11:30 BEBEL E42

Diffraction Effects in the Molecular-Frame Photoelectron Angular Distributions of Halomethanes. — •Cedric Bomme[1], Denis Anielski[1,2], Sadia Bari[1], Benjamin Erk[1], Rebecca Boll[1,2], Evgeny Savelyev[1], Jens Kienitz[1], Nele Mueller[1], Thomas Kierspel[1], Sebastian Trippel[1], Jochen Kuepper[1], Jens Viefhaus[1], Mauro Stener[3], Piero Decleva[3], and Daniel Rolles[1] — [1]Deutsches Elektronen-Synchrotron(DESY), Hamburg, Germany. — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany. — [3]Universita' di Trieste, Trieste, Italy

We have measured the molecular-frame photoelectron angular distributions (MFPADs) for inner-shell photoionization of the halomethanes CH3F, CH3I, and CF3I in the gas-phase. Using our new double-sided velocity map imaging (VMI) spectrometer optimized for electron-ion coincidence measurements of high-kinetic energy electrons, we are able to determined MFPADs for photoelectrons up to 300 eV. For these high kinetic energies, the MFPADs are dominated by diffraction effects that encode information on the molecular geometry in the MFPADs.

A 51.6 Fri 11:45 BEBEL E42

Angular Distribution of Fluorescence Transitions in XeII obtained by Photon-Induced Fluorescence Spectroscopy after Excitation with Synchrotron Radiation — •Philipp Reiss[1], Christian Ozga[1], Witoslaw Kielich[1], Stefan Klumpp[2], André Knie[1], and Arno Ehresmann[1] — [1]Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology, Universität Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany — [2]Institute for Experimental Physics, University of Hamburg Faculty of Mathematics, Informatics and Natural Sciences Department of Physics, Luruper Chaussee 149, D22761 Hamburg, Germany

Xenon with its high number of electrons and their manifold interactions is a commonly used sample for the study of quantum-mechanical electron-correlative effects.

In this experiment, Photon-Induced Fluorescence Spectroscopy has been used to determine fluorescence excitation cross-sections and the angular distribution of the fluorescence from selected transitions after excitation of the XeI ground state to the doubly excited state [Kr] $5s^2$ $5p^4$ $(^3P_2)$ nl n^*l^* with narrow-band synchrotron radiation and its subsequent autoionization into XeII $5p^46p$ satellite states.

The fluorescence angular distribution shows an exciting-photon energy dependent variation. Thereby, the calculation of alignment and orientation parameters for certain electronic states in XeII and an electron partial wave analysis is feasible [Schill et. al., J. Phys. B. 36, L57 (2003)].

A 52: Characterization and control of complex quantum systems SYQS 1 (with Q, MO, MS, MP, AGjDPG)

Time: Friday 10:30–12:30 Location: Audimax

Invited Talk A 52.1 Fri 10:30 Audimax
Tutorial Complex Systems: From Classical to Quantum, from Single to Many Particle Problems — •Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

There does not exist a common notion of what defines a complex (quantum) system; depending on context and community perception of complex behavior varies a lot. I will first review aspects and characteristics of complexity in classical systems, where it has been originally considered, pointing out analogies between complex phenomena in simple low-dimensional settings and emergent complexity from interactions in the many-body case. Thereby I will put forward the notion that complex behaviour is linked to discontinuities. In the second part of the lecture I will discuss implications for complex quantum systems.

Questions & answers (11:15 - 11:30)

Invited Talk A 52.2 Fri 11:30 Audimax
Multiphoton random walks: Experimental Boson Sampling on a photonic chip — •Ian Walmsley[1], Justin Spring[1], Ben Metcalf[1], Peter Humphreys[1], Steve Kolthammer[1], Xianmin Jin[1], Animesh Datta[1], James Gates[2], and Peter Smith[2] — [1]University of Oxford, Department of Physics, Clarendon Laboratory, Parks Rd. Oxford, OX2 3PU, UK — [2]Optoelectronics Research Center, University of Southampton, SO17 1BJ, UK

Photonics provides a feasible platform for implementing many quantum information protocols, with the opportunity to realise quantum enhancements to technologies from sensing to computation. For instance, ideal universal quantum computers may be exponentially more efficiently than classical machines for certain classes of problems. Nonetheless, the formidable challenges in building such a device motivate the search for and demonstration of alternative problems that still promise a quantum speedup. Quantum boson sampling (QBS) provides such an example. We have constructed a photonic quantum boson sampling machine (QBSM) to sample the output distribution resulting from the nonclassical interference of photons in an integrated photonic circuit, a problem thought to be exponentially hard to solve classically. Unlike universal quantum computation, boson sampling merely requires indistinguishable bosons, linear state evolution, and detectors, imperfections of which may result in systematic errors. Our studies open the way to larger devices that could offer the first definitive quantum enhanced computation.

A 52.3 Fri 12:00 Audimax
Antiresonance in a Strongly-Coupled Atom-Cavity System — •Christoph Hamsen, Christian Sames, Haytham Chibani, Paul A. Altin, Tatjana Wilk, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching

The strongly-coupled atom-cavity system has proven useful for the observation of fundamental quantum effects. Recently, it has found application as a building block for more complex structures in elementary quantum circuits for quantum information processing. Moreover, large networks of strongly-coupled systems have been proposed for simulation of quantum phase transitions. However, due to the strong coupling these compound systems cannot be treated perturbatively, but require a holistic analysis of all constituents making characterization a challenging task.

Here, we provide a route to address this challenge. It is based on an experiment where, by heterodyne detection of the light transmitted through a cavity containing a single atom, we see a hitherto unobserved negative phase shift which is associated with an antiresonance. The linewidth and frequency of this antiresonance are solely determined by the atom. The corresponding phase shift can be optically controlled via the AC stark shift and reaches values of up to 140° - the largest ever reported for a single emitter. We explain how this opens up new routes towards characterization of complex quantum circuits.

A 52.4 Fri 12:15 Audimax
Tuning the Quantum Phase Transition of Bosons in Optical Lattices via Periodic Modulation of s-Wave Scattering Length — Tao Wang[1,2], •Xue-Feng Zhang[1], Francisco Ednilson Alves dos Santos[3], Sebastian Eggert[1], and Axel Pelster[1] — [1]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Department of Physics, Harbin Institute of Technology, China — [3]Instituto de Física de São Carlos, Universidade São Paulo, Brazil

We investigate how the superfluid-Mott insulator quantum phase transition for bosons in a 2D square and a 3D cubic optical lattice changes due to a periodic modulation of the s-wave scattering length. At first we map the underlying periodically driven Bose-Hubbard model approximately to an effective time-independent Hamiltonian with a conditional hopping [1]. Combining different analytical approaches with quantum Monte Carlo simulations then reveals that the location of the quantum phase boundary turns out to depend quite sensitively on the driving amplitude. A more quantitative analysis shows even that the effect of driving can be described within the usual Bose-Hubbard model provided that the hopping is rescaled appropriately with the driving amplitude. This finding indicates that the Bose-Hubbard model with a periodically driven s-wave scattering length and the usual Bose-Hubbard model belong to the same universality class from the point of view of critical phenomena.

[1] A. Rapp, X. Deng, and L. Santos, Phys. Rev. Lett. **109**, 203005 (2012).

A 53: Precision measurements and metrology III (with Q)

Time: Friday 10:30–12:30 Location: DO24 1.101

Group Report A 53.1 Fri 10:30 DO24 1.101
Towards the Quantum Limit: Update from the AEI 10-meter Prototype — •Conor Mow-Lowry and the 10m prototype team — Max-Planck Institute for Gravitational Physics, Hannover, Germany

At the Albert Einstein Institute in Hannover we are building a prototype facility capable of housing experiments that will probe the boundaries of interferometric sensitivity. Our core experiment is a Fabry-Perot Michelson interferometer designed to reach the Standard Quantum Limit (SQL), the point where quantum radiation pressure noise and photon shot noise are equal. From there we can investigate techniques to surpass this limit.

Many of the infrastructure components of our facility are themselves research projects, borrowing from developments in space-based metrology and from the most sensitive devices in the world, interferometric gravitational-wave detectors. I will describe the status of the 10-meter project with a focus on the many interesting challenges between us and meeting our design goals.

A 53.2 Fri 11:00 DO24 1.101
Growing and characterisation of (thorium-doped) calcium fluoride crystals for a solid-state nuclear clock — •Matthias Schreitl[1], Georg Winkler[1], Christoph Tscherne[1], Simon Stellmer[1], Philipp Dessovic[2], Peter Mohn[2], Robert Jackson[3], and Thorsten Schumm[1] — [1]Vienna Center for Quantum Science and Technology (VCQ), Atominstitut, Technische Universität Wien — [2]Center for Computational Materials Science, Technische Universität Wien — [3]School of Physical and Geographical Sciences, Keele University

The isotope ^{229}Th is predicted to provide a unique low-energy excited nuclear state situated only 7.8 ± 0.5 eV [1] above the ground state, opening the possibility to access nuclear physics with lasers. An estimated lifetime of hours [1] makes this narrow transition an excellent candidate for a new time standard.

The transition energy still remains to be determined with higher precision. Our experimental approach is based on embedding ^{229}Th (> 10^{14} nuclei) in the UV-transparent crystal structure of Calcium fluoride (CaF_2).

We present progress in CaF_2 growth in order to produce single crystals which are transparent in the relevant wavelength region. As the relevant isotope ^{229}Th is radioactive and only available in very small quantities, preliminary measurements are carried out with the stable isotope ^{232}Th. Here, we investigate the implantation of thorium ions into the crystal lattice and how this affects the transparency.

[1] B. R. Beck et al., Phys. Rev. Lett. 98, 142501 (2007)

A 53.3 Fri 11:15 DO24 1.101

Characterization of a Transportable Strontium Lattice Clock — •Stefan Vogt, Sebastian Häfner, Stephan Falke, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt (PTB); Bundesallee 100; 38116 Braunschweig

The excellent performance of optical frequency standards offers new prospects for applications as well as for fundamental research. Applications include the operation as optical clock and relativistic methods for geodesy. In fundamental research, new bounds for variations of e.g. the fine structure constant can be set and hence experimental input to the search for physics beyond the standard model can be provided.

Here we present the progress on a new apparatus for a lattice clock with strontium atoms, which is designed to be transportable. Laser cooling of strontium atoms into an optical lattice has been achieved and spectroscopy on the clock transition has been carried out. First characterizations of the apparatus indicate that a low inaccuracy of about 10^{-17} will be feasible with the transportable setup.

This work was supported by QUEST, DFG (RTG 1729), EU-FP7 (SOC2, Project No. 263500), and the European Metrology Research Programme (EMRP) in IND14, ITOC, and QESOCAS. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

A 53.4 Fri 11:30 DO24 1.101

Spectroscopy of the $^1S_0 \rightarrow {}^3P_0$ clock transition in magnesium — •André Kulosa, Steffen Rühmann, Dominika Fim, Klaus Zipfel, Steffen Sauer, Birte Lampmann, Leonie Theis, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

We report on the latest status of the magnesium optical lattice clock experiment at IQ in Hannover. 10^4 magnesium atoms are optically trapped in a lattice at the predicted magic wavelength of 469 nm. In order to fulfill the power requirements for sufficient trapping, the lattice is generated within a build-up cavity with a power enhancement factor of 30. The maximum circulating power is 2 W which can be computer-controlled for removing the hottest atoms during a ramping sequence.

As the bosonic isotope ^{24}Mg does not possess a nuclear spin and thus no hyperfine structure, the linewidth of the spin-forbidden clock transition naturally equals zero as there is no coupling to other states. However, laser excitation is possible under presence of a strong magnetic field coupling the $^3P_0$ state to the $^3P_1$ state.

Performing spectroscopy on the clock transition, we observe a clear asymmetry between the red and the blue sideband of the carrier signal where we calculate the temperature of the atoms to be 1.3 μK. Varying lattice power and wavelength, we are able to give a first estimate on the magic wavelength between 467.66 and 468.95 nm.

A 53.5 Fri 11:45 DO24 1.101

Detection of a single charge using the NV center in diamond — Florian Dolde[1], Marcus Doherty[2], Julia Michl[1], •Ingmar Jakobi[1], Philipp Neumann[1], Neil Manson[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut und SCoPE Research Center, Universität Stuttgart, Germany — [2]Laser Physics Centre, Australian National University, Canberra, Australia

Advancement towards the characterization of nanoscale systems is a matter of particular interest in metrology. A fundamental step in this progress is the sensing of single particles.

Using electric field sensing techniques with nitrogen-vacancy (NV) centers in diamond we are able to detect a single charge under ambient conditions [1].

We use a pair of NV centers for our studies. One NV center can be employed as a sensitive electrometer to detect changes in the electric field. The second NV is used as a source, where a single electron can be displaced by optically switching between its neutral and negative charge states. For this purpose the NV centers need to have a close distance which we show using super-resolution techniques. In consequence, our measurements provide direct insight into the charge dynamics inside the material on a nanoscopic scale.

[1] F.Dolde, et al., arXiv:1310.4240 (2013)

A 53.6 Fri 12:00 DO24 1.101

Long spin coherence of nitrogen-vacancy centres in high purity nanodiamonds — •Dhiren Kara, Helena Knowles, and Mete Atature — Cavendish Laboratory, University of Cambridge, Cambridge, UK

The nitrogen-vacancy centre (NV) in diamond provides a highly localised spin-state that can be initialised and probed optically, and coherently manipulated with microwave fields. In addition to quantum information applications, the centre can be used for magnetic field and temperature sensing in a wide range of environments. NVs embedded in nanodiamond crystals are of particular interest for sensing purposes because they can be placed in close proximity to the target and, being bio-compatible, inserted into cells. However, their use has been limited by low sensitivity due to poor spin coherence times.

This talk focuses on measurements performed in ambient conditions on nanocrystals milled from low nitrogen content (50 ppm) bulk diamond, where we are able to extend the free precession time from 0.4 to 1.27 μs by driving dark paramagnetic spin impurities in the lattice into the motionally averaged regime [1]. Further, using dynamical decoupling schemes we achieve a coherence time of 60 μs, an order of magnitude improvement on previous reports. Our results show that these nanodiamonds offer a d.c. and a.c. magnetic field sensitivity of 600 and 140 $\mathrm{nT\,Hz^{-1/2}}$ respectively.

[1] H. S. Knowles, D. M. Kara and M. Atature, Nat. Mater. DOI:10.1038/NMAT3805 (2013)

A 53.7 Fri 12:15 DO24 1.101

Angle Resolved Electric Field Sensing with Single Spin Defects in Solids — •Julia Michl[1], Marcus Doherty[2], Ingmar Jakobi[1], Florian Dolde[1], Philipp Neumann[1], Tokuyuki Teraji[3], Junichi Isoya[4], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Germany — [2]Australian National University, Canberra, Australia — [3]National Institute for Materials Science, Tsukuba, Japan — [4]Research Center for Knowledge Communities, University of Tsukuba, Japan

In recent years, the nitrogen-vacancy (NV) center in diamond has emerged as a promising candidate not only for quantum computing, but also for sensing applications. Electric field sensing via NV, contrary to magnetic field sensing, is a rather unexplored topic of research. Here, we conduct new measurements using transverse magnetic and electric fields, which allows further verification and refinement of the Stark-shift Hamiltonian.

With such measurements, the strength of electric fields in transverse direction can be measured. Additionally, conclusions about its angular direction can be drawn, as the C_{3v} symmetry of the NV center affects the Stark-shift under certain angles. Hence, these measurements allow to assert the orientation along the symmetry axis of the NV.

A 54: Precision measurements and metrology IV (with Q)

Time: Friday 14:00–15:45 Location: DO24 1.101

Group Report A 54.1 Fri 14:00 DO24 1.101

States, schemes and detection for quantum atom optics — •Ion Stroescu, Wolfgang Muessel, Daniel Linnemann, Helmut Strobel, Jonas Schulz, David B. Hume, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

We present our recent advances in creation and detection of quantum states in atomic systems.

We generate spin squeezed states containing more than 10000 Bose condensed atoms by making use of paralleled nonlinear evolution of two component Bose-Einstein condensates in an optical lattice. The access to the on-site properties allows for precise characterization of technical noise sources, which are found to be the only limitation for the scalability of squeezing with atom number.

Moreover, we report on the first experimental implementation of an SU(1,1) interferometer for an atomic system, which uses active beam splitters realized by spin-changing collisions. We measure the phase-dependent output signal for small average atom numbers inside the interferometer (~ 1 per side mode) and characterize its phase sensitivity, which is predicted to be at the Heisenberg limit.

Harnessing these resources at the ultimate level requires detection with single-atom resolution. We explore the limits of atom number counting via resonant fluorescence detection, reaching single-particle resolution for atom numbers up to 1200. We also develop a hybrid atom trap capable of simultaneous atom counting for multiple spin states, as required for Heisenberg-limited measurements of spin-entangled atoms.

A 54.2 Fri 14:30 DO24 1.101

Simultaneous dual species matter wave interferometry — •Dennis Schlippert, Henning Albers, Logan Richardson, Christian Meiners, Jonas Hartwig, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

We report on the first realization of a simultaneous dual species matter wave interferometer employing ^{39}K and ^{87}Rb aiming to test Einstein's equivalence principle. Our method is complementary to classical tests. With pulse separation times of up to T=20ms in a Mach-Zehnder geometry, we realize simultaneous absolute measurements of acceleration. We present first results, a stability analysis and the leading order systematic errors. We discuss future use of a dual species dipole trap and large momentum transfer beamsplitters to further increase the stability and accuracy of the apparatus.

A 54.3 Fri 14:45 DO24 1.101

Multiparticle singlet states and their metrological applications — •Iñigo Urizar-lanz[1], Zoltán Zimboras[1], Iagoba Apellaniz[1], and Géza Tóth[1,2,3] — [1]Theoretical Physics, The University of the Basque Country, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Wigner Research Centre for Physics, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest, Hungary

Singlet states are quantum states of vanishing angular momentum. When composing the angular momenta of two spin-j particles, there appears a unique singlet state, however, for an ensemble of N particles there exists a plethora of different types of singlets. We present a partial classification of them, and then focus on the permutationally invariant (PI) ones. Their basic properties and characterization is presented, and some specific PI singlets are studied for metrological applications. In particular, we calculate the maximal achievable accuracy when measuring the gradient of a magnetic field using these states. Moreover, we single out a measurement set-up that saturates the bound given by the quantum Fisher Information.

A 54.4 Fri 15:00 DO24 1.101

Coating Thermal Noise Interferometer — •Tobias Westphal and the AEI 10m Prototype team — Albert Einstein Institut Hannover

Coating thermal noise (CTN) is becoming a more and more significant noise source as the sensitivity of interferometry is pushed to its limits. It arises from inherent mechanical loss of thin films in dielectric coatings. Deeper understanding and verification of its theory such as frequency dependence of losses requires direct (off-resonant) observation. The AEI 10 m Prototype facility is probably the best suited environment for this kind of experiment in a frequency range of special importance for earth bound gravitational wave detectors.

In this presentation the CTN- interferometer, being at the transition from construction to commissioning phase, will be presented. The range that is solely limited by CTN is designed to reach from 10 Hz to about 50 kHz, limited by seismic noise at low frequencies and shot noise (photon counting noise) at high frequencies. Therefore the interferometer is suspended in multiple stages. Digitally controlled actuation as well as active damping schemes were successfully demonstrated.

A 54.5 Fri 15:15 DO24 1.101

Microwave Electrometry with Rydberg Atoms in a Vapor Cell — •Harald Kübler[1,2], Jonathan A. Sedlacek[1], Arne Schwettmann[1], Renate Daschner[2], Haoquan Fan[1], Santosh Kumar[1], Robert Löw[2], Tilman Pfau[2], and James P. Shaffer[1] — [1]Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, 440 W. Brooks St. Norman, Oklahoma 73019, USA — [2]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany

Quantum based standards of length and time as well as measurements of other useful physical quantities, ex. magnetic fields, are important because quantum systems, like atoms, show clear advantages for providing stable and uniform measurements. We demonstrate a new method for measuring microwave electric fields based on quantum interference in a Rubidium atom. Using a bright resonance prepared within an electromagnetically induced transparency window we are able to achieve a sensitivity of $30\mu V cm^{-1}\sqrt{Hz}^{-1}$ and demonstrate detection of microwave electric fields as small as $\sim 8\mu V cm^{-1}$ with a modest setup [1]. This method can be used for vector electrometry with a precision below 1° [2]. We show first results on microwave field imaging with a sub-wavelength resolution.

[1] J.A. Sedlacek, et.al. "Quantum Assisted Electrometry using Bright Atomic Resonances" *Nature Physics* **8**, 819 (2012)

[2] J.A. Sedlacek, et.al. "Atom-Based Vector Microwave Electrometry Using Rubidium Rydberg Atoms in a Vapor Cell" *Phys. Rev. Lett.* **111**, 063001 (2013)

A 54.6 Fri 15:30 DO24 1.101

Characterization of a high-power fiber amplifier — •Patrick Oppermann[1], Thomas Theeg[2], Hakan Sayinc[2], and Benno Willke[1] — [1]Albert-Einstein-Institut Hannover — [2]Laser Zentrum Hannover e. V.

A detailed beam characterization of continuous-wave single frequency fiber amplifier with an output power of more than 200 W at a wavelength of 1064 nm is presented. The power noise, frequency noise, beam pointing fluctuations and spatial beam quality were measured with a diagnostic instrument called diagnostic breadboard based on an optical ring resonator. The results are compared with the Advanced LIGO Pre-Stabilized Laser system. The laser was automatically characterized over a period of three weeks to investigate the long-term behavior. During this time the laser was running 24 hours a day, without showing any significant problems.

A 55: Characterization and control of complex quantum systems SYQS 2 (with Q, MO, MS, MP, AGjDPG)

Time: Friday 14:00–16:00 Location: Audimax

Invited Talk A 55.1 Fri 14:00 Audimax

Charge transfer and quantum coherence in solar cells and artificial light harvesting systems — •Christoph Lienau — Carl von Ossietzky University, Institute of Physics, Oldenburg, Germany

In artificial light harvesting systems the conversion of light into electrical or chemical energy happens on the femtosecond time scale [1], and is thought to involve the incoherent jump of an electron from the optical absorber to an electron acceptor. Here we investigate the primary dynamics of the photoinduced electronic charge transfer process in two prototypical structures: (i) a carotene-porphyrin-fullerene triad, a prototypical elementary component for an artificial light harvesting system and (ii) a polymer:fullerene blend as a model system for an organic solar cell. Our approach [2] combines coherent femtosecond spectroscopy and first-principles quantum dynamics simulations. Our experimental and theoretical results provide strong evidence that the driving mechanism of the primary step within the current generation cycle is a quantum-correlated wavelike motion of electrons and nuclei on a timescale of few tens of femtoseconds. We furthermore highlight the fundamental role played by the flexible interface between the light-absorbing chromophore and the charge acceptor in triggering the coherent wavelike electron-hole splitting.

[1] C. J. Brabec et al., Chem. Phys. Lett. 340, 232 (2001). [2] C. A. Rozzi et al., 'Quantum coherence controls the charge separation in a prototypical artificial light-harvesting system', Nature Communications 4, 1602 (2013).

A 55.2 Fri 14:30 Audimax

Designing Disorder-Assisted Energy Transfer — •Mattia Walschaers[1,2], Roberto Mulet[1,3], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany — [2]Instituut voor Theoretische Fysica, KU Leuven, Celestijnenlaan 200D, B-3001 Heverlee, Belgium — [3]Complex Systems Group, Department of Theoretical Physics, University of Havana, Havana, Cuba

Common wisdom suggests that complex structures typically have a negative impact on quantum transport, due to localization phenomena and the strong fluctuations which they cause. We show that localization and strong fluctuations can also be used to the benefit of transport.

By controlling typical spectral properties of an ensemble of complex systems, we design localization properties. In doing so, we can build systems such that the energy transport is mainly governed by only two scattering resonances.

When, however, these resonances start to overlap considerably, the transfer efficiency decreases drastically. We explain that a suitable control of some average properties of the energy spectrum gives rise to a statistical repulsion between the two scattering resonances. Hereby we can avoid drastic losses of the transfer efficiency, rendering the transport mechanism very robust.

A 55.3 Fri 14:45 Audimax

Cooperative effects of external control and dissipation in open quantum systems — •Rebecca Schmidt, Jürgen T. Stockburger, and Joachim Ankerhold — Institut für Theoretische Physik, Universität Ulm, Albert Einstein-Allee 11, 89069 Ulm

Coherent optimal control of non-Markovian open quantum systems is crucial in tailored-matter such as quantum information processing. In general, the presence of dissipative reservoirs is considered as detrimental to quantum coherence and entanglement. However, tailored control pulses [1] may change the role of a heat bath from being destructive on quantum resources to an asset promoting them. Here we show that the cooperative interplay between optimal control signals and a dissipative medium may indeed induce phenomena such as entropy reduction (cooling) [1,2] and creation of bi-partite entanglement [3].

[1] R. Schmidt, A. Negretti, J. Ankerhold, T. Calarco and J.T. Stockburger, PRL **107**, 130404 (2011)

[2] R. Schmidt, S. Rohrer, J.T. Stockburger and J. Ankerhold, Phys. Scr. **T151**, 014034 (2012)

[3] R. Schmidt, J.T. Stockburger, and J. Ankerhold, PRA **88**, 052321 (2013)

A 55.4 Fri 15:00 Audimax

Nonlinear spectroscopy with quantum light — •Frank Schlawin[1], Konstantin Dorfman[2], Benjamin Fingerhut[2], and Shaul Mukamel[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79108 Freiburg, Germany — [2]Department of Chemistry, University of California, Irvine, California 92697-2025, USA

Nonlinear spectroscopy has evolved into an indispensable tool to probe non-equilibrium dynamics of complex quantum systems. Typically, the interpretation of these signals suffers from the enormous number of free parameters in the underlying Hamiltonians of the system and its coupling to the environment. It is highly desirable to develop new tools to extract further information from those systems. We will discuss the possibility of exploiting strong correlations of entangled light to manipulate nonlinear spectra of complex quantum systems such as photosynthetic complexes. Exciton transport can be suppressed, and two-exciton states can be selectively excited.

A 55.5 Fri 15:15 Audimax

Dynamical Algebras and Many-body Physics — •Zoltán Zimborás[1], Robert Zeier[2], Zoltán Kádár[3], Michael Keyl[2], and Thomas Schulte-Herbrüggen[2] — [1]University of the Basque Country (UPV/EHU), Bilbao, Spain — [2]Technische Universität München (TUM), Germany — [3]University of Leeds (UL), UK

Dynamical algebras, i.e., Lie algebras generated by Hamiltonians, are basic tools both in Quantum Control and Quantum Simulation Theory. In this talk, we will argue that these algebras might also have relevance in Many-Body Physics. By studying Lie closures of translation-invariant Hamiltonians, we show that nearest-neighbor Hamiltonians do not generate all translation-invariant interactions. We discuss the relevance of this result in simulating many-body dynamics. Furthermore, we point out that our results [1] also provides a surprising Lie algebraic explanation of a previous finding of ours concerning the absence of gap in quasifree models with (twisted) reflection-symmetry breaking [2].

[1] Z. Zimborás, R. Zeier, M. Keyl, and T. Schulte-Herbrüggen, “A Dynamic Systems Approach to Fermions and Their Relations to Spins”, arXiv:1211.2226.

[2] Z. Kádár and Z. Zimborás, “Entanglement entropy in quantum spin chains with broken reflection invariance”, Phys. Rev. A 82, 032334 (2010).

Invited Talk A 55.6 Fri 15:30 Audimax

Feedback control: from Maxwell's demon to quantum phase transitions — •Tobias Brandes — TU Berlin

I will give an overview of our recent attempts to understand the thermodynamics and quantum mechanics of closed loop (feedback) control. I will discuss a minimal implementation of Maxwell's demon in a solid state system with only four states [1], but also the opposite case of many collective degrees of freedom, i.e. models for phase transitions (Dicke superradiance model [2], quantum Ising chain [3]).

[1] P. Strasberg, G. Schaller, T. Brandes, and M. Esposito, Phys. Rev. Lett. 110, 040601 (2013). [2] T. Brandes, Phys.Rev.E 88 032133 (2013). [3] M. Vogl, G. Schaller, T. Brandes, Phys. Rev. Lett. 109, 240402 (2012).

A 56: Ultracold atoms and molecules II (with Q)

Time: Friday 14:00–15:30 Location: DO26 208

A 56.1 Fri 14:00 DO26 208

3D motional ground state cooling of a single atom inside a high-finesse cavity — •Natalie Thau, Wolfgang Alt, Tobias Macha, Lothar Ratschbacher, René Reimann, Seokchan Yoon, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn

Tight control and knowledge of the motional states of single atoms are a prerequisite for many cavity-QED experiments. In our system single cesium atoms coupled to a high finesse optical cavity are cooled close to the 2D motional ground state by means of resolved Raman sideband cooling [1,2]. We drive Raman transitions between two hyperfine ground states, where the blue detuned intracavity dipole trap acts as one of the two perpendicular adjusted Raman beams. Thereby we strongly suppress motional carrier transitions along the cavity axis and implement effective cooling. A Raman spectrum is recorded by mapping out the population of the motional ground states to one hyperfine ground state by Raman transitions for different two-photon detunings. Each time the atomic state is efficiently detected with the cavity as a non-destructive measurement tool. Currently, we expand the scheme to reach 3D ground state cooling.

[1] A. Boca *et al.*, Phys. Rev. Lett. **93**, 233603 (2004)

[2] A. Reiserer *et al.*, Phys. Rev. Lett. **110**, 223003 (2013)

A 56.2 Fri 14:15 DO26 208

Efficient demagnetization cooling and its limits — •Jahn Rührig, Tobias Bäuerle, Tilman Pfau, and Axel Griesmaier — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, Stuttgart, 70569 , Germany

We present the latest data on the demagnetization cooling of a dipolar chromium gas and discuss the limitations regarding reabsorption of optical pumping photons and light assisted collisions. Demagnetizaiton cooling utilizes dipolar relaxations that couple the internal degree of freedom (spin) to the external (angular momentum) to efficiently cool an atomic cloud [1]. Optical pumping into a dark state constantly recycles the atoms that were promoted to higher spin states. The net energy taken away by a single photon is very favorable as the lost energy per atom is the Zeeman energy rather than the recoil energy. The cooling scheme was proposed by Kastler already in 1950 [2] and demonstrated in a proof of principle experiment in 2006 [3].

[1]:S. Hensler et al. , Europhys. Lett. 71,918 (2005).
[2]:A. Kastler, Le Journal de Physique et le Radium 11, 255 (1950).
[3]:M. Fattori et al. , Nature Physics 2, 765 (2006).

A 56.3 Fri 14:30 DO26 208

Continuous loading of a mesoscopic atom chip — •Ilka Geisel, Jan Mahnke, Andreas Hüper, Wolfgang Ertmer, and Carsten Klempt — Institut für Quantenoptik, Leibniz Universität Hannover

While microscopic atom chips enhance cooling rates significantly, they typically suffer from smaller atomic ensembles. Our aim is to combine the advantages of atom chips with those of conventional BEC experiments by using a mesoscopic wire structure to provide the magnetic fields for magneto-optical and magnetic trapping.

This structure consists of millimeter-scale wires and is used to create a quadrupole field for a magneto-optical trap [1] and a flexible magnetic trapping potential, connected by a magnetic guide. The magnetic trapping region is shielded from the magneto-optical trap and thus provides better vacuum conditions and perfect stray light protection.

We investigate continuous loading mechanisms of a magnetic trap [2]. We demonstrate the production of a continuously replenished ultracold atomic cloud. Due to continuous evaporation, the cloud has an increasing number of atoms and a decreasing temperature until reaching a final equilibrium.

[1] S. Jöllenbeck, Phys. Rev. A 83, 043406 (2011)
[2] C. F. Roos, Europhys. Lett. 61, 187 (2003)

A 56.4 Fri 14:45 DO26 208

Ground state cooling in an 1D optical lattice — •Ricardo Gomez, Carsten Robens, Isabelle Boventer, Jonathan Zopes, Wolfgang Alt, Andrea Alberti, and Dieter Meschede — Institut für Andgewante Physik (IAP), Bonn, Germany

Discrete-time quantum walks of neutral atoms in optical lattices allows to experimentally investigate complex transport phenomena, where the single constituents are allowed to coherently interact with each other [1].

We report on the ground state cooling of neutral atoms in the ground state of a 1D optical lattice. Microwave and Raman sideband cooling are used as cooling mechanisms for the axial and radial direction, respectively. To achieve a tight confinement in the radial direction, we use a blue-detuned doughnut-shaped dipole trap overlapped to the optical lattice.

The preparation in the motional ground state opens the way to use onsite coherent collisions between atoms to realize interacting quantum walks.

[1] A. Ahlbrecht, A. Alberti, D. Meschede, V. B. Scholz, A. H. Werner, and R. F. Werner, Molecular binding in interacting quantum walks, New J. Phys. 14, 073050 (2012)

A 56.5 Fri 15:00 DO26 208

Simultaneous D_1 line sub-Doppler laser cooling of fermionic ^{6}Li and ^{40}K – Experimental results and theory — •Franz Sievers[1], Norman Kretzschmar[1], Diogo Fernandes[1], Daniel Suchet[1], Michael Rabinovic[1], Saijun Wu[2], Lev Khaykovich[3], Frédéric Chevy[1], and Christophe Salomon[1] — [1]Laboratoire Kastler Brossel, ENS/UPMC/CNRS, 75005 Paris, France — [2]Department of Physics, College of Science, Swansea University, SA2 8PP Swansea, United Kingdom — [3]Department of Physics, Bar-Ilan University, 52900 Ramat-Gan, Israel

We report on simultaneous sub-Doppler laser cooling of fermionic ^{6}Li and ^{40}K on the D_1-transition. We compare the experimental results to a numerical simulation of the cooling process using a semi-classical MonteCarlo wavefunction method. The simulation takes into account the three dimensional optical molasses setup and the vectorial interaction between the polarized light and single atoms at the D_1-manifold spanned by the hyperfine Zeeman sub-levels. We find that the simulation and experimental results are in good qualitative agreement.

The D_1-molasses phase largely reduces the temperature for both ^{6}Li and ^{40}K, with a final temperature of 44 μK and 20 μK respectively. For both species this leads to a phase-space density close to 10^{-4}. These conditions are well suited to directly load an optical dipole trap or magnetic traps.

Furthermore, we explore a potential application of D_1-cooling for ^{6}Li in a lattice trap enabling a quantum gas microscope similar to the case of ^{87}Rb.

A 56.6 Fri 15:15 DO26 208

Thermodynamics and redistributional laser cooling in dense gaseous ensembles — •Katharina Knicker, Stavros Christopoulos, Peter Moroshkin, Anne Sass, Lars Weller, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn

Laser cooling via collisional redistribution of fluorescence is a very efficient cooling technique applicable to ultradense gaseous ensembles. A high pressure environment ensures frequent collisions of optically active rubidium atoms with a noble buffer gas which shift the atomic resonances, allowing for absorption of a far red-detuned irradiated laser beam. Subsequent spontaneous decay occurs closer to the unperturbed resonances resulting in the extraction of kinetic energy of the order of $k_B T$ during each cooling cycle. The induced temperature changes are determined through thermal deflection spectroscopy and can be as high as 500K. Kennard-Stepanov analysis of the pressure-broadened absorption and fluorescence spectra allows for the determination of temperature changes in a non-interacting manner. Further investigations include redistributional cooling of molecular systems.

A 57: Precision measurements and metrology V (with Q)

Time: Friday 16:30–18:15 Location: DO24 1.101

Group Report A 57.1 Fri 16:30 DO24 1.101

The GRACE Follow-On Laser Ranging Interferometer — •Alexander Görth — Max Planck Institut für Gravitationsphysik, Leibniz Universität Hannover, Deutschland

In the year 2017 a follow-on mission to the very successful joint German / NASA mission GRACE (Gravity Recovery And Climate Experiment) will be launched. The two GRACE satellites have been mapping the spatial and temporal variations of the Earth's gravitational field by satellite-to-satellite tracking for more than ten years now. While only a microwave ranging instrument has been used for this measurement in GRACE, an additional laser ranging interferometer (LRI) will be implemented into the architecture of the GRACE Follow-On satellites as a technology demonstrator. It is intended to verify the benefits of a laser-based measurement which is expected to eventually become the main science instrument in future geodesy missions. We will present the status of the development of the LRI as well as the latest results of experimental tests on sub-units of the LRI.

A 57.2 Fri 17:00 DO24 1.101

Towards the Demonstration of a BEC-based Atom Interferomter in Space — •Stephan Tobias Seidel[1], Dennis Becker[1], Maike Lachmann[1], Ernst Maria Rasel[1], and The Quantus-Team[1,2,3,4,5,6,7,8] — [1]Institut für Quantenoptik, LU Hannove — [2]ZARM, Universität — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham — [8]FBH, Berlin

A central goal of modern physics is the test of fundamental principles of nature with ever increasing precision. One of these contains of a differential measurement on freely falling ultra-cold clouds of two atomic species and thus using atom interferometry to test the weak equivalence principle in the quantum domain. By performing such an experiment in a weightless environment the precision of the interferometer can be considerably increased.
Here we demonstrate an apparatus for the first realization of a Bose-

Einstein-condensate on a sounding rocket and its use as a source for atom interferometry in space. Its planned launch in November 2014 will be an important step towards the goal of placing high-precision atom-interferometric measurement devices in space.

A 57.3 Fri 17:15 DO24 1.101

High-precision phasemeter for the Deep Phase Modulation Interferometry — •Thomas S. Schwarze — Albert-Einstein-Institut Hannover

We present our results of the development of a dedicated-hardware modulation signal synthesis and phasemeter system for the Deep Modulation Interferometry technique. For this technique, a sinusoidal modulation is applied through a ring piezo-electric actuator to one arm of a Mach-Zehnder interferometer in order to reach large modulation depths in the order of 10 rad. The interferometer phase is extracted by a complex fit to the harmonic amplitudes of the modulation frequency. The presented system prototype uses a Direct Digital Synthesizer and a Digital Signal Processing core, both implemented on a Field Programmable Gate Array. The first allows generation and control of the modulation signal to drive the ring piezo-electric actuator. The latter computes the harmonic amplitudes by performing multiple single-bin discrete Fourier transforms. These amplitudes are subsequently transmitted to a PC via Ethernet to conduct the complex fit computations. The results obtained from a zero measurement with an optical signal revealed a phasemeter precision of 2.3 pm/rtHz below and 0.1 pm/rtHz above 10 Hz.

A 57.4 Fri 17:30 DO24 1.101

Absolut distance interferometry based on a physical reference — •Günther Prellinger, Karl Meiners-Hagen, and Florian Pollinger — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

We present an absolute distance interferometer based on frequency-sweeping interferometry with an envisioned range of up to 100 m and a targeted measurement uncertainty well below 1E-6. We use in-situ high resolution spectroscopy to establish traceability with low uncertainty. The basic idea of frequency-sweeping multi-wavelength metrology is to vary the optical frequency over a known frequency interval for a fixed unknown distance in a classical interferometer. In our study, we investigated the use of a spectroscopic reference for the frequency measurement. Therefore, we combine the interferometric phase measurement with simultaneous Doppler-free iodine high resolution spectroscopy at 637 nm. This approach provides direct traceability of the distance measurement together with a lowered demand on environmental stability. The experimental results demonstrate that the relative uncertainty of the position (frequency) determination is approximately 3E-9. For the absolute distance measurement itself, a heterodyne interferometer with vibration compensation has been developed and simultaneous spectroscopic and interferometric measurements have been performed. The authors would like to acknowledge financial support by the Deutsche Forschungsgemeinschaft (DFG) under grant PO1560/1-1.

A 57.5 Fri 17:45 DO24 1.101

Study of photoreceivers for space-based interferometry — •Germán Fernández Barranco — Albert-Einstein-Institut Hannover

The photoreceiver is a basic element in laser interferometry systems presented in space-based missions such as Lisa Pathfinder or GRACE-FO. The special requirements demanded by those systems rule out any commercial solution for the photoreceiver. Therefore, new photoreceiver designs have been developed and characterized in the Max Planck Institute for Gravitational Physics, Hannover, focusing the efforts on the bandwidth and noise performance. Additionally, a high-accuracy measurement system was configured to perform scans of the photodiodes' surface, which allow a real understanding of the spatial response of those devices.

A 57.6 Fri 18:00 DO24 1.101

Precision measurements of temperature and chemical potential of quantum gases — Ugo Marzolino[1,2,3] and •Daniel Braun[3,4] — [1]Albert-Ludwigs-Universiät Freiburg, D-79104 Freiburg, Deutschland — [2]Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenija — [3]Laboratoire de Physique Théorique (IRSAMC), Université de Toulouse and CNRS, F-31062 Toulouse, France — [4]Institut für theoretische Physik, Universität Tübingen, 72076 Tübingen, Germany

We investigate the sensitivity with which the temperature and the chemical potential characterizing quantum gases can be measured. We calculate the corresponding quantum Fisher information matrices for both fermionic and bosonic gases. For the latter, particular attention is devoted to the situation close to the Bose-Einstein condensation transition, which we examine not only for the standard scenario in three dimensions, but also for generalized condensation in lower dimensions, where the bosons condense in a subspace of Hilbert space instead of a unique ground state, as well as condensation at fixed volume or fixed pressure. We show that Bose-Einstein condensation can lead to sub-shot-noise sensitivity for the measurement of the chemical potential. We also examine the influence of interactions on the sensitivity in three different models and show that meanfield and contact interactions deteriorate the sensitivity but only slightly for experimentally accessible weak interactions.

A 58: Characterization and control of complex quantum systems SYQS 3 (with Q, MO, MS, MP, AGjDPG)

Time: Friday 16:30–18:30 Location: Audimax

A 58.1 Fri 16:30 Audimax

Exciton-polariton lasing in disordered ensembles of correlated Mie resonators — •Regine Frank[1] and Andreas Lubatsch[2] — [1]Institute for Theoretical Physics, Eberhard-Karls University Tübingen, Germany Center for Light-Matter-Interaction, Sensors and Analytics (LISA+) and Center for Complex Quantum Phenomena (CQ) — [2]Electrical Engineering, Precision Engineering, Information Technology, Georg-Simon-Ohm University of Applied Sciences, Kesslerplatz 12, 90489 Nürnberg, Germany

The spectral density of electronic states of ZnO is investigated for experimentally relevant pump power values of random lasers. Non-equilibrium Keldysh theory and numerics for the Hubbard model predicts unusal broadening of the electronic bands. We discuss whether this leads to exciton-polariton coupling within the single ZnO cylinders in the Mie resonance condition. The cylinders are considered random in space but coherently correlated by photonic transport and multiple scattering. Long range interferences are found to be crucial for the development of a polariton condensate and lasing of large-area quantum efficiency.

R. Frank, A. Lubatsch, Phys. Rev. A 84, 013814 (2011) R. Frank, Phys. Rev. B 85, 195463 (2012)

A 58.2 Fri 16:45 Audimax

Tomography of squeezed and oversqueezed states of mesoscopic atomic ensembles — •Baptiste Allard, Roman Schmied, Caspar F. Ockeloen, and Philipp Treutlein — Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland

The experimental characterization of the quantum state of a mesoscopic ensemble of particles is a major challenge in quantum physics, especially when multi-particle entanglement is present.

We experimentally demonstrate tomographic state reconstruction of non-classical many-body (pseudo-)spin states. The system consists of a two-component ^{87}Rb Bose-Einstein condensate of a few hundred atoms created on an atom-chip [1]. A state-selective potential gives rise to a S_z^2 interaction term in the Hamiltonian in the collective spin representation. Using this one-axis twisting dynamics [2], we prepare non-classical spin states such as spin-squeezed and spin-oversqueezed states.

Using well-controlled Rabi rotations and projective measurements, we perform a Stern-Gerlach-type analysis to characterize the many-body quantum states. From the results of measurements along many quantization axes, we determine the most likely positive-semidefinite density matrix; this represents an improvement over our previously published backprojection technique [3].

[1] M. F. Riedel, *et al.*, Nature **464**, 1170 (2010). [2] M. Kitagawa and M. Ueda, Phys. Rev. A **47**, 5138-5143 (1993). [3] R. Schmied and P. Treutlein, New J. Phys. **13**, 065019 (2011).

A 58.3 Fri 17:00 Audimax

On the versatility of quantum master equations: an effective description of disorder dynamics — •Chahan M. Kropf, Clemens Gneiting, and Andreas Buchleitner — Institute of Physics, Albert-Ludwigs University of Freiburg, Hermann-Herder-Str.3, D-79104 Freiburg, Germany

In order to describe the dynamics of quantum systems subject to disorder, one typically computes the ensemble average either with a perturbative approach or by direct numerical simulation. Another possibility consists in an effective description of the ensemble-averaged dynamics.

Here we propose to derive general, local-in-time, quantum master equations for the ensemble-averaged dynamics of finite, isolated, disordered quantum systems. To do so, we first invert the exact dynamics for single realizations, and then perform the ensemble averaging explicitly. Under rather general conditions do we find Non-Markovian dynamics and master equations with time-dependent decay rates and Hermitian Lindblad operators.

Invited Talk A 58.4 Fri 17:15 Audimax

Multi-photon dynamics in complex integrated structures — •Fabio Sciarrino — Dipartimento di Fisica, Sapienza Università di Roma, Italy

Integrated photonic circuits have a strong potential to perform quantum information processing. Indeed, the ability to manipulate quantum states of light by integrated devices may open new perspectives both for fundamental tests of quantum mechanics and for novel technological applications. The evolution of bosons undergoing arbitrary linear unitary transformations quickly becomes hard to predict using classical computers as we increase the number of particles and modes. Photons propagating in a multiport interferometer naturally solve this so-called boson sampling problem, thereby motivating the development of technologies that enable precise control of multiphoton interference in large interferometers. Here, we use novel three-dimensional manufacturing techniques to achieve simultaneous control of all the parameters describing an arbitrary interferometer. We implement a small instance of the boson sampling problem by studying three-photon interference in a nine-mode integrated interferometer, confirming the quantum-mechanical predictions. Scaled-up versions of this set-up are a promising way to demonstrate the computational advantage of quantum systems over classical computers. The possibility of implementing arbitrary linear-optical interferometers may also find applications in high-precision measurements and quantum communication.

Invited Talk A 58.5 Fri 17:45 Audimax

Complexity and many-boson coherence — •Malte Tichy — Department of Physics and Astronomy, Aarhus University, DK-8000 Aarhus, Denmark

Many-boson systems feature a subtle interplay of complexity and coherence. Many-boson coherence is a source of complexity, which makes Boson-Sampling – the simulation of many-boson interference – a paradigm that may demonstrate the superiority of quantum devices. However, current protocols that aim at certifying the functionality of Boson-Sampling setups are shown to be bypassed by an efficient model with randomly prepared independent particles. An alternative test based on a solvable instance of the problem is shown to permit more stringent certification for arbitrarily many particles [1]. The protocol paves the road to rule out alternative models for many-particle behavior that extricate themselves from true complexity. Bosonic composites made of two constituents, however, deviate from ideal elementary bosonic behavior when their constituents are not sufficiently entangled. The complexity of the constituent wavefunction thus becomes a requirement for the ideal collective bosonic behavior of composites and the absence of complexity leads to observable deviations [2].

[1] Malte C. Tichy, Klaus Mayer, Andreas Buchleitner, Klaus Mølmer, arXiv:1312.3080 (2013). [2] Malte C. Tichy, P. Alexander Bouvrie, Klaus Mølmer, Phys. Rev. A 86, 042317 (2012); Phys. Rev. A 88, 061602(R) (2013).

Questions & answers (18:15 - 18:30)