Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture Rooms B 302, B 305, and F 428; Poster Empore Lichthof)

Invited Talks

A 1.1	Mon	11:00–11:30	B 305	**Dynamics of Ultra-cold Atoms in Optical Lattices** — •Sandro Wimberger
A 5.1	Mon	14:00–14:30	B 305	**Taming light waves: Attosecond triggering and clocking of electronic processes** — •Eleftherios Goulielmakis
A 9.1	Mon	16:30–17:00	B 305	**Attosecond physics at a nanoscale metal tip** — •Peter Hommelhoff, Michael Krüger, Michael Förster, Sebastian Thomas, Lothar Maisenbacher, Peter Dombi, Johannes Hoffrogge, Jakob Hammer, Dominik Ehberger, John Breuer, Georg Wachter, Christoph Lemell, Joachim Burgdörfer
A 11.1	Mon	16:30–17:00	B 302	**Spectra of cold molecular ions from hot helium nanodroplets** — •Marcel Drabbels
A 15.1	Tue	11:00–11:30	B 305	**X-ray laser spectroscopy with trapped highly charged ions** — •Sven Bernitt
A 17.1	Tue	14:00–14:30	B 302	**Ultrafast dynamics in molecular systems and clusters** — •Maria Krikunova, Theophilos Maltezopoulos, Philipp Wessels, Ulrike Frühling, Marek Wieland, Markus Drescher, Alaa Al-Shemmary, Nikola Stojanovic, Maria Müller, Jan P. Müller, Bernd Schütte, Thomas Möller
A 18.1	Tue	14:00–14:30	B 305	**Der g-Faktor des gebundenen Elektrons - Test des Standardmodells und Zugang zu fundamentalen Konstanten** — •Sven Sturm, Florian Köhler, Anke Wagner, Zoltan Harman, Jacek Zatorski, Wolfgang Quint, Günter Werth, Christoph H. Keitel, Klaus Blaum
A 26.1	Wed	14:00–14:30	B 302	**Dipolar Physics with Ultracold Atomic Magnets** — •Ferlaino Francesca
A 34.1	Thu	14:00–14:30	B 302	**Interatomic Coulombic decay following electronic excitations** — •Kirill Gokhberg
A 36.1	Thu	14:00–14:30	F 428	**Size selective vibrational spectroscopy of strongly bound neutral clusters** — •Andre Fielicke
A 43.1	Fri	11:00–11:30	B 305	**Accurate, stable, transportable: lattice clocks at PTB** — •Christian Lisdat, Stephan Falke, Nathan Lemke, Thomas Middelmann, Stefan Vogt, Sebastian Häfner, Uwe Sterr
A 45.1	Fri	11:00–11:30	B 302	**Attosecond time-resolved high-resolution spectroscopy of two-electron dynamics in helium, and impulsive control of light** — •Thomas Pfeifer

Invited talks of the joint symposium SYQG

See SYQG for the full program of the symposium.

SYQG 1.1	Tue	11:00–11:30	E 415	**Does time exist in quantum gravity?** — •Claus Kiefer
SYQG 1.2	Tue	11:30–12:00	E 415	**How Attractive is the Moon for Relativity?** — •Jürgen Müller, Liliane Biskupek, Enrico Mai, Franz Hofmann
SYQG 1.3	Tue	12:00–12:30	E 415	**Interferometry with Bose-Einstein condensates in microgravity** — •Ernst Rasel

SYQG 1.4	Tue	12:30–13:00	E 415	**Relativistic effects in atom and neutron interferometry** — •Wolfgang Schleich

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Wed	11:00–11:30	E 415	**Photonic Quantum Computing** — •Stefanie Barz
SYAD 1.2	Wed	11:30–12:00	E 415	**Comparative Studies on some Blackcurrant Odorants and Fruit Esters using a Combination of Microwave Spectroscopy and Quantum Chemical Calculations** — •Halima Mouhib
SYAD 1.3	Wed	12:00–12:30	E 415	**The Standard Model under Extreme Conditions: The g-Factor of Highly Charged Ions** — •Sven Sturm
SYAD 1.4	Wed	12:30–13:00	E 415	**Entanglement and Interference of Identical Particles** — •Malte Christopher Tichy

Invited talks of the joint symposium SYUD

See SYUD for the full program of the symposium.

SYUD 1.1	Wed	14:00–14:30	E 415	**Electron emission from nanospheres in strong, few-cycle laser fields** — •Matthias Kling, Frederik Süßmann, Sergey Zherebtsov, Johannes Stierle, Jürgen Plenge, Eckart Rühl, Lennart Seifert, Thomas Fennel
SYUD 1.2	Wed	14:30–15:00	E 415	**Ultrafast dynamics of gas-phase anions** — •Jan R. R. Verlet
SYUD 1.3	Wed	15:00–15:30	E 415	**Attosecond Larmor Clock for Ionization** — •Olga Smirnova, Jivesh Kaushal, Ingo Barth, Misha Ivanov
SYUD 1.4	Wed	15:30–16:00	E 415	**Clusters in intense x-ray pulses** — •Christoph Bostedt

Invited talks of the joint symposium SYCD

See SYCD for the full program of the symposium.

SYCD 1.1	Thu	11:00–11:30	E 415	**Ultralong range ICD in the He dimer, resonant Auger - ICD cascade processes** — •Till Jahnke
SYCD 1.2	Thu	11:30–12:00	E 415	**Inter-atomic Coulombic decay in endohedral fullerenes** — Narges Bahmanpour, •Vitali Averbukh
SYCD 1.3	Thu	12:00–12:30	E 415	**ICD-like decays in aqueous electrolytes** — •Gunnar Öhrwall, Niklas Ottosson, Olle Björneholm
SYCD 1.4	Thu	12:30–13:00	E 415	**Intermolecular Coulomb decay at heterogeneous interfaces** — •Thomas Orlando, Gregory Grieves

Invited talks of the joint symposium SYMS

See SYMS for the full program of the symposium.

SYMS 1.1	Fri	11:00–11:30	E 415	**MS for environmental and radiochemical applications** — •Clemens Walther
SYMS 1.2	Fri	11:30–12:00	E 415	**Modern nuclear mass models** — •Stephane Goriely
SYMS 1.3	Fri	12:00–12:30	E 415	**High-accuracy mass measurements for nuclear astrophysics** — •Susanne Kreim
SYMS 1.4	Fri	12:30–13:00	E 415	**Storage ring mass and lifetime measurements** — •Fritz Bosch
SYMS 2.1	Fri	14:00–14:30	E 415	**Search for resonant double-electron capture** — •Sergey Eliseev, Klaus Blaum, Michael Block, Christian Droese, Dmitriy Nesterenko, Yuri Novikov, Enrique Minaya Ramirez, Christian Roux, Lutz Schweikhard, Kay Zuber
SYMS 2.2	Fri	14:30–15:00	E 415	**Towards accurate T-3He Q-value** — •Tommi Eronen, Martin Höcker, Jochen Ketter, Sebastian Streubel, Robert S. Van Dyck, Klaus Blaum
SYMS 2.3	Fri	15:00–15:30	E 415	**The Avogadro constant and a new definition of the kilogram** — •Peter Becker

SYMS 2.4	Fri	15:30–16:00	E 415	**Dating human DNA with the 14C bomb peak** — •Walter Kutschera, Jakob Liebl, Peter Steier
SYMS 2.5	Fri	16:00–16:30	E 415	**Resonance ionization mass spectrometry** — •Klaus Wendt

Sessions

A 1.1–1.5	Mon	11:00–12:30	B 305	**Ultra-cold atoms, ions and BEC I (with Q)**
A 2.1–2.6	Mon	11:00–12:30	B 302	**Precision spectroscopy of atoms and ions I (with Q)**
A 3.1–3.5	Mon	11:00–12:30	F 128	**Precision measurements and metrology I (with Q)**
A 4.1–4.7	Mon	11:00–12:45	F 102	**Cluster (with MO)**
A 5.1–5.6	Mon	14:00–15:45	B 305	**Attosecond physics**
A 6.1–6.8	Mon	14:00–16:00	F 428	**Ultra-cold atoms, ions and BEC II (with Q)**
A 7.1–7.8	Mon	14:00–16:00	B 302	**Interaction with VUV and X-ray light I**
A 8.1–8.6	Mon	14:00–15:45	F 128	**Precision measurements and metrology II (with Q)**
A 9.1–9.7	Mon	16:30–18:30	B 305	**Interaction with strong or short laser pulses I**
A 10.1–10.6	Mon	16:30–18:00	F 428	**Precision spectroscopy of atoms and ions II (with Q)**
A 11.1–11.7	Mon	16:30–18:30	B 302	**Atomic clusters I (with MO)**
A 12.1–12.8	Mon	16:30–18:45	E 415	**Ultracold plasmas and Rydberg atoms (with Q)**
A 13.1–13.4	Tue	11:00–13:00	E 415	**Quantum meets gravity and metrology I**
A 14.1–14.6	Tue	11:00–12:30	B 302	**Ultra-cold atoms, ions and BEC III (with Q)**
A 15.1–15.5	Tue	11:00–12:30	B 305	**Precision spectroscopy of atoms and ions III (with Q)**
A 16.1–16.6	Tue	11:00–12:30	F 428	**Photoionization**
A 17.1–17.7	Tue	14:00–16:00	B 302	**Interaction with strong or short laser pulses II**
A 18.1–18.7	Tue	14:00–16:00	B 305	**Precision spectroscopy of atoms and ions IV (with Q)**
A 19.1–19.8	Tue	14:00–16:00	F 428	**Interaction with VUV and X-ray light II**
A 20.1–20.24	Tue	16:00–18:30	Empore Lichthof	**Poster: Precision spectroscopy of atoms and ions (with Q)**
A 21.1–21.6	Tue	16:00–18:30	Empore Lichthof	**Poster: Photoionization**
A 22.1–22.15	Tue	16:00–18:30	Empore Lichthof	**Poster: Interaction with strong or short laser pulses**
A 23.1–23.4	Wed	11:00–13:00	E 415	**Dissertation Prize Symposium**
A 24.1–24.6	Wed	11:00–12:30	F 428	**Ultra-cold atoms, ions and BEC IV (with Q)**
A 25.1–25.6	Wed	11:00–12:30	B 302	**Precision spectroscopy of atoms and ions V (with Q)**
A 26.1–26.7	Wed	14:00–16:00	B 302	**Ultra-cold atoms, ions and BEC V (with Q)**
A 27.1–27.4	Wed	14:00–16:00	E 415	**Visualizing Ultrafast Dynamics in atoms, molecules, and clusters**
A 28.1–28.7	Wed	14:00–16:00	E 001	**Precision measurements and metrology III (with Q)**
A 29.1–29.27	Wed	16:00–18:30	Empore Lichthof	**Poster: Ultra-cold atoms, ions and BEC (with Q)**
A 30.1–30.13	Wed	16:00–18:30	Empore Lichthof	**Poster: Interaction with VUV and X-ray light**
A 31.1–31.4	Thu	11:00–13:00	E 415	**Interatomic and Intermolecular Coulombic Decay**
A 32.1–32.6	Thu	11:00–12:30	B 305	**Ultra-cold atoms, ions and BEC VI (with Q)**
A 33.1–33.6	Thu	11:00–12:30	B 302	**Interaction with strong or short laser pulses III**
A 34.1–34.5	Thu	14:00–15:30	B 302	**SYCD Interatomic and intermolecular Coulombic decay (contributed for SYCD in A, MO)**
A 35.1–35.8	Thu	14:00–16:00	B 305	**Ultra-cold atoms, ions and BEC VII (with Q)**
A 36.1–36.5	Thu	14:00–15:30	F 428	**Atomic clusters II (with MO)**
A 37.1–37.7	Thu	14:00–16:00	F 128	**Precision measurements and metrology IV (with Q)**
A 38.1–38.8	Thu	16:00–18:30	Empore Lichthof	**Poster: Atomic clusters (with MO)**
A 39.1–39.13	Thu	16:00–18:30	Empore Lichthof	**Poster: Atomic systems in external fields**
A 40.1–40.10	Thu	16:00–18:30	Empore Lichthof	**Poster: Ultra-cold plasmas and Rydberg systems (with Q)**
A 41.1–41.9	Thu	16:00–18:30	Empore Lichthof	**Poster: Electron scattering and recombination**
A 42.1–42.4	Thu	16:00–18:30	Empore Lichthof	**Poster: Attosecond physics**
A 43.1–43.5	Fri	11:00–12:30	B 305	**Precision spectroscopy of atoms and ions VI (with Q)**
A 44.1–44.4	Fri	11:00–13:00	E 415	**100 Years of Mass Spectrometry 1**
A 45.1–45.5	Fri	11:00–12:30	B 302	**Atomic systems in external fields I**
A 46.1–46.6	Fri	11:00–12:30	F 428	**Ultra-cold plasmas and Rydberg systems (with Q)**
A 47.1–47.6	Fri	11:00–12:30	E 001	**Precision measurements and metrology V (with Q)**
A 48.1–48.6	Fri	11:00–12:30	F 142	**Ultracold atoms: Manipulation and detection (with Q)**
A 49.1–49.5	Fri	14:00–16:30	E 415	**100 Years of Mass Spectrometry 2**
A 50.1–50.7	Fri	14:00–15:45	B 302	**Atomic systems in external fields II**

A 51.1–51.7 Fri 14:00–15:45 E 001 **Precision measurements and metrology VI (with Q)**

Annual General Meeting of the Atomic Physics Division

Donnerstag 13:30–14:00 B 305

- Bericht
- Wahl
- Verschiedenes

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

Time: Monday 11:00–12:30 Location: B 305

Invited Talk A 1.1 Mon 11:00 B 305
Dynamics of Ultra-cold Atoms in Optical Lattices — •Sandro Wimberger — Institut für Theoretische Physik, Universität Heidelberg

Modern quantum and atom-optical experiments allow for an unprecedented control of microscopic degrees of freedom, not just in the initialization but also in the dynamical evolution of quantum states. This talk focuses on the dynamics of ultra-cold bosons in optical lattice structures. Experimental as well as theoretical results for two paradigm systems are reported: on (1) the interband transport in a tilted lattice, i.e. a realization of the famous Wannier-Stark problem, and (2) on the stability of the temporal evolution in kicked lattice potentials. General perspectives on future directions of our study of strongly correlated bosons in lattice structures conclude the talk.

A 1.2 Mon 11:30 B 305
Interaction induced modification of tunnelling rates in a 1D tilted optical lattice — •Florian Meinert[1], Manfred Mark[1], Emil Kirilov[1], Katharina Lauber[1], Philipp Weinmann[1], Andrew Daley[2], and Hanns-Christoph Nägerl[1] — [1]Institut für Experimentalphysik, Universität Innsbruck — [2]Physics and Astronomy, University of Pittsburgh

Cold atoms confined in optical lattice potentials offer unique access to study condensed matter Hamiltonians, e.g. the bosonic Hubbard model. Magnetic Feshbach resonances provide high control and tunability of the interparticle on-site interaction strength allowing for the preparation of Mott insulating phases with both, attractive and repulsive interaction.

We study correlated tunnelling dynamics of degenerate bosonic Cs atoms prepared in one dimensional singly occupied Mott insulating chains. Subjecting the atoms to a linear potential gradient that is adiabatically ramped through resonance with the interaction energy results in a doublon-hole density wave order, a situation that maps onto the quantum phase transition from the paramagnetic to the antiferromagnetic state in the 1D transverse Ising model.

By quenching the system onto the phase transition point we initiate non-equilibrium tunnelling dynamics as detected in the number of created doubly occupied lattice sites. The observed coherent response of the system provides a direct measure of the tunnelling rate. We observe striking modification of this rate by interactions when tuned from attractive to repulsive.

A 1.3 Mon 11:45 B 305
Strontium in an Optical Lattice as a Portable Frequency Reference — Ole Kock, Wei He, Lyndsie Smith, Huadon Cheng, Steven Johnson, Kai Kai, and •Yeshpal Singh — School of Physics and Astronomy, University of Birmingham, Edgbaston Park Road, Birmingham B15 2TT, UK

A major scientific development over the last decade, namely clocks based on optical rather than microwave transitions, has opened a new era in time/frequency metrology. Several Physics Nobel prizes (1997, 2001, 2005, 2012) were awarded for methods that have enabled optical clocks.In optical clocks the (laser) electromagnetic wave beats 10^15 times per second instead of 10^10 as in microwave clocks. Optical clocks have now achieved a performance significantly beyond that of the best microwave clocks, at a fractional frequency inaccuracy of 8.6 *10^-18. The essential techniques used in optical clocks are the confinement of the atoms to regions significantly smaller than the wavelength of light, provision of an environment as free of disturbing influences (magnetic and electric fields, residual gas, black-body fields) as possible, choice of adequate atomic species, and the narrowing of the spectral width of the clock laser to relative levels of 10^-15 and less. With the rapidly improving performance of optical clocks, in the future, most applications requiring the highest accuracy will require optical clocks. They cover the fields of fundamental physics (tests of General Relativity and its foundations), time and frequency metrology (comparison of distant terrestrial clocks, operation of a master clock in space).

A 1.4 Mon 12:00 B 305
A novel 2D-confinement scheme for ultracold ^{40}K atoms — •Martin Reitter[1,2], Lucia Duca[1,2], Tracy Li[1,2], Josselin Bernardoff[1,2], Henrik Lüschen[1,2], Monika Schleier-Smith[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

We report on a novel scheme for compressing an ultracold cloud of ^{40}K atoms into a single two-dimensional layer. The use of a single layer not only provides an analog to two-dimensional electron gases in condensed matter systems, but also allows for direct imaging of the atom cloud without the typical averaging effects due to the integration along the line-of-sight. A standard approach to compressing atoms into a single two-dimensional plane is to load them into a deep vertical lattice and remove atoms from all but one lattice plane. During this procedure, however, a significant number of atoms is lost. To overcome this disadvantage, we realize a vertical lattice with a dynamically variable lattice constant. By continuously changing the confinement, we will be able to compress almost all atoms held in a crossed-beam dipole trap into a single two-dimensional layer. Subjecting this two-dimensional system to an artificial gauge field will enable studies of topologically ordered states of fermions.

A 1.5 Mon 12:15 B 305
Measuring and controlling quantum transport of heat in trapped-ion crystals — Alejandro Bermudez, •Martin Bruderer, and Martin B Plenio — Institut für Theoretische Physik, Albert-Einstein Allee 11, Universität Ulm, 89069 Ulm, Germany

Measuring heat flow through nanoscale systems poses formidable practical difficulties as there is no 'ampere meter' for heat. We propose to overcome this problem by realizing heat transport through a linear chain of trapped ions. Steady laser cooling of the chain edges to different temperatures induces a current of local vibrations (vibrons) across the bulk ions. We show how to efficiently measure and control this heat current (including fluctuations) by coupling vibrons to internal ion states, which are easily manipulated. That makes ion crystals an ideal tool for studying thermal quantum transport and, in particular, gives access to the expectedly large fluctuations in the bosonic current.

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

Time: Monday 11:00–12:30 Location: B 302

A 2.1 Mon 11:00 B 302
Progress Towards Antihydrogen Hyperfine Spectroscopy — •Stefan Ulmer — RIKEN Advanced Science Institute, Hirosawa,Wako, Saitama 351-0198, Japan — on behalf of the ASACUSA-CUSP collaboration

The CUSP experiment at the CERN Antiproton Decelerator (AD) is a part of the ASACUSA physics program. It is dedicated to perform precise hyperfine spectroscopy of antihydrogen. A comparison to the hydrogen hyperfine structure provides a sensitive test of matter/ antimatter symmetry. Mixing antiprotons with positrons in a so-called nested trap scheme, antihydrogen is produced. The mixing takes place in the cusp (anti-Helmholz) magnet, which acts as well as a unique spin polarization filter. Transmitted low-field seeking hyperfine states pass a radio frequency spin-flip cavity followed by a sextupole analyser and an antihydrogen detector. A measurement of the antihydrogen signal as a function of the frequency irradiated to the cavity gives direct access to the hyperfine structure. The status of this Rabi-like antiatomic spectroscopy experiment will be reported.

A 2.2 Mon 11:15 B 302
Myonic hydrogen and the proton radius puzzle — •Randolf Pohl — Max-Planck-Institut für Quantenoptik, Garching

Our recent measurement of the Lamb shift (2S-2P energy splitting) in muonic hydrogen has revealed a ten times more precise value of the proton charge radius, Rp. This new value differs, however, by 7 standard deviations from the 2010 CODATA value of Rp which is extracted from hydrogen spectroscopy and elastic electron-proton scattering.

This so-called "proton radius puzzle" has created many ideas ranging from novel proton structure effects all the way to physics beyond the Standard Model.

We will present new measurements of transitions in muonic hydrogen and deuterium, and give an update on the "proton radius puzzle"

A 2.3 Mon 11:30 B 302

The Lamb shift measurement in muonic helium ions. — •Marc Diepold and The CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

In 2013, the CREMA collaboration will measure the 2S - 2P transition frequencies (Lamb shift) in μ^4He $^+$ and μ^3He$^+$ using laser spectroscopy.

This measurement will achieve ten times more accurate values for the absolute nuclear charge radii of the lightest helium isotopes, as well as evaluate the μ^3He$^+$ hyperfine structure to determine the magnetic moment distribution of the ^{3}He nucleus.

Charge radii provided by this experiment will serve as a benchmark for few-nucleon nuclear models and as the basis for stringent tests of higher order bound-state QED contributions.

In addition, the muonic helium measurements should be able to shed new light on the "proton size puzzle", i.e. the seven sigma discrepancy of our charge radius determination in muonic hydrogen and the 2009 CODATA value.

A 2.4 Mon 11:45 B 302

Simulation zur Laserkühlung von Antiwasserstoff — •Burkhard Mayer[1,2], Thomas Diehl[1,2], Daniel Kolbe[1,2], Andreas Koglbauer[1,2], Matthias Stappel[1,2], Ruth Steinborn[1,2], Andreas Müllers[1,2] und Jochen Walz[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Deutschland — [2]Helmholtz-Institut Mainz, Johannes Gutenberg-Universität, 55099 Mainz, Deutschland

Die künftige Laserspektroskopie von Antiwasserstoff bietet die Möglichkeit für einen präzisen Test der fundamentalen Symmetrie zwischen Materie und Antimaterie. Dazu werden die Antiwasserstoff-Atome in einer Ioffe-Falle gespeichert. Für eine präzise Laserspektroskopie soll die Zeeman-Verbreiterung durch das inhomogene Magnetfeld der Falle durch Kühlen minimiert werden.
Eine Möglichkeit ist die Laserkühlung auf dem geschlossenem $1S-2P$ Übergang mit einer Wellenlänge $\lambda_{\text{Lyman-}\alpha} = 121,56\,\text{nm}$. Zur Bestimmung der optimalen Kühlparameter ist eine Simulation des Kühlvorgangs sinnvoll und wichtig. In der Simulation werden die Energieniveauverschiebung im Fallenpotential, das Fallenpotential, die Anregungsraten und die Bewegungsgleichung der Atome mit analytischen und numerischen Verfahren berechnet. Es werden die aktuellen Ergebnisse der Simulation und der unterschiedlichen Verfahren präsentiert.

A 2.5 Mon 12:00 B 302

Precision spectroscopy of the $\mathbf{2S-4P_{1/2}}$ transition in atomic hydrogen on a cold thermal beam of optically excited 2S atoms — •Axel Beyer[1], Nikolai Kolachevsky[1], Janis Alnis[1], Dylan C. Yost[1], Ksenia Khabarova[2], Arthur Matveev[1], Christian G. Parthey[1], Randolf Pohl[1], Thomas Udem[1], and Theodor W. Hänsch[1,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]FSUE 'VNIIFTRI', 141570 Moscow — [3]Ludwig-Maximilians-Universität, 80799 München

The 'proton size puzzle', i.e. the discrepancy between the values for the proton r.m.s. charge radius deduced from precision spectroscopy of atomic hydrogen and electron-proton-scattering on one side and the value deduced from muonic hydrogen spectroscopy on the other side, has been persisting for more than two years now. Although huge efforts have been put into trying to resolve this discrepancy from experimental and theoretical side, no convincing argument could be found so far. In this talk, we report on a unique precision spectroscopy experiment on atomic hydrogen, which is aiming to bring some light to the hydrogen part of the puzzle: In contrast to any previous high resolution experiment probing a transition frequency between the meta-stable 2S state and a higher lying nL state ($n = 3, 4, 6, 8, 12$, $L = \text{S}, \text{P}, \text{D}$), our measurement of the $2\text{S} - 4\text{P}_{1/2}$ transition frequency is the first experiment being performed on a cold thermal beam of hydrogen atoms optically excited to the 2S state. We will discuss how this helps to efficiently suppresses leading systematic effects of previous measurements and present the preliminary results we obtained so far.

A 2.6 Mon 12:15 B 302

Eine um eine Größenordnung verbesserte Elektronenmasse — •Florian Köhler[1,2], Sven Sturm[3], Anke Wagner[1,3], Günter Werth[4], Wolfgang Quint[1,2] und Klaus Blaum[1,3] — [1]Fakultät für Physik, Universität Heidelberg, 69120 Heidelberg, Germany — [2]GSI Darmstadt, 64291 Darmstadt, Germany — [3]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [4]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany

Zur Bestimmung des g-Faktors des gebundenen Elektrons benötigt man neben dem experimentell gemessenen Frequenzverhältnis aus Larmor- und Zyklotronfrequenz, die Ionen- und die Elektronenmasse. Durch die Hochpräzisionsmessung des g-Faktors von wasserstoffähnlichem Silizium $^{28}\text{Si}^{13+}$ wurden die Rechnungen der Quantenelektrodynamik gebundener Zustände (BS-QED) mit einer relativen Genauigkeit von $8.5 \cdot 10^{-10}$ erfolgreich bestätigt [1]. Aufgrund der Skalierung einiger theoretischer Beiträge mit $Z\alpha$ kann der g-Faktor von wasserstoffähnlichem Kohlenstoff $^{12}\text{C}^{5+}$ auf mindestens $1.5 \cdot 10^{-11}$ genau berechnet werden. Durch eine Reihe von Verbesserungen [2], kann das Verhältnis Larmor- zur Zyklotronfrequenz bei $^{12}\text{C}^{5+}$ auf etwa $2 \cdot 10^{-11}$ gemessen werden. Dies ermöglicht eine Bestimmung der Elektronenmasse, die um mindestens eine Größenordnung genauer ist als der derzeitige CODATA Wert. Der momentane Stand des Experiments, sowie erste Ergebnisse, werden präsentiert.

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

A 3: Precision measurements and metrology I (with Q)

Time: Monday 11:00–12:30 Location: F 128

Group Report A 3.1 Mon 11:00 F 128

Quantum Metrology and Tomography with Bose–Einstein Condensates — •Roman Schmied, Caspar Ockeloen, Max Riedel, and Philipp Treutlein — Departement Physik, Universität Basel, Klingelbergstrasse 82, 4056 Basel, Schweiz

We present our recent results on the creation, manipulation, use, and analysis of entangled states of Bose–Einstein condensates of about 1000 Rubidium-87 atoms.

We have used a Bose–Einstein condensate as an interferometric scanning probe to map out a microwave field near a chip surface with a few micrometers resolution [1]. Using entanglement between the atoms we overcome the standard quantum limit of interferometry by 4 dB and maintain enhanced performance for interrogation times up to 20 ms. This demonstrates the usefulness of quantum metrology with entangled states when the particle number is limited due to the small probe size, and extends high-precision atomic magnetometry to the micrometer scale and microwave frequencies.

To analyze the many-body states of our Bose–Einstein condensates we extend our previously published quantum-state tomography [2] by enforcing that tomographically reconstructed many-body density matrices are positive semi-definite. We use this method to extract quantitative data such as the Fisher information.

[1] C.F. Ockeloen *et al.*, *submitted.*
[2] R. Schmied and P. Treutlein, New J. Phys. **13**, 065019 (2011).

A 3.2 Mon 11:30 F 128

Noisy metrology beyond the standard quantum limit — •Rafael Chaves[1,2], Jonatan Bohr Brask[2], Marcin Markiewicz[3], Janek Kołodyński[4], and Antonio Acin[2,5] — [1]Institute for Physics, University of Freiburg, Germany — [2]ICFO-Institut de Ciències Fotòniques, Castelldefels (Barcelona), Spain — [3]Institute of Theoretical Physics and Astrophysics, University of Gdańsk, Poland — [4]Faculty of Physics, University of Warsaw, Poland — [5]ICREA-Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

Parameter estimation is of fundamental importance in areas from atomic spectroscopy to gravitational wave-detection. Entangled probes provide a significant precision gain over classical strategies in the absence of noise. However, recent results seem to indicate that any small amount of realistic noise restricts the advantage of quantum strategies to an improvement by at most a multiplicative constant. We identify a relevant scenario in which one can overcome this restriction and attain super-classical precision scaling even in the presence of uncorrelated noise. We show that the quantum improvement can be significantly enlarged when the noise is concentrated along some spatial direction, while the Hamiltonian governing the evolution which depends on the parameter to be estimated can be engineered to point along a different direction. In particular, in the case of perpendicular orientation, we find a maximal asymptotic precision scaling of $1/N^{5/6}$, where N is the number of probe particles, and identify a state which achieves this.

A 3.3 Mon 11:45 F 128

Accuracy Limits on the Estimation of the Magnetic Field Gradient — •Iagoba Apellaniz and Philipp Hyllus — University of the Basque Country, P. O. Box 644, E-48080 Bilbao, Spain.

Entanglement between particles is a useful resource for quantum information processing tasks as well as for quantum metrology. For instance, it allows us to have a metrological accuracy higher than the shot-noise limit. The accuracy in the estimation of the phase shift θ in a Mach-Zehnder Interferometer can be improved by a factor of $\sqrt{N}$ with respect to the shot-noise limit, $\Delta\theta \sim 1/\sqrt{N}$, where N is the number of particles on the system which are analyzed to estimate θ.

The usefulness of a multi-particle system for measuring the magnetic field gradient is investigated in Ref. [1]. They consider a multi-particle singlet state for this purpose and incorporate the information about the particle positions in the Hamiltonian.

In our presentation, we use a general Hamiltonian for this class of systems, and the information about the position of the particles involved is encoded in the state, not the Hamiltonian.

We investigate bounds on the sensitivity of measuring the magnetic field gradient, b_1, with a one dimensional N-particle system. We use the so-called Cramér-Rao bound and the Quantum Fisher Information (QFI) in order to get the bounds for the shot-noise limit and the Heisenberg limit.

[1] I. Urizar-Lanz, P. Hyllus, I. Egusquiza, M.W. Mitchell, G. Tóth, *Macroscopic singlet states for gradient magnetometry*, arxiv:1203.3797.

A 3.4 Mon 12:00 F 128

Application of multipartite quantum states for gradient magnetometry — •Iñigo Urizar-Lanz[1], Philipp Hyllus[1], Iñigo Egusquiza[1], Morgan Mitchell[2], and Geza Toth[1,3,4] — [1]Theoretical Physics, University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — [2]Institute of Photonic Sciences, ICFO, Mediterranean Technology Park, Barcelona, Spain — [3]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [4]Wigner Research Centre for Physics, H-1525 Budapest, Hungary

Singlet states are states with vanishing angular momentum. We investigate the possibilities of these states for measuring the gradient of a magnetic field. This kind of magnetometry is invariant under a homogeneous magnetic field. We calculate the precision of the measurement for this type of states, as well as for other states that are not invariant under homogeneous fields. We also consider the case of spins larger than 1/2 and the effect of noise.

A 3.5 Mon 12:15 F 128

Enhancement of a single electron spin based magnetometer by utilizing a small nuclear spin quantum register — •Sebastian Zaiser[1], Philipp Neumann[1], Gerald Waldherr[1], Fedor Jelezko[2], and Jörg Wrachtrup[2] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Institut für Quantenoptik, Universität Ulm

The negatively charged nitrogen-vacancy (NV) center in diamond and its associated nuclear spins form a versatile small quantum register. Apart from its potential applications in quantum information processing the susceptibility of its quantum coherence to external stimuli like magnetic and electric fields render the NV center a tiny quantum sensor. Its high spatial confinement allows to build very small sensing devices which lead to a sample-probe distance of only a few nanometers potentially enabling the detection of single electron or even nuclear spins.

Here we show how a small quantum register of proximal nuclear spins around the NV center can be used to drastically increase the performance of the NV electron spin as a magnetic field sensor.

A 4: Cluster (with MO)

Time: Monday 11:00–12:45 Location: F 102

A 4.1 Mon 11:00 F 102

Vibrational Spectroscopy of the Atmospherically Relevant Clusters NO3-(HNO3)m(H2O)n — •Nadja Heine[1], Tara Yacovitch[2], Claudia Brieger[1], Torsten Wende[1], Christian Hock[2], Knut Asmis[1], and Dan Newmark[2] — [1]Fritz-Haber-Institut der MPG, Berlin — [2]University of California, Berkeley, California

Ions influence various chemical and physical processes in the atmosphere, such as the electrical conductivity and the formation of polar stratospheric clouds. They also play a critical role in aerosol formation through ion nucleation. Among the most abundant anions in the troposphere and stratosphere is nitrate (NO3-) and clusters of these ions with nitric acid and water. In order to understand the chemical and physical properties of these anionic clusters, as well as to test the structural predictions from previous computational studies, experimental information on the cluster structure is required. Here, we present first infrared multiple photon dissociation (IRMPD) spectra of NO3-(HNO3)m(H2O)n measured with the infrared free electron laser FELIX in the fingerprint region (550-1800cm-1), directly probing the NO-stretching and -bending modes. The assignment of the spectra is aided by electronic structure calculations. The IRMPD spectrum of m=1/n=0 is distinctly different from all other spectra exhibiting a strong absorption at 813cm-1, which we attribute to a strongly bound shared proton in-between two nitrate ions, and lacking the characteristic H-O-N bending mode absorption close to 1650cm-1. Addition of at least one nitric acid molecule or water breaks the symmetry of this arrangement.

A 4.2 Mon 11:15 F 102

Isomer-Selective Double Resonance Spectroscopy: Isolating the Spectral Signatures of $H^+ \cdot (H_2O)_7$ Isomers — Nadja Heine, •Matias R. Fagiani, Torsten Wende, and Knut R. Asmis — Fritz-Haber-Institut der Max-Planck Gesellschaft, Faradayweg 4-6,14195 Berlin, Germany

Understanding how protons are hydrated remains an important and challenging research area. The anomalously high proton mobility of water can be explained by a periodic isomerization between the Eigen, H_3O^+(aq), and Zundel, $H_2O \cdot \cdot H^+ \cdot \cdot OH_2$(aq), binding motifs, even though the detailed mechanism is more complex. These rapidly interconverting structures from the condensed phase can be stabilized, isolated and studied in the gas phase in the form of protonated water clusters. The smallest protonated water clusters that exhibits structural isomers related to the Eigen and Zundel motifs experimentally is the protonated water hexamer $H^+(H_2O)_6$. For the heptamer, $H^+(H_2O)_7$, the presence of at least three isomers has been suggested but, due to spectral congestion, these could not be unambiguously assigned. Here, we present results on isomer-selective infrared/infrared (IR/IR) double resonance experiments on $H^+(H_2O)_7$. Protonated water clusters are formed by electrospray ionization, mass-selected, cooled to cryogenic temperatures and messenger-tagged (H_2) in a buffer gas filled ion trap. Isomer-selective IR photodissociation spectra are measured from $2880-3850\ cm^{-1}$ by population-labeling IR/IR double resonance spectroscopy. Aided by electronic structure calculations four isomers, three Eigen and one Zundel-type isomers, are identified.

A 4.3 Mon 11:30 F 102

Ultraschnelle Relaxationsdynamik von SiO_2 Nanopartikeln nach Anregung im Vakuum-UV Bereich — •Christopher Raschpichler, Ina Halfpap, Holger Bahro, Alan Dorssers, Valerie Mondes, Burkhard Langer, Jürgen Plenge und Eckart Rühl — Institut für Chemie und Biochemie, Freie Universität Berlin, Takustr. 3, 14195 Berlin

Es werden Experimente vorgestellt, in denen die Ionisations- und Relaxationsdynamik von isolierten, größenselektierten SiO_2 Nanopartikeln ($d = 92 \pm 9$ nm) nach Anregung im Vakuum-UV Bereich mit Hilfe der zeitaufgelösten Photoelektronenspektroskopie untersucht wurden. Dabei erfolgte die primäre Anregung der freien Nanopartikel durch die 5. Harmonische eines Titan-Saphir Lasersystems bei 7,70 eV, so dass Zustände unterhalb der Leitungsbandkante von amorphem SiO_2 angeregt werden konnten. Nachfolgend führte die Mehrphotonen-Anregung durch einen zeitverzögerten Laserpuls ($\lambda = 805$ nm) zur Photoemission. Zeitaufgelöste Photoelektronenausbeutekurven spiegeln die Relaxationsdynamik der primär angeregten Nanopartikel wider, wobei eine Lebensdauer von 120 ± 40 fs beobachtet wird. Die experimentellen Ergebnisse werden im Zusammenhang mit der nichtradiativen Relaxation von Defektzuständen von amorphem SiO_2 diskutiert und können zu einem verbesserten Verständnis der Ladungsträgerdynamik in dielektrischen nanoskopischen Materialien beitragen.

A 4.4 Mon 11:45 F 102

Electronic structure of diamondoid aggregates — •Tobias Zimmermann[1], Robert Richter[1], Torbjörn Rander[1], Andrey A. Fokin[2], Tetyana V. Koso[2], Lesya V. Chernish[2], Pavel A. Gunchenko[2], Peter Schreiner[2], and Thomas Möller[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Germany — [2]Institut für Organische Chemie, Justus-Liebig Universität Gießen, Germany

We investigate the electronic structure of diamondoid aggregates in the gas phase with valence photoelectron spectroscopy. The samples are aggregates of the lower diamondoids adamantane, diamantane and triamantane. The diamandoid constituents are connected with CC-single- or double-bonds. The investigations show an influence on the electronic structure of the samples by the bond type as well as the combination of the bonding partners. For singly bound aggregates only a small impact of the bond type on the electronic structure is observed. In fact a superposition of the bonding partner orbitals describes the aggregate orbitals well. The strength of quantum confinement effects is shown to depend on the bonding partner orbital energy difference. The spectra of doubly bound aggregates show significantly lower influence of the bonding partner sizes instead. Rather the HOMO can be ascribed to the CC-double-bond. Density functional theory supports our interpretations.

A 4.5 Mon 12:00 F 102

Coordination-driven magnetic-to-nonmagnetic transition in manganese doped silicon clusters — Vicente Zamudio-Bayer[1,2], Linn Leppert[3], Konstantin Hirsch[1,2], Andreas Langenberg[1,2], Jochen Rittmann[1,2], Martin Kossick[1,2], Robert Richter[2], Akira Terasaki[4,5], Thomas Möller[2], Bernd von Issendorff[6], Stefan Kümmel[3], and •Tobias Lau[1] — [1]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin — [2]Institut für Optik und Atomare Physik, Technische Universität Berlin, 10623 Berlin — [3]Theoretische Physik IV, Universität Bayreuth, 95440 Bayreuth — [4]Cluster Research Laboratory, Toyota Technological Institute, Chiba, Japan — [5]Department of Chemistry, Kyushu University, Fukuoka, Japan — [6]Fakultät für Physik, Universität Freiburg, 79104 Freiburg

X-ray Magnetic Circular Dichroism (XMCD) spectroscopy allows to obtain fundamental insight into magnetic properties of free, size-selected clusters. Using a combination of XMCD and non-empirical density functional theory, we demonstrate that the magnetic moment of $MnSi_n^+$ is completely quenched as soon as a cluster size of $n = 10$ is exceeded. This is the result of a structural transition with an abrupt increase of the impurity coordination, which takes place between $MnSi_{10}^+$ and $MnSi_{11}^+$ and is accompanied by marked changes in the local electronic structure of the manganese impurity.

A 4.6 Mon 12:15 F 102

Infrared photo dissociation spectroscopy of perhalogenated closo-dodecaborate clusters $[B_{12}X_{12}]^{2-}$ (X=Br, I) — Matias R. Fagiani[1], •Tim Esser[1], Jonas Warneke[2], Nadja Heine[1], and Knut R. Asmis[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Institute for Applied and Physical Chemistry, University of Bremen, Leobener Strasse, NW2, 28359 Bremen, Germany

Closo-dodecaborates are important materials and subject to recent research on ionic liquids, lithium ion batteries and stabilization of reactive cations. Recent collision-induced dissociation studies by Warneke et al. showed complex fragmentation patters for the perhalogenated dianions $[B_{12}X_{12}]^{2-}$ (X=F, Cl, Br, I). The brominated cluster $[B_{12}Br_{12}]^{2-}$ showed a higher tendency to fragment under loss of an X^- anion then the iodinated cluster $[B_{12}I_{12}]^{2-}$ wich is more likely to loose a $X^\bullet$ radical. In order to characterize the structure of these ions we performed infared photodissociation (IRPD) experiments. To this end, dianions are produced by ion spray, mass-selected by a quadrupole mass filter and accumulated in a cryogenically cooled ion trap which is filled with a buffer gas. The ion trap serves for accumulation, thermalization and messenger tagging of the ions. After extraction from the ion trap the ion/messenger clusters are exposed to IR radiation. IRPD spectra of $[B_{12}Br_{12}]^{2-}$ and $[B_{12}I_{12}]^{2-}$, measured in the range from 700 to 1500 cm^{-1}, are presented and assigned on the basis of electronic structure calculations.

A 4.7 Mon 12:30 F 102

Extreme ultraviolet fluorescence spectroscopy of pure and core-shell rare gas clusters at FLASH — •Lasse Schroedter[1], Andreas Kickermann[1], Andreas Przystawik[1], Marcus Adolph[2], Maria Krikunova[2], Maria Müller[2], Tim Oelze[2], Daniela Rupp[2], Christoph Bostedt[3], Thomas Möller[2], and Tim Laarmann[1] — [1]Deutsches Elektronen-Synchrotron, DESY Photon Science, Hamburg, Germany — [2]Institut für Optik und Atomare Physik, Technische Universität Berlin, Germany — [3]SLAC National Accelerator Laboratory, Linac Coherent Light Source, USA

Rare gas clusters exposed to strong laser fields at short wavelength have attracted considerable interest in the last decade. The most common way to study the interaction is by time-of-flight spectroscopy of the resulting charged particles [1]. However, recent imaging experiments give evidence that the measured mass spectra do not reflect the charge states that are initially formed [2]. We present experiments on pure and core-shell Xe and Ar clusters to analyze the initially produced charge states by their extreme ultraviolet fluorescence. The clusters were excited by strong free-electron laser pulses from FLASH at 13 nm. Characteristic fluorescence of multiply charged species reveals detailed information on energy deposition and redistribution as a function of cluster size and FEL intensity.

[1] M. Hoener et al., J. Phys. B: At. Mol. Opt. Phys. 41 (2008), 181001 [2] C. Bostedt et al., Phys. Rev. Lett. 108 (2012), 093401

A 5: Attosecond physics

Time: Monday 14:00–15:45 Location: B 305

Prize Talk A 5.1 Mon 14:00 B 305

Taming light waves: Attosecond triggering and clocking of electronic processes — •Eleftherios Goulielmakis — Max Planck Institute for Quantum Optics, Garching, Germany — Laureate of the Gustav-Hertz-Prize

Real-time control of electrons in the microcosm calls for electromagnetic forces confinable and tunable over sub-femtosecond time intervals. We will discuss how recent progress in lightwave technologies [1-5] has enabled important steps towards this essential milestone in science and technology. With novel types of light synthesizers that manipulate ultrawideband coherent light sources, spanning the visible and flanking spectral ranges, it is now possible to sculpt [4],[5] and trace [1] the waveform of light with subcyclic precision opening up the root to attosecond photonics.

To explore the potential of the new tools for advancing microscopic manipulation of matter, we have used synthesized light transients to demonstrate basic elements of sub-femtosecond control of electrons such as attosecond triggering and clocking of electron dynamics in the valence shell of atoms [6],[7] and their real-time tracing [6].

[1] E. Goulielmakis et al., Science 305, 1267 (2004).
[2] E. Goulielmakis et al., Science 320, 1614 (2008).

[3] E. Goulielmakis et al., Science 317, 769 (2007).
[4] A. Wirth et al., Science 334,195 (2011).
[5] M. Th. Hassan et al., Rev. Sci. Instrum. 83,111301 (2012).
[6] E. Goulielmakis et al., Nature 466, 739 (2010).
[7] M. Th. Hassan et al., in preparation (2013).

A 5.2 Mon 14:30 B 305

Interferometric Laser Control of Attosecond Pulse Generation — •Philipp Raith, Christian Ott, Andreas Kaldun, Kristina Meyer, Christopher Anderson, Martin Laux, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg , Germany

Tailored attosecond pulses would allow to measure and control electron quantum dynamics in atoms and molecules on their natural time scale. Here, we control the generation of attosecond pulses and pulse trains, produced by high-harmonic generation, by two control variables: The carrier-envelope phase (CEP) of the driving laser field and a time delay between two variable sections of the laser spectrum [1]. We experimentally and numerically demonstrate that this multidimensional control scheme allows to independently set several properties of the produced attosecond pulses or pulse trains such as their relative phase and intensity ratio. Moreover, we show that the controlled interference of two temporally-spaced attosecond pulse trains leads to the generation of fractional high-harmonic combs [2]. Furthermore, we give experimental and computational evidence that an interference effect drastically magnifies the influence of subcycle time delays between spectral channels on the effective carrier-envelope phase of the synthesized laser field by rapidly moving the envelope temporally across a quasi-stationary carrier wave. This finding has important consequences for the CEP stabilization of few-cycle synthesized light fields.

[1] P. Raith et al., Opt. Lett. 36, 283-285 (2011).
[2] P. Raith et al., Appl. Phys. Lett. 100, 121104 (2012).

A 5.3 Mon 14:45 B 305

On imaging the instantaneous electron density with ultrafast x-rays: Is it possible? — •Jan Malte Slowik[1,2], Gopal Dixit[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

Tracing the dynamical evolution of the electron density has enormous relevance to understanding ultrafast phenomena occurring for example in chemical and biological processes. Scattering of ultrashort x-ray pulses from an electronic wavepacket would appear to be an obvious approach to image the electronic motion in real-time and real-space. However, the scattering pattern in the far-field regime does not encode the instantaneous electron density of the wavepacket, but probes spatio-temporal density-density correlations. Here, we propose a possible way to image the instantaneous electron density of the wavepacket via ultrafast x-ray phase contrast imaging. Moreover, we show that inelastic scattering processes, which plague ultrafast scattering in the far-field regime, do not contribute in ultrafast x-ray phase contrast imaging as a consequence of an interference effect. Our general findings will be illustrated by means of a wavepacket that lies in the time and energy range of the dynamics of valence electrons in complex molecular and biological systems. This approach offers a potential to image not only instantaneous snapshots of electron dynamics in non-stationary quantum systems, but also the Laplacian of these snapshots which provides information about the complex bonding and topology of the charge distributions in the systems.

A 5.4 Mon 15:00 B 305

Kinematically complete photoionization studies with online monitoring of XUV attosecond pulse properties — •Michael Schönwald[1], Philipp Coerlin[1], Andreas Fischer[1], Alexander Sperl[1], Arne Senftleben[1], Thomas Pfeifer[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Deutschland

We are producing attosecond pulses (AP) via high harmonic generation (HHG) in a small gas cell filled with rare gases in order to do pump-probe experiments in a reaction microscope (ReMi). A self-phase modulation hollow fiber filled with Neon in combination with a chirped mirror compressor is used to broaden the spectrum and to shorten the infrared (IR) laser pulses from 30 fs to less than 10 fs for experiments with single AP. We perform kinematically complete experiments using a Reaction Microscope (ReMi) which require long-term stability of the incoming radiation. To monitor the HHG spectra and to be able to estimate the pulse durations of the AP, we build a new extended ultraviolet (XUV) spectrometer which uses the light transmitted through the interaction region of the ReMi. A spherical mirror is then used to focus the high harmonics onto a MCP detector. Before hitting the detector the XUV radiation is spectrally resolved by a reflection grating. We will show first experiments in which we combine the information given by the spectrometer and by an optical autocorrelation of the IR laser field. With the online monitoring we are able to perform and to compare experiments with different pulse durations.

A 5.5 Mon 15:15 B 305

Prediction of attosecond light pulses in the VUV range in a high-harmonic generation regime — •Jost Henkel[1,2], Tobias Witting[2], Davide Fabris[2], Manfred Lein[1], Peter L. Knight[2], John W. G. Tisch[2], and Jonathan P. Marangos[2] — [1]Institut für Theoretische Physik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover Appelstraße 2, 30167 Hannover, Germany — [2]Blackett Laboratory, Imperial College London, Prince Consort Road, South Kensington, London SW7 2AZ, UK

Attosecond (as) pump-probe experiments are one of the ultimate goals for the investigation of electron and hole dynamics in atoms and molecules. For an efficient transient population of specific excited states, strong short light pulses with a narrow frequency spectrum are needed. To overcome limitations of current XUV sources, we propose to select high-harmonic frequencies in the VUV range with an indium filter. Its transmission window is centered at 15 eV and has a bandwidth of 3.7 eV, yielding a Fourier limit of 700 as. We confirm this by calculating high-order harmonic spectra from the solution of the time-dependent Schrödinger equation (TDSE). For a model neon atom we compare linearly polarised laser pulses to the polarisation gating method with elliptical pulses. Such below threshold harmonics have low sensitivity to the generating field's ellipticity, leading to elliptically polarized attosecond pulses. The problematic lack of spontaneous decay in the TDSE, which causes strong below-threshold emission peaks, can be circumvented by accounting for macroscopic intensity averaging.

A 5.6 Mon 15:30 B 305

Phase-Matching Studies of High-Order Harmonic Generation from Water Droplets — •Heiko G. Kurz[1,2], Daniel S. Steingrube[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 systematic investigations of frequency up-conversion into the extreme ultraviolet spectral domain. Two intense femtosecond laser pulses interact with a micrometer-sized liquid water droplet under vacuum conditions. Therein, high-order harmonic radiation of the fundamental frequency is generated (HHG) in a target with controllable density, reaching from liquid state to gaseous, and even the plasma state. We investigate how the density and the dynamics of a complex target influence the HHG yield. Harmonic radiation up to the 29th harmonic order is generated and a strong dependency of the harmonic yield on the spatio-temporal behaviour of the target is found. We detect only a small amount of incoherent radiation. The spatio-temporal dynamics of the droplet, such as the expansion of the droplet and plasma formation during interaction with intense laser pulses are controlled by variation of the intensity of the pump pulse and its influence onto HHG is observed.

A 6: Ultra-cold atoms, ions and BEC II (with Q)

Time: Monday 14:00–16:00 Location: F 428

A 6.1 Mon 14:00 F 428

Observing the Drop of Resistance in the Flow of a Superfluid Fermi Gas — •David Stadler, Sebastian Krinner, Jakob Meineke, Jean-Philippe Brantut, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich

The ability of particles to flow with very low resistance is a distinctive character of a superfluid or superconducting state and led to its discovery in the last century. While the particle flow in liquid Helium or superconducting materials is essential to identify superfluidity or superconductivity, an analogous measurement has not been performed with superfluids based on ultracold Fermi gases. Here we report on the direct measurement of the conduction properties of strongly interacting fermions, and the observation of the celebrated drop of resistance associated with the onset of superfluidity. We observe variations of the atomic current over several orders of magnitude by varying the depth of the trapping potential in a narrow channel, which connects two atomic reservoirs. We relate the intrinsic conduction properties to thermodynamic functions in a model-independent way, making use of high-resolution in-situ imaging in combination with current measurements. Our results show that, similar to solid-state systems, current and resistance measurements in quantum gases are a sensitive probe to explore many-body physics. The presented method is closely analogous to the operation of a solid-state field-effect transistor. It can be applied as a probe for optical lattices and disordered systems, and paves the way towards the modeling of complex superconducting devices.

A 6.2 Mon 14:15 F 428

Ultracold fermions in two and three dimensions — •Igor Boettcher[1], Sebastian Diehl[2,3], Jan Pawlowski[1,4], and Christof Wetterich[1] — [1]Institut fuer Theoretische Physik, Universitaet Heidelberg — [2]Institut fuer Theoretische Physik, Universitaet Innsbruck — [3]IQOQI, Innsbruck — [4]ExtreMe Matter Insitute EMMI, GSI Darmstadt

The increasing experimental advances in realizing ultracold atom ensembles constitute an unprecedented possibility for testing and constraining predictions from quantum field theory. Key observables in equilibrium are the equation of state and the phase diagram of the system. I will present results on the BCS-BEC crossover of two-component ultracold fermions in both two and three dimensions, obtained with the Functional RG. We aim at quantitative precision. For this purpose we incorporate renormalization effects like the Contact, which is related to the high energy behavior of the momentum distribution of particles, and study its influence on the thermodynamics. The two-dimensional case is particularly interesting due to strong quantum fluctuations and can be realized in experiment with highly anisotropic traps.

A 6.3 Mon 14:30 F 428

A SU(N) symmetric Fermi degenerate gas of ytterbium for lattice many-body physics — •F. Scazza, C. Hofrichter, P. C. De Groot, M. Höfer, C. Schweizer, E. Davis, I. Bloch, and S. Fölling — MPI für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching and Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München, Germany

Ytterbium and other alkaline-earth-like atoms have some peculiar properties compared to alkali atoms which make them very attractive in the context of quantum simulation with ultracold atoms, especially in the presence of periodic potentials such as optical lattices.

Ytterbium possesses a metastable excited state which can be used to implement state-dependent optical lattices, enabling the simulation of new complex types of many-body Hamiltonians, e.g. the Kondo lattice model. In addition, the high nuclear spin of the fermionic ^{173}Yb, which is highly decoupled from the electronic state, gives rise to an enlarged SU(N) symmetry of the many-body Hamiltonian.

We describe preparation and detection of the nuclear and electronic spin state populations of a degenerate Fermi gas of Yb in the “magic lattice”, used for coupling to the $^3P_0$ metastable state via a narrow line “clock” laser on the doubly forbidden clock transition.

A 6.4 Mon 14:45 F 428

Two-component few-fermion mixtures in a one-dimensional trap — •Ioannis Brouzos and Peter Schmelcher — Zentrum für Optische Quantentechnologien, Universität Hamburg

We explore a few-fermion mixture consisting of two components which are repulsively interacting and confined in a one-dimensional harmonic trap. Different scenarios of population imbalance ranging from the completely imbalanced case where the physics of a single impurity in the Fermi-sea is discussed to the partially imbalanced and equal population configurations are investigated. For the numerical calculations the multi-configurational time-dependent Hartree (MCTDH) method is employed, extending its application to few-fermion systems. Apart from numerical calculations we generalize our Ansatz for a correlated pair wave-function proposed in [1] for bosons to mixtures of fermions. From weak to strong coupling between the components the energies, the densities and the correlation properties of one-dimensional systems change vastly. The numerical and analytical treatments are in good agreement with respect to the description of this crossover. We show that for equal populations each pair of different component atoms splits into two single peaks in the density while for partial imbalance additional peaks and plateaus arise for very strong interaction strengths. The case of a single impurity atom shows rich behaviour of the energy and density as we approach fermionization, and is directly connected to recent experiments.

[1] I. Brouzos and P. Schmelcher, PRL 108, 045301 (2012).

A 6.5 Mon 15:00 F 428

Measurements on first and second sound in a unitary Fermi gas — •Leonid A. Sidorenkov[1,2], Meng Khoon Tey[1,2], Rudolf Grimm[1,2], Yan-Hua Hou[3], Lev Pitaevskii[3,4], and Sandro Stringari[3] — [1]Institut für Quantenoptik und Quanteninformation (IQOQI), Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria — [2]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria — [3]Dipartimento di Fisica, Universitá di Trento and INO-CNR BEC Center, 38123 Povo, Italy — [4]Kapitza Institute for Physical Problems RAS, 119334 Moscow, Russia

We report on the propagation of first- and second-sound-like excitations in a highly elongated Fermi gas with unitarity-limited interactions around the critical temperature for superfluidity. Our measurements on first sound are in excellent agreement with calculations based on the recently measured equation of state (EoS) of the unitary Fermi gas for the whole temperature range explored. Given the available knowledge of thermodynamic quantities from the EoS, we investigate second-sound-like excitations in the unitary Fermi gas, and their connection to the superfluid hydrodynamics. Observation of these second-sound-like excitations offers, in analogy to superfluid helium, a direct access to the local superfluid density. This quantity cannot be obtained in EoS measuremens and requires additional knowledge of the elementary excitation spectrum of the unitary Fermi gas.

A 6.6 Mon 15:15 F 428

Attractive atom-dimer interaction on the repulsive side of a ^{6}Li-^{40}K Feshbach resonance — •Michael Jag[1,2], Matteo Zaccanti[1], Marko Cetina[1], Rianne Lous[1], Dmitri Petrov[3], Jesper Levinsen[4], Florian Schreck[1], and Rudolf Grimm[1,2] — [1]IQOQI, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Inst. für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria — [3]LPTMS, CNRS, Université Paris Sud, Orsay, France — [4]Cavendish Laboratory, Cambridge, UK

Mass imbalance in strongly interacting mixtures of ultracold fermions is predicted to lead to new pairing phenomena and quantum phases. We investigate a mass-imbalanced ^{6}Li-^{40}K Fermi-Fermi mixture in the regime of strong interactions on the repulsive side of an interspecies Feshbach resonance. We find that, for a sufficiently strong repulsive s-wave interaction, the ^{40}K atoms and the ^{6}Li^{40}K dimers interact attractively, which is in strong contrast to the mass-balanced case. This surprising behavior is related to the existence of a $\uparrow\uparrow\downarrow$ trimer state in $\uparrow\downarrow$ Fermi-Fermi mixtures with a mass ratio $m_\uparrow/m_\downarrow > 8.2$. For lower mass ratios (i.e. $m_K/m_{Li} = 6.64$) this trimer state turns into a p-wave atom-dimer scattering resonance. Here, we present our experimental results on interactions in a resonantly interacting atom-dimer mixture. Employing radio-frequency spectroscopy over a range of temperatures and interaction strengths, we confirm the presence of a strong attraction on the repulsive side of a Feshbach resonance, in good agreement with theory.

A 6.7 Mon 15:30 F 428

Towards optical trapping of a single Ba^+ ion — •Michael Zugenmaier, Thomas Huber, Alexander Lambrecht, Julian Schmidt, and Tobias Schaetz — Albert-Ludwigs Universität Freiburg

In 2010 our group demonstrated the trapping of an Mg^+ ion in an optical dipole trap [1,2]. The lifetime in the optical potential was limited by heating due to photon recoils out of the optical field, detuned by only 7000 Γ (depth ∼40 mK).

We are setting up a new experiment to trap a Ba^+ ion in a far off-resonance dipole trap. At first the Ba^+ ion is trapped and cooled in a linear Paul trap. The Ba^+ ion will then be transferred into an optical dipole trap which will be provided by a focussed laser at 532 nm. Using a far-detuned trapping laser of enhanced power features a comparable depth of the potential (∼20 mK) while minimizing the photon scattering rate and will result in longer trapping durations.

The results of this experiment will be our first step towards the trapping of a Ba^+ ion and Rb atoms in one common trap. Combining the optically trapped ion with atoms in the same optical trap might allow us sympathetically cool the ion and to enter the regime of ultracold chemistry, where quantum phenomena are predicted to dominate.

[1] Ch. Schneider et al., Nat. Phot. 4, 772-775 (2010)
[2] M. Enderlein et al., Phys. Rev. Lett. 109, 233004 (2012)

A 6.8 Mon 15:45 F 428

A single ion coupled to an optical fibre cavity — •Matthias Steiner[1], Hendrik-Marten Meyer[1], Christian Deutsch[2], Jakob Reichel[2], and Michael Köhl[1] — [1]Department of Physics, University of Cambridge, Cavendish Laboratory, Cambridge, United Kingdom — [2]Laboratoire Kastler-Brossel, ENS/UPMC-Paris 6/CNRS, F-75005 Paris, France

The development of an efficient ion-photon interface is a major challenge which needs to be overcome to realize large scale ion-based quantum networks. Such an interface could consist of a single ion coupled to a high finesse optical cavity. Existing ion-cavity systems operate in a regime, where the coupling of light and ion is smaller than the excited state decay rate[1]. In order to enhance the coupling, smaller cavity mode volumes must be used.

We report on the realization of a combined trapped-ion and optical cavity system, in which a single Yb^+ ion is confined by a micron-scale ion trap inside a 230 μm-long optical fibre cavity. We characterize the spatial ion-cavity coupling and measure the ion-cavity coupling strength using a cavity-stimulated Λ-transition [2]. Owing to the small mode volume, the coherent coupling strength between the ion and a single photon exceeds the natural decay rate of the dipole moment. Our results demonstrate that stable trapping of single ions in close vicinity of dielectric surfaces does not impose fundamental problems, even at room temperature.

[1] G. R. Guthöhrlein et al., Nature, 414, (2001).
[2] M. Steiner et al, arXiv:1211.0050.

A 7: Interaction with VUV and X-ray light I

Time: Monday 14:00–16:00 Location: B 302

A 7.1 Mon 14:00 B 302

EUV Ionization of Bare and Alkali Doped Helium Nanodroplets — •D. Buchta[1], S.R. Krishnan[2], N. Brauer[3], C. Callegari[4], M. Coreno[4], K. Prince[4], P. O'Keeffe[5], F. Stienkemeier[1], R. Moshammer[2], and M. Mudrich[1] — [1]Physikalisches Institut, Universität Freiburg, D-79104 Freiburg im Breisgau — [2]Max-Planck-Institut für Kernphysik, D-69117 Heidelberg — [3]Laboratoire de Chimie Physique Moléculaire, Swiss Federal Institute of Technology Lausanne, CH-1015 Lausanne — [4]Sincrotrone Trieste, I-34149 Basovizza — [5]CNR Istitudo di Metodologie Inorganiche e dei Plasmi, I-00016 Monterotondo Scalo

He nanodroplets are widely used as a cold and weakly interacting matrix for spectroscopy of embedded species. In this work we excite or ionize the He droplets using synchrotron radiation and study the back action onto the impurity atoms. Using photoelectron-photoion coincidence imaging spectroscopy at variable photon energies (20-25eV), we compare charge-transfer to Penning ionization of impurities located inside the droplets (rare gases) and those located at the droplet surface (alkali metals). The surprising finding is that alkali metals are very efficiently Penning ionized upon excitation of the 1s2p-band of He droplets, in contrast to rare gases. This speaks for rapid exciton migration to the surface, followed by relaxation and eventually the energy transfer to the alkali impurity.

A 7.2 Mon 14:15 B 302

Electron emission following collective autoionization of He nanodroplets irradiated by intense XUV pulses — •Yevheniy Ovcharenko[1], Viktor Lyamayev[2], Raphael Katzy[2], Michele Devetta[3], Aaron LaForge[2], Oksana Plekan[4], Patrick O'Keeffe[5], Robert Richter[4], Tommaso Mazza[6], Michele Di Fraia[7], Nils-Benedict Brauer[8], Marcello Coreno[5], Paola Finetti[4], Paolo Piseri[3], Marcel Drabbels[8], Stefano Stranges[9], Kevin Prince[4], Carlo Callegari[4], Frank Stienkemeier[2], and Thomas Möller[1] — [1]Technische Universität Berlin, Germany — [2]Universität Freiburg, Germany — [3]University of Milan, Italy — [4]Sincrotrone Trieste, Italy — [5]CNR-IMIP Rome, Italy — [6]European XFEL GmbH, Germany — [7]University of Trieste, Italy — [8]EPFL Lausanne, Switzerland — [9]University of Rome "Sapienza", Italy

The narrow bandwidth and tunability of FERMI@Elettra seeded FEL (Free Electron Laser) open new areas in the study of ultrafast radiation-matter interaction. Using this unique source with high-brilliance femtosecond XUV-pulses, photoelectron spectroscopy of He-nanodroplets has been performed by velocity map imaging technique in the photon energy range 20-27 eV. The electron spectra show that ionization occurs not only by a direct process at photon energies above the ionization potential (IP) but also below the threshold. It was found that electron spectra below IP strongly depend on the total energy absorbed by nanodroplets and give evidence for a collective autoionization process with energy transfer between neighboring atoms.

A 7.3 Mon 14:30 B 302

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[1], Viktor Lyamayev[6], Tommaso Mazza[7], Thomas Möller[8], Marcel Mudrich[6], Yevheniy Ovcharenko[8], Paolo Piseri[4], Kevin Prince[3], Robert Richter[3], Michele Di Fraia[10], Stefano Stranges[9], and Frank Stienkemeier[1] — [1]Universität Freiburg, Germany — [2]CNR-IMIP Rome, Italy — [3]Sincrotrone Trieste, Italy — [4]University 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 the VUV- seeded FEL FERMI@Elettra. Using the FEL's high intensity and broad wavelength tunability, one can resonantly excite a large percentage of either the dopant or the cluster to look for effects of mutual interaction, such as the formation of nanoplasmas or energy transfer between dopant and cluster. In this regard, various dopants and their abundance along with cluster size were varied in order to fully exploit any possible observables.

A 7.4 Mon 14:45 B 302

Attosecond-resolved electron dynamics around the 1st ionization threshold of helium measured by multidimensional absorption spectroscopy — •Andreas Kaldun, Christian Ott, Veit Stooss, Philipp Raith, Kristina Meyer, Martin Laux, Alexander Blaettermann, Thomas Ding, and Thomas Pfeifer — Max-Planck Institut f. Kernphysik, Heidelberg, Germany

We recently developed a transient-coupling measurement scheme, which we employed to uncover coherent laser-induced coupling of doubly-excited helium states to continuum states [1]. Here, we apply this measurement scheme to study in detail the coherent electron dynamics and general absorption phenomena arising for single-excitation of helium around 24 eV with attosecond-pulsed VUV light fields. Exploiting a multidimensional control by (a) varying the time delay between the attosecond and a coupling laser pulse, (b) tuning the coupling laser intensity and (c) analyzing the propagation direction of the transmitted VUV attosecond pulse we observe the transformation of the original (Lorentzian) resonance shapes into Fano line shapes. To understand the mechanism behind this quantum control we performed numerical simulations to model our experimental results, which include the attosecond-pulsed excitation and laser coupling of multiple excited states [2]. These simulations allowed us to identify the ponderomotive dressing of the states in the laser field as a key component for understanding the control of several line shapes of the observed absorption spectra. [1]C. Ott et al., arXiv:1205.0519v1 [physics.atom-ph] (2012) [2]A. Kaldun et al., in preparation (2013)

A 7.5 Mon 15:00 B 302

XUV induced dissociative photo-ionization of H_2 observed by electron-ion correlation — •Andreas Fischer[1], Alexander Sperl[1], Philipp Cörlin[1], Michael Schönwald[1], Arne Senftleben[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

We studied the dissociative photo-ionization of H_2 induced by XUV radiation. The use of a reaction microscope enables us to perform kinematically complete coincidence measurements. In an ion–electron-correlation measurement we observed an asymmetric dissociation in the molecular frame, similar to the asymmetry observed by [1], caused by path interference of two different dissociation channels. The first channel includes the $H_2^+(A\,^2\Sigma_u)$ state and the second the $H_2^+(X\,^2\Sigma_g)$ state and the doubly excited $H_2(Q_1\,^1\Sigma_u)$ states. A semi-classical simulation, using phase integrals, reproduces the observed asymmetry.

[1] F. Martín, J. Fernández, T. Havermeier, L. Foucar, T. Weber, K. Kreidi, M. Schöffler, L. Schmidt, T. Jahnke, O. Jagutzki, et al., Science 315, 629 (2007)

A 7.6 Mon 15:15 B 302

Ly-α coincidence after dissociation of hydrogen molecules in superexcited states into neutral fragments — •Philipp Schmidt, Philipp Reiss, Benjamin Kambs, André 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 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 at different pressures in the range of 0.1 to 0.4 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 coincidence time spectra as well as individual detector intensity has been analysed with respect to the fluorescence lifetimes for the different pressures, especially the $2p$-$1s$ decay by Lyα emission.

A 7.7 Mon 15:30 B 302

Development of an apparatus for the angle-resolved detection of two photons in coincidence — •Philipp Reiss, Philipp Schmidt, Benjamin Kambs, André Knie, and Arno Ehresmann — Institute of Physics, University of Kassel, Heinrich-Plett-Str.40, 34132 Kassel, Germany

The detection of photons emitted in coincidence by fragments of doubly or multiply excited molecules offers a method to study processes where no ions are formed, i.e. neutral dissociation. In addition to the time-resolved detection, the possibility to perform angular correlations of the emitted photons gives rise to a more thorough investigation of the ongoing processes.

Experimental realizations of a dedicated apparatus are presented and compared in terms of solid angle coverage, optical properties, monitoring of the target pressure and applicability for the use at synchrotron facilities.

A 7.8 Mon 15:45 B 302

Investigation of resonant X-ray absorption structures of different terpenes by total ion yield measurements in the vicinity of C1s-edge — •Benjamin Kambs[1], Kari Jänkälä[2,3], Philipp Schmidt[1], Andreas Hans[1], Christian Ozga[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

Structures differing from their own mirror images are called chiral. In a variety of biochemical reactions there is a crucial difference in the behaviour of both types of one chiral molecule. For an understanding of those processes, it is of essential importance to know the electronic architecture of such molecules and how it is influenced by the chiral molecular potential.

A small prototypical class of chiral substances often found in nature are terpenes. In the present experiment we investigated Limonene, α-Pinene, Carvone and Fenchone at the beamline UE56/2 at Bessy, Berlin. Those molecules have been excited by monochromatized synchrotron radiation in the regime of the C1s edge. We measured the total ion yield spectra during their subsequent decay and relaxation. The results yield information about the absorption of X-rays and are compared to spectra calculated by means of the time dependent density functional theory method.

A 8: Precision measurements and metrology II (with Q)

Time: Monday 14:00–15:45 Location: F 128

Group Report A 8.1 Mon 14:00 F 128

Miniaturized laser systems for precision measurement applications — •Markus Krutzik[1], Achim Peters[1,2], Andreas Wicht[2], Ernst Rasel[3], Klaus Sengstock[4], and The LASUS Team[1,2,3,4] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Insitut, Leibniz Institut für Höchstfrequenztechnik, Berlin — [3]Institut für Quantenoptik, LU Hannover — [4]Institut für Laserphysik, U Hamburg

Rapid progress in the field of ultra cold quantum gases has led to the development of new measurement tools with unprecedented precision such as high performance optical clocks and matter wave interferometers. Their ultimate performance can only be reached in space by providing access to unperturbed long evolution times and low-noise environments, altogether leading to outperform existing inertial sensors in accuracy and precision. Space-borne experiments in particular, but also those instruments targeting practical applications on ground, depend to a large degree on the availability of robust, compact and energy-efficient laser system technology. We present the development of a new generation of compact laser systems specifically optimized for precision applications on sounding rockets and satellites.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR 50 WM 1131-1137, 1237-1240, 1141 and 50QT1201.

A 8.2 Mon 14:30 F 128

High resolution Sagnac atom interferometer — •Gunnar Tackmann, Peter Berg, Sven Abend, Teresa Feld, Katja Baxmann, Paul Kaebert, Christian Schubert, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

We present a compact dual source cold-atom gyroscope with flat parabolic atomic trajectories in which an area of 19 mm^2 is realised on a baseline of 13.7 cm. This gyroscope resolves a rotation rate of $5.3{\cdot}10^{-7}$ rad/s at one second, mainly limited by inertial noise, and reaches a final sensitivity of $3{\cdot}10^{-8}$ rad/s. We introduce ways to further improve the stability of the device and to increase its sensitivity to the 10^{-9} rad/s regime by monitoring the rotational noise with auxiliary seismic sensors.

This work is supported by the DFG, the cluster of excellence QUEST, and IQS.

A 8.3 Mon 14:45 F 128

High sensitivity temperature measuerements on the nanometer scale — •Philipp Neumann[1], Florian Dolde[1], Ingmar Jakobi[1], Gerald Waldherr[1], Rolf Reuter[1], Junichi Isoya[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Graduate School of Library, Information and Media Studies, University of Tsukuba, Japan

Here we demonstrate a novel method to measure temperatures with a sensitivity of ~ 10 mK/$\sqrt{Hz}$ and nanometer spatial resolution. Its temperature application range is at least from 120 K to 600 K and includes ambient conditions. It is therefore interesting for material and lifescience. We employ a single optically active paramagnetic defect in a nanometer size diamond, namely the nitrogen-vacancy center. More precisely the spin state can be read out optically and its energy levels depends on temperature among others. We have developed a novel technique to circumvent the main detrimental effects to achieve the stated sensitivity.

A 8.4 Mon 15:00 F 128

Spectroscopy of the clock transition in ^{171}Yb with a transportable setup — •Tobias Franzen, Charbel Abou Jaoudeh, Gregor Mura, Axel Görlitz, Heiko Luckmann, Alexander Nevsky, Ingo Ernsting, and Stephan Schiller — Institut für Experimentalphysik, HHU Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Optical lattice clocks based on elements with two valence electrons are strong competitors in the quest for next generation time and frequency standard. While promising results have already been obtained on several stationary setups using Sr and Yb, transportable clocks are desirable for both performance evaluation and applications.

In the framework of the Space Optical Clocks 2 project, we are developing a transportable Yb lattice clock demonstrator. Our setup is based on diode and fiber lasers and features an intra-vacuum enhancement resonator to allow the formation of a large volume lattice using moderate laser power.

Here we present first results of spectroscopy of the $^1S_0 \rightarrow {}^3P_0$ transition in ^{171}Yb confined in an one dimensional optical lattice, a first evaluation of systematics and ongoing work towards competitive clock operation as well as more compact and robust subsystems.

A 8.5 Mon 15:15 F 128

Compact mode-locked diode laser system for highly accurate frequency comparisons — •Heike Christopher[1,2], Evgeny Kovalchuk[1], Achim Peters[1,2], and the LASUS Team[1,2,3,4] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Insitut, Leibniz-Institut für Höchstfrequenztechnik Berlin — [3]Institut für Quantenoptik, LU Hannover — [4]Institut für Laserphysik, Universität Hamburg

We have developed a compact mode-locked diode laser system designed to generate an optical frequency comb spanning the wavelength range from 767 nm to 780 nm. It will thus allow highly accurate frequency comparisons in microgravity experiments testing the Einstein equivalence principle (EEP) for Rubidium and Potassium quantum gases.

The passively mode-locked semiconductor laser system is configured as an extended-cavity laser, allowing for high flexibility in optimizing performance parameters to match the application requirements. The intra-cavity output of the two-section ridge-waveguide (RW) laser diode, consisting of a short saturable absorber and a long gain section, is collimated and reflected by a dielectric mirror. The group velocity dispersion (GVD) of this mirror can be adjusted to provide optimal performance by compensating the laser diode dispersion. Here we present the current status of our work and discuss options for further improvements.

This project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM1237-1240.

A 8.6 Mon 15:30 F 128

Broadband femtosecond filtering cavities for quantum limited projective metrology — •Roman Schmeissner, Valerian Thiel, Jonathan Roslund, Claude Fabre, and Nicolas Treps — Laboratoire Kastler Brossel, 4 Place Jussieu, 75252 Paris cedex 05, France

We have shown theoretically that balanced homodyne detection with a temporally shaped local oscillator extracts timing information and any other parameter of femtosecond(fs)-pulses with ultimate sensitivity [1]. To reach limits predicted by information theory, the scheme requires a laser beam that is quantum-limited in amplitude and phase. We propose to use optical cavities: they are intrinsic, passive low-pass filters that address frequency scales difficult to reach with active feedback mechanisms. Similar systems are used for broadband spectroscopy [2,3]. We construct and characterize a readily implementable filtering cavity that is simultaneously resonant over 100nm. This exceptional broadband property enables a wide range of applications from parameter estimation to ultra-precise spectroscopy. When seeded with a 25fs frequency comb, intensity and phase noise are reduced by up to 10dB at and below the relaxation oscillation band at 1MHz. Furthermore, noise quadrature interconversion enables qualitative identification of phase noise at sidebands above 100kHz. In conclusion, a frequency comb that is quantum limited in amplitude and phase for frequencies larger than 500kHz is obtained from a commercial Ti:Sa laser system.

[1] B. Lamine et al., Phys. Rev. Lett. 101, 2008, 123601, 1-4 [2] Ch. Gohle et al., Phys. Rev. Lett. 100, 2008, 1-4 [3] M.J. Thorpe et al., Optics Express 16, 2008, 2387-2397

A 9: Interaction with strong or short laser pulses I

Time: Monday 16:30–18:30 Location: B 305

Invited Talk A 9.1 Mon 16:30 B 305

Attosecond physics at a nanoscale metal tip — •Peter Hommelhoff[2,1], Michael Krüger[1], Michael Förster[1], Sebastian Thomas[1], Lothar Maisenbacher[1], Peter Dombi[1], Johannes Hoffrogge[1], Jakob Hammer[1], Dominik Ehberger[1], John Breuer[1], Georg Wachter[3], Christoph Lemell[3], and Joachim Burgdörfer[3] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Physik-Department, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen — [3]Theoretische Physik, TU Wien, Wiedner Hauptstraße 8-10, A-1040 Wien

We focus few-cycle laser pulses onto sharp metal tips. Electrons are emitted from the apex of the tip, and their energy is analysed. We observe a strong carrier-envelope phase (CEP) dependence and can switch on and off the high-energy part of the electron current by the CEP. We can describe the spectra with the three-step model borrowed from high-harmonic generation in atomic gases. Because of the broken symmetry in tip-based experiments, the spectra can be explained with few trajectories only, alleviating their interpretation. We will compare the spectra to more appropriate TDDFT simulation results and will report on ongoing experiments focusing on understanding the interaction of few-cycle laser pulses and nanoscale matter on sub-fs time scales.

A 9.2 Mon 17:00 B 305

Imaging the nanoplasma of single large xenon clusters with the Free-Electron Laser FLASH — •D Rupp[1], M Adolph[1], L Flückiger[1], T Gorkhover[1], M Krikunova[1], M Sauppe[1], D Wolter[1], S Toleikis[2], R Treusch[2], S Schorb[3], C Bostedt[3], and T Möller[1] — [1]TU Berlin — [2]Hasylab@DESY — [3]LCLS@SLAC

Intense short pulses from Free-Electron Lasers in the short wavelength regieme as FLASH provide access to new fields of experiments such as imaging of single nanosized structures. We use rare gas clusters as ideal targets to study the interaction between matter and strong light pulses in a combined approach of measuring both ion spectra and scattered light. From the scattering patterns of single clusters, the particle size can be extracted, but also light induced changes in the clusters on a fs timescale are encoded in the scattered light [1]. Intensity profiles of the scattering patterns analyzed with Mie's theory yield optical properties of the clusters. Strong modulations found in intense patterns of large clusters point to the formation of a core-shell system of the nanoplasma with a highly absorbing core and a weakly absorbing, tens of nanometers thick shell. In contrast, the ion spectra of the same clusters indicate the explosion of highly charged ions from only a very thin outer shell driven by coulombic repulsion and effective recombination of the remaining, quasi-neutral nanoplasma. Those results emphasize the capability of simultaneous imaging and ion spectroscopy of single clusters, to address different timescales of a complex process and thus gain a more complete picture.

[1] C. Bostedt et al, PRL 108, 093401 (2012)

A 9.3 Mon 17:15 B 305

Time-dependent density functional calculations of enhanced fast electron emission from laser-irradiated sodium clusters — •Thomas Keil and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

The investigation of clusters promises insight into the transition from atomic systems to the bulk material. Moreover, this transient regime gives rise to a variety of phenomena driven by collective effects in small systems subject to intense laser pulses [1,2], such as enhanced absorption and scattering of radiation and modified cut-offs in photoelectron spectra.

We study the interaction between short intense laser pulses and sodium clusters. A comparison with the hydrogen atom shows that for clusters the emission of fast electrons is significantly increased. This effect is studied using time-dependent density functional theory and a jellium cluster model.

We calculate electron energy spectra to show correlations between electron-electron interaction and the effect of increased fast electron emission. We identify collective effects in the multipole-expanded interaction potentials and characterize the underlying acceleration mechanism.

[1] Th. Fennel et al., Rev. Mod. Phys. 82, 1793 (2010).
[2] Th. Fennel et al., Phys. Rev. Lett. 98, 143401 (2007).

A 9.4 Mon 17:30 B 305

Adiabatic versus nonadiabatic effects in tunneling ionization of atoms — •Antonia Karamatskou[1,2], Stefan Pabst[1,2], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany

We discuss the tunneling regime of atoms in a strong laser field within the framework of the adiabatic representation. This representation is commonly used in the field of molecular dynamics, where the motion of the nuclei is assumed to be so slow compared to the electronic motion that it justifies the usage of the Born-Oppenheimer approximation. This yields discrete potential energy curves of the system that are connected by nonadiabatic transitions. Here, we extend this method to the treatment of the strong-field ionization of atoms. By adding a complex absorbing potential the Hamiltonian becomes non-Hermitian. In this way, we obtain discrete eigenstates and the associated complex eigenvalues contain the physical tunneling rates. Via the full diagonalization of the instantaneous Hamiltonian we are able to observe the transition from the adiabatic regime to the region where nonadiabatic transitions become significant for the ionization. In our study we also clarify the impact of few-cycle pulses on the tunneling behavior. Thereby we refine the language employed for nonadiabaticity in strong field physics. Furthermore, we analyze the usage of the Keldysh parameter as an adiabaticity parameter for strong field ionization.

A 9.5 Mon 17:45 B 305

Geometric effects in dopant-induced helium nanoplasmas — Barbara Grüner, Manuel Rometsch, Frank Stienkemeier, and •Marcel Mudrich — Physikalisches Institut, Universität Freiburg

He nanodroplets are widely used as a cold and weakly perturbing matrix for studying embedded molecules and clusters by laser spectroscopy. However, when the impurity atoms are ionized using strong NIR laser pulses the He droplets can turn into highly absorbing nanoplasmas. As a result, we measure high yields of He^+ and He^{2+} ions as well as increased charge states of the impurities compared to the neat impurity clusters. Surprisingly, we find the efficiency of igniting the He nanoplasma to strongly depend on the location of the impurities with respect to the droplet surface, as demonstrated using alkali and earth-alkali metals instead of rare gases as dopants.

A 9.6 Mon 18:00 B 305

Characterization of an axis-density modulated plasma waveguide based on laser-cluster interaction — •yin tao[1], siew jean goh[1], peter van der slot[1], bert bastiaens[1], edwin van der weide[1], rob hagmeijer[1], jennifer herek[1], sandra biedron[2], steven milton[2], miltcho danailov[3], and klaus boller[1] — [1]Laser Physics and Nonlinear Optics, Optical Sciences, Engineering Fluid Dynamics, Mesa+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands — [2]Colorado State University, Colorado, USA — [3]FERMI@Elettra, Sincrotrone Trieste S.C.p.A., Basovizza, Trieste, Italy

We investigate the possibility to realize a fully coherent light source emitting XUV down to 4 nm by using high harmonic generation (HHG) in an ionized medium. However, due to the strong ionization, current phase-matching techniques for HHG are not suitable. Instead, we will investigate quasi-phase matching (QPM) and wave guiding over an extended interaction length to increase the output pulse energy. For this, we will ionize a density modulated cluster jet to prepare a plasma waveguide with an appropriate density modulation along its axis for QPM. Here, we first report on the characterization of the argon cluster jet with a modulated grid. We employ Rayleigh scattering imaging and interferometry to infer the cluster size and the density distribution in the jet. Later, the modulated plasma waveguide will be generated. We present the temporal and spatial evolution of total electron density as measured by transverse interferometry technique. Additionally, the shortest possible modulation period will be discussed.

A 9.7 Mon 18:15 B 305

Autoionization of Helium Nanodroplets Induced by Intense VUV Light Pulses — •Aaron LaForge[1], Michele Alagia[6], Lorenzo Avaldi[2], Carlo Callegari[3], Marcello Coreno[2], Michele Devetta[4], Marcel Drabbels[5], Raphael Katzy[1], Antti Kivimaki[6], Viktor Lyamayev[1], Tommaso Mazza[7], Thomas Möller[8], Marcel Mudrich[1], Yevheniy Ovcharenko[8], Paolo Piseri[4], Kevin Prince[3], Robert Richter[3], Michele Di Fraia[10], Stefano Stranges[9], and Frank Stienkemeier[1] — [1]Universität Freiburg, Germany — [2]CNR-IMIP Rome, Italy — [3]Sincrotrone Trieste, Italy — [4]University 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

Ionization of helium nanodroplets was performed by the VUV-seeded FEL FERMI@Elettra. Using the unique tunability of the seed laser along with the high intensity of the FEL, it is possible to resonantly excite the nanodroplets such that almost the entire cluster is excited. In this state, neighboring excited atoms can decay via energy transfer similar to a doubly excited state decaying by autoionization. This effect leads to an enhancement in the abundance of ions. To observe the effects, one compares the power dependencies on the ion yield for various excited states to those of non-resonant ionization and direct ionization.

A 10: Precision spectroscopy of atoms and ions II (with Q)

Time: Monday 16:30–18:00 Location: F 428

A 10.1 Mon 16:30 F 428

Microwave field imaging using microfabricated vapor cells — •Guan-Xiang Du[1], Andrew Horsley[1], Matthieu Lucien Pellaton[1], Christoph Affolderbach[2], Gaetano Mileti[2], and Philipp Treutlein[1] — [1]Department of Physics, University of Basel, CH-4056 Basel, Switzerland — [2]Laboratoire Temps-Fréquence - University of Neuchâtel, 2000 Neuchâtel, Switzerland

We have recently demonstrated a technique for 2D microwave (mw) field imaging using alkali atoms in a milimeter-thick vapor cell.[1] Micrometer-scale miniaturized microwave circuits in industry, however require microfabricated vapor cell to look at details into the vicinity of the circuit waveguides. The 3D spatial resolution is achieved via micrometer-scale sensing volume with one dimension confined by the thickness of the vapor cell and the other two by introducing a buffer gas. The factors that suppress the coherence time include, collisions of alkali atoms with cell wall, alkali-buffer gas collisions, and alkali-alkali spin exchange collisions, are investigated. We report the status of our experiments on mw field imaging with such microcells.

[1]Pascal Bohi and Philipp Treutlein, Appl. Phys. Lett. 101, 181107

(2012).

A 10.2 Mon 16:45 F 428

Hochspannungsmessung mittels kollinearer Laserspektroskopie — •Elisa Will[1], Nadja Frömmgen[1], Christopher Geppert[1,2,3], Christian Gorges[1], Michael Hammen[1,3], Simon Kaufmann[1], Andreas Krieger[1,2,3], Wilfried Nörtershäuser[1,2,3] und die TRIGA-SPEC-Kollaboration[1] — [1]Institut für Kernchemie Mainz — [2]Helmholtz-Institut Mainz — [3]TU Darmstadt

Bereits im Jahr 1982 wurde experimentell demonstriert, dass es möglich ist, aus der Dopplerverschiebung der Resonanzlinien schneller Atome oder Ionen in der kollinearen Laserspektroskopie, die Hochspannung zu bestimmen, mit der die Ionen zuvor beschleunigt wurden [1]. Dies stellt eine Alternative zur elektronischen Messung mittels Spannungsteilern dar. Der letzte Versuch, die Genauigkeit der Methode zu steigern, erfolgte im Jahr 2004. Dabei konnten Hochspannungen im Bereich von -20 kV bis -50 kV mit einer relativen Genauigkeit von etwa 10^{-4} gemessen werden [2]. Die präzise Messung von Hochspannungen ist von generellem Interesse für die Metrologie, aber auch für verschiedene Experimente der aktuellen Grundlagenforschung, beispielsweise für das KATRIN-Experiment, welches eine relative Genauigkeit in der Hochspannungsmessung von 10^{-6} erfordert [3]. Aktuell werden Tests zur Erhöhung der Genauigkeit der kollinearen Methode am TRIGA-LASER-Experiment in Mainz durchgeführt. Erste Ergebnisse werden vorgestellt.

[1] O. Poulsen, Nucl. Instr. and Meth. 202 (1982), 503-509
[2] S. Götte et al., Rev. Sci. Instrum. 75 (2004) 1039-1050
[3] T. Thümmler, New J. Phys. 11 (2009) 103007

A 10.3 Mon 17:00 F 428

Sensitive detection of fast, neutral hydrogen atoms for the Bound Beta-Decay (BoB) Experiment — •Josephine McAndrew — Technische Universität München

We are currently exploring methods to detect hydrogen atoms with 325.7 eV kinetic energy. These atoms form the decay signature of the theoretically-predicted three-body decay of the neutron into a hydrogen atom and an anti-neutrino. The challenge in designing and building such a hydrogen detector lies in the small predicted branching ratio for this decay (~10^-6 of the three-body decay), the low energy of the atoms and the requirement to identify them over background hydrogen. This talk will describe our preliminary work investigating three possible detection schemes: quenching of H(2s) atoms and subsequent detection of the resulting Lyman-α photon, charge-exchange of hydrogen atoms in argon gas and laser ionisation.

A 10.4 Mon 17:15 F 428

Towards Radiation Detected Resonance Ionization Spectroscopy on transfermium elements in a buffer gas cell — •Felix Lautenschläger[1], Mustapha Laatiaoui[2,3], Michael Block[2,3], Werner Lauth[4], Hartmut Backe[4], Thomas Walther[1], and Fritz-Peter Hessberger[2] — [1]Institut für Angewandte Physik, TU Darmstadt, 64289 Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt — [3]Helmholtzinstitut Mainz, 55128 Mainz — [4]Institut für Kernphysik, JGU Mainz, 55128 Mainz

The study of the atomic structure of transfermium elements like nobelium (No) and lawrencium (Lr) via Radiation Detected Resonance Ionization Spectroscopy (RADRIS) is one of the most fascinating disciplines of modern atomic physics. It allows the determination of relativistic effects at the heaviest elements and provides a critical test of theoretical predictions. For these transfermium elements no experimental data on atomic level schemes are available at present.

First experiments on ^{254}No were performed in 2007, in which a buffer gas cell with an overall efficiency of 1% [H. Backe et al., Eur. Phys. J. D 45 (2007) 99] was employed. In this experiment the evaporation temperature of nobelium was determined for the first time. To increase the efficiency of the buffer gas cell, off-line measurements have been performed with nat. ytterbium, the chemical homologue of nobelium. Also on-line experiments during a parasitic beamtime in 2012 provided an insight into the critical parameters of our setup. The results of the off-line and on-line measurements are briefly summarized in this talk.

A 10.5 Mon 17:30 F 428

Ion-lithium dynamics studied with an in-ring MOTReMi — Elisabeth Bruehl[1], Natalia Ferreira[1], •Johannes Goullon[1], Renate Hubele[1], Aaron LaForge[2], Hannes Lindenblatt[1], and Daniel Fischer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisches Institut, Universität Freiburg

The understanding of few-particle dynamics is a fundamental and challenging task in physics. With the investigation of ion-atom collisions simple few-body Coulomb-systems can be studied and theoretical models can be tested, especially since kinematically complete experiments with Reaction Microscopes (ReMi) are feasible. In our experiment such a ReMi is combined with a magneto-optical trap (MOT) preparing a cold lithium target and all implemented in an ion storage ring which provides brilliant and intense projectile beams. Due to the optical transitions driven in the MOT also excited and even polarized targets become available. In this contribution fully differential cross sections of different scattering processes like single ionization, single capture and transfer ionization will be presented.

A 10.6 Mon 17:45 F 428

Broadband lasercooling of relativistic ions at the ESR — •Danyal Winters[1], Michael Bussmann[2], Weiqiang Wen[1,3], Johannes Ullmann[1], Rodolfo Sanchez[1,4], Matthias Lochmann[1,4], Colin Clark[1], Tobias Beck[5], Benjamin Rein[5], Sascha Tichelmann[5], Mathias Siebold[2], Michael Seltmann[2], Dacheng Zhang[3], Jie Yang[3], Christina Dimopoulou[1], Fritz Nolden[1], Markus Steck[1], Wilfried Nörtershäuser[1,4,5], Ulrich Schramm[2], Thomas Kühl[1,4,7], Gerhard Birkl[5], Thomas Walther[5], Xinwen Ma[3], and Thomas Stöhlker[1,6,7] — [1]GSI Darmstadt — [2]HZDR Dresden — [3]IMP CAS Lanzhou, China — [4]Uni Mainz — [5]TU Darmstadt — [6]Uni Jena — [7]HI Jena

We present new results on broadband laser cooling of stored relativistic C^{3+} ion beams at the ESR in Darmstadt. For the first time we could show laser cooling of bunched relativistic ion beams using a UV-laser which could scan over a very large range and thus cool all the ions in the 'bucket'. This scheme is much more versatile than a previous scheme, where the bunching frequency was scanned relative to a fixed laser frequency. We have also demonstrated that this cooling scheme works without pre-electron cooling, which is a prerequisite for its general application to future storage rings and synchrotrons, such as the HESR and the SIS100 at FAIR. We also present results from in vacuo VUV-fluorescence detectors, which have proven to be very effective.

A 11: Atomic clusters I (with MO)

Time: Monday 16:30–18:30 Location: B 302

Invited Talk A 11.1 Mon 16:30 B 302

Spectra of cold molecular ions from hot helium nanodroplets — •Marcel Drabbels — EPFL, Lausanne, Switzerland

The function of a molecule is intimately related to its structure. Accordingly, in the quest for a better understanding of molecular function, the development of spectroscopic methods to elucidate molecular structures increasingly takes central stage. The amount of detail that can be derived from spectra depends on the experimental conditions, most notably on the temperature of the sample and the intermolecular interactions a molecule experiences. Helium nanodroplets provide in this respect an almost ideal matrix. For neutral molecules, helium nanodroplet spectroscopy thus has led to important discoveries related to the structure of key molecular systems and has provided insight into the mechanisms underlying chemical reactions.

Compared to the level of sophistication that has been reached for neutrals, the spectroscopic exploration of ions is still in its infancy. The use of helium droplets as a cryogenic matrix could potentially solve many of the technical challenges associated with recording high-resolution spectra of cold molecular ions. Here, we will present a method to record spectra of ion containing helium nanodroplets that finds its roots in the nonthermal cooling dynamics of excited molecular ions. In addition, spectra of several molecular ions will be present and the influence of the helium environment on these spectra will be discussed.

A 11.2 Mon 17:00 B 302

Angular resolved photoionization study of C60 in ultrashort (4 fs) and short (40 fs) laser pulses — •S. Skruszewicz[1], H. Li[2], S. Zherebtsov[3], R. Irsig[1], F. Süssmann[3], Th. Fennel[1], J. Tiggesbäumker[1], M. F. Kling[2,3], and K.-H. Meiwes-Broer[1] — [1]Institut für Physik, Universitätsplatz 3, 18051 Rostock, Germany — [2]J.R. Macdonald Laboratory, Department of Physics, Kansas State University, Manhattan, KS 66506, USA — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Recently, the existence of Superatom Molecular Orbitals (SAMO) bound to the core of the hollow C_{60} cage has been reported [1,2]. Few-cycle as well as two-color pulses (w/2w) [3] are applied to study angule-resolved photoelectron emission from C_{60} in order to characterize SAMO in more details. As tool we utilize Velocity Map Imaging spectrometer to map angular dependence in the photoelectron emission. Multiple nodal structures appear in the angular signal distribution as we excite C_{60} with few-cycle laser pulses. At pulse durations of 40 fs, one observes distinct changes in the photoelectron angular distribution. We also made attempt to compare the CEP dependence on the electron emission to the result obtained with w/2w pulses of 40 fs.

[1] M. Feng et.al., Science **320**, 359 (2008)
[2] O. Johansson et.al., Phys. Rev. Lett. **108** 173401 (2012)
[3] N. Dudovich et. al., Nature **2**, 781 (2006)

A 11.3 Mon 17:15 B 302

Magnetic Moments of Chromium-Doped Gold Clusters: Anderson Impurity Model in Finite Systems — Konstantin Hirsch[1,2], Vicente Zamudio-Bayer[1,2], Andreas Langenberg[1,2], Markus Niemeyer[1,2], Bruno Langbehn[1,2], Thomas Möller[1], Akira Terasaki[3,4], Bernd von Issendorff[5], and •Tobias Lau[2] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, 10623 Berlin — [2]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin — [3]Cluster Research Laboratory, Toyota Technological Institute, 717-86 Futamata, Ichikawa, Chiba 272- 0001, Japan — [4]Department of Chemistry, Kyushu University, 6-10- 1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan — [5]Fakultät für Physik, Universität Freiburg, 79104 Freiburg

The interaction of a single magnetic impurity with a free electron gas is a long standing problem in condensed matter physics. It results in interesting phenomena like the Kondo effect or Friedel oscillations. In recent years substantial progress was made by studying these phenomena in atomic scale systems. Here we follow this approach and investigate the interaction of a single magnetic impurity with a finite free electron gas. $CrAu_n^+$ clusters serve as a model system. We show that the size dependence of the local spin magnetic moment of $CrAu_n^+$ can well be described within in the Anderson impurity model, where the interaction of the localized impurity states with the electron bath of the gold matrix is governed by quantum confinement in the host, which is abscent in the corresponding bulk material.

A 11.4 Mon 17:30 B 302

Clusters in intense femtosecond XUV pulses: Direct simulation of light scattering — •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

Recent XUV experiments on rare gas clusters at FLASH have proven that single-shot imaging of clusters contains valuable information on transient matter properties under intense XUV excitation [1]. These advances show that IR-XUV pump-probe experiments are in reach to illuminate the ultrafast dynamical evolution of highly excited nanosystems via the XUV scattering. However, so far no well established theory exists to fully describe the light scattering of strongly dynamical systems including nonlinear and transient effects. We propose a route to such theoretical analysis based on the recently introduced microscopic particle-in-cell (MicPIC) approach [2]. MicPIC enables us to simultaneously account for the nonlinear laser-cluster interaction dynamics including ionization, heating, and expansion along with light propagation on the fully microscopic level and without any restrictions on particle geometry. We report first theory results on XUV only and IR-XUV pump probe scenarios for large rare gas clusters up to (D∼80nm), which show the typical geometry-induced Mie scattering as well as elastic and inelastic XUV light scattering signals stemming from nonlinear effects and plasmonic excitations of the nanoplasma.

[1] C. Bostedt et al., Phys. Rev. Lett. **108**, 093401 (2012)
[2] C. Varin et al., Phys. Rev. Lett. **108**, 175007 (2012)

A 11.5 Mon 17:45 B 302

Time resolved electron spectra from clusters in the light of FLASH — •M. Müller[1], D. Rupp[1], T. Oelze[1], M. Sauppe[1], L. Flückiger[1], T. Gorkhover[1], A. Przystawik[2], M. Adolph[1], U. Frühling[2], M. Wieland[2], B. Schütte[3], A. Al-Shemmary[2], N. Stojanovic[2], S. Toleikis[2], J.-P. Müller[1], M. Krikunova[1], T. Laarmann[2], and T. Möller[1] — [1]TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]HASYLAB (DESY), Notkestr. 85, 22607 Hamburg — [3]Max-Born-Institut, Rudower Chaussee 17, 12489 Berlin

During the last ten years free-electron lasers (FEL) made highly intense and short pulses from the soft to the hard X-ray regime for the first time accessible. Facilities like FLASH opened a wide range of new research fields concerning the interaction of light with matter for example in physics, chemistry and biology.

We use rare gas clusters as a model system to study the complex interaction, which proceeds on different time scales. At first the cluster is ionized. Due to the loss of electrons and further ionization the Coulomb potential of the cluster gets deeper and the electrons are trapped in the cluster - a nanoplasma is built up. Finally the cluster is destroyed either by coulomb explosion or hydrodynamic expansion of the nanoplasma. By measuring electron and ion spectra, further insight into the ionization and recombination processes can be gained. The temporal evolution of the FEL induced plasma dynamics in clusters was further investigated by means of streaking the photoelectrons with a THz pulse, a very promising new tool at FLASH. We will give an overview of our setup and discuss first results.

A 11.6 Mon 18:00 B 302

Non-adiabatic quantum molecular dynamics with trajectory surface hopping — •Michael Fischer[1,2], Jan Handt[2], and Rüdiger Schmidt[2] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, D-01187 Dresden, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden, Germany

We present a simple and straightforward extension of non-adiabatic quantum molecular dynamics to approximately include electron-nuclear correlations by combining electron dynamics within time-dependent density functional theory with trajectory surface hopping dynamics for the nuclei. This approach allows for the qualitative understanding of experimentally measured collision spectra as well as photoinduced processes as radiationless electron-nuclear relaxation. Benchmark examples from collision physics and photochemistry illustrate the improvements gained over ordinary non-adiabatic quantum molecular dynamics.

A 11.7 Mon 18:15 B 302

Die Greifswald EBIT — •Stephan Gierke[1], Christoph Biedermann[2], Gerrit Marx[1], Birgit Schabinger[1] und Lutz Schweikhard[1] — [1]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald — [2]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald

In einer Elektronenstrahl-Ionenfalle (EBIT) werden Ionen mittels eines hoch- und monoenergetischen Elektronenstrahls erzeugt und gespeichert. Mit einem starken magnetischen Feld von 3 Tesla wird der Elektronenstrahl komprimiert, wodurch Stromdichten von 4000 A/cm^2 erreicht werden. In radialer Richtung erfolgt der Einschluss der Ionen durch die Raumladung des Elektronenstrahls und eines elektrostatischen Speicherpotentials an drei Driftröhren. Neutrale Atome werden durch Elektronenstoßionisation in der Falle schrittweise ionisiert. Der maximale Ladungszustand der erzeugten Ionen lässt sich über die Energie des Elektronenstrahls kontrollieren.

Die erzeugten hochgeladenen Ionen sollen in einem ersten Schritt in Wechselwirkung mit Fullerenen gebracht und deren Reaktionsprodukte mit einem Flugzeit-Massenspektrometer gemessen werden. Erste Voruntersuchungen mit der in Greifswald wieder in Betrieb genommenen ehemaligen Berlin EBIT [1] werden vorgestellt.

[1] C. Biedermann *et.* al, Phys. Scr. T. 73 (1997) 360

A 12: Ultracold plasmas and Rydberg atoms (with Q)

Time: Monday 16:30–18:45 Location: E 415

Group Report A 12.1 Mon 16:30 E 415

Steady-state crystallization of Rydberg excitations in optically driven atomic ensembles — •Michael Höning[1], Dominik Muth[1], David Petrosyan[2], and Michael Fleischhauer[1] — [1]Fachbereich Physik und Landesforschungszentrum OPTIMAS, TU Kaiserslautern — [2]Institute of Electronic Structure and Laser, FORTH, GR-71110 Heraklion, Crete, Greece

We study the emergence of many-body correlations in strongly-interacting, driven dissipative systems. Specifically, we examine resonant optical excitations of Rydberg states of atoms interacting via long-range van der Waals potential employing exact numerical methods such as t-DMRG and semiclassical Monte-Carlo simulations. In a one-dimensional lattice of atoms with nearly complete blockade of simultaneous excitation at the adjacent sites, we find that, under appropriate (dark-state) driving, the atoms can develop finite-range crystalline order of Rydberg excitations. At higher atomic densities, all atoms within the blockade radius form "superatoms", each accommodating at most one Rydberg excitation. Under strong uniform driving, the saturation of superatoms leads to quasi-crystallization of Rydberg excitations whose correlations exhibit damped spatial oscillations. The behavior of the system can be approximated by an analytically soluble model based on a "hard-rod" interatomic potential.

A 12.2 Mon 17:00 E 415

Spontaneous avalanche ionization of a strongly blockaded Rydberg gas — •Christoph S. Hofmann, Martin Robert-de Saint-Vincent, Hanna Schempp, Georg Günter, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We report the sudden and spontaneous evolution of an initially correlated gas of repulsively interacting Rydberg atoms to an ultracold plasma [1]. Under continuous laser coupling we create a Rydberg ensemble in the strong blockade regime, which at longer times undergoes an ionization avalanche. By combining optical imaging and ion detection, we access the full information on the dynamical evolution of the system, including the rapid increase in the number of ions and a sudden depletion of the Rydberg and ground state densities. Rydberg–Rydberg interactions are observed to strongly affect the dynamics of plasma formation. We use a coupled rate-equation model to describe our data and to reveal that the initial correlations of the Rydberg ensemble should persist through the avalanche. The latter would mitigate disorder-induced-heating [2], and offer a route to enter new strongly-coupled regimes.

[1] M. Robert-de Saint-Vincent *et al.* arXiv:1209.4728 (2012)
[2] M. Murillo PRL **87** 115003 (2001)

A 12.3 Mon 17:15 E 415

Light propagation in strongly interacting Rydberg gases — •Martin Gärttner and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Electromagnetically induced transparency in Rydberg gases has proven a valuable tool for applications in non-linear optics. Recently, single photons and other non-classical states of light have been produced using light propagation through strongly interacting Rydberg gases. We present a model describing the propagation of a weak probe beam in the presence of a strong coupling beam, coupling to a strongly interacting Rydberg level. Our model is based on the rate equation ansatz [1,2] and includes the attenuation of the probe beam. We test our model by comparing to experimental results of the group of M. Weidemüller [3] covering a large range of atomic densities and to other state of the art models. We find that all properties but the excitation statistics are described well by the rate equation model, indicating that quantum correlations in the light field should be taken into account.

[1] C. Ates et *al.*, Phys. Rev. A 76, 013413 (2007)
[2] K. P. Heeg et *al.*, arXiv:1202.2779 (2012)
[3] C. Hofmann et *al.*, arXiv:1211.7265 (2012)

A 12.4 Mon 17:30 E 415

Optical imaging of Rydberg atoms in dense atomic gases — •Georg Günter, Hanna Schempp, Martin Robert-de Saint-Vincent, Stephan Helmrich, Vladislav Gavryusev, Christoph Hofmann, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We experimentally investigate a new all-optical method to image Rydberg atoms embedded in dense atomic gases [1]. The method exploits strong interactions between the Rydberg atoms and highly polarizable excited states of the surrounding gas. The resulting level-shifts of the excited states are mapped via electromagnetically induced transparency on a strong optical transition, leading to absorption for many atoms surrounding each Rydberg impurity in an otherwise transparent gas. Using this novel technique we show single shot images of small numbers of Rydberg atoms. Furthermore we characterize the time resolution and state-selectivity of the method. This makes it a promising tool for dynamical studies of strongly correlated many-body states as well as transport phenomena in Rydberg aggregates.

[1] G. Günter et al Phys.Rev.Lett. 108, 013002 (2012)

A 12.5 Mon 17:45 E 415

Crystallization of photons via light storage in Rydberg gases — Johannes Otterbach[1,2], •Matthias Moos[1], Dominik Muth[1], and Michael Fleischhauer[1] — [1]Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

Light exciting atoms to Rydberg states under conditions of electromagnetically induced transparency (EIT) can be described in terms of slow-light Rydberg-polaritons. The strong interaction mediated by the Rydberg atoms can give rise to crystallization of photons, i.e., to density waves with long-range power-law correlations. In an 1D setting the low-energy physics can be described by a Luttinger liquid model. When the corresponding Luttinger parameter K becomes smaller than $1/2$, the density wave dominates the correlations marking the onset of crystallization. We calculate the K parameter by DMRG simulations and compare it to analytic approximations. We find that under typical slow-light conditions K is much larger than $1/2$ and thus no crystalline order can emerge. However, storing the polaritons in a stationary spin wave by switching off the control laser the effective mass and thus the kinetic energy vanish and K approaches zero. If the storage is done sufficiently adiabatic, long range crystalline order can be generated. We analyze the dynamics of this build-up in terms of a time-dependent Luttinger theory and derive conditions for an optimal storage scenario.

A 12.6 Mon 18:00 E 415

Binding by dissipation — •Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover

I will demonstrate how dissipative forces can act as a binding mechanism between two strongly interacting particles, even when the interaction potential is purely repulsive [1]. The bound state arises as a quasi-stationary state of the dynamical evolution of the system. This method also carries the potential to serve as a cooling mechanism for strongly interacting quantum gases. Finally, I will discuss a possible experimental realization with ultracold Rydberg atoms.

[1] M. Lemeshko, H. Weimer, arXiv:1211.4035 (2012).

A 12.7 Mon 18:15 E 415

Rydberg Physics on the Millisecond Timescale — •Thomas Niederprüm, Tobias Massimo Weber, Torsten Manthey, Vera Guarrera, Giovanni Barontini, and Herwig Ott — Research Center Optimas, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Several proposals have demonstrated that dressing ultracold atoms with highly excited Rydberg states can be an extremely powerful tool to tune the interactions among them. The changed interactions create a new equilibrium state for the system that is reached typically on a timescale of milliseconds. 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 give an overview on recent experiments in our group aiming to address this regime of Rydberg physics. The ionization of Rydberg atoms inside cold clouds turns out to be an important process in such experiments. Monitoring these ion signals and combining the Rydberg excitation with a Scanning Electron Microscope we are able to study blockade phenomena in samples with dimensions down to 500 nm inside of optical lattices. Furthermore the influence of high energetic electrons on the excitation of Rydberg atoms inside a BEC is reported.

A 12.8 Mon 18:30 E 415

Sub-Poissonian statistics of Rydberg-interacting dark-state polaritons — •Hanna Schempp[1], Christoph S. Hofmann[1], Georg Günter[1], Martin Robert-de-Saint-Vincent[1], Martin Gärttner[2,3], Jörg Evers[2], Shannon Whitlock[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut , Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany

Interfacing light and matter at the quantum level is at the heart of modern atomic and optical physics and enables new quantum technologies involving the manipulation of single photons and atoms. A prototypical atom-light interface is electromagnetically induced transparency, in which quantum interference gives rise to hybrid states of photons and atoms called dark-state polaritons. We have observed individual dark-state polaritons as they propagate through an ultracold atomic gas involving Rydberg states [1]. Strong long-range interactions between Rydberg atoms give rise to an effective interaction blockade for dark-state polaritons, which results in large optical nonlinearities and modified polariton number statistics. The observed statistical fluctuations drop well below the quantum noise limit indicating that photon correlations modified by the strong interactions have a significant back-action on the Rydberg atom statistics.

[1] C.S. Hofmann et al., arXiv:1211.7265

A 13: Quantum meets gravity and metrology I

Time: Tuesday 11:00–13:00 Location: E 415

Invited Talk A 13.1 Tue 11:00 E 415

Does time exist in quantum gravity? — •Claus Kiefer — Universität zu Köln

Time is absolute in standard quantum theory and dynamical in general relativity. The combination of both theories into a theory of quantum gravity thus leads to a ‘problem of time’. In my talk, I shall investigate those consequences for the concept of time that can be drawn without a detailed knowledge of quantum gravity. The only assumptions are the experimentally supported universality of the linear structure of quantum theory and the recovery of general relativity in the classical limit. Among the consequences are the fundamental timelessness of quantum gravity, the approximate nature of a semiclassical time, and the correlation of entropy with the size of the Universe.

Ref.: C. Kiefer, arXiv:0909.3767 [gr-qc].

Invited Talk A 13.2 Tue 11:30 E 415

How Attractive is the Moon for Relativity? — •Jürgen Müller[1,2], Liliane Biskupek[1], Enrico Mai[1], and Franz Hofmann[1] — [1]Institut für Erdmessung (IfE), Leibniz Universität Hannover, Schneiderberg 50, 30167 Hannover, Germany — [2]QUEST – Centre for Quantum Engineering and Space-Time Research, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

In 1969, a new era for studying relativity has started. With the first returns of laser pulses sent from observatories on Earth to reflector arrays on the Moon, a new space technique – Lunar Laser Ranging (LLR) – has been providing an ongoing time series of highly accurate Earth-Moon distance measurements. To enable data analysis at the mm level of accuracy, all elements of the tracking process have to be modeled at appropriate (relativistic) approximation, i.e. the orbits of the major bodies of the solar system, the rotation of Earth and Moon, the signal propagation, but also the involved reference and time systems.

We will show where relativity enters the LLR analysis and how the whole measurement process is modeled, including the major classical (Newtonian) effects like gravity field of Earth and Moon, tidal effects, ocean loading, lunar tidal acceleration (that causes the increase of the Earth-Moon distance by about 3.8 cm/year), etc.

By analysing the 43-year record of range data, LLR is one of the best tools to test General Relativity in the solar system. It allows for constraining gravitational physics parameters related to the strong equivalence principle, geodetic precession, preferred-frame effects, or the time variability of the gravitational constant. We will present recent results for the various relativistic parameters.

[1] Hofmann, F., Müller, J., Biskupek, L.: Lunar laser ranging test of the Nordtvedt parameter and a possible variation of the gravitational constant. Astronomy and Astrophysics, Vol. 522, No. L5, 2010, doi: 10.1051/0004-6361/201015659.

[2] Müller, J., Hofmann, F., Biskupek, L.: Testing various facets of the equivalence principle using Lunar Laser Ranging. Classical and quantum gravity, Vol. 29, 184006 (9pp), 2012, doi:10.1088/0264-9381/29/18/184006.

[3] Müller, J., Murphy, T., Schreiber, U., Shelus, P., Torre, J., Williams, J., Boggs, D., Bouquillon, S. Francou, G.: Lunar Laser Ranging – A Tool for General Relativity, Lunar Geophysics and Earth Science. ILRS JoG special issue, submitted 2012.

Invited Talk A 13.3 Tue 12:00 E 415

Interferometry with Bose-Einstein condensates in microgravity — •Ernst Rasel — QUEST, Institut für Quantenoptik-Leibniz Universität, Hannover, Germany

A new field in matter wave optics is emerging, which is based on very long baseline atom interferometry (VLBAI). These interferometers strive to increase the sensitivity by coherently spitting and separating wave packets over macroscopic spatial and temporal scales. Bose-Einstein condensates (BECs), representing a textbook example for a macroscopic wave packet, are the ideal source for performing this kind of interferometry and were exploited for the first time in the extended free fall with a chip-based atom laser for Rubidium ^{87}Rb. Combining delta kick cooling with BEC we can produce ensembles with energies equal to temperatures falling below one nK. Employing an asymmetric Mach-Zehnder type interferometer we could study over hundreds of milliseconds the coherent evolution of a wave-packet and analyse delta kick cooling with the help of the observed interference fringes. This experiment can be considered as a gigantic double slit experiment in microgravity. A novel generation of atom chips allows to improve the performance of these flexible devices. We could demonstrate loading of the chip with far more than 10^9 atoms in roughly a second and generate large condensates of more than 100000 atoms, up to now only achievable in room filling devices, in a shoebox sized setup. We discuss as a possible spin-off a chip based quantum gravimeter for ground based applications, recently demonstrated with our device. The design will be employed for a rocket based test of such an interferometer, which will demonstrate the feasibility of satellite based tests of Einsteins principle of equivalence as pursued by the STE-QUEST mission.

The QUANTUS cooperation comprises the group of C. Lämmerzahl (Univ. Bremen), A. Peters (Humboldt Univ. Berlin), T. Hänsch/J.Reichel (MPQ/ENS), K. Sengstock (Univ. Hamburg), R. Walser (TU Darmstadt), and W.P. Schleich (Univ. Ulm).

This project is supported by the German Space Agency Deutsches Zentrum für Luft- und Raumfahrt (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWI) under grant number DLR 50 WM 0346. We thank the German Research Foundation for funding the Cluster of Excellence QUEST Centre for Quantum Engineering and Space-Time Research

Invited Talk A 13.4 Tue 12:30 E 415

Relativistic effects in atom and neutron interferometry — •Wolfgang Schleich — Institut für Quantenphysik, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm

Motivated by the recent debate if the Kasevich-Chu atom interferometer can measure the gravitational redshift, we show [1, 2, 3] that the physical origin of the observed phase shift depends on the representation of quantum mechanics chosen for the calculation. We illustrate this phenomenon using the position and the momentum representations and demonstrate that the decomposition of the total phase shift into three dynamical phases, which emerges in the Feynman path integral approach and is at the very heart of the redshift controversy, does not appear in position space. This feature stands out most clearly in a representation-free analysis of the Kasevich-Chu interferometer where two rather than three phases contribute to the phase shift. We also compare and contrast atom and neutron interferometry.

[1] W.P. Schleich, D.M. Greenberger, and E.M. Rasel, A representation-free description of the Kasevich-Chu interferometer: A resolution of the redshift controversy, New J. Phys. 15, 013007 (2013)
[2] W.P. Schleich, D.M. Greenberger, and E.M. Rasel, The redshift controversy in atom interferometry: Representation dependence of origin of phase shift, Phys. Rev. Lett. 110, 010401 (2013)
[3] D.M. Greenberger, W.P. Schleich, and E.M. Rasel, Relativistic effects in atom and neutron interferometry and the differences between them, Phys. Rev. A 86, 063622 (2012)

A 14: Ultra-cold atoms, ions and BEC III (with Q)

Time: Tuesday 11:00–12:30 Location: B 302

A 14.1 Tue 11:00 B 302

Shedding light on three-body recombination in ultracold atomic gases — •Artjom Krükow[1], Arne Härter[1], Markus Deiss[1], Björn Drews[1], Eberhard Tiemann[2], and Johannes Hecker Denschlag[1] — [1]Institut für Quantenmaterie and Center for Integrated Quantum Science and Technology IQST, Universit ät Ulm, 89069 Ulm, Germany — [2]Institute of Quantum Optics, Leibniz Universität Hannover, 30167 Hannover, Germany

We investigate three-body recombination in an optically confined ultracold cloud of ^{87}Rb atoms, in which Rb_2 molecules are formed. We examine the distribution of the molecular quantum states that are populated in this process. For this we ionize the Rb_2 molecules in a 3-photon REMPI scheme with a narrow-linewidth laser at a wavelength of around 1064nm. Subsequently the ionized molecules are trapped in a linear Paul trap where they are detected with single particle sensitivity and virtually no background. As we scan the frequency of the ionization laser, we observe a dense spectrum of narrow resonance lines which contains the information on the final states populated in the recombination events. We can resolve vibrational, rotational and hyperfine levels of the triplet and singlet ground state molecules. We observe deeply bound states with binding energies up to 750 GHz $\times$ h. We expect this method to provide a pathway to understanding three-body recombination in ultracold atomic gases which so far lacks a full theoretical treatment.

A 14.2 Tue 11:15 B 302

Transport spectroscopy in the Bose-Hubbard model — •Christian Nietner — Technische Universität Berlin

Motivated by recent experiments [1] we consider a Bose-Hubbard model with a single defect lattice site. This defect is weakly coupled to the surrounding which gives rise to bosonic currents through the defect. In order to describe these defect currents we develop a Lindblad master equation. We treat the remaining bosonic lattice as an effective bath for the defect and obtain a rate equation which depends on the 2-point correlation functions of the Bose-Hubbard model. To calculate these quantities we follow the approach outlined in Ref. [2]. Finally, we obtain defect currents which show signatures of the Mott phase and allow transport spectroscopy of the energy gap.

[1] T. Gericke, P. Würtz, D. Reitz, T. Langen et. al., Nature Physics **4**, 949 (2008)
[2] B. Bradlyn, F. E. A. dos Santos, and A. Pelster, Phys. Rev. A **79**, 013615 (2009)

A 14.3 Tue 11:30 B 302

Interference effects in Fock space in Bose-Hubbard systems — •Thomas Engl[1], Juan Diego Urbina[1], Arturo Argüelles Parra[2], Julien Dujardin[2], Peter Schlagheck[2], and Klaus Richter[1] — [1]Universität Regensburg — [2]Universite de Liege

Semiclassical techniques have so far been applied mainly to single particle systems. For these systems they provide a powerful toolbox to study interference effects and allow analytical calculations even in the presence of classical chaos.

On the other hand there have been attempts to apply the semiclassical approximation to the Feynman path integral for bosonic quantum fields in coherent state representation. The resulting coherent state path integral however leads to complex actions which does not give clear insight in interference effects.

We have succeeded in finding a representation in which the semiclassical approximation leads to a van-Vleck propagator with real action and therefore shows interference in Fock space explicitly. We use this propagator to predict various interference effects for Bose-Hubbard systems in three different regimes of the ratio of interaction and hopping strength, and we show that the probability of return is enhanced due to interference.

A 14.4 Tue 11:45 B 302

Optimal control of ultracold atomic quantum systems — •Antonio Negretti[1], Simone Montangero[2], Tommaso Calarco[2], Sandrine van Frank[3], Wolfgang Rohringer[3], Tarik Berrada[3], Thorsten Schumm[3], and Jörg Schmiedmayer[3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg (Germany) — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert-Einstein-Alle 11, 89069 Ulm (Germany) — [3]Atominstitut, Universität Wien, Stadionallee 2, 1020 Wien (Austria)

In the recent past, experiments with ultracold quantum gases have reached an extremely high degree of control, in which the manipulation and detection of single particles like atoms and ions have been demonstrated. For the purposes of quantum information processing and interferometry it is needed not only a high degree of control, but also that the desired quantum transformation is obtained as fast as possible. To this aim optimal control is a valuable resource to achieve high performance in the shortest possible time.

In my talk I shall present recent and very promising achievements in the optimized quantum dynamics of degenerate quasi 1D quantum Bose gases experiments.

A 14.5 Tue 12:00 B 302

Excitation spectrum of supersolids with soft-core bosons — •Tommaso Macri, Fabio Cinti, Fabian Maucher, and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Motivated by recent experimental efforts to realize quantum phases of matter with cold atomic Rydberg gases, I will discuss the excitation spectrum of supersolids in a two dimensional bosonic system with soft-core interactions. Previous works showed an exceptional agreement between Monte Carlo simulations and a numerical mean-field approach.

I will present a variational analysis of the Gross-Pitaevskii equation with a non-local interaction term and show that we can quantitatively reproduce the superfluid-supersolid transition at finite interaction strength in agreement with Monte Carlo results. We then test the validity of this mean-field analysis perturbing the ground state wave function and looking at the spectrum of the corresponding Bogoliubov equations. This approach provides an intuitive physical insight to the low energy dynamics of the system and is validated through the comparison of our findings with recent Monte Carlo simulations.

A 14.6 Tue 12:15 B 302

Eigenvalue structure of Bose-Einstein condensates in $\mathcal{PT}$-symmetric double-well potentials — •Dennis Dast, Daniel Haag, Holger Cartarius, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Hamiltonians which obey parity-time ($\mathcal{PT}$) symmetry are a special class of non-Hermitian Hamiltonians that can have entirely real eigenvalue spectra in certain parameter regimes. We investigate a Bose-Einstein condensate in a realistic $\mathcal{PT}$-symmetric double-well potential where particles are removed in one well and coherently injected into the other well. The stationary solutions of the nonlinear Gross-Pitaevskii equation are calculated by variational and numerically exact methods. Special attention is drawn to the influence of the Gross-Pitaevskii nonlinearity. The system shows an unusual structure with two exceptional points which are analyzed by means of an analytic continuation.

A 15: Precision spectroscopy of atoms and ions III (with Q)

Time: Tuesday 11:00–12:30 Location: B 305

Invited Talk A 15.1 Tue 11:00 B 305

X-ray laser spectroscopy with trapped highly charged ions — •Sven Bernitt — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The X-ray spectra of many astrophysical objects, as observed by X-ray observatories like Chandra and XMM-Newton, are dominated by emission lines of highly charged ions. However, even today's most sophisticated spectral models only poorly fit certain prominent spectral features. For this reason, precise laboratory measurements of astrophysically relevant transition wavelengths and intensities are needed to be able to interpret astronomical observations.

Laser spectroscopy is a remarkably successful experimental method. However, the X-ray wavelength regime has not been accessible due to the lack of appropriate lasers, until in recent years free-electron lasers have become available. In the experiments presented, an electron beam ion trap was used to provide a target of trapped highly charged ions, interacting with femtosecond X-ray pulses from the Linac Coherent Light Source free-electron laser. This introduced the techniques of laser spectroscopy into the 1 keV spectral range, allowing to directly address photonic excitations in highly charged ions.

Results of an experiment, potentially resolving a continuing controversy about the relative intensity ratio of two bright lines in the Fe XVII spectrum, will be presented, as well as new results and applications.

A 15.2 Tue 11:30 B 305

High-precision X-ray spectroscopy of highly charged ions with microcalorimeters — •Saskia Kraft-Bermuth[1], Victor Andrianov[2,3], Alexander Bleile[2], Artur Echler[2], Peter Egelhof[2], Patrick Grabitz[2], Stoyanka Ilieva[2], Caroline Kilbourne[4], Oleg Kiselev[2], Dan McCammon[5], Jan Meier[2], and Pascal Scholz[1] — [1]Institut f. Atomphysik, Justus-Liebig-Universität, Gießen, Germany — [2]Helmholtzzentrum f. Schwerionenforschung, Darmstadt, Germany — [3]Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia — [4]NASA/Goddard SFC, Greenbelt, USA — [5]Dept. Physics, University of Wisconsin, Madison, USA

The precise determination of the energy of the Lyman-α lines in hydrogen-like heavy ions provides a sensitive test of quantum electrodynamics in very strong Coulomb fields. In 2010, a test array of 8 silicon thermistors with Sn and Pb absorbers was used in the first measurement of the Lyman-α energies of lead ions Pb^{81+} with a microcalorimeter at the Experimental Storage Ring (ESR) at GSI. The experimental result agreed well with the theoretical predictions. The overall uncertainty amounted to 26 eV. In 2012, a larger array of 32 silicon thermistors with Sn absorbers and an improved energy resolution was applied to measure the Lyman-α energies of gold ions Au^{78+}. The systematic error of the measurement was reduced by using a new calibration source and an improved beam diagnostics. This contribution will present the results of this experiment. Perspectives for new applications at GSI as well as at the FAIR facility will be presented.

A 15.3 Tue 11:45 B 305

The *g* factor of lithiumlike silicon $^{28}Si^{11+}$ — •Anke Wagner[1], Sven Sturm[1,2], Florian Köhler[3], Dmitry A. Glazov[4,5], Andrey V. Volotka[4,5], Günter Plunien[5], Wolfgang Quint[3], Günter Werth[2], Vladimir M. Shabaev[4], and Klaus Blaum[1] — [1]MPI für Kernphysik, 69117 Heidelberg, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany — [3]GSI, 64291 Darmstadt, Germany — [4]Deparment of Physics, St. Petersburg State University, St. Petersburg 198504, Russia — [5]Institut für Theoretische Physik, TU Dresden, 01062 Dresden, Germany

High-precision measurements of the g factor of the valence electron bound in a many-electron system provide excellent possibilities to test the relativistic interelectronic interaction. This is particularly true for 3-electron systems, since they can be calculated with high precision. Moreover, for heavy elements a comparison of the g factors of the lithium- and the hydrogenlike charge state of the same isotope allows for a better test of bound-state QED calculations [1]. To this end we have determined the g factor of $^{28}Si^{11+}$ with the double-trap technique [2]. It is derived from a measurement of the Larmor precession frequency and the free cyclotron frequency of a single ion confined in a cylindrical Penning trap. Our result has an uncertainty of $\delta g/g = 1.1 \cdot 10^{-9}$ and is in excellent agreement with the theoretical value [3]. The measurement technique and the results will be presented.

[1] Shabaev *et al.*, Phys. Rev. A **65**, 062104 (2002)
[2] Häffner *et al.*, Eur. Phys. J. D **22**, 163 (2003)
[3] Wagner *et al.*, Phys. Rev. Lett., submitted (2012)

A 15.4 Tue 12:00 B 305

The proton *g*-factor — •Sascha A. Bräuninger[1,3], Klaus Blaum[1,3], Holger Kracke[2,4], Clemens Leiteritz[2], Andreas Mooser[2,4], Wolfgang Quint[3,5], Cricia Rodegheri[1,2], Stefan Ulmer[1,6], and Jochen Walz[2,4] — [1]Max-Planck-Institut für Kernphysik, D-69117 Heidelberg — [2]Johannes Gutenberg-Universität, D-55099 Mainz — [3]Ruprecht Karls-Universität, D-69047 Heidelberg — [4]Helmholtz Institut, D-55099 Mainz — [5]Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt — [6]Riken Advanced Science Institut, Wako, Saitama 351-0198, Japan

The aim of our experiment is the first direct high-precision measurement of the g-factor of a single proton with a relative precision of 10^{-9} or better. The g-factor is determined by the ratio $g = 2\frac{\nu_L}{\nu_c}$ of the free cyclotron frequency ν_c and the Larmor frequency ν_L. ν_c is determined by the three eigenfrequencies of the trapped proton. ν_L is extractable by a measured probability distribution given by the number of induced spin transitions driven by an external field as a function of the excitation frequency. The continuous Stern-Gerlach effect is utilized to detect the induced spin transitions in a second Penning trap with an inhomogenous magnetic field. A change of the spin state due to an excitation of the magnetic dipole transition results in a change of the axial eigenfrequency. The status of the experiment and current developments with a measurement at the 10^{-6} level are presented.

A 15.5 Tue 12:15 B 305

Electron correlation effects in resonant photorecombination and excitation processes with highly charged ions — •Zoltán Harman[1,2] and Christoph H. Keitel[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg — [2]ExtreMe Matter Institute EMMI, Darmstadt

Relativistic electron correlation effects greatly determine the recombination and excitation dynamics of highly charged ions, and thus the time evolution of astrophysical and magnetically confined plasmas. In case of resonant recombination, we have found that three-body correlation effects may give rise to significant additional reaction channels beyond what is known from the usual two-body theory describing dielectronic recombination [1]. Bound-electron correlation effects also determine the intensity of x-ray emission of highly charged ions excited by photons or electron collisions in stellar plasmas. These intensities play an important role in astrophysical modeling and in the analysis of spectra recorded by space observatories. We compare our theoretical results to experimental measurements with electron beam ion traps [1,2]. – [1] C. Beilmann *et al.*, Phys. Rev. Lett. **107**, 143201 (2011). [2] S. Bernitt *et al.*, Nature, **492**, 225 (2012).

A 16: Photoionization

Time: Tuesday 11:00–12:30 Location: F 428

A 16.1 Tue 11:00 F 428

The effect of dimensionality in the photoionization of inversion symmetric systems — •Markus Ilchen[1,2], Uwe Becker[3,7], Piero Decleva[4], Marshaal AlKhaldi[7], Markus Braune[2], Sascha Deinert[2], Leif Glaser[2], Gregor Hartmann[3], André Knie[5], Burkhard Langer[6], André Meissner[3], Frank Scholz[2], Jörn Seltmann[2], Peter Walter[2], Omar Al-Dossary[7], and Jens Viefhaus[2] — [1]European XFEL GmbH — [2]Deutsches Elektronen Synchrotron DESY — [3]MPI für Mikrostrukturphysik Halle — [4]Universita di Trieste — [5]Universität Kassel — [6]Freie Universität Berlin — [7]King Saud University

Quantum coherence and resulting interferences are widely studied fields of atomic and molecular physics highlighting quantum mechanics in an impressive way. One of the most famous experiments in this respect is the molecular double slit experiment which was predicted to reveal fingerprints of coherent electron emission from the valence of inversion symmetric systems. We will show results for partial ionization cross sections as well as angular distributions of N_2, O_2 and also C_{60} providing first experimental proofs of the Cohen-Fano oscillations. For N_2 and O_2 the σ and β-oscillations are phase shifted by π for the valence gerade states and parallel for the ungerade states. For C_{60} our results show that the three-dimensionality of this system leads to an anti-parallel behavior. The important role of dimensionality in studies of inversion symmetric systems will be discussed.

A 16.2 Tue 11:15 F 428

Coronium & friends: High-precision calculation of the structure of astrophysically relevant Fe ions — •Natalia S. Oreshkina[1], Zoltán Harman[1,2], and Christoph H. Keitel[1] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]ExtreMe Matter Institute (EMMI), Planckstrasse 1, 64291 Darmstadt, Germany

The dynamics of astrophysical objects, such as coronal plasmas, stellar winds, outflows, and accretion disks can be studied using the Doppler shifts and widths of emission lines of highly charged Fe ions, recorded by space observatories. High-precision calculations of these systems may be important for astrophysical research: as an example, velocities of astrophysical objects relative to the observer may be determined once the frequency in the emitter (ionic) frame is well known from theoretical calculations or from photoionization (or photoexcitation) experiments.

In the talk, accurate calculations of the visible and x-ray transition energies in highly charged ${}^{56}_{26}\mathrm{Fe}^{13+}$ to ${}^{56}_{26}\mathrm{Fe}^{16+}$ ions are presented. Relativistic electron correlation calculations are performed within the framework of the configuration interaction method with Dirac-Fock-Sturmian basis functions. For the $3p_{3/2} \rightarrow 3p_{1/2}$ green magnetic dipole transition in ${}^{56}_{26}\mathrm{Fe}^{13+}$, we take into account quantum electrodynamic effects by employing an effective screening potential. The results are compared to electron beam ion trap measurements.

A 16.3 Tue 11:30 F 428

Recoil induced transition from coherent to randomly oriented target properties — •Gregor Hartmann[1,2], Markus Braune[3], Axel Reinköster[1], Sanja Korica[1], Toralf Lischke[1,2], André Meissner[1], Burkhard Langer[4], André Knie[5], Arno Ehresmann[5], Markus Ilchen[3], Max Stammer[1,2], Omar Al-Dossary[6,7], and Uwe Becker[1,2,6] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [3]DESY Notkestraße 85, 22067 Hamburg, Germany — [4]Physikalische Chemie, Freie Universität Berlin, Takustr. 3, 14195 Berlin, Germany — [5]Institut für Physik and CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [6]Physics Department, College of Science, King Saud University, Riyadh 11451, Saudi Arabia — [7]National Center for Mathematics and Physics, KACST, Saudi Arabia

The electronic states of homonuclear diatomic molecules give rise to double slit like oscillations in the photoabsorption cross section of these molecules, depending whether the electrons are emitted from a randomly distributed or an oriented target. We show this phase shift effect and a transition phenomenon from coherent to randomly oriented target properties unambiguously for the first time for the photoionization of molecular hydrogen.

A 16.4 Tue 11:45 F 428

The transition from coherent behavior to random order — •Rainer Hentges[1], Toralf Lischke[2], Gregor Hartmann[2], Burkhard Langer[3], Arno Ehresmann[1], and Uwe Becker[2] — [1]Institut für Physik, Universität Kassel Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany — [3]Institut für Chemie und Biochemie, Freie Universität Berlin, Takustr. 3, 14195 Berlin, Germany

One of the basic discoveries of quantum physics regarding the properties of nature was the duality of wave like and particle like behavior. Wave like behavior is determined by coherent superpositions of wave like quantum objects, whereas particle like behavior follows the rules of classical mechanics rather than the rules of quantum mechanics. Following quantum mechanics the outcome of measurements in this regime would be random. One of the most beautiful example in this respect is Wheelers "delayed choice experiment" realized for the first time only some years ago by the group of Alain Aspect.

We studied a similar problem in the context of photoionization. The transition from coherent behavior to random order is the transition from coherent determinism in form of interference pattern to non-coherent but "which way" carrying pattern, the regime of random order. In between these two regimes is another regime, the "coherent order" regime which will be discussed in more detail in the talk.

A 16.5 Tue 12:00 F 428

Angular distribution of electrons emitted in photoionization with twisted photons — •Oliver Matula[1,2], Armen Hayrapetyan[1], Stephan Fritzsche[2,3], and Andrey Surzhykov[1,2] — [1]Physikalisches Institut, Universität Heidelberg, D-69120 Heidelberg, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany — [3]FIAS Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

Photoionization of atoms and ions has been studied intensively in the last decades for various different charge states and photon energies, both in experiment and theory [1]. Apart from total ionization cross sections, much attention has been paid to the angular distribution of the emitted photoelectrons. So far, however, these angle-differential investigations dealt only with the spin degree of freedom of the incoming photons and outgoing photoelectrons. Recent advances in photo-optics allow nowadays to control not only the spin (polarization) of photon beams but also their orbital angular momentum (so-called twisted photons) [2]. In this contribution we perform a theoretical analysis of the angular distribution of electrons emitted in photoionization of hydrogen-like ions with (twisted) Bessel beams. Special attention is paid to the dependence of the electron distribution on the photon-ion impact parameter. Detailed computations and results are presented for photoionization of atomic hydrogen and hydrogen-like carbon and argon for a range of different impact parameters.

[1] J. Eichler et al., Phys. Rep. 439, 1 (2009).
[2] G. Molina-Terriza et al., Nature Phys. 3, 305 (2007).

A 16.6 Tue 12:15 F 428

Stopping power measurements with Calorimetric Low Temperature Detectors — •Patrick Grabitz[1,2], Artur Echler[1,2,3], Saskia Kraft-Bermuth[3], Wladyslaw Trzaska[4], Heikki Kettunen[4], Mikko Rossi[4], Katrin Müller[3], and Ari Virtanen[4] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [2]Johannes Gutenberg Universität, Mainz, Germany — [3]Justus-Liebig-Universität, Gießen, Germany — [4]University of Jyväskylä, Finland

Compared to conventional ionization detectors calorimetric low temperature detectors (CLTD's) provide, due to their detection principle, substantial advantages in detector performance, such as energy resolution, linearity and the absence of any pulse hight defect [1].
One potential application of such detectors is the determination of electronic stopping powers for slow heavy ions which are important for our understanding of the interaction of heavy ions with matter. Recently a combined setup of a CLTD-array and a time-of-flight detector (E-TOF) has been used to perform transition type energy loss measurements at the accelerator facility of the University of Jyväskylä.

The new experimental technique allowed to determine precise data on electronic stopping powers for 0.05-1 MeV/u ^{131}Xe-Ions in Carbon, Nickel and Gold. The results will be presented in comparison with theoretical predictions and data from the literature.

[1] P. Egelhof and S. Kraft-Bermuth, Topics Appl. Phys. 99 (2005) 469-500

A 17: Interaction with strong or short laser pulses II

Time: Tuesday 14:00–16:00 Location: B 302

Invited Talk A 17.1 Tue 14:00 B 302

Ultrafast dynamics in molecular systems and clusters — •Maria Krikunova[1], Theophilos Maltezopoulos[2], Philipp Wessels[2], Ulrike Frühling[2], Marek Wieland[2], Markus Drescher[2], Alaa Al-Shemmary[3], Nikola Stojanovic[3], Maria Müller[1], Jan P. Müller[1], Bernd Schütte[4], and Thomas Möller[1] — [1]Technische Universität, Berlin — [2]Universität Hamburg — [3]HASYLAB, DESY — [4]Max-Born-Institut Berlin

Intense light fields can produce highly excited non-equilibrium states of matter ultimately causing the explosion of molecules and nanoparticles into atomic fragments. Understanding these processes in even simple systems is challenging because it requires experiments that can follow the dynamics on extremely short time-scales. Novel light sources, such as the free-electron laser (FEL) facility in Hamburg, FLASH, now deliver synchronized ultra-short pulses in the soft X-ray, near-infrared (NIR) and far-infrared (terahertz, THz) spectral ranges allowing the realization of new types of pump-probe schemes.

Due to the different interaction mechanisms of pump and probe pulses with the target the tracing of dynamical details within the envelope of the exciting pulse itself becomes possible. With the soft X-ray pulses from FLASH we were able to track the electron redistribution in iodine molecules exposed to a strong NIR field. Utilization of a THz-field driven streak camera principle allowed the access to nanoplasma dynamics in rare gas clusters upon ionization with soft X-ray FEL pulses.

A 17.2 Tue 14:30 B 302

Generation of High Harmonics with 100 μJ Femto Second Pulses at 100 kHz Repetition Rate — •Philipp Klaus[1], Martin Laux[2], Christian Ott[2], Maksim Kunitski[1], Robert Wallauer[1], Thomas Pfeifer[2], and Reinhard Dörner[1] — [1]Institut für Kernphysik, Goethe Universität, Frankfurt, Deutschland — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

The setup for the generation of high harmonics (HHG) using the output of an amplified Ti:sapphire laser with a repetition rate of 100 kHz will be presented. High harmonic generation with a high repetition rate is rather challenging since the pulse energy is limited, in our case to 100 μJ. Usually pulse energies lie in the mJ range. The high repetition rate is however desirable for coincidence single molecule studies on gas and solid-state targets. First tests of the HHG setup with Ar gas showed a total harmonics yield of $4 \cdot 10^9$ photons per second.

A 17.3 Tue 14:45 B 302

Covariance mapping of Coulomb explosion in N_2 and I_2 after excitation with 90 eV XUV pulses at FLASH — •Oleg Kornilov[1], Leszek J. Frasinski[2], Claus Peter Schulz[1], and Marc J.J. Vrakking[1] — [1]Max Born Institute, Max-Born-Str. 2a, 12489 Berlin, Germany — [2]Imperial College London, South Kensington Campus, London, United Kingdom

Intense femtosecond XUV pulses produced by Free Electron Lasers can remove many electrons from inner-shell and valence molecular orbitals. The ensuing dynamics lead to Coulomb explosion due to separation of charges on constituent molecular fragments. In this contribution we report detailed measurements of Coulomb explosion in N_2 and I_2 at 91 eV recorded at FLASH by ion time-of-flight technique. The correlation of the different ionic fragments is evaluated using partial covariance mapping, a technique that allows to extract information on correlated detection events, where conventional coincidence methods cannot be applied. Different ionic fragment pairs $N^{+q}+N^{+q'}$ are identified and their kinetic energy distributions are extracted with help of the covariance maps. The results are compared to a model calculation, which implements classical trajectories for description of the Coulomb explosion dynamics.

A 17.4 Tue 15:00 B 302

Signatures of Interchannel Interactions in the High-Harmonics Spectrum of Krypton and Xenon – An Ab-Initio Study — •Stefan Pabst[1,2], Arina Sytcheva[1], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Notkestrasse 85, 22607 Hamburg — [2]Department of Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg

We investigate the relevance of multiorbital effects during high-harmonic generation (HHG) in krypton and xenon with an ab-initio time-dependent configuration-interaction singles (TDCIS) approach. With this approach, we are studying many-body effects in the presence of a strong laser field from first principle. We show that spin-orbit splitting within the outermost p-shell and the electronic dynamics within theses shells is reflected the HHG spectrum. Also the giant dipole resonance in xenon is studied where the strong resonance involving the 4d shell influences the recombination of the field-driven photoelectron with the 5p hole. The direct contribution of the 4d shell to the HHG yield is, however, negligibly small. This work has been supported by the DFG under Grant No. SFB 925/A5.

A 17.5 Tue 15:15 B 302

Characterization of high harmonic beam generated in a gas-filled capillary for seeding of free-electron lasers — •siew jean goh[1], yin tao[1], bert bastiaens[1], peter van der slot[1], jennifer herek[1], sandra biedron[2], steven milton[2], miltcho danailov[3], and klaus boller[1] — [1]Laser Physics and Nonlinear Optics, Optical Sciences, Mesa+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands — [2]Colorado State University, Colorado, USA — [3]FERMI@Elettra, Sincrotrone Trieste S.C.p.A., Basovizza, Trieste, Italy

We study the beam characteristics of a gas filled capillary based high harmonic source for seeding of the free-electron laser FERMI@Elettra. The stability requirements for seeding include pointing stability, divergence and energy jitter. These parameters are important due to the large distance between the source and the undulator where the seed needs to overlap with the electron beam of the free-electron laser. Here, we investigate the influence of the gas pressure and drive laser energy on the high harmonic generation in an Argon-filled capillary, driven by a Ti:Sapphire laser with 45 fs pulses. We report on the optimization of the harmonic yield as well as the properties of the harmonic beam, and compare our experimental results with the requirements of the FERMI@Elettra laser. To scale up the yield further, the build-up of a new high harmonic source with larger capillary diameter, suited for higher drive laser energy, is currently in progress.

A 17.6 Tue 15:30 B 302

Strong Field Ionization as Inhomogeneous Schroedinger Equation — •Zachary Walters and Jan-Michael Rost — Max Planck Institute for Physics of Complex Systems, Dresden

The ionization of an atom or molecule by an intense laser field is difficult to describe theoretically, due to the different approaches needed to describe a molecular bound state on one hand and a time dependent continuum state on the other. This talk shows how the time dependent Schroedinger equation can be decomposed into an inhomogeneous equation in which a previously computed initial state acts as a source term for a time dependent tunneling component. By using an improved Hamiltonian approximation to calculate the initial state, a major source of wavefunction error can be reduced or eliminated at a relatively minor computational cost. The gauge invariance of the resulting theory is used to clarify an apparent gauge dependence which has long been noted in the context of strong field S-matrix theory.

A 17.7 Tue 15:45 B 302

Time-resolved imaging of ulra-fast collective electron motion in argon — •Lutz Fechner[1], Nicolas Camus[1], Thomas Pfeifer[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bun-

desanstalt, Braunschweig

Using a pump-probe scheme for sequential double ionization of Ar-atoms in strong few-cycle laser pulses we prepare and probe electronic Spin-Orbit Wavepackets in singly charged Ar-ions[1]. As a result of the first ionization step, a multi-electron bound-state wavepacket is launched in the ion that gives rise to a time-delay dependant $Ar^{+} \rightarrow Ar^{++}$ yield for ionization within the second pulse[2] and thus allows us to probe the electronic motion as a function of time. Performing $Ar^{++}/2e^{-}$ triple-coincidence measurements utilizing a Reaction Microscope (REMI) we obtain kinematically complete, time-resolved photoelectron spectra. This enables us to uncover the periodic redistribution of population in different electronic orbitals and hence the multi-electron dynamics. A comparison of the experimental data with simple model calculations supports our interpretation. In addition, the method enables us to extract state-selective information about the tunnelling process itself.

[1] H.J. Wörner & P.B. Corkum, J. Phys. B **44** (2011), 041001
[2] A. Fleischer *et al.*, Phys. Rev. Lett. **107** (2011), 113003

A 18: Precision spectroscopy of atoms and ions IV (with Q)

Time: Tuesday 14:00–16:00 Location: B 305

Invited Talk A 18.1 Tue 14:00 B 305

Der g-Faktor des gebundenen Elektrons - Test des Standardmodells und Zugang zu fundamentalen Konstanten — •Sven Sturm[1], Florian Köhler[1,2], Anke Wagner[1], Zoltan Harman[1], Jacek Zatorski[1], Wolfgang Quint[2], Günter Werth[3], Christoph H. Keitel[1] und Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]GSI Helmholtzzentrum, Darmstadt — [3]Johannes-Gutenberg Universität Mainz

Der g-Faktor des in hochgeladenen Ionen gebundenen Elektrons ist eine einmalige Möglichkeit um die Grenzen der Gültigkeit des Standardmodells in extrem starken Feldern zu untersuchen. In Penningfallen kann der g-Faktor bis auf 10 signifikante Stellen bestimmt werden, so dass es möglich wird auch Beiträge der Quantenelektrodynamik (QED) in höherer Ordnung zu überprüfen. Entsprechend stellt die Messung des g-Faktors von $^{28}Si^{13+}$ den zur Zeit empfindlichsten Test der QED in großen Feldern da. Darüber hinaus eröffnet der Vergleich von Theorie und Experiment einen Zugang zur Bestimmung fundamentaler Konstanten. Durch die Entwicklung neuartiger Detektionstechniken ist es jüngst möglich geworden, die Masse des Elektrons mit einer Genauigkeit zu bestimmen, die den aktuellen Literaturwert deutlich überschreitet. Das Experiment sowie Ergebnisse werden präsentiert.

A 18.2 Tue 14:30 B 305

Messung von Isotopieverschiebung und Hyperfeinstruktur von Uranisotopen mittels hochauflösender Resonanzionisationsspektroskopie — •Amin Hakimi[1], Thomas Fischbach[1], Nicolas Tolazzi[1], Norbert Trautmann[2] und Klaus Wendt[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz — [2]Institut für Kernchemie, Johannes-Gutenberg-Universität Mainz

Uran ist das schwerste der natürlich vorkommenden Aktiniden. Mit seiner Grundzustandskonfiguration $5f^{3}6d7s^{2}$ eröffnet es mannigfaltige Kopplungsmöglichkeiten. Dadurch wird es zu einem sehr interessanten System zur Untersuchung atomarer Effekte, z.B. der JJ-Kopplung. Mittels hochauflösender Resonanzionisationsspektroskopie steht eine präzise und sensitive Nachweismethode zu Verfügung, da an Stelle von Fluoreszenzphotonen resonant erzeugte Photoionen empfindlich nachgewiesen werden. Die Methode wurde mit einem neu entwickelten, durch kommerzielle Diodenlaser betreibbaren Anregungsschema auf die Isotope $^{233-236,238}U$ angewandt. Für zwei gebundene sowie einen autoionisierenden Zustand wurden die Isotopieverschiebungen bestimmt, sowie in den Isotopen ^{235}U und ^{233}U mit einem Kernspin von $\frac{7}{2}$ bzw. $\frac{5}{2}$ die Hyperfeinstruktur aufgelöst. Die A- und B-Faktoren der Hyperfeinstruktur wurden dabei für zwei gebundene Zustände bestimmt. Die Ergebnisse zu Hyperfeinstruktur und Isotopieverschiebung sowie die experimentelle Messstrategie werden vorgestellt.

A 18.3 Tue 14:45 B 305

Hyperfine splitting in lithium-like bismuth — Matthias Lochmann[1], Zoran Andelkovic[2], Benjamin Botermann[3], Michael Bussmann[4], Andreas Dax[5], Nadja Frömmgen[1], Michael Hammen[1], Volker Hannen[6], Raphael Jöhren[6], Christopher Geppert[1,2], Thomas Kühl[2], Yuri Litvinov[2], Jonas Vollbrecht[6], Wilfried Nörtershäuser[3], Thomas Stöhlker[2,7], Richard Thompson[8], Andrey Volotka[9], Christian Weinheimer[6], Weiqiang Wen[10], Elisa Will[1], Danyal Winters[2], and •Rodolfo Sánchez[2] — [1]Universität Mainz — [2]GSI Helmholtzzentrum, Darmstadt — [3]Technische Universität Darmstadt — [4]Helmholtzzentrum Dresden-Rossendorf — [5]CERN, Genf — [6]Universität Münster — [7]Universität Heidelberg — [8]Imperial College, London — [9]Technische Universität Dresden — [10]IMP Lanzhou

High-precision measurements of the hyperfine splitting values on Li- and H-like bismuth ions, combined with precise atomic structure calculations allow us to test QED-effects in the regime of the strongest magnetic fields that are available in the laboratory. Performing laser spectroscopy at the experimental storage ring (ESR) at GSI Darmstadt, we have now succeeded in measuring the hyperfine splitting in Li-like bismuth. Probing this transition has not been easy because of its extremely low fluorescence rate. Details about this challenging experiment will be given and the achieved experimental accuracy will be presented.

A 18.4 Tue 15:00 B 305

Absolute energy determination of He-like Krypton Kα transitions — •René Steinbrügge[1], Sascha Epp[2], Jan Rudolph[1,3], Christian Beilmann[1], Hendrik Bekker[1], Sven Bernitt[1], Sita Eberle[1], Oscar Versolato[1], Hasan Yavas[4], Hans-Christian Wille[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max Planck Advanced Study Group, CFEL, Hamburg — [3]Institut für Atom- und Molekülphysik, Gießen — [4]DESY, Hamburg, Germany

Helium-like 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 measurement of the $1s^2 - 1s2p$ transitions in He-like krypton (Z=36) ions. They were produced and trapped at conditions below the electron-impact excitation threshold using the transportable electron beam ion trap FLASH-EBIT [1,2], and excited with X-ray photons at the beamline P01 at PETRA III. The transition energies were measured by scanning the photon energy with the double-crystal monochromator, and detecting fluorescence photons. For absolute energy determinations, we compared measurements at different crystal orientations and calibrations using absorption edges as references. The energy measurements have achieved unprecedented uncertainties well below 5 ppm at 13keV.

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

A 18.5 Tue 15:15 B 305

First imaging of cold ion clouds in SpecTrap - ion dynamics in the Penning trap — •Stefan Schmidt[1,2,3], Tobias Murböck[2,4], Zoran Andelkovic[2], Manuel Vogel[2,4], Alexander Martin[2,4], Volker Hannen[6], Jonas Vollbrecht[6], Christian Weinheimer[6], Gerhard Birkl[4], Richard Thompson[5], and Wilfried Nörtershäuser[1,2,3] — [1]Institut für Kernphysik, TU Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]Institut für Kernchemie, Johannes Gutenberg Universität Mainz — [4]Institut für Angewandte Physik, TU Darmstadt — [5]Imperial College London, South Kensington Campus London — [6]Institut für Kernphysik, Westfälische Wilhelms-Universität Münster

Heavy Highly Charged Ions (HCI) are particularly promising candidates for high precision experiments. This includes precision spectroscopy of dipole-forbidden transitions in HCIs at low energies, which will serve as a novel test of strong-field quantum electrodynamics with an accuracy of the order of 10^{-7}.

This talk will present the current status of the SpecTrap apparatus, designed to produce a cold and dense sample of low-Z ions, HCIs and their combination. Recently, we confined singly charged Mg^{+} ions in the trap and performed laser cooling inside the Penning trap. By means of optical and electronic detection methods the properties of the ion cloud such as storage time and temperature were further investigated. In future, the laser cooled ion cloud will serve as an ideal tool for sympathetic cooling of HCIs.

A 18.6 Tue 15:30 B 305

The puzzle of the La line 6520.77 Å — •Laurentius Windholz[1], Bettina Gamper[1], Przemyslaw Glawocki[2], and Jerzey Dembczynski[2] — [1]Institut für Experimentalphysik, Technische Universität Graz, Petersgasse 16, A-8010 Graz, Österreich — [2]Chair of Quantum Engineering and Metrology, Faculty of Technical Physics, Poznań University of Technology, 60 965 Poznań, Poland

The strong La line 6520.770 Å is present in a Fourier transform spectrum available to us as a blend of two lines: a weak one at 6520.735 Å and a strong one at 6520.644 Å (signal to noise ratio of 250 in the Fourier transform spectrum). The latter we could not classify using all known energy levels of the La atom (La I) and its first ion (La II). It appears as a single broadened peak (FWHM 3.5 GHz), while the FWHM of a single hyperfine (hf) structure component is 1.2 GHz.

When setting the laser wavelength to 6520.65 Å, we observed a very strong optogalvanic (OG) modulation of the discharge current, and this did lead to the observation of more than 200 lines which showed laser-induced fluorescence (LIF) signals. Trying to use upper levels of LIF lines with opposite phase (compared to OG in-phase signals) as lower levels of the excited transition did lead to the assumption that a new upper level, 35449.041 cm-1, even, J=13/2, is participating. We applied Doppler-reduced intermodulated OG spectroscopy and were able to find the hf constants A of the involved levels. The angular momentum is 13/2 due to theoretical considerations. The new upper level shows only one combination with known lower levels, located in the infrared region (14908.421 Å).

A 18.7 Tue 15:45 B 305

Few-Photon Spectroscopy of a trapped ion through sensitive recoil detection — •Yong Wan[1], Florian Gebert[1], Boerge Hemmerling[2], and Piet O. Schmidt[1] — [1]QUEST Inst. for Exp. Quantum Metrology, PTB Braunschweig and Leibniz Univ. of Hannover, Germany — [2]Department of Physics, Havard University, Cambridge, MA02138, USA

Traditional laser spectroscopy, e.g. laser-induced fluorescence, allowed us to perform precision spectroscopy with high accuracy. The signal-noise-ratio of this spectroscopy technique is rather limited by the number of photons that can be detected. We present here a highly sensitive spectroscopy technique, which is well-suited in case only a low number of photons or atoms are available. In this scheme, a spectroscopy ion is trapped simultaneously with a single logic ion, which is used for laser cooling and detection of the spectroscopy signal. Starting from the ground state of motion of a common motional mode, photon recoil from probing the spectroscopy transition is detected with high efficiency by the logic ion. We apply spectroscopy pulses synchronized with the motion of the ions in the trap to enhance the sensitivity through resonant driving. This way, we are able to detect scattering of less than 16 photons. We discuss the sensitivity of the experiment and systematic frequency shifts.

The spectroscopy technique discussed is of general interest for high precision spectroscopy and can be applied to various species of atomic and molecular ions. Furthermore, a variation of the technique might be useful for preparation of molecular ions in their internal ground state.

A 19: Interaction with VUV and X-ray light II

Time: Tuesday 14:00–16:00 Location: F 428

A 19.1 Tue 14:00 F 428

First direct seeding at FLASH — •Theophilos Maltezopoulos[1], Sven Ackermann[2], Armin Azima[1], Sasa Bajt[2], Joern Boedewadt[1], Francesca Curbis[1], Hossein Delsim-Hashemi[1], Markus Drescher[1], Stefan Duesterer[2], Bart Faatz[2], Matthias Felber[2], Josef Feldhaus[2], Eugen Hass[1], Ulrich Hipp[1], Katja Honkavaara[2], Rasmus Ischebeck[3], Shaukat Khan[4], Tim Laarmann[2], Christoph Lechner[1], Velizar Miltchev[1], Manuel Mittenzwey[1], Marie Rehders[1], Juliane Roensch-Schulenburg[1], Joerg Rossbach[1], Holger Schlarb[2], Siegfried Schreiber[2], Lasse Schroedter[2], Michael Schulz[1], Roxana Tarkeshian[1], Markus Tischer[2], and Marek Wieland[1] — [1]University of Hamburg and CFEL — [2]DESY, Hamburg — [3]PSI, Villigen, Switzerland — [4]DELTA, Dortmund

Direct seeding with a high-harmonic generation source can improve the spectral, temporal, and coherence properties of a free-electron-laser (FEL) and reduces intensity- and arrival-time fluctuations. In the seeding experiment at the XUV-FEL in Hamburg, FLASH, which is normally operated in the self-amplified spontaneous emission mode, the 21st harmonic of an 800 nm laser is focused into a dedicated seeding undulator. The interaction with the relativistic electrons acts as an amplifier for the seed radiation. We present the setup of the seeding section of FLASH and first experimental results. This work is supported by the Federal Ministry of Education and Research in the framework of the FSP301 program.

A 19.2 Tue 14:15 F 428

Spontaneously Generated Coherences in the X-ray regime — •Kilian Heeg[1], Ralf Röhlsberger[2], Hans-Christian Wille[2], Kai Schlage[2], Tatyana Guryeva[2], Ingo Uschmann[3], Berit Marx[3], Kai-Sven Schulze[4], Tino Kämpfer[4], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Germany — [4]Helmholtz-Institut Jena, Germany

We investigate the reflected signal of a thin film cavity [1] probed by hard x-rays. For the interaction of the photons and resonant Mößbauer nuclei ^{57}Fe under the influence of a magnetic field, a consistent quantum optical description is established. By this we can identify the fundamental interaction processes on a quantum level. We find that Spontaneously Generated Coherences (SGC, [2,3]) emerge in our system and can give rise to pronounced interference minima. SGC arise due to vacuum-induced couplings, but most of their effects and consequences only appear in level schemes which do not exist in real atomic systems. The effective level scheme in our cavity, however, permits the direct observation of SGC, rendering it a powerful device to observe advanced quantum optical effects.

[1] R. Röhlsberger et al., Science 328, 1248-1251 (2010)
[2] G. S. Agarwal, Springer Tracts in Modern Physics 70, 1-128 (1974)
[3] M. Kiffner et al., Progress in Optics 55, 85-197 (2010)

A 19.3 Tue 14:30 F 428

Coherent storage and phase modulation of single hard-x-ray photons — •wen-te liao, adriana pálffy, and christoph h. keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg

Forwarding optics and quantum information to shorter wavelengths in the x-ray region has the potential of shrinking computing elements in future photonic devices such as the quantum photonic circuit. Here we present two important control tools for single hard-x-ray photons using resonant scattering of light off nuclei in a nuclear forward scattering setup: coherent storage and phase modulation of x-ray single-photon wave packets. The formation of a nuclear exciton consisting of a single delocalized excitation opens the possibility to control the coherent decay and therefore emission of the scattered photon. We theoretically show that by switching off and on again the magnetic field in the nuclear sample, phase-sensitive storage of photons in the keV regime can be achieved. Furthermore, a PI phase modulation of the stored photon can be accomplished if the retrieving magnetic field is rotated by 180 degrees [1,2].

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

[2] Focus: Storing an X-ray Photon, D. Lindley, Physics 5, 125 (2012).

A 19.4 Tue 14:45 F 428

Inner-shell multiphoton multiple ionization dynamics of xenon atoms by x-ray free-electron laser pulses — •Sang-Kil Son[1] and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Germany — [2]Department of Physics, University of Hamburg, Germany

When atoms and molecules are irradiated by an x-ray free-electron laser (XFEL), they are highly ionized via a sequence of one-photon ionization and relaxation processes. To describe the ionization dynamics during XFEL pulses, a rate equation model has been employed. Even though this model is straightforward for the case of light atoms, it generates a huge number of coupled rate equations for heavy atoms like xenon, which are not trivial to solve directly. Here, we employ the Monte Carlo method to address this problem and investigate multiphoton multiple ionization dynamics of xenon atoms induced by XFEL pulses. The photon energy used ranges from 1.5 keV to 5.5 keV, which can initially ionize *M*-shell and/or *L*-shell electrons of xenon atoms, respectively. We present charge state distributions, photoelectron and Auger electron spectra, and fluorescence spectra from the ionization dynamics of xenon atoms and compare them with recent XFEL experiments conducted at LCLS and SACLA.

A 19.5 Tue 15:00 F 428

Revealing the structure of large water clusters with x-ray scattering at the FLASH free-electron laser — •Leonie Flückiger[1], Daniela Rupp[1], Mario Sauppe[1], Tim Oelze[1], Sebastian Schorb[2], Rolf Treusch[3], Christoph Bostedt[2], Maria Krikunova[1], and Thomas Möller[1] — [1]Technische Universität, Berlin — [2]LCLS, SLAC National Accelerator Laboratory — [3]Deutsches Elektronen-Synchrotron, Hamburg

With brilliant x-ray pulses of free-electron-lasers the structure of nanoparticles can be imaged by means of x-ray scattering. The diffraction patterns are recorded on the femtosecond timescale during the intense light pulse. Especially water is a hot topic target with its unique physical, chemical, and thermodynamic properties resulting from its three-dimensional hydrogen bond network.

For the first time water clusters have been imaged at the free-electron laser in Hamburg FLASH. The scattering patterns reveal the geometry of single water particles with various sizes in the range from nanometers to mircrometers and from different aggregation states. Upon illumination with the strong FEL pulse the sample becomes completely destroyed. Therefore, the dynamics of radiation damage - which is mostly driven by Coulomb explosion - was studied by coinsident measurement of fragment ion spectra.

A 19.6 Tue 15:15 F 428

Tracing Interatomic Coulombic Decay of Ne_2 by XUV-pump–XUV-probe Experiments at FLASH — •Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Artem Rudenko[2], Alexander Broska[1], Lutz Foucar[2], Matthias Kübel[3], Denis Anieleski[2], Thomas Pfeifer[1], Kristina Meyer[1], Georg Schmid[1], Matthias Kling[3], Joachim Ullrich[1], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max Planck Advanced Study Group, Hamburg — [3]Max-Planck-Institut für Quantenoptik

We present the first time-resolved measurement of Interatomic Coulombic Decay (ICD) in Ne_2 using a XUV-pump–XUV-probe scheme at FLASH. ICD is a radiationless decay mechanism where deexcitation of one atom is achieved via an energy transfer to a van-der-Waals–bound neighbouring atom which then emits an electron. The process has been theoretically predicted and experimentally confirmed in clusters and molecules. Although the decay time of ICD is a crucial parameter for understanding the underlying mechanism, no time-resolved investigation has been performed so far.

In our measurement a 58 eV pump pulse of approximately 60 fs creates a 2s hole, initiating the decay process which is probed after an adjustable time delay by an exact copy of the first pulse. Only if the decay has happened by the time the probe pulse arrives, a certain energy level is populated. The resluting fragmentation channel can be seperated by using a Reaction Micrsoscope which allows us to study charged particles in coincidence.

A 19.7 Tue 15:30 F 428

Multiphoton inner-shell excitation in rare gas atoms — •Tommaso Mazza[1], Markus Ilchen[1], Thomas J. Kelly[2], Sadegh Bakhtiarzadeh[1], Amir Jones Rafipoor[1], John Costello[2], Stefan Dusterer[3], Peter Lambropoulos[4], Stephan Fritzsche[5], and Michael Meyer[1] — [1]European XFEL GmbH, Hamburg, Germany — [2]DCU, Dublin, Ireland — [3]Hasylab@DESY, Hamburg, Germany — [4]University of Crete, Heraklion, Greece — [5]GSI, Darmstadt, Germany

We present a study of direct and resonant two- and multi-photon ionization processes in the XUV regime in Xe and Ar, performed at the Free electron LASer in Hamburg (FLASH). The strong interaction of short wavelength intense radiation with the strongly bound core electron results in new and mostly unexplored photoexcitation phenomena through the simultaneous absorption of two (or more) photons. These are responsible for the highly charged states observed earlier by ion spectroscopy, and are investigated here in detail by means of photoelectron spectroscopy. In particular, we were able to unambiguously identify the signatures of direct 2-photon as well as sequential multiphoton ionization processes of Ar3p and Xe4d, and of the Auger decay of the (1photon forbidden) 2-photon Ar2p-4p resonance excitation.

Detailed understanding of these non-linear processes, which are driven by the very intense FEL radiation and which have been almost completely unexplored up to now in the XUV wavelength regime to date, is crucial not only for gas phase experiments, but also for FEL-based studies in all other targets from molecules to solids.

A 19.8 Tue 15:45 F 428

Deexcitation Cascade effects in Xe II observed by fluorescence spectroscopy after excitation by synchrotron radiation — •Christian Ozga[1], Witoslaw Kielich[1], Philipp Reiss[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 Straße 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, D-22761 Hamburg, Germany

Due to the high number of electrons and their interdependency within the electron shells xenon atoms provide a good benchmark system to investigate quantum mechanical correlation effects. For example cascade effects in the de-excitation process can be investigated providing information of the relaxation dynamics of electron correlation effected systems. Typically these cascade effects are observed by electron or ion spectroscopy yielding data about electron systems successively losing electrons. Here we show that it is possible to observe cascade effects with constant electron numbers directly by fluorescence spectroscopy after excitation of Xe I ground state [Kr] $5s^2\ 5p^6\ {}^1S_0$ to a doubly excited state [Kr] $5s^2\ 5p^4({}^3P_2)$nln*l* and subsequent autoionization.

A 20: Poster: Precision spectroscopy of atoms and ions (with Q)

Time: Tuesday 16:00–18:30 Location: Empore Lichthof

A 20.1 Tue 16:00 Empore Lichthof

The ARTEMIS Experiment: Precision Spectroscopy of Highly Charged Ions in a Penning Trap — •Manuel Vogel[1,2], Gerhard Birkl[1], David von Lindenfels[2,3], Alexander Martin[1], Wolfgang Quint[2,3], and Marco Wiesel[1] — [1]Institut für Angewandte Physik, TU Darmstadt, 64289 Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt — [3]Physikalisches Institut, Ruprecht Karls-Universität Heidelberg, 69120 Heidelberg

We present the concept and setup of the ARTEMIS experiment located at the HITRAP facility at GSI, Germany. It is dedicated to laser-microwave double-resonance spectroscopy of confined and cooled highly-charged ions with high precision. Such spectroscopy allows a simultaneous determination of electronic and nuclear magnetic moments with respective relative accuracies on the ppb and ppm level. In single- and few-electron highly charged ions this opens the possibility to resolve QED contributions to the electron g-factor due to the bound state. At the same time, nuclear magnetic moments can be measured in absence of electronic shielding and corresponding models can be tested for the first time.

A 20.2 Tue 16:00 Empore Lichthof

Parity violation effects in superconductors — •Nikolay A. Belov[1] and Zoltán Harman[1,2] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]ExtreMe

Matter Institute (EMMI), Planckstraße 1, 64291 Darmstadt, Germany

Parity violation effects in a circular superconducting Josephson junction has been investigated in the eighties. That time it appeared that this phenomenon was not significant enough to be experimentally observable.

In our work we show, that this rate can be increased in the case of a circular Josephson junction of an unconventional superconductor. Furthermore, this phenomenon can be more significant in the case of the ferromagnetic p-wave unconventional superconductor, since the effect is stronger for polarized pairs.

A 20.3 Tue 16:00 Empore Lichthof

Techniques for few photon spectroscopy of a trapped ion through sensitive recoil detection — •Florian Gebert[1], Yong Wan[1], Boerge Hemmerling[2], and Piet O. Schmidt[1] — [1]QUEST Inst. for Exp. Quantum Metrology, PTB Braunschweig and Leibniz Univ. of Hannover, Germany — [2]Department of Physics, Harvard University, Cambridge, MA02138, USA

We present the theoretical and experimental basis for a highly-sensitive spectroscopy technique, based on the detection of motional excitation through photon recoil. In the experiment we trap an ion crystal consisting of two ions, the spectroscopy ion and the logic ion for cooling and detection. Spectroscopy is performed by first cooling the axial modes of the ion crystal to the motional ground state. Scattering of photons on the spectroscopy ion results in recoil kicks, which populate excited motional states. We present a theoretical model of the motional state evolution of this system.

The population of the motional mode can be detected through application of a red sideband pulse on the logic ion, which changes the internal state of the ion if the system is in an excited motional state. This detection techniques suffers from an incomplete transfer of population, since the Rabi frequency is a function of the initial motional state. We present theoretical and experimental results on the investigation of adiabatic passage techniques for state independent population transfer, which increases the signal to noise ratio of the spectroscopy signal.

A 20.4 Tue 16:00 Empore Lichthof

Single Ra^+ ion spectroscopy - towards a measurement of Atomic Parity Violation — •Mayerlin Nunez Portela, A. Mohanti, E.A. Dijck, H. Bekker, O. Boell, J. van den Berg, G.S. Giri, K. Jungmann, C.J.G. Onderwater, B. Santra, R.G.E. Timmermans, O.O. Versolato, L.W. Wansbeek, L. Willmann, and H.W. Wilschut — KVI, University of Groningen, Groningen , The Netherlands

The sensitivity of the Atomic Parity Violation (APV) signal grows faster than the third power of the atomic number Z. Ra^+ (Z=88)is heaviest alkaline earth ion available. A single trapped Ra^+ ion opens a very promising path for a measurement atomic parity violation. One of the experimental challenges is the localization of the ion within a fraction of an optical wavelength. For this the current experiments are focused on trapping and laser cooling of Ba^+ ions as a precursor for Ra^+. Ba^+ ions are trapped and laser cooled in a precision hyperbolic Paul trap. Work towards single Ba^+ ion localization and detection is in progress. Recently the hyperfine structure of the $6d_2D_{3/2}$ states and the isotope shift of the $6d_2D_{3/2}$-$7p_2P_{1/2}$ transition in the isotopes $^{209-214}Ra^+$ has been measured [1]in online laser spectroscopy experiments at the KVI AGOR/TRIμP facility. These results are essential for the interpretation of an APV measurement in Ra^+. [1] G.S. Giri et al., Phys. Rev. A 84, 020503(R) (2011)

A 20.5 Tue 16:00 Empore Lichthof

Structure of highly charged ions: towards a determination of the variation of the fine-structure constant — •Natalia S. Oreshkina[1], Zoltán Harman[1,2], and Christoph H. Keitel[1] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]ExtreMe Matter Institute (EMMI), Planckstrasse 1, 64291 Darmstadt, Germany

The possibility of the time-variation of the fine structure constant α, as one of the fundamental constants, has a great interest for modern science. Specifically, a varying α has been proposed as a way of solving puzzles in cosmology and astrophysics. Transitions in highly charged ions can have an extremely high sensitivity to α variation and can be observed in laboratory by high-precision spectroscopy. We present a set of ionic optical transitions which may be utilized to observe a frequency shift due to α variation.

A 20.6 Tue 16:00 Empore Lichthof

Spezifikation der Energieunschärfe gekühlter und gepulster Ionenstrahlen mittels Laserspektroskopie am TRIGA-Mainz — •S. Kaufmann[1], T. Beyer[2], K. Blaum[2], Ch. E. Düllmann[1,3,4], K. Eberhardt[1,4], M. Eibach[2,5], N. Frömmgen[1], Ch. Geppert[1,4,6], C. Gorges[1], M. Hammen[1,6], A. Krieger[1,4,6], S. Nagy[2], W. Nörtershäuser[1,4,6], D. Renisch[1], E. Will[1] und Die TRIGA-SPEC-Kollaboration[1] — [1]Institut für Kernchemie, Universität Mainz — [2]MPIK Heidelberg — [3]GSI Darmstadt — [4]HIM Mainz — [5]Fakultät für Physik und Astronomie, Universität Heidelberg — [6]TU Darmstadt

Der Aufbau zur kollinearen Laserspektroskopie am Forschungsreaktor TRIGA Mainz dient zur Untersuchung radioaktiver Isotope und als Prototyp für das LASPEC-Experiment an FAIR [1]. Zur Akkumulation und Kühlung der Ionen ist ein gasgefüllter Radiofrequenz-Quadrupol (RFQ) in der gemeinsamen Strahlstrecke implementiert. Die Energie und die Energieverteilung der daraus extrahierten Ionen ist sowohl für den Einschuss in die nachfolgende Penningfalle (TRIGA-TRAP) als auch für die kollineare Laserspektroskopie (TRIGA-LASER) von großer Bedeutung und kann mittels Laserspektroskopie sehr genau ermittelt werden. Geplant ist die Untersuchung der Abhängigkeit dieser Größen von den Parametern des RFQ. Der Status des Projektes und erste Ergebnisse werden vorgestellt. Unter anderem wird die benötigte Laserstabilisierung auf eine Absolutfrequenz und eine verbesserte Datenaufnahme mittels eines FPGA-basierten Sequencers diskutiert.

[1] D. Rodriguez et al., Eur. Phys. J. Special Topics 183, 1-123 (2010)

A 20.7 Tue 16:00 Empore Lichthof

High resolution fluorescence spectroscopy of Kα transitions in highly charged iron ions at a synchrotron — •Jan Rudolph[1,2], René Steinbrügge[1], Sven Bernitt[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institut für Atom- und Molekühlphysik, Gießen, Germany

Most prominent features in active galactic nuclei X-ray spectra originate from photoexcited iron K_α transitions. An experimental approach to study these processes needs a high X-ray photon flux near 6.7 keV and a target of highly charged iron ions. For this experiment we used the Heidelberg transportable electron beam ion trap FLASH-EBIT to produce a dense ion target. To resonantly photo excite K_α transitions in this ion cloud and detect fluorescence the PETRA III photon source was used. A double crystal monochromator at beam line P01 provided $10^{12}\gamma\ s^{-1}$ with a resolution of 0.1 eV. By scanning the monochromator energy from 6.4 to 6.7 keV several electric dipole allowed K_α transitions in $Fe^{17+\cdots 24+}$ ions were detected. Absolute line energies with an accuracy of a few ppm had been measured. Even the natural line width of the fluorescence lines were determined. This method of measuring absolute line energies combining an EBIT with a highly resolved and focused X-ray beam at a synchrotron overcomes classical methods like crystal spectrometer measurements. We achieve higher statistics in a much shorter period of time. The complexity of the measurement setup is reduced compared to classical spectroscopy as well as the susceptibility to disturbances in the experimental surroundings.

A 20.8 Tue 16:00 Empore Lichthof

Ion Coulomb crystals for precision spectroscopy and dynamical studies — •Heather L. Partner, Karsten Pyka, Jonas Keller, Tobias Burgermeister, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Braunschweig

We present our experimental setup, in which we trap and store Coulomb crystals of $^{172}Yb^+$ and $^{115}In^+$ ions. We provide technical details of the chip-based segmented linear Paul trap which we developed for metrological applications. It is specifically designed for minimizing excess micromotion, includes a protected spectroscopy segment and provides three dimensional laser access. This well-controlled environment allows to create and perform spectroscopy on 1D, 2D, and 3D Coulomb crystals. Using these crystals, we create topological defects and study the dynamics in laser cooled coupled ion systems.

A 20.9 Tue 16:00 Empore Lichthof

Spectroscopy of a narrow-line optical pumping transition in atomic dysprosium — •Holger Kadau, Thomas Maier, Matthias Schmitt, Michaela Nickel, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Dysprosium is a rare-earth element with a complex energy level structure with several possible cooling and optical pumping transitions. We have prepared samples of dysprosium atoms at ~ 1 mK in a magneto-optical trap by laser cooling on a broad transition at 421 nm. One possibility to laser cool the atoms further is to use a narrow-line optical transition at 626 nm and reach conditions suitable for forced evaporative cooling in an optical dipole trap.

One alternative to forced evaporative cooling is lossless demagnetization cooling [1]. It requires an atomic sample with inelastic dipolar scattering in its lowest energetic state, a controllable magnetic field and an optical pumping transition. We present a suitable candidate for such optical pumping at a wavelength of 684 nm. We assign the positions of the so far unknown fermionic hyperfine shifts of the transition. We measured the transition linewidth and give an upper limit for the branching ratio between decay to the groundstate and other states. Our measurements show that this transition is usable for optical pumping and demagnetization cooling.

[1] M. Fattori *et al.*, Nat. Phys. **2**, 126401 (2006)

A 20.10 Tue 16:00 Empore Lichthof

Lifetime and natural line width determination of Kα transitions in highly charged iron ions — •Jan K. Rudolph[1,2], René Steinbrügge[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institut für Atom- und Molekühlphysik, Gießen, Germany

Resonance spectroscopy measurements have been performed on photoexcited highly charged iron ions in the X-ray regime near 6.7 keV photon energy. The transportable Heidelberg electron beam ion trap FLASH-EBIT was used to produce and store $Fe^{22+\cdots 24+}$ ions. The beamline P01 with its double-crystal monochromator at the PETRA III facility served as X-ray source. The energy resolution of the monochromator was 0.1 eV sufficient to determine natural line widths with good accuracy. While scanning the monochromator energy, ions were continuously extracted from the trap, separated by their charge-to-mass ratio and detected with a position sensitive detector. Thus, by simultaneously measuring the photoionization yield and the line width of all the signals, the Auger and radiative decay rates could be determined independently of geometric factors.

A 20.11 Tue 16:00 Empore Lichthof

Spectroscopy of hole transitions in Ir^{17+} — •Hendrik Bekker[1], Alexander Windberger[1], Christian Beilmann[2], Renee Klawitter[3], Piet O. Schmidt[4,5], Oscar O. Versolato[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik — [2]Karlsruhe institut für Technologie — [3]Tri University Meson Facility — [4]Physikalisch-Technische Bundesanstalt — [5]Leibniz Universität Hannover

Astronomical observations hint at a spatial gradient of the fine structure constant α [1]. Since the Earth moves along this spatial gradient, a temporal variation in α, $\dot{\alpha}$, should be observable in the lab. Current estimates for the variation are $\dot{\alpha}/\alpha < 10^{-19}$/year. For a lab measurement of $\dot{\alpha}$ to be feasible in the foreseeable future, two accurate optical clocks with different sensitivities to $\dot{\alpha}$ are required. An optical clock with high sensitivity to $\dot{\alpha}$ can be found by looking at hole transitions in highly charged ions. It has been calculated that due to level crossings the hole transitions in Ir^{17+} are within optical range, while at the same time this system has one of the highest sensitivities to $\dot{\alpha}$ [2]. In our electron beam ion trap, Ir^{17+} ions are prepared and collisionally excited. A grating spectroscope is employed to study the level structure at an aimed accuracy of 1 ppm. Theory cannot predict the electronic structure as accurately as needed. Knowledge of the level structure is therefore an essential prerequisite for future laser spectroscopy experiments in the cryogenic Paul trap CryPTEx.

[1] J.K. Webb *et al., Phys. Rev. Lett.* **107**, 191101 (2011).

[2] J.C. Berengut *et al., Phys. Rev. Lett.* **106**, 210802 (2011).

A 20.12 Tue 16:00 Empore Lichthof

A cryogenic Paul trap for highly charged ions — •Maria Schwarz[1,2], Oscar O. Versolato[1], Alexander Windberger[1], Lisa Schmöger[1], Sita Eberle[1], Piet O. Schmidt[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Quest, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

A linear cryogenic Paul trap experiment (CryPTEx) has been set up inline with an electron beam ion trap. It will provide long storage times for highly charged ions (HCIs) due to the extremely low background pressure within a 4 K enclosure. First experiments on the storage of HCIs in this trap are presently under way. Since HCIs generally do not allow for direct laser cooling, one needs to apply sympathetic cooling. The trapped HCIs will be coupled by Coulomb-interaction to a low-temperature bath of laser-cooled ions what ultimately should allow to resolve the natural linewidth of forbidden transitions. Our final goal is the application of quantum logic spectroscopy, where a singly charged ion species (Be^+) is responsible for the sympathetic cooling and state detection of the HCI. For the purpose of these high precision measurements, a second cryogenic Paul trap is currently being designed at MPIK in collaboration with the PTB. The design of this trap is based on CryPTEx but will focus on extremely precise and stable trapping conditions.

A 20.13 Tue 16:00 Empore Lichthof

A Radium Ion Optical Clock — •Elwin A. Dijck, M. Nuñez Portela, O. Böll, S. Hoekstra, K. Jungmann, A. Mohanty, C.J.G. Onderwater, R.G.E. Timmermans, L. Willmann, and H.W. Wilschut — KVI, University of Groningen, Groningen, The Netherlands

Single-ion based optical clocks are currently the best candidates for a future time and frequency standard with their stability exceeding that of the current ^{133}Cs standard. In particular, the 7s $^2S_{1/2}$ (F=2, mF=0)-6d $^2D_{3/2}$ (F=0, mF=0) at 828 nm transition in $^{223}Ra^+$ could be exploited as a robust atomic clock operating at a fractional frequency uncertainty of 10^{-17} since it exhibits no linear Zeeman and electric quadrupole shifts[1]. Laser spectroscopy of trapped $^{209-214}Ra^+$ yielded the hyperfine structure of the 6d $^2D_{3/2}$ state and isotope shift of the 6d $^2D_{3/2}$-7p $^2P_{1/2}$ transition, providing input for the design of a Ra^+ clock. Application include the direct comparison of the clock frequencies via an optical fiber networks and an optical frequency comb to determine frequency shifts in the gravitational field, and the implementation in an improved earth-bound positioning system. The comparison of different ions species is of fundamental interest because of their specific dependence on possible changes of fundamental constants, e.g. the fine structure constant. The Ra^+ clock transition is much more sensitive to $d\alpha/dt$ than e.g. the Al^+ clock, and the shift would have the opposite sign than that of Hg^+. [1] O.O. Versolato et al., Physical Review A 83 (4), 043829. [2] G.S. Giri et al., Phys. Rev. A 84, 020503(R) (2011)

A 20.14 Tue 16:00 Empore Lichthof

Laser Systems for the Preparation of Cold Highly Charged Ions — •Sita Eberle[1], Oscar O. Versolato[1], Matthias Kohnen[2], Alexander Windberger[1], Maria Schwarz[1], Piet O. Schmidt[2], Joachim Ullrich[1,2], and José R. Crespo Lopez-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

Highly charged ions (HCIs) are of particular interest for metrology as well as for studying fundamental physics. Narrow optical transitions would provide for new frequency standards with low sensitivity to external fields. Stringent tests of bound-state QED as well as parity violation benefit from strong enhancement effects. For these purposes we have designed a cryogenic Paul trap that enables the trapping and sympathetic laser cooling of HCIs for precision spectroscopy. The coolant of choice is the Be+ ion which requires a Doppler-cooling laser system operating at 313nm wavelength that we constructed in collaboration with PTB. A separate system was developed for the photo-ionization of Be+ ions at 235nm wavelength that can deliver up to several 10mW of UV. It is based on frequency quadrupling an amplified diode laser system operating at 940nm with up to 1500mW output power. Thermal lensing issues limit the first second harmonic generation (SHG) stage, based on resonance enhanced doubling in a bow-tie cavity using an AR-coated PPKTP crystal. The second SHG system also relies on resonance enhanced doubling in a bow-tie cavity employing a Brewster-cut BBO crystal.

A 20.15 Tue 16:00 Empore Lichthof

Search for the permanent electric dipole moment of ^{129}Xe — •Olivier Grasdijk[4], Werner Heil[1], Sergei Karpuk[1], Anja Scharth[1], Yuri Sobolev[1], Kathlynne Tullney[1], Fabian Allmendinger[2], Ulrich Schmidt[2], Martin Burghoff[3], Wolfgang Kilian[3], Allard Schnabel[3], Frank Seifert[3], Lutz Trahms[3], Klaus Jungmann[4], and Lorenz Willmann[4] — [1]Institut für Physik, Universität Mainz — [2]Physikalisches Institut, Universität Heidelberg — [3]PTB Berlin — [4]KVI, University of Groningen

Permanent electric dipole moments (EDMs) violate parity and time reversal symmetry at the same time. Assuming CPT invariance a non-zero EDM would also violate CP symmetry, which could provide an explanation for the observed matter-antimatter asymmetry in the universe. An EDM at the present limit of experimental sensitivity would provides unambiguous evidence for physics beyond the Standard Model. Our approach is to observe the coherent spin-precession of co-located ^{3}He/^{129}Xe polarized samples over extended periods of 1 day, typically. Based on results of measurements on Lorentz-invariance [1], we intend to reach a measurement sensitivity that will improve the present upper limit $d_{Xe} = 3\cdot 10^{-27}$ecm significantly. Phase I of this experiment will be performed in the magnetically shielded room BMSR-2 of the PTB Berlin using very sensitive SQUID gradiometers as magnetic flux detectors and electric fields of 2 kV/cm. The experimental setup, in particular the implementation of the electric field, and current status of work will be presented. [1] C.Gemmel et al., Eur. Phys. J D 47, 303 (2010; C.Gemmel et al., Phys. Rev D 82, 111901(R)(2010).

A 20.16 Tue 16:00 Empore Lichthof

A low-energy beamline for injection of highly charged ions into a cryogenic Paul trap — Lisa Schmöger[1], •Maria Schwarz[1,2], Oscar O. Versolato[1], Alexander Windberger[1], Thomas M. Baumann[1], Joachim Ullrich[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Electron beam ion traps (EBITs)are efficient tools for highly charged ion (HCI) production and studies. However, due to the high ion temperature inside of an EBIT (on the order of MK), laser spectroscopy on HCIs is severely constrained by Doppler broadening [1]. A novel cryogenic Paul trap (CryPTEx) operating at the MPIK [2] will allow for sympathetic cooling of HCIs by 9 orders of magnitude, down to the mK regime, and thus for resolving the natural linewidth of forbidden optical transitions in HCI. A compact beamline for transport, deceleration and transfer of HCIs from Hyper-EBIT into CryPTEx has been designed, built and commissioned at MPIK. Simulations have been performed to optimize the ion optics. The new beamline guides HCIs extracted from an EBIT into CryPTEx in both pulsed and continuous modes. Deceleration and time-focussing of the ion bunches are performed by a drift cavity which also reduces the initial energy spread of the ions. The setup allows for efficient HCI transfer and injection of slow HCIs into the Paul trap.

[1] V. Mäckel et al., Phys. Rev. Lett. **107**, 143002 (2011)
[2] M. Schwarz et al., Rev. Sci. Instrum. **83**, 083115 (2012)

A 20.17 Tue 16:00 Empore Lichthof

X-ray measurements of highly charged ions with a microcalorimeter — Sebastian Georgi[1], Sönke Schäfer[2], Thomas M. Baumann[1], Andreas Fleischmann[2], Christian Enss[2], Joachim Ullrich[3], and •José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Ruprecht-Karls-Universität, Heidelberg — [3]Physikalisch-Technische Bundesanstalt, Braunschweig

A metallic magnetic microcalorimeter for photons in the spectral region 100-15000 eV was commissioned at the Heidelberg Electron Beam Ion Trap facility. It consists of eight absorber pixels made of erbium-doped gold held at 30 mK. Their temperature change due to the absorption of a single X-ray photon is used to determine its energy: Each absorber is thermally linked to a paramagnetic sensor in which a magnetization change is precisely measured by a superconducting interference device. A nested focusing X-ray mirror system is used for increased detection efficiency. We investigated the dielectronic recombination resonances of He-like and Li-like iron ions, and directly excited M-shell transitions of tungsten ions, achieving a resolution of 9,eV. The iron results were compared with multi-configuration Dirac-Fock calculations; those of the 4f → 3d transitions of Ni-like to Ti-like, and of 5f → 3d transitions of Ni-like to Cr-like tungsten ions, with Flexible Atomic Code [1] calculations of our own and with data from [2,3].

[1] M. F. Gu, Can. J. Phys. **86** (2008) 675
[2] P. Neill et al., Can. J. Phys., **82** (2004) 931
[3] J. Clementson et al., Phys. Scripta **81** (2010) 015301

A 20.18 Tue 16:00 Empore Lichthof

High precision x-ray measurements with a metallic magnetic microcalorimeter at the MPIK Hyper-EBIT — •Sebastian Georgi[1], Sönke Schäfer[2], Thomas M. Baumann[1], Andreas Fleischmann[2], Joachim Ullrich[1], Christian Enss[2], and José R. Crespo López-Urrutia[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]Kirchhoff-Institute for Physics, Heidelberg, Germany

A metallic magnetic microcalorimeter for photons in the spectral region between 100 eV and 15 keV was commissioned at the Heidelberg Electron Beam Ion Trap facility. It is cooled to 30mK and consists of eight absorber pixels (250 μm x 250 μm sensitive area each) made of 5 μm thick gold (5N). Each absorber is thermally linked to a paramagnetic sensor made of erbium doped gold, so that the temperature increase due to the absorption of a photon result in a magnetization change of the sensor which can be precisely measured by a SQUID magnetometer. We investigated the dielectronic recombination resonances of He-like and Li-like iron ions, and also directly exited M-shell transitions of tungsten ions. The recorded iron spectra were compared with results from theoretical multi-configuration Dirac-Fock calculations. The measured energies of seven 4f → 3d and five 5f → 3d transitions of Ni- to Ti-like tungsten ions were compared to calculations carried out with the Flexible Atomic Code [1] and with results from [2,3].

[1] M. F. Gu, Can. J. Phys. 86 (2008) 675
[2] P. Neill et al., Can. J. Phys., 82 (2004) 931
[3] J. Clementson et al., Phys. Scripta 81 (2010) 015301

A 20.19 Tue 16:00 Empore Lichthof

Precision Laser Spectroscopy of the 1S-2S Transition in Positronium — Paolo Crivelli[1], David Cooke[1], Aldo Antognini[1], Klaus Kirch[1,4], •Janis Alnis[2], and Theodor W. Hänsch[2,3] — [1]ETH Zurich, Institute for Particle Physics, CH-8093 Zürich — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching — [3]Ludwig-Maximilians-Universität, 80799 München — [4]Paul Scherrer Institute, Villigen, Switzerland

We aim to improve the current accuracy in the measurement of the energy interval of positronium (Ps) from its ground state (1S) to the first excited state (2S) by a factor of 5. This will provide a very stringent test of the theory describing atomic systems called bound states quantum electrodynamics (QED). Very recently a serious discrepancy of 5 sigma in the charge radius of the proton extracted from the muonic-hydrogen experiment at PSI compared to other experiments was found and has not yet been explained. This increases the importance of studying hydrogen-like and especially non-baryonic (with no quarks, e.g no protons) systems like positronium or muonium where finite-size effects due to the nucleus are absent. The proposed measurement will also result in the best determination of the positron-electron mass ratio that should be exactly one in order for the CPT symmetry to be conserved. This symmetry is a pillar of quantum field theory which is the base of our current understanding of particles and their interactions.

A 20.20 Tue 16:00 Empore Lichthof

Investigation of the structure of the solar corona by imaging spectroscopy — •Adalbert Ding[1,2] and Shadia Rifai Habbal[3] — [1]Institut für Optik und Atomare Physik, TU Berlin — [2]Institut für Technische Physik, Berlin — [3]Institute for Astronomy, University of Hawaii, Honolulu, USA

The emission of highly ionized Fe atoms in the solar corona has been investigated during the solar eclipses of 2010 (in French Polynesia)and 2012 (in Northern Australia)using wavelength selected imaging techniques. In particular, two imaging spectrometers have been used to record the solar emission spectrum along a line transversing the corona over several solar radii thereby obtaining the relative intensities of all relevant emission lines. Besides the intense Hydrogen, Helium and Calcium lines, emission from optically forbidden transitions of a number of Fe ions (Fe^{9+}: 637.4 nm, Fe^{13+}: 530.3 nm) were observed.

During the 2012 solar eclipse an improved high resolution double spectrometer was used to measure the Doppler broadening of 2 emission lines (Fe^{9+}, Fe^{13+}).

The results are compared with the 2D visible emission profiles of a number optically forbidden transitions using narrow band interference filters 1)

The data provide information about the electron temperature distribution in different coronal structures and the excitation mechanisms of the ions.

1) S.R. Habbal et al., APJ 734, 120 (2011)

A 20.21 Tue 16:00 Empore Lichthof

A high resolution double imaging spectrometer for the investigation of ion emission in the solar corona — •Adalbert Ding[1,2] and Shadia Rifai Habbal[3] — [1]Institut für Optik und Atomare Physik, TU Berlin — [2]Institut für Technische Physik, Berlin — [3]Institute for Astronomy, University of Hawaii, Honolulu, USA

Doppler shift of emission lines can be used to obtain information about the velocity of light emitting particles in the gas phase. An easily transportable optical spectrometer has been designed and set up for such uses in solar eclipse expeditions .

An echelle grating operated under grazing incidence in high order (appr. 40^{th}) is used to significantly increase the resolution. A combination of optical cut-off filters and dichroic mirrors preselects a narrow wavelength range for order sorting. Two sets of such filters and two gratings allow the simultaneous measurement in two relevant wavelength ranges. The optical properties of the spectrometer have been chosen such that a 2 to 3 orders are simultaneously recorded with a low noise CCD-chip. This allows the deconvolution of the lines by using Fourier transform techniques.

By using an extended entrance slit it is possible to also record the intensity distribution along the slit which has been designed as a mirror. Thus it is possible to record the sun's position with respect to the slit using a separate video camera.

First results - both from natural and artificial sources - will be presented. The influence of the spectrometer parameters and the camera noise of the deconvoluted spectra will be discussed.

A 20.22 Tue 16:00 Empore Lichthof

Metallic magnetic calorimeters for high resolution x-ray spectroscopy - Latest results from maXs-20 and maXs-200 — •Mathäus Krantz[1], Sönke Schäfer[1], Christian Pies[1], Daniel Hengstler[1], Simon Uhl[1], Sebastian Heuser[1], Thomas Wolf[1], Loredana Gastaldo[1], Christian Enss[1], Andreas Fleischmann[1], Sebastian Georgi[2], Thomas M. Baumann[2], and Jose R. Crespo Lopez-Urrutia[2] — [1]Kirchhoff-Institut für Physik, Uni Heidelberg, INF 227, 69120 Heidelberg — [2]Max Planck Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Deutschland

We are developing metallic magnetic calorimeters (MMC) for high resolution x-ray spectroscopy on highly charged ions in the energy range up to 200keV. MMCs use a paramagnetic temperature sensor, readout by a SQUID, to measure the energy deposited by single x-ray photons. The recently micro-fabricated and tested prototypes include two linear 8-pixel detector arrays, maXs-20 and maXs-200, optimized for energies up to 20 keV and 200 keV, respectively. We summarize the performance of both detector prototypes. maXs-200 with its 1mm^2 large and 200 μm thick absorbers made of electro-deposited gold has high stopping power for hard x-rays and achieves an energy resolution of 40-60 eV (FWHM). maXs-20 with its 250μm×250 μm large and 5 μm thick absorbers has a stopping power of 98% for 6 keV photons and presently achieves an experimental line width of 3,3 eV (FWHM), with a signal rise time of 90 ns and excellent linearity. We are presently operating maXs-20 at an electron-beam-ion-trap at the MPI-K Heidelberg and will report on first atomic physics measurements.

A 20.23 Tue 16:00 Empore Lichthof

Hyperfine Structure Investigations by Modelling Emission Spectra — •Bettina Gamper and Laurentius Windholz — Institut für Experimentalphysik, Technische Universität Graz, Petersgasse 16, A-8010 Graz, Österreich

We present studies of the spectral lines of Praseodymium by modelling the emission spectrum by a sum of the hyperfine (hf) profiles of all spectral lines in a certain region. Pr has a huge amount of spectral lines, mostly in the visible region. Many transitions have nearly the same center of gravity (cg) wavelength which leads to overlapping of two or more spectral lines. To distinguish the different lines which take part in these so called blend situations we use laser-induced fluorescence (LIF) spectroscopy. We get the excitation wavelength for the investigations of a promising structure from a highly resolved Fourier transform (FT) spectrum. Our goal is to classify as many spectral lines as possible and to discover new energy levels. In the last years our group enlarged the list of the spectral lines from 12000 to 26000 and found about 300 new energy levels of the Pr atom as well as of the Pr ion. With our new program we can now summarize all classified transitions and compare them to the FT spectrum, in order to judge whether all lines contributing to the emission spectrum are known or not. The program can be adapted to every other element. An application of such a modelling could be analyzing highly resolved stellar spectra.

A 20.24 Tue 16:00 Empore Lichthof

Transportable Apparatus for a Strontium Lattice Clock — •Stefan Vogt, Sebastian Häfner, Stephan Falke, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

The best measurements of optical transition frequencies in atoms or ions are today limited by the realization of the SI second. The natural way to avoid this limitation is to directly compare frequencies in the optical regime. This will enable tests of physical theories such as possible variations of fundamental constants or tests of general relativity, or enable a new way of measuring the difference in gravitional potential between two places. Nevertheless the number of optical frequency-ratio measurements performed so far is small, because remote comparisons at that level are still difficult and so far there are no clock setups that are in fact transportable.

Here we will present the progress on a new transportable setup for an optical lattice clock working with ^{87}Sr. The system consists of a vacuum chamber and laser systems for trapping, cooling and interrogating the atoms. We will present the latest results on a Zeeman slower based on permanent magnets and field coils for the magneto-optical trap that are compatible with temperature gradients of well below one Kelvin on the vacuum chamber. This is crucial for correcting the frequency shift caused by the blackbody radiation emitted form the environment seem by the atoms. This work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and EU through the Space Optical Clocks (SOC2) project.

A 21: Poster: Photoionization

Time: Tuesday 16:00–18:30 Location: Empore Lichthof

A 21.1 Tue 16:00 Empore Lichthof

Investigation of shake-up processes in Beryllium with the Multiconfigurational time-dependent Hartree-Fock method — •Christopher Hinz, David Hochstuhl, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15 24098 Kiel, Germany

The Multiconfigurational time-dependent Hartree-Fock (MCTDHF) method is an extension of Hartree-Fock to gradually include correlations, in addition to the contributions of the mean-field. Extending our previous work on Helium [1], we apply MCTDHF to the full four-electron system of Beryllium in an external electro-magnetic field for different amounts of correlation, while previous works [2,3] using traditional approaches—like Configuration interaction (CI)—were only capable of treating two active electrons. Of special interest are shake-up processes, in which a second electron is excited during photoionization, which can be subsequently ionized by a second photon with a higher resulting electron energy. Since the shake-up is a consequence of correlations between the shake-up electron and the first photoelectron this process is not treatable with pure Hartree-Fock methods. To resolve the time evolution of the shake-up process, we apply a pump-probe scheme to the atomic system, which is not accessible with a time-independent method.

[1] D. Hochstuhl, M. Bonitz, J. Chem. Phys. **134**, 084106 (2011)

[2] S. Laulan, H. Bachau, Physical review A **69**, 033408 (2004)

[3] F.L. Yip et al., Physical review A **81**, 063419 (2010)

A 21.2 Tue 16:00 Empore Lichthof

Photoelectrons below the low-energy structure — •Elias Diesen, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS, Dresden, Germany

Only recently the LES was discovered, a pronounced structure in the low energy photoelectron spectrum resulting from the interaction with a high intensity infrared laser pulse [1]. As shown in [2,3], the LES can be understood classically as an energy bunching effect due to the Coulomb field of the parent ion in so-called soft recollisions. Motivated by new experimental results [4,5] we have investigated the dynamics very close to threshold which reveals a rich structure of the spectrum below the LES.

[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] Wu et al, Phys. Rev. Lett. 109, 043001 (2012)
[5] Moshammer, private communication

A 21.3 Tue 16:00 Empore Lichthof

The time-dependent restricted active space Configuration Interaction method for the photoionization of many-electron atoms — David Hochstuhl, •Christopher Hinz, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15 24098 Kiel, Germany

We present the time-dependent restricted active space Configuration Interaction method, which was introduced in Ref. [1] to solve the time-dependent Schrödinger equation for many-electron atoms, and particularly apply it to the treatment of photoionization processes in atoms. We proof the applicability of the method by calculating the photoionization cross sections of Helium and Beryllium. Further, we consider the time-delay in the photoionization from the 2s and 2p shell of neon [2] and apply a correlated and explicitly time-dependent treatment for its simulation.

[1] D. Hochstuhl, M. Bonitz, Phys. Rev. A **86**, 053424 (2012)
[2] Schultze et al., Science, **328**, 1658 (2010)

A 21.4 Tue 16:00 Empore Lichthof

The influence of electron-electron interaction on localization effects in microwave-driven helium — •Felix Jörder, Markus Heinrich, Klaus Zimmermann, Alberto Rodrigues, and Andreas Buchleitner — Physikalisches Institut, Uni Freiburg, Deutschland

The driven helium atom defines a paradigmatic scenario of a fragmenting quantum system, characterized by high spectral densities and decay channels into multiple continua. The microwave-induced excitation process of helium Rydberg atoms is retarded by dynamical localization effects, leading to strongly reduced multiphoton decay rates. We present numerical simulations of this process within a collinear model, tuning the impact of the interelectronic repulsion by varying the initial energies of both electrons and the spatial configuration of electrons and nucleus.

A 21.5 Tue 16:00 Empore Lichthof

Vergleich von Rydbergionisation von Yb in Hoch- und Niederspannungsmassenseparatoren — •Fabian Schneider[1], Charlotte Andersson[2], Dag Hanstorp[2], Tobias Kron[1], Nils Odebo Länk[2], Johanna Olsson[2], Sven Richter[1], Johannes Rossnagel[1] und Klaus Wendt[1] — [1]Institut für Physik, Universität Mainz — [2]Department of Physics, University of Gothenburg

Die Resonanzionisationsspektroskopie bietet eine sehr effiziente Methode zur Erzeugung von elementreinen Ionenstrahlen. Die Entwicklung von Anregungsschemata für On-Line-Ionenquellen, die üblicherweise eine Beschleunigung der Ionen auf 30. . . 60 kV aufweisen, wird dabei häufig an kompakten und betriebsgünstigen Apparaturen mit niedriger Beschleunigungsspannung durchgeführt. Dies beeinflusst die resonante Anregung im Allgemeinen nicht wesentlich.

Unterscheide in den Anregungsspektren der Ionisation von Ytterbium über Rydbergzustände bei Verwendung einer Ionenquelle mit Nieder- und Hochspannungsbeschleunigung wurden untersucht. Aufgrund identischer Ionisationsöfen sind diese nur durch den unterschiedlich starken Eingriff des Extraktionsfeldes in den Ofen zu erklären.

A 21.6 Tue 16:00 Empore Lichthof

Disentanglement of different excitation and decay pathways in the O 1s shape-resonance region of CO — •R. Püttner[1], D. Ceolin[2], O. Travnikova[2], J. Palaudoux[3], C. Miron[3], M. Hoshino[4], H. Kato[4], H. Tanaka[4], Y. Tamenori[5], C. C. Wang[6], K. Ueda[6], and M. N. Piancastelli[3,7] — [1]Freie Universität Berlin, Germany — [2]Synchrotron SOLEIL, Gif-sur-Yvette, France — [3]Universite Pierre et Marie Curie, Paris, France — [4]Sophia University, Tokyo, Japan — [5]Japan Synchrotron Radiation Research Institute, Hyogo, Japan — [6]Tohoku University, Sendai, Japan — [7]Uppsala University, Sweden

Auger spectra of CO subsequent to O 1s ionization with 549.85 eV-photons, i.e. on top of the shape resonance, are presented. These spectra are compared with the normal Auger spectrum recorded at a photon energy well above the shape resonance revealing distinct differences. In particular, in the energy region of the O $1s^{-1} \rightarrow b^1\Pi$ and O $1s^{-1} \rightarrow a^1\Sigma^+$ Auger transitions additional narrow lines are found in the spectra.

In a detailed fit analysis of the spectra based on the approach presented in Ref. [1] it was found that distortions caused by post-collision interaction are absent. This identifies the additional lines as caused by resonant Auger processes. In addition, the angular distribution of these lines was investigated. From the analysis the resonant Auger decays could be assigned to transitions from the doubly excited state O $1s^{-1}4\sigma^{-1}2\pi3l\sigma$ to the excited state $4\sigma^{-2}3l\sigma$ of CO^+ with l = s or p.

[1] R. Püttner et al., Chem. Phys. Lett. **445**, 6 (2007).

A 22: Poster: Interaction with strong or short laser pulses

Time: Tuesday 16:00–18:30 Location: Empore Lichthof

A 22.1 Tue 16:00 Empore Lichthof

Trap-Assisted Studies at High-Intensity Lasers — •Manuel Vogel[1,2], Wolfgang Quint[2,3], Gerhard Paulus[4,5], and Thomas Stöhlker[2,3,4] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt — [3]Physikalisches Institut, Ruprecht Karls-Universität Heidelberg, 69120 Heidelberg — [4]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, 07743 Jena — [5]Helmholtz-Institut Jena, 07743 Jena

We present a Penning trap experiment dedicated to studies with atomic and molecular ions in extreme laser fields. Within this experiment, trap-specific manipulation techniques allow control over the stored particles' localization and spatial density on a high level. It is possible to select and prepare well-defined particle ensembles and to control the laser-particle interaction. 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 non-linear processes such as multiphoton ionization of atoms, singly-, and particularly highly-charged ions.

A 22.2 Tue 16:00 Empore Lichthof

Spin Dynamics in Tunnel Ionization — •Enderalp Yakaboylu[1], Michael Klaiber[1], Carsten Müller[2], Heiko Bauke[1], and Karen Z. Hatsagortsyan[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institut für Theoretische Physik I, Heinrich-Heine Universität Düsseldorf, Universitätsstrasse 1, 40225 Düsseldorf, Germany

Spin effects at above-threshold ionization of hydrogen-like highly-charged ions in a laser field are investigated. The spin-resolved ionization rates are calculated employing the relativistic standard strong-field approximation (SFA) and a modified Coulomb-corrected SFA. Analytical expressions for the spin-resolved ionization rates are obtained and the scaling laws for the spin asymmetry and spin-flip parameters are derived. An intuitive explanation for the spin effects is given. It is shown that the intuitive picture supports the results for the spin effects obtained in the modified Coulomb-corrected SFA where the impact of the laser field on the electron spin evolution in the bound state is taken into account.

A 22.3 Tue 16:00 Empore Lichthof

High-harmonic spectra of molecular hydrogen H_2 — •Johann Förster, Yulian V. Vanne, and Alejandro Saenz — Institut für Physik, Humboldt-Universität zu Berlin, Germany

High-harmonic spectra of molecules are of steadily growing interest. However, full-dimensional theoretical *ab-initio* high-harmonic spectra of even the simplest multi-electron molecule H_2 have (even for fixed nuclei) - to our knowledge - not yet been reported. The approach developed in our group [1-3] allows us to solve the time-dependent Schrödinger equation of the two-electron problem with a fixed inter-nuclear distance in full dimensionality. This includes an arbitrary alignment of the molecule. Therefore, it is possible to examine how well widely used models work out in "reality" and how the expected structure (plateau, cutoff, etc.) is influenced by the use of spectral filters. We present high-harmonic spectra of H_2 generated by ultrashort linear polarized laser pulses for different orientations of the laser polarization with respect to the molecular axis. Effects like the minimum in the high-harmonic spectra of "two-dimensional H_2" [4] are thus reinvestigated in full dimensionality. Additionally, we compare our results with the ones obtained if we "turn on" the widely used single-active-electron approximation.

[1] Y.V. Vanne and A. Saenz, *J. Phys. B* **37**, 4101 (2004).
[2] Y.V. Vanne and A. Saenz, *J. Mod. Opt.* **55**, 2665 (2008).
[3] Y.V. Vanne and A. Saenz, *Phys. Rev. A* **82**, 011403(R) (2010).
[4] M. Lein *et al.*, *Phys. Rev. Lett.* **88**, 183903 (2002).

A 22.4 Tue 16:00 Empore Lichthof

Multiple Ionization of Fullerenes in Intense XFEL Pulses — •Abraham Camacho Garibay, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS Dresden, Germany

Ultra-intense ultra-short pulses, as provided from XFEL sources, allow the study of many-body dynamics in molecules and clusters. In the case of fullerenes, when irradiated by photons with energy well above the ionization threshold, many electrons are removed, creating a Coulombic potential in the fullerene. For the current state of intensities, we find that this process is carried on in a sequential fashion. Electron spectra differ qualitatively from low-intensity spectra as measured with synchrotrons. Emerging plateaus can be understand by means of simple model.

A 22.5 Tue 16:00 Empore Lichthof

Comparison of the carrier-envelope phase dependence of strong-field photoemission from atomic Xenon and a sharp metal tip — Lothar Maisenbacher[1], Dominik Hoff[2], •Michael Krüger[1], Michael Förster[1], A. Max Sayler[2], Gerhard G. Paulus[2], and Peter Hommelhoff[1,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching bei München — [2]Institut für Optik und Quantenelektronik and Helmholtz-Institut Jena, 07743 Jena — [3]Universität Erlangen-Nürnberg, 91058 Erlangen

The carrier-envelope phase (CEP) dependence of strong-field photoionization is a powerful tool to understand electron dynamics on ångström and attosecond scales. Recently, photoemission from metal nanotips has also been shown to be highly sensitive to the CEP [1]. The solid-state material response leads to a strongly enhanced near-field that is phase-shifted with respect to the incident field. So far, it was possible to assign the CEP only by comparison to theory. Here we present a direct comparison of the CEP dependence of photoemission from atomic Xenon and a metal nanotip employing a phase-tagging scheme [2]. We are able to characterize the full dielectric response of different nanotips for the first time, which is of high interest in the emerging field of nano-optics. Moreover, the nanotip represents an ideal electric field sensor due to its size. By scanning through the focal spot of a Gaussian beam it is possible to map out the spatial phase and intensity of such a beam.

[1] M. Krüger, M. Schenk, P. Hommelhoff, *Nature* **475**, 78 (2011).
[2] T. Rathje et al., *J. Phys. B: AMOP* **45**, 074003 (2012).

A 22.6 Tue 16:00 Empore Lichthof

Time evolution of the vacuum – pair production in high intensity laser fields — •Anton Wöllert, Heiko Bauke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Interaction between the vacuum and high intensity lasers will lead to new possibilities in high-field physics [1–2]. We present numerical ab initio studies for time evolution of the vacuum state into multiple pair states. The high intensity laser field of two counter-propagating beams is treated classically and in the non-perturbative regime ($E_0/\omega \sim 1$). In this regime, the time needed by an electron to become relativistic in presence of a static field E_0 is of same order as the period of the laser field. Pair state probabilities as well as correlations are investigated in real-time depending on polarization and field strength.

[1] The Extreme Light Infrastructure, http://www.extreme-light-infrastructure.eu
[2] A. Di Piazza *et al.*, Rev. Mod. Phys. **84**, 1177 (2012)

A 22.7 Tue 16:00 Empore Lichthof

Comparison of atomic photoelectron spectra obtained using the strong field and Coulomb-Volkov approximations with ab initio TDSE results — •Mohammad Adel Almajid and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

We investigate the agreement between photoelectron spectra for intense laser-atom interaction obtained using the strong field approximation (SFA) with or without Coulomb-Volkov approximation (CVA) and the results from the ab initio solution of the time-dependent Schrödinger equation (TDSE). In particular, we calculate the electron momentum distributions following strong-field ionization of atomic hydrogen by few-cycle, linearly polarized laser pulses. Within the plain-SFA the Coulomb potential is neglected after the emission of the photoelectron. A good agreement with the TDSE results is obtained only for the most energetic, rescattered photoelectrons whereas the low-energy part of the electron spectra differs significantly. For instance, the SFA is not able to reproduce the bouquet-shape patterns in the low-energy part of the photoelectron spectra, clearly visible in the TDSE results. Within the CVA the influence of the Coulomb potential on the outgoing photoelectron is accounted for in an approximate manner. In the multiphoton regime, the low-energy part of the photoelectron spectra obtained in CVA is in good agreement with the TDSE results. However, the agreement deteriorates as the tunneling regime is approached.

A 22.8 Tue 16:00 Empore Lichthof

Dense Monoenergetic Proton Beams from Chirped Laser-Plasma Interaction — •Jianxing Li[1], Benjamin J. Galow[1], Yousef I. Salamin[1,2], Zoltán Harman[1,3], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69029 Heidelberg, Germany — [2]Department of Physics, American University of Sharjah, POB 26666, Sharjah, United Arab Emirates — [3]ExtreMe Matter Institute EMMI, Planckstrasse 1, 64291 Darmstadt, Germany

Interactions of linearly and radially polarized frequency-chirped laser pulses with single protons and hydrogen gas targets are studied analytically and by means of particle-in-cell simulations, respectively. The feasibility of generating ultraintense (10^7 particles per bunch) and phase-space collimated beams of protons is demonstrated. Phase synchronization of the protons and the laser field, guaranteed by the appropriate chirping of the laser pulse, allows the particles to gain sufficient kinetic energy (around 250 MeV) required for such applications as hadron cancer therapy, from state-of-the-art laser systems of intensities of the order of 10^{21} W/cm^2.

A 22.9 Tue 16:00 Empore Lichthof

Electron-Positron Pair Generation in a Bichromatic Laser Field — •Martin Josef Alexander Jansen and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

The creation of an electron-positron pair resulting from the collision of photons was first considered by Breit and Wheeler [1] and experimentally observed at SLAC [2]. We regard the case of a bichromatic laser field, where quantum inferences can be expected [3]. In our analysis, the generated particles are described by Volkov solutions of the corresponding Klein-Gordon Equation. We discuss effects related to the relative phase of the two fields as well as interference effects between different absorption channels.

[1] G. Breit and J.A. Wheeler, Phys. Rev. 46, 1087 (1934)
[2] D.L. Burke et al., Phys. Rev. Lett. 79, 1626 (1997)
[3] N.B. Narozhny and M.S. Fofanov, J. Exp. Theor. Phys. 90, 415 (2000)

A 22.10 Tue 16:00 Empore Lichthof

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].

In this contribution, we study a generalization of the Kapitza-Dirac effect to the case of a bifrequent light field, where quantum interferences can be expected. To this end, we solve the Schrödinger equation numerically with a ponderomotive potential. Besides, a mathematical model in reduced dimensionality for the transition amplitude is presented. We demonstrate distinct interference signatures for various commensurate frequency ratios.

[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)

A 22.11 Tue 16:00 Empore Lichthof

High-resolution electron momentum spectra for single ionization of atoms in strong laser fields for various wavelengths — •Lutz Fechner[1], Nicolas Camus[1], Andreas Krupp[1], Thomas Pfeifer[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Using a Reaction Microscope we studied single ionization of noble-gas atoms and small molecules in femtosecond laser pulses over a large range of intensities and wavelengths. By means of an optical parametric amplifier (OPA) that is pumped by 25 fs laser pulses (at 800 nm) we generate intense pulses ($> 10^{13}$ W/cm^2) with central wavelengths covering the range from 350 to 1300 nm. First results show unexpected and pronounced target specific features in the momentum distributions especially in the low energy region (up to 0.5 eV). The appearance of these "low-energy-rings" can be attributed to the decay highly excited states, which are populated during the laser pulse and autoionize long after. As a next step, and to further probe the dynamics of highly excited electronic states, we intend to perform two-color pump-probe experiments using the variable wavelength output of the OPA as a pump and the 800 nm pulse as probe (cf. poster A 159).

A 22.12 Tue 16:00 Empore Lichthof

Two-colour pump-probe experiments on single ionization of atoms in strong laser fields — •Andreas Krupp[1], Lutz Fechner[1], Nicolas Camus[1], Thomas Pfeifer[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

In order to study the ultra-fast dynamics of atoms and molecules we apply a two colour pump-probe scheme with intense ($> 10^{13}$ W/cm^2) 25 fs laser pulses. After splitting the output of an amplified laser system at 800 nm central wavelength we sent one part into an optical parametric amplifier (OPA) to generate pulses in the wavelength range of 350 to 1300 nm. With these we induce dynamics probed after variable time delays with the 800 nm pulses. A Reaction Microscope (REMI) provides us with kinematically complete data. Results obtained in experiments on noble gases with single pulses from the OPA showed unexpected and pronounced target specific features in the electron momentum distributions especially in the low energy region (cf. poster A 158). The new setup can help to uncover the dynamics underlying these features.

A 22.13 Tue 16:00 Empore Lichthof

Solving the Kohn-Sham equations for matter in high-intensity laser fields — •Volker Mosert and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

Solving for the many-body wave function of the interacting electrons via the time-dependent Schrödinger equation is prohibitive. Instead, in time-dependent density functional theory the problem is transformed to a set of one-particle, nonlinear Schrödinger-like equations, the time-dependent Kohn-Sham (KS) scheme. However, solving one-particle Schrödinger equations for strong-field interactions is still very demanding because large simulation volumes due to the extensive electron excursions are required. Pseudo potentials are commonly used in order to avoid dealing explicitly with inner electrons and the need to resolve the small spatial scale set by them. However, we found that a proper description of the inner electrons is essential to obtain, e.g., the correct ionization rate. Moreover, inner electrons are directly involved in the dynamics if the interaction with short-wavelength (e.g., FEL) radiation is to be simulated. We implement a method which can handle the large simulation volumes necessary for strong-field simulations without resorting to pseudo potentials. For this purpose we use an adaptive resolution strategy to handle the Coulomb potentials close to the ionic centers via a coordinate transformation in our finite difference approximation of the KS-Hamiltonian. An important goal of our work is high scalability with respect to the number of grid points. We show that the application of multi-grid techniques to the discretized KS equations leads to very good scaling properties.

A 22.14 Tue 16:00 Empore Lichthof

Combining a reaction microscope with a high repetition laser system — •Sascha Birkner, Federico Furch, Claus Peter Schulz, and Marc J.J. Vrakking — Max Born Institute, Max-Born-Str. 2a, 12489 Berlin, Germany

Strong field and attosecond induced electron dynamics and electron localisation in small molecules, e.g. H_2, have been studied in recent years [1,2]. In these experiments the energy and angular distribution of the ions from the laser induced dissociative ionisation have been measured. To study these type of photo induced reactions in more detail we have built a reaction microscope which enables experiments to measure the energy and angular distributions of ions and electrons in coincidence. Coincidence experiments typically have low data rates and thus require long data acquisition times. To overcome this problem we have combined our setup with a high repetition 400 kHz laser system delivering carrier envelope phase (CEP) stable sub-10 fs pulses with pulse energies up to 4 μJ. With tight focusing an intensity of $> 10^{14}$ W/cm^2 can be reached. First data on strong field ionisation will be presented.

[1] M. F. Kling, *et al.*, Science **312**, 246 (2006).
[2] G. Sansone, *et al.*, Nature **465**, 763 (2010).

A 22.15 Tue 16:00 Empore Lichthof

Single shot scattering and ion spectroscopy of silver clusters — •Ramona Rothfischer[1], Tais Gorkhover[1], Leonie Flückiger[1], Daniela Rupp[1], Mario Sauppe[1], Ingo Barke[2], Stephan Bartling[2], Hannes Hartmann[2], Karl-Heinz Meiwes-Broer[2], and Thomas Möller[1] — [1]TU Berlin — [2]Universität Rostock

Cluster birdge the gap between atomic and condensed matter. As size scalable particles in the gas phase, they are ideal model systems for analyzing of the interaction of intense laser pulses with matter. A new type of experiments, simultaneous single cluster imaging and ion spectroscopy at free-electron lasers, gives access to processes and mechanisms of this interaction on different timescales[1]. A new setup with a combination of a light scattering detector and ion spectroscopy measurement was designed which uses a table-top picosecond-UV-laser system as light source. In first measurements on large silver clusters using only ion spectroscopy, charge states up to 5+ were observed and single particle ion spectra could be achieved. The setup will be discussed and first results will be presented.

[1] T. Gorkhover et al., Phys. Rev. Lett 108, 245005(2012)

A 23: Dissertation Prize Symposium

Time: Wednesday 11:00–13:00 Location: E 415

Invited Talk A 23.1 Wed 11:00 E 415

Photonic Quantum Computing — •Stefanie Barz — Vienna Center for Quantum Science and Technology, Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria

Quantum physics has revolutionized our understanding of information processing and enables computational speed-ups that are unattainable using classical computers. In this talk I will present a series of experiments in the field of photonic quantum computing.

The first experiment is in the field of photonic state engineering and realizes the generation of heralded polarization-entangled photon pairs. It overcomes the limited applicability of photon-based schemes for quantum information processing tasks, which arises from the probabilistic nature of photon generation.

The second experiment uses polarization-entangled photonic qubits to implement “blind quantum computing,” a new concept in quantum computing. Blind quantum computing enables a nearly-classical client to access the resources of a more computationally-powerful quantum server without divulging the content of the requested computation.

Finally, the concept of blind quantum computing is applied to the field of verification. A new method is developed and experimentally demonstrated, which verifies the entangling capabilities of a quantum computer based on a blind Bell test.

Invited Talk A 23.2 Wed 11:30 E 415

Comparative Studies on some Blackcurrant Odorants and Fruit Esters using a Combination of Microwave Spectroscopy and Quantum Chemical Calculations — •Halima Mouhib — IPC, RWTH Aachen University, Aachen, Germany

Using a combination of molecular beam Fourier transform microwave spectroscopy (MB-FTMW) and different quantum chemical calculations, highly accurate structural information on the lowest energy conformers of molecules can be obtained. This kind of information is especially needed, when a large number of conformations make it difficult to decide which is the lowest in energy.

During the first part of my PhD thesis, I investigated the structures of valerianic ethyl ester (ethyl isovalerate) and its structural isomers ethyl pivalate, ethyl valerate, and 2-methyl ethyl butyrate. The investigated fruit esters turned out to possess large amplitude motions, causing difficulties for the prediction of the theoretical geometries at different levels of theory. The correct geometries could therefore not be predicted properly using calculations at the MP2/6-311++G(d,p) level. Here, the experimental data were crucial to validate the results obtained from quantum chemical calculations and yielded new insight into the structure and dynamics of these small esters. In the second part, the same technique was applied to investigate different types of blackcurrant odorants. Although microwave spectroscopy has recently moved towards solving the structures of sizeable molecules, this was the first approach to determine the gas phase structure of odorants and show the usefulness of this method for structure-odor correlations.

Invited Talk A 23.3 Wed 12:00 E 415

The Standard Model under Extreme Conditions: The *g*-Factor of Highly Charged Ions — •Sven Sturm — Max-Planck Institute for Nuclear Research, Heidelberg, Germany

A single electron, bound to a heavy nucleus, is exposed to electric fields of up to 10^{16} V /cm, the strongest fields obtainable in the laboratory. We have addressed the question whether fundamental symmetries and interactions, described by Quantum Electrodynamics (QED), are still valid under these conditions. To this end, we have developed a Penning trap system that allowed us to store a single, hydrogenlike $^{28}Si^{13+}$ ion for several months at an extremely low restgas pressure of 10^{-16} mbar and determine its magnetic moment with an unprecedented relative accuracy of a few parts in 10^{10}. The comparison of the hereby determined value of the g-factor of the bound electron with the similarly precise prediction of theory yielded the most stringent test of QED in strong fields, probing for the first time higher-order contributions to the two-loop QED of bound states. Beyond that, the development of a novel, phase-sensitive detection method for the eigenfrequencies of the ion has enabled a breakthrough in the attainable precision of Penning trap experiments and allowed a further improvement of the precision of the g-factor measurement by an order of magnitude to a few parts in 10^{11}. The developed method paves the way towards a determination of fundamental constants as e.g. the mass of the electron, with unrivaled precision.

Invited Talk A 23.4 Wed 12:30 E 415

Entanglement and Interference of Identical Particles — •Malte Christopher Tichy — Physikalisches Institut, Universität Freiburg, Germany — Department of Physics and Astronomy, University of Aarhus, Denmark

Entanglement and the indistinguishability of identical particles pose a great challenge to our intuition, owing to the lack of classical counterparts. In particular, the connection between these phenomena is often elusive, especially for many particles. Here, we trace back correlated behavior, such as many-particle interference and entanglement, to the permutation symmetry of few and many identical particles.

We first restrict ourselves to two particles, comparing the classical behavior of distinguishable particles to the quantum dynamics of identical bosons and fermions. Bunching of bosons is opposed to anti-bunching of fermions, but both species are equivalent sources for bipartite entanglement. The realms of two indistinguishable and distinguishable particles are connected by a monotonic quantum-to-classical transition. As we move to larger systems, any attempt to understand many particles via the two-particle paradigm fails: In contrast to two-particle bunching and anti-bunching, the same correlations can be exhibited by bosons and fermions, and many bosons generate more multipartite entangled states than many fermions. Finally, the many-particle quantum-to-classical transition features experimentally confirmed non-monotonic structures. While the same physical principles govern small and large systems, it is the intrinsic complexity of many-particle interference that makes more particles behave differently.

A 24: Ultra-cold atoms, ions and BEC IV (with Q)

Time: Wednesday 11:00–12:30 Location: F 428

A 24.1 Wed 11:00 F 428

Mott-insulator state of ultracold atoms in optical lattices: comparison of exact numerical results with controlled approximations — •Konstantin Krutitsky, Friedemann Queisser, Patrick Navez, and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany

A wide class of phenomena for ultra-cold atoms in deep optical lattices is well described by the Bose-Hubbard model. Using exact numerical and approximate analytical methods, we have studied the ground-state energy, probabilities of the occupation numbers of the individual lattice sites, two-point correlation functions, and the excitation spectrum, in the Mott-insulator regime. Exact results are obtained for one-dimensional lattices up to 14 sites and for two-dimensional lattices of 3x3 sites. They are compared with the fourth order expansion in the ratio of the tunneling rate J and the interaction constant U valid in an arbitrary dimensions and the inverse coordination number 1/Z valid for arbitrary interaction strengths. The zeroth order in 1/Z is equivalent to the Gutzwiller mean field [3]. In one dimension, numerical data nearly coincide with perturbation theory in J/U whereas the first-order results in 1/Z deviate a bit for increasing J. In two dimensions, the 1/Z expansion is already superior to the J/U expansion, and should become even better in three and higher dimensions.

[1] J.K.Freericks and H.Monien, Phys.Rev.B 53, 2691 (1996).

[2] F.Queisser, K.V.Krutitsky, P.Navez, R.Schützhold, arXiv:1203.2164.

[3] S.Sachdev, Quantum phase transitions, Cambridge University Press, 2001.

A 24.2 Wed 11:15 F 428

Density waves in dipolar Bose-Einstein condensates — •Alexandru Nicolin — Horia Hulubei National Institute for Physics and Nuclear Engineering, Magurele, Romania

Density waves in cigar-shaped dipolar Bose-Einstein condensates are analysed by variational means and we show analytically how the dipole-dipole interaction between the atoms generates a roton-maxon excitation spectrum. A simple model is used to derive the effective equations which describe the emergence of the density waves.

A 24.3 Wed 11:30 F 428

Mode Entanglement in Systems of Massive, Indistinguishable Bosons — •Felix Binder[1], Libby Heaney[2], Dieter Jaksch[1,2], and Vlatko Vedral[1,2,3] — [1]Clarendon Laboratory, Department of Physics, University of Oxford, Parks Road, Oxford OX1 3PU, UK — [2]Center for Quantum Technologies, National University of Singapore, 3 Science Drive2, 117543, Singapore — [3]Department of Physics, National University of Singapore, 2 Science Drive 3, 117542, Singapore

The standard notion of entanglement breaks down in systems of indistinguishable particles due to a loss of the tensor product structure of Hilbert space. Nevertheless, second quantisation allows us to describe entanglement between spatial modes which arises naturally in Bose-Einstein condensates or optical lattices.

Under particle-number superselection rules the only basis for the description of these systems is the mode-occupation basis, where it is possible to study and quantise correlations, for example via their relation to the visibility of interference fringes and the single-particle reduced density matrix.

In order to genuinely detect or harness entanglement, however, it is ultimately necessary to locally overcome the particle-number superselection rules by providing a suitable reference frame. It will be shown how this is possible using a BEC reservoir as the reference frame and a proposed implementation scheme for an optical lattice system will be described. This scheme could be used to experimentally test entanglement between modes of massive, indistinguishable bosons for the first time.

A 24.4 Wed 11:45 F 428

Dynamics of Bose-Einstein condensates in $\mathcal{PT}$-symmetric double-well potentials — •Daniel Haag, Dennis Dast, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

The study of non-Hermitian Hamiltonians has attracted large attention in recent years. A special class of such systems are described by non-Hermitian but $\mathcal{PT}$-symmetric Hamiltonians that can have entirely real spectra. In general, non-Hermitian systems do not conserve the norm of a wave packet, which has a severe effect on the dynamics of nonlinear systems such as Bose-Einstein condensates described by the Gross-Pitaevskii equation. We investigate the stability of the eigenstates and solve the time-dependent GPE for a $\mathcal{PT}$-symmetric double well, where in one well particles are removed while particles are coherently injected into the other.

A 24.5 Wed 12:00 F 428

Superfluidity with disorder in a quantum gas thin film — •Sebastian Krinner, David Stadler, Jakob Meineke, Jean-Philippe Brantut, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Switzerland

We investigate the properties of a strongly interacting, superfluid gas of $^6Li_2$ Feshbach molecules forming a thin film confined in a quasi two-dimensional channel with a tunable random potential, creating a microscopic disorder. We measure the atomic current and extract the resistance of the film in a two-terminal configuration, and identify a superfluid state at low disorder strength, which evolves into a normal, poorly conducting state for strong disorder. The transition takes place when the chemical potential reaches the percolation threshold of the disorder.

The evolution of the conduction properties contrasts with the smooth behavior of the density and compressibility across the transition, measured in-situ at equilibrium. These features suggest the emergence of a glass-like phase at strong disorder.

A 24.6 Wed 12:15 F 428

Three-body recombination in a quasi-two-dimensional quantum gas — •Bo Huang[1], Alessandro Zenesini[1], Martin Berninger[1], Hanns-Christoph Nägerl[1], Francesca Ferlaino[1], and Rudolf Grimm[1,2] — [1]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation (IQOQI), Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

Collisional properties of interacting particles can dramatically change when the dimensionality of the system is reduced. One intriguing example is the disappearance of the weakly bound trimers known as Efimov states in two dimensions. Many open questions remain about the details of the crossover from three to two dimensions and how the Efimov-related three-body recombination losses are affected. We use ultracold cesium atoms trapped tightly in a harmonic potential along one spatial direction to realize a quasi-two-dimensional system with tunable confinement and tunable interactions. In our latest results, we succeed to trace a smooth transition of the three-body recombination rate from a three-dimensional to a nearly two-dimensional system, in good agreement with recent theoretical models.

A 25: Precision spectroscopy of atoms and ions V (with Q)

Time: Wednesday 11:00–12:30 Location: B 302

A 25.1 Wed 11:00 B 302

The Baryon Antibaryon Symmetry Experiment BASE — •Christian Smorra[1], Kurt Franke[2], Georg Schneider[3], Klaus Blaum[2,4], Andreas Mooser[3,5], Wolfgang Quint[4,6], Jochen Walz[3,5], Yasunori Yamazaki[1], and Stefan Ulmer[1] — [1]RIKEN Advanced Science Institute, Hirosawa, Wako, Saitama 351-0198, Japan — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany — [3]Institut für Physik, Johannes-Gutenberg-Universität Mainz, D-55099 Mainz, Germany — [4]Ruprecht-Karls-Universität Heidelberg, D-69047 Heidelberg, Germany — [5]Helmholtz Institut Mainz, D-55099 Mainz, Germany — [6]GSI-Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany

The Baryon Antibaryon Symmetry Experiment (BASE) planned at the Antiproton Decelerator (AD) at CERN is dedicated to compare fundamental properties of proton and antiproton with high precision. Such matter/antimatter comparisons are sensitive tests of the CPT theorem. As one of these quantities, the g-factors of both particles are currently only compared with a moderate precision of $\delta g/g = 3\times10^{-3}$, limited by the antiproton value. Recently, we succeeded in measuring the proton g-factor with a relative precision of 8.9×10^{-6} using the continuous Stern-Gerlach effect on a single proton in a cryogenic Penning trap. Using the same method on a single antiproton, we aim for a 100-fold improved CPT test with baryons. By applying the so-called double-trap technique, BASE ultimately aims for a relative precision of 10^{-9} or better, resulting at least in a factor of one million improved CPT test. In this talk, the BASE experiment will be presented.

A 25.2 Wed 11:15 B 302

BASE : Single Particle Detector Systems — •Kurt Franke[1], Christian Smorra[2], Georg Schneider[3], Klaus Blaum[1,4], Andreas Mooser[3,5], Wolfgang Quint[3,6], Jochen Walz[3,5], Yasunori Yamazaki[2], and Stefan Ulmer[2] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany — [2]RIKEN Advanced Science Institute, Hirosawa, Wako, Saitama 351-0198, Japan — [3]Institut für Physik, Johannes-Gutenberg-Universität Mainz, D-55099 Mainz, Germany — [4]Ruprecht-Karls-Universität Heidelberg, D-69047 Heidelberg, Germany — [5]Helmholtz Institut Mainz, D-55099 Mainz, Germany — [6]GSI-Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany

The BASE experiment planned at the Antiproton Decelerator (AD) at CERN aims at a high-precision measurement of the magnetic moment of the antiproton. The heart of the apparatus consists of a stack of four cylindrical Penning traps. These traps will be used for catching and storing of antiprotons from the AD, and for the magnetic moment measurement, which will be carried out by application of the continuous Stern-Gerlach effect. Six cryogenic single particle detection systems, each consisting of a high-Q resonator and a low-noise amplifier, are planned and currently under construction. These detection circuits will be used for precision measurements of the particle*s eigenfrequencies, giving direct access to the particle*s fundamental properties. In this talk, an overview of the detection systems and status of the construction and characterization will be presented.

A 25.3 Wed 11:30 B 302

Highly charged ions for mass determinations of short-lived isotopes — Martin C. Simon[1], Dieter Frekers[2], •Vanessa V. Simon[1,3,4], José R. Crespo López-Urrutia[4], and Jens Dilling[1] — [1]TRIUMF, Vancouver, Canada — [2]Westfälische Wilhelms-Universität, Münster, Germany — [3]Ruprecht-Karls-Universität Heidelberg, Germany — [4]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

TRIUMF*s Ion Trap for Atomic and Nuclear science (TITAN) is the only high precision Penning trap mass measurement setup coupled to a rare isotope facility using charge breeding of short-lived nuclides for accurate mass determinations [1,2].

Experiments on isotopes with half-lives as low as 65 ms, such as 74-Rb [3], and in charge states as high as 22+ have been carried out. Results on Ge and Ga relevant to neutrino-detector flux calibrations will be reported. Future plans include a new electron beam ion source for re-acceleration applications [4].

[1] J. Dilling, et al. Int. J. Mass Spectrosc. **251**, 198 (2006).
[2] M. Froese, et al., Hyperfine Interact. **173**, 85 (2006)
[3] S. Ettenauer et al., Phys. Rev. Lett. **107**, 272501 (2011)
[4] M. C. Simon, et al., Rev. Sci. Instrum. **83**, 02A912 (2012)

A 25.4 Wed 11:45 B 302

Pair production processes by nuclear decay and in muonic atoms — •Nikolay A. Belov[1] and Zoltán Harman[1,2] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]ExtreMe Matter Institute (EMMI), Planckstraße 1, 64291 Darmstadt, Germany

The pair production process by γ-emission of nuclei has been investigated so far both theoretically and experimentally. But, in all works only the production of a free electron and positron was considered. The case when an electron is "born" in a bound state of atom has been neglected as a relatively small effect. We investigate this bound-free pair conversion process for different multipolarities of nuclear γ decay. We use a relativistic description of the electron and positron wave functions as it is necessary for heavy elements. It appears that the contribution of this bound-free process for bare heavy ions at low γ-energies close to $2m_ec^2$ gives a contribution comparable to or stronger than the free-free process and that it may be the dominant electromagnetic decay channel in case of E0 nuclear transitions.

We also investigate the similar bound-free pair production process in electromagnetic muonic transitions in muonic atoms. In this case, all matrix elements can be calculated exactly. Photon energies have the same order as the γ-energies in the nuclear case, so one expects a similar dominance of the bound-free process over the free-free process at low transition energies (for transitions between excited muonic states). Our calculations have confirmed this behaviour.

A 25.5 Wed 12:00 B 302

Quantum Logic Enabled Test of Discrete Symmetries — •Timko Dubielzig[1], Malte Niemann[1], Anna-Greta Paschke[1], Martina Carsjens[1,2], Matthias Kohnen[2,1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik and Centre for Quantum Engineering and Space Time Research (QUEST), Leibniz Universität Hannover — [2]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, which has not been realized yet at the single-shot level, as would be desirable for an accurate and competitive g-factor CPT test. We describe concepts and simulations for an experiment which will implement single-shot fast readout using quantum logic operations according to the proposal by Heinzen and Wineland [3]. We discuss trapping geometries, concepts for single (anti-)proton rf sideband control, and for ground state cooling of the atomic quantum logic ion at fields exceeding 1 Tesla in a miniaturized Penning trap.

[1] S.Ulmer et al., Phys. Rev. Let. **106**, 253001 (2011)
[2] N. Guise et al., Phys. Rev. Let. **104**, 143001 (2010)
[3] Heinzen and Wineland, PRA **42**, 2977 (1990)

A 25.6 Wed 12:15 B 302

Upgrade des optischen Nachweises des TRIGA-LASER Experiments und Charakterisierung gebunchter Ionenstrahlen — •C. Gorges[1], T. Beyer[2], K. Blaum[2], Ch. E. Düllmann[1,3,4], K. Eberhardt[1,4], M. Eibach[2,5], N. Frömmgen[1], Ch. Geppert[1,4,6], M. Hammen[1,6], S. Kaufmann[1], A. Krieger[1,4,6], S. Nagy[2], W. Nörtershäuser[1,4,6], D. Renisch[1], E. Will[1] und die TRIGA-SPEC Kollaboration[1] — [1]Institut für Kernchemie, Universität Mainz — [2]MPI-K Heidelberg — [3]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [4]HIM Mainz — [5]Fakultät für Physik und Astronomie,Universität Heidelberg — [6]TU Darmstadt

Ziel des TRIGA-SPEC Experimentes am Forschungsreaktor TRIGA Mainz ist es, Massenspektrometrie und kollineare Laserspektroskopie an kurzlebigen Isotopen durchzuführen, die durch die neutroneninduzierte Spaltung von ^{235}U, ^{239}Pu oder ^{249}Cf produziert und in einer online Ionenquelle ionisiert werden[1]. Zum Kühlen und Akkumulieren der Ionen wird ein gasgefüllter RF-Quadrupol (RFQ) eingesetzt. In der Laserspektroskopie ist die Optimierung des Signal/Rausch-Verhältnisses essentiell. Die Weiterentwicklung der optischen Nachweisregion bewirkt eine Erhöhung der Signalrate und eine Unterdrückung des Laser-Streulichtuntergrunds. Durch zeitaufgelöste Messungen des Restgasleuchtens in der optischen Nachweisregion wird die zeitliche Struktur der Ionenpakete charakterisiert und der RFQ-Betrieb für online Laserspektroskopie optimiert. Erste Ergebnisse zum optischen Nachweises und zur Bunchstruktur werden präsentiert.

[1] Ketelaer et al., Nucl. Instr. Meth. A 594, 162 (2008)

A 26: Ultra-cold atoms, ions and BEC V (with Q)

Time: Wednesday 14:00–16:00 Location: B 302

Invited Talk A 26.1 Wed 14:00 B 302

Dipolar Physics with Ultracold Atomic Magnets — •Ferlaino Francesca — Institut für Experimentalphysik Universität Innsbruck Technikerstraße 25 6020 Innsbruck, Austria

We report on the production of the first Bose-Einstein condensate of erbium [1]. Erbium is a very special multi-valence-electron atom, belonging to the lanthanide series. It possesses a strongly magnetic dipolar character, a rich energy level diagram, and various isotopes, among which one has a fermionic nature. Despite the complex atomic properties of such unconventional species, we find a surprisingly simple and efficient approach to reach quantum degeneracy by means of laser cooling on a narrow-line transition and standard evaporative cooling techniques. We observe favorable scattering properties of 168Er, resulting in remarkably high evaporation efficiency and in a large number of Feshbach resonances at very low magnetic field values. We recently employed a Feshbach resonance to magnetically associate Er_2 Feshbach molecules, which are of extreme dipolar character. Our observations make Er a dream system for ultracold quantum gas experiments.

[1] K. Aikawa, A. Frisch, M. Mark, S. Baier, A. Rietzler, R. Grimm, and F. Ferlaino, Bose-Einstein Condensation of Erbium, Phys. Rev. Lett. 108, 210401 (2012).

A 26.2 Wed 14:30 B 302

Novel resonant states in three-body problem — •Maxim A. Efremov[1], Lev Plimak[1,2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik and and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, 89069 Ulm, Germany — [2]Max-Born-Institut, 12489 Berlin, Germnay

We consider the bound states of a three-body system consisting of a light particle and two heavy ones when the heavy-light short-range interaction potential has a resonance corresponding to the non-zero orbital momentum. Within the Born-Oppenheimer approach we suggest a novel method to find the effective potential between the heavy particles by a self-consistent scattering of a light particle by two heavy ones. In the case of the exact resonance in the p-wave scattering the effective potential is shown to be attractive and long-range, namely it decreases as the third power of inter-atomic distance. Moreover, the range and power of the potential, as well as the number of the bound states are determined mainly by the mass ratio of the heavy and light particles and the parameters of the heavy-light short-range potential.

A 26.3 Wed 14:45 B 302

Quantum Phases of Soft-Core Dipolar Bosons in Optical Lattices — •Sebnem Günes Söyler[1], Daniel Grimmer[2], and Barbara Capogrosso-Sansone[2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]University of Oklahoma, Norman, USA

We perform quantum Monte Carlo simulations of a system of soft-core ultracold bosonic atoms with dipolar interactions, confined in a two dimensional optical lattice. We consider long range isotropic repulsive interactions which refers to dipoles are alligned perpendicular to the plane. We calculate the ground state phase diagram for a parameter range that exhibits various solids, superfluid and supersolid phases. We also present finite temperature results and discuss the experimental feasibility of such phases.

A 26.4 Wed 15:00 B 302

Ultracold Lattice Gases with Periodically Modulated Interactions — •Akos Rapp, Xiaolong Deng, and Luis Santos — Institut für Theoretische Physik, Leibniz Universität, 30167 Hannover

We show that a time-dependent magnetic field inducing a periodically modulated scattering length may lead to interesting novel scenarios for cold gases in optical lattices, characterized by a nonlinear hopping depending on the number difference at neighboring sites. We discuss the rich physics introduced by this hopping, including pair superfluidity, exactly defect-free Mott-insulator states for finite hopping, and pure holon and doublon superfluids. We also address experimental detection, showing that the introduced nonlinear hopping may lead in harmonically trapped gases to abrupt drops in the density profile marking the interface between different superfluid regions.

A 26.5 Wed 15:15 B 302

Coherent Backscattering of Ultracold Atoms — •Fred Jendrzejewski[1,3], Kilian Müller[1], Jeremie Richard[1], Philippe Bouyer[2], Alain Aspect[1], and Vincent Josse[1] — [1]Laboratoire Charles Fabry, Palaiseau, France — [2]LP2N, Talence, France — [3]Joint Quantum Institute, Gaithersburg, USA

Quantum interference effects play a fundamental role in our understanding of quantum transport through disordered media, as it can lead to the suppression of transport, i.e. Anderson Localization. Recently it became possible to directly observe Anderson Localization with ultracold atoms. Convincing as they are, none of these experiments includes a direct evidence of the role of coherence.

For weak disorder, a first order manifestation of coherence is the phenomenon of coherent backscattering (CBS), i.e. the enhancement of the scattering probability in the backward direction, due to a quantum interference of amplitudes associated with two opposite multiple scattering paths.

In this talk, I present our work on the direct observation of such a CBS peak. Launching atoms with a well-defined momentum in a laser speckle disordered potential, we follow the progressive build up of the momentum scattering pattern, consisting of a ring associated with multiple elastic scattering, and the CBS peak in the backward direction. The observation of the CBS peak is a smoking gun of the existence of quantum coherence in quantum transport in disordered media.

A 26.6 Wed 15:30 B 302

Sympathetic cooling of OH^--ions using Rb atoms in a MOT — •Bastian Höltkemeier[1], Matthias Weidemüller[1], Thorsten Best[2], and Roland Wester[2] — [1]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Institut f. Ionenphysik und Angewandte Physik, Technikerstr. 25/3, 6020 Innsbruck

Based on previous experiments on ion-atom reactions, we present a new setup to investigate the interaction of ultracold rubidium atoms in a Dark-SPOT and mass-selected OH^--water clusters. The ions are trapped in an octupole RF-trap consisting of thin wires instead of metal rods to give maximum optical access.

As a first step we have performed numerical simulations using SimIon to investigate the possibility to sympathetically cool the OH^- ions using the ultracold rubidium atoms. These simualtions suggest, that with our trap configuration cooling by at least one order of magnitude can be achived. As an outlook we will report on the current status of the experiment and possible future applications.

A 26.7 Wed 15:45 B 302

Photoassociation near the intercombination line of ^{40}Ca — •Max Kahmann[1], Oliver Appel[1], Eberhard Tiemann[2], Fritz Riehle[1], and Uwe Sterr[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Welfengarten 1, 30167 Hannover — [2]Institut für Quatenoptik, Universität Hannover, Welfengarten 1, 30167 Hannover

We have measured for the first time photoassociation resonances in the narrow-line system $^1S_0 + {}^3P_1$. We use about 10^5 calcium atoms that are trapped and evaporatively cooled to about 1 μK in a crossed optical dipole trap at a density of 10^{13} cm^{-3}. Precisely tunable laser light is produced by offset locking a diode laser to a laser which is resonant to the atomic line. The light is applied for typically 1 s to the trapped atoms and the trap loss is observed from absorption images of the atomic cloud. In a range of up to 25 GHz below the asymptote we have observed 6 photoassociation resonances in the two molecular potentials $\Omega = 0$ and $\Omega = 1$ correlating to the $^3P_1 + {}^1S_0$ asymptote. In both the $\Omega = 0$ and 1 excited states we observe a Zeeman splitting.

A theoretical model was developed in order to describe the Zeeman splitting and the energy of the bound molecular states in both potentials. The data helps to improve our knowledge of the molecular parameters and the dispersion coefficients and allows the use of low-loss optical Feshbach resonances to manipulate the atomic scattering length.

A 27: Visualizing Ultrafast Dynamics in atoms, molecules, and clusters

Time: Wednesday 14:00–16:00 Location: E 415

Invited Talk A 27.1 Wed 14:00 E 415

Electron emission from nanospheres in strong, few-cycle laser fields — •Matthias Kling[1,2], Frederik Süssmann[1], Sergey Zherebtsov[1], Johannes Stierle[1], Jürgen Plenge[3], Eckart Rühl[3], Lennart Seifert[4], and Thomas Fennel[4] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Kansas-State University, Manhattan, KS66506, USA — [3]Freie Universität Berlin, 14195 Berlin, Germany — [4]Universität Rostock, 18051 Rostock, Germany

The interaction of nanometer sized materials with strong laser fields opens new avenues to control collective electron motion with attosecond precision and on nanometer length scales. Recent studies will be highlighted, where the electron emission from spherical nanoparticles of various dielectric and semiconducting materials in strong, few-cycle laser fields was explored. By using a beam of isolated nanoparticles, the target is replaced after every laser shot and we can explore the regime near, at and beyond the material damage threshold. The extremely short pulse duration of only a few cycles in our studies ensures that the electron dynamics responsible for the observed phenomena occurs before any nuclear dynamics. We have furthermore explored the effect of the carrier-envelope phase on the electron emission and studied propagation effects in large silica nanoparticles. The potential attosecond observation of the collective dynamics has been explored theoretically and will be outlined.

Invited Talk A 27.2 Wed 14:30 E 415

Ultrafast dynamics of gas-phase anions — •Jan R. R. Verlet — University of Durham, Durham, United Kingdom

Anions isolated in the gas-phase are studied using femtosecond photoelectron spectroscopy. The use of electrospray ionisation and mass-spectrometry prior to spectroscopy enables the study of a wide range of anionic species. Some recent results on specific systems will be presented. Specifically, the dynamics of polyanions will be discussed with a particular focus on recent developments on how these can provide a route to studying structural dynamics in real-time. We will also discuss results form recent work on molecules of biological importance such as quinones, nucleotides and chromophores of fluorescent protein .

Invited Talk A 27.3 Wed 15:00 E 415

Attosecond Larmor Clock for Ionization — •Olga Smirnova, Jivesh Kaushal, Ingo Barth, and Misha Ivanov — Max Born Institute, Berlin, Germany

How much time does it take to absorb a photon and remove an electron from an atom or a molecule, and how does this time depend on the number of photons required for ionization? Recent experiments suggest that it may take much less time to absorb many photons than it takes to absorb one, and that for the very large number of absorbed photons the required time tends to zero. Does it mean that, in this latter case, formation of the hole associated with electron rearrangement is instantaneous? Here we introduce a clock that resolves this paradox. We show that the spin-orbit interaction, which is the interaction of the spin of the liberated electron, or of the hole left behind, with the magnetic field created by their orbital motion, offers a built-in analogue of the famous Larmor clock for measuring time-delays during tunnelling. We calibrate the clock by first applying it to one-photon ionization and show that the time delays it measures is linked directly to the well-known Wigner-Smith time delays. We then apply the same clock to ionization in IR fields, which requires many photons. Using an example of a Krypton atom, we find delays in the hole formation and show how they depend on the number of absorbed photons. Larmor clock allows us to introduce the rigorous definition of time-delays in multi-photon ionization.

Invited Talk A 27.4 Wed 15:30 E 415

Clusters in intense x-ray pulses — •Christoph Bostedt — SLAC National Accelerator Laboratory, Stanford CA (USA)

Free-electron lasers deliver extremely intense, coherent x-ray flashes with femtosecond pulse length, opening the door for imaging single nanoscale objects in a single shot. All matter irradiated by these intense x-ray pulses, however, will be transformed into a highly-excited non-equilibrium plasma within femtoseconds. During the x-ray pulse complex electron dynamics and the onset of atomic disorder will be induced, leading to a time-varying sample.

We have performed experiments about intense x-ray pulse – matter interaction at both, the FLASH and LCLS x-ray free-electron lasers using atomic clusters. Imaging experiments with xenon clusters in the soft x-ray regime have revealed power-density dependent changes in the scattering patterns. The data show that the scattering signal carries information about transient charge states in the cluster. Single-shot single-particle experiments with keV x-rays reveal that for the highest power densities an highly excited and hot cluster plasma is formed for which recombination is suppressed. Studying the ionization dynamics of smaller clusters shows that the energy absorption depends on the particle size which is attributed to changing Auger rates in the x-ray induced nanoplasma. Recent single-shot experiments with hard x-rays yield insight into the crystalline order of the particles.

A 28: Precision measurements and metrology III (with Q)

Time: Wednesday 14:00–16:00 Location: E 001

Group Report A 28.1 Wed 14:00 E 001

Status of the LISA mission — •Gerhard Heinzel — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) Hannover

LISA is a planned gravitational wave detector in space, under intensive study since more than a decade. Recent changes in the programmatic situation at NASA and ESA have required a redefinition of the mission, to save cost. This talk give an overview of the new mission design and its current status.

A 28.2 Wed 14:30 E 001

LISA Pathfinder: Vorbereitung des Betriebs im Orbit — •Heather Audley, Martin Hewitson, Natalia Korsakova, Jens Reiche, Gerhard Heinzel und Karsten Danzmann — Max Planck Institute für Gravitationsphysik/AEI, Hannover

LISA (Laser Interferometer Space Antenna) ist der erste weltraumbasierte Gravitationswellendetektor, der beabsichtigt, Quellen im Frequenzbereich von 0.1 mHz bis 1 Hz zu erfassen. Die Haupttechnologien, die auf der Erde nicht getestet werden, werden mit der Vorgängermission LISA Pathfinder überprüft. Hierzu gehören die Kontrolle der Testmassen im schwerelosen Raum, Interferometrie auf Picometer-Level sowie Tests der Micro-Newton-Antriebsdüsen. Dieser Beitrag gibt einen Überblick der LISA Pathfinder Mission und hebt speziell die neuesten Ergebnisse, Entwicklungen und die Vorbereitung des Betriebs im Orbit hervor.

A 28.3 Wed 14:45 E 001

Towards the Quantum Limit: Update from the AEI 10-meter Prototype — •Tobin Fricke and The AEI 10 meter Prototype team — Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

Future gravitational wave detectors will be limited in sensitivity by quantum radiation pressure noise and quantum shot noise. At the AEI 10-meter prototype facility we are building a Fabry-Perot Michelson interferometer designed to meet the Standard Quantum Limit (SQL) at 200 Hz, allowing investigation into techniques to surpass this limit. One technical challenge is the use of marginally stable optical cavities. I will describe the status of the 10-meter project with a focus on an initial configuration that will allow us to gain early experience with marginally stable cavities.

A 28.4 Wed 15:00 E 001

GRACE Follow-on - Ein Überblick — •Gunnar Stede, Daniel Schütze, Vitali Müller, Alexander Görth, Christoph Mardt, Oliver Gerberding, Benjamin Sheard, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationspyhsik und Institut für Gravitationsphysik der Universität Hannover

GRACE (Gravity Recovery And Climate Experiment) isteine sehr erfolgreiche Mission, welche seit 10 Jahren das Schwerefeld der Erde mit Hilfe einer Abstandsmessung zweier hintereinander herfliegenden Satelliten bestimmt. Das aus der Abstandsmessung berechnete Schwerefeld hilft zum Beispiel dabei geodynamische und hydrologische Prozesse besser zu verstehen, kommt aber auch in anderen wissenschaftlichen Bereichen wie der Ozeanografie zum Einsatz. Aufgrund des großen Erfolges und des hohen wissenschaftlichen Interesses ist eine Nachfolgemission für 2017 geplant. Zusätzlich zum aktuell benutzten Mikrowelleninterferometer, welches auch bei der Nachfolgemission das primäre Messinstrument ist, werden die Satelliten um ein Laserinterferometer ergänzt, um die Abstandsmessung zu verbessern. Hier geben wir einen Überblick über die Mission, sowie über die Technologien und Konzepte, welche für das Laserinterferometer zur Zeit am Albert Einstein Institut Hannover entwickelt werden.

A 28.5 Wed 15:15 E 001

Gravity measurements with the mobile atom-interferometer GAIN — •Matthias Hauth, Christian Freier, Vladimir Schkolnik, Alexander Senger, Malte Schmidt, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

The Gravimetric Atom Interferometer (GAIN) uses ensembles of laser cooled ^{87}Rb atoms to determine the gravitational acceleration with a targeted accuracy of a few parts in 10^{10}g. The atoms interfere in a Mach-Zehnder type interferometer realized by means of Raman transitions between the hyperfine ground states.

Here we introduce our experimental setup and different sub-systems, which allow for characterization and reduction of systematic effects like e.g. the Coriolis effect of the Earth, vibrational noise and $\mu-$radian tilts of the experiment.

We also present our latest measurement campaigns, where we have reached a sensitivity of $3 \cdot 10^{-8} g/\sqrt{Hz}$, compare them to data taken with classical gravimeters and give an outlook to future improvements and measurement campaigns.

A 28.6 Wed 15:30 E 001

Suspension Platform Interferometer für das AEI 10 m-Prototypinterferometer — •Sina Köhlenbeck for the AEI 10m Prototype Team — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) und Institut für Gravitationsphysik der Leibniz Universität Hannover, 30167 Hannover, Deutschland

Am AEI in Hannover wird momentan das 10 m-Prototypinterferometer aufgebaut. In einem $100\,\mathrm{m}^3$ umfassenden Ultrahochvakuumsystem wird ein Michelson-Interferometer mit Fabry-Perot Resonatoren in den Interferometerarmen installiert, dessen Empfindlichkeit im Messband nur noch durch Quantenrauschen limitiert sein wird. Diese physikalische Grenze nennt man das Standard Quanten Limit. Die klassischen Rauschquellen, wie seismisches Rauschen, müssen zu diesem Zweck vom Interferometer entkoppelt oder hinreichend reduziert werden. Dazu werden die optischen Komponenten auf drei seismisch isolierten optischen Tischen aufgebaut. Diese werden durch interferometrische Messungen zueinander stabilisiert um eine gemeinsame Arbeitsplattform zu erzeugen. Für die differentielle Stabilisierung der optischen Tische wurde das Suspension Platform Interferometer (SPI) entwickelt. Im Frequenzband von 10 mHz bis 10 Hz muss die Sensitivität des SPI dazu $100\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ in der longitudinalen Weglängenänderung und $10\,\mathrm{nrad}/\sqrt{\mathrm{Hz}}$ in der Winkeländerung zwischen den optischen Tischen erreichen. Das Design und die Umsetzung des SPI werden vorgestellt.

A 28.7 Wed 15:45 E 001

Seismic isolation for the 10 m Prototype — •Gerald Bergmann for the AEI 10m Prototype Team — Leibniz Universität Hannover — MPG für Gravitationsphysik (AEI)

A 10 m arm length prototype interferometer is currently being setup at the AEI in Hannover, Germany. This facility will not only be used for developing novel techniques for future gravitational wave detectors, but furthermore it will provide a platform for high precision experiments such as measuring the standard quantum limit (SQL) of interferometry. To achieve the high requirements on displacement noise for these experiments a very good isolation from seismic motion is required. Here we present the pre-isolation stage for the 10 m prototype interferometer based on a set of passively isolated optical tables. Geometric anti-spring filters provide vertical isolation, attenuation in the horizontal direction is provided by inverted pendulum legs. Several sensors and a Suspension Platform Interferometer will be used to measure the residual table motion. These signals will be used to control the tables at and below their fundamental resonances. Attenuation of more than 70 dB below 10 Hz was shown in first experiments with purely mechanically passive isolation. Currently two out of three tables are installed in the interferometer vacuum envelope.

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

Time: Wednesday 16:00–18:30 Location: Empore Lichthof

A 29.1 Wed 16:00 Empore Lichthof

Degenerate mixtures of ultracold ^{40}K-^{6}Li Fermions and Sub-Doppler laser cooling of ^{40}K atoms on the D1 atomic transition — •Franz Sievers[1], Diogo Fernandes[1], Norman Kretzschmar[1], Daniel Suchet[1], Saijun Wu[2], Christophe Salomon[1], and Frederic Chevy[1] — [1]Laboratoire Kastler-Brossel, Ecole Normale Supérieure, Paris, France — [2]Department of Physics, College of Science, Swansea University, Swansea, United Kingdom

We present the design of our apparatus for creating cold mixtures of ^{6}Li and ^{40}K Fermions with which we intend to study condensed matter physics phenomena. Our experimental setup will allow us to simulate several Hamiltonians describing interacting many-body Fermionic systems in one, two and three dimensions. We report on the performances of the magnetic transport and our improved vacuum setup.
Furthermore we report on Sub-Doppler laser cooling of fermionic ^{40}K atoms in three-dimensional gray optical molasses on the D1 atomic transition.

A 29.2 Wed 16:00 Empore Lichthof

Two-channel Bose-Hubbard model of atoms at a Feshbach resonance — •Philipp-Immanuel Schneider and Alejandro Saenz — AG Moderne Optik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin

Based on the analytic model of Feshbach resonances in harmonic traps described in [1] a Bose-Hubbard model is introduced that allows for the accurate description of two atoms in an optical lattice at a Feshbach resonance with only a small number of Bloch bands. The approach circumvents the problem that the eigenenergies in the presence of a delta-like coupling do not converge to the correct energies, if an uncorrelated basis is used.

Furthermore, we describe a possibility to realistically mimic Feshbach resonances within non-perturbative single-channel approaches by using a square-well interaction potential. This allows to compare the predictions of the Bose-Hubbard model to non-perturbative calculations of the stationary eigenenergies and the dynamical behavior of the atoms during an acceleration of the optical lattice.

[1] P.-I. Schneider and A. Saenz, Phys. Rev. A **83**, 030701(R) (2011).

A 29.3 Wed 16:00 Empore Lichthof

Vortex-bright soliton dipoles: bifurcations, symmetry breaking and soliton tunneling in a vortex-induced double well — •Jan Stockhofe[1], Martina Pola[1], Panayotis G. Kevrekidis[3], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Deutschland — [2]The Hamburg Centre for Ultrafast Imaging, Germany — [3]Department of Mathematics and Statistics, University of Massachusetts, USA

The emergence of vortex-bright soliton dipoles in two-component Bose-Einstein condensates through bifurcations from suitable eigenstates of the underlying linear system is examined. These dipoles can have their bright solitary structures be in phase (symmetric) or out of phase (anti-symmetric). The dynamical robustness of each of these two possibilities is considered and the out-of-phase case is found to exhibit an intriguing symmetry-breaking instability that can in turn lead to tunneling of the bright wavefunction between the two vortex "wells". We interpret this phenomenon by virtue of a vortex-induced double well system, whose spontaneous symmetry breaking leads to asymmetric vortex-bright dipoles, in addition to the symmetric and anti-symmetric ones. The theoretical prediction of these states is corroborated by detailed numerical computations.

A 29.4 Wed 16:00 Empore Lichthof

Compressional and surface modes of the trapped dipolar gases — •Alexey Filinov[1,2] and Michael Bonitz[1] — [1]Institut für Theoretische Physik und Astrophysik, D-24098 Kiel, Germany — [2]Joint Institute for High Temperatures RAS, 125412 Moscow, Russia

The low-lying collective excitations -monopole and multipole modes- are analyzed based on the excitation-energy sum rules [1]. This formalism allows to estimate an upper bound for the excitation energies. The involved frequency moments of the strength function are estimated as a trace over the corresponding commutators between an excitation operator and the many-body Hamiltonian in thermodynamic equilibrium. Temperature and dipole interaction strength dependencies of the breathing and quadrupole modes of a 3D trapped dipolar gas are presented. One of our goals is to analyze the frequency shifts of the modes similar to that observed in the experiments with a ^{87}Rb gas at temperatures near T_c [2]. Our analysis is based on finite-temperature quantum MC simulations [3].

[1] E. Lipparini and S. Stringari, Phys. Rep. **175**, 103 (1989); S. Stringari, Phys. Rev. Lett. **77**, 2360 (1996). [2] D.S. Jin and et al., *ibid* **78**, 764 (1997); D.M. Stamper-Kurn and et al., *ibid* **81**, 500 (1998). [3] A. Filinov and et al., *ibid* **105**, 070401 (2010).

A 29.5 Wed 16:00 Empore Lichthof

Collision studies in ultracold calcium atoms — •Purbasha Halder and Andreas Hemmerich — Institut für Laserphysik, Universität Hamburg

We present collision studies of optically trapped calcium atoms in their long-lived triplet states and discuss the feasability of achieving Bose-Einstein condensation in these states by evaporative cooling methods. The metastable states of alkaline earth and rare earth elements have novel elastic and inelastic scattering properties [1], and have important implications for applications like time metrology and lattice-based quantum computing.

The atoms are prepared by an alternative method analogous to the one used to create a ground state BEC [2].

[1] V. Kokoouline, R. Santra, and C. Greene, Phys. Rev. Lett. **90**, 253201 (2003).

[2] P. Halder, C.-Y. Yang and A. Hemmerich, Phys. Rev. A **85**, 031603 (2012).

A 29.6 Wed 16:00 Empore Lichthof

Strontium in an Optical Lattice as a Portable Frequency Reference — •Lyndsie Smith, Ole Kock, Wei He, Huadon Cheng, Steven Johnson, Kai Kai, and Yeshpal Singh — School of Physics and Astronomy, University of Birmingham, Edgbaston Park Road, Birmingham B15 2TT, UK

The higher frequencies (approx. 10^15) of the atomic transitions enable a greater accuracy than the current microwave frequency (approx. 10^10) standard. Optical clocks have now achieved a performance significantly beyond that of the best microwave clocks, at a fractional frequency inaccuracy of 8.6 *10^-18. With the rapidly improving performance of optical clocks, in the future, most applications requiring the highest accuracy will require optical clocks. We are setting up an experiment aimed at a mobile frequency standard based on strontium (Sr) in a blue detuned optical lattice. We have 2D-3D MOT setup where initially cooled atoms in 2D are collected in the 3D MOT. Very recently we have realized our 3D MOT. We have also observed an effect of our 2D MOT on our 3D MOT. However, it should be mentioned that these are preliminary results and a thorough optimization as well as characterization will be done in due course of time. In addition to that we have designed a very compact and robust frequency distribution module for our European collaborative project, Space Optical Clock (SOC-2). An up to date progress on a compact and robust frequency standard experiment will be presented.

A 29.7 Wed 16:00 Empore Lichthof

Imaging vortices in a Bose–Einstein condensate with tracer particles — •Chris Billington[1,2], Philip Starkey[1], Shaun Johnstone[1], Mikhail Egorov[1], and Kristian Helmerson[1] — [1]School of Physics, Monash University, Victoria, Australia — [2]Physikalisches Institut, Universität Tübingen, Tübingen, Germany

Vortex cores in Bose–Einstein condensates are minima in atomic density. As such, an atom experiencing repulsive interactions with a condensate will see vortex cores as potential wells, and may become trapped within them. We are developing an experiment to image vortices *in-situ* using this effect. We will introduce ^{87}Rb atoms to a ^{41}K condensate containing vortices, and image the ^{87}Rb atoms in order to discern the positions of vortex cores.

In order to perform this and other experiments, we have developed a powerful control and analysis system called *labscript*. In labscript, experiments are written as code in a high level language, before being compiled to hardware instructions suitable for programming into devices. Many such experiments can be compiled at once—scanning over one or more input parameters to the experiment—and will be queued up and executed one after the other on the hardware. User-written analysis routines run automatically as new data arrives from the experiment, with plots updating in real time. Analysis results can also determine the input parameters to the next experiment, which we use for closed loop optimization of experiment results using a genetic algorithm.

A 29.8 Wed 16:00 Empore Lichthof

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

Ultracold chemistry is a highly interesting research field. 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 large paul trap, with conventional doppler cooling and furthermore with an ambient rubidium MOT. By switching off our RF-potential we overcome the limitations set by heating due to the RF micromotion[4]. We describe the experimental apparatus in its recent stage and the very first experiments done with it.

[1]A.T.Grier, M.Cecina, 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.Rev.Lett. 107 243201 (2011)
[4]L.H.Nguyen, A.Kalev, M.D.Barett and B.Engelert, Phys.Rev.A 85, 052718 (2012)

A 29.9 Wed 16:00 Empore Lichthof

Quantum magnetism of mass-imbalanced fermionic mixtures — •Andrii Sotnikov[1], Daniel Cocks[1], Michiel Snoek[2], and Walter Hofstetter[1] — [1]Goethe Universität, Frankfurt am Main, Germany — [2]Universiteit van Amsterdam, The Netherlands

We study magnetic phases of two-component mixtures of ultracold fermions with repulsive interactions in optical lattices in the presence of hopping and population imbalance by means of dynamical mean-field theory (DMFT). According to our analysis, mass-imbalanced mixtures have important advantages over balanced systems in thermodynamic characteristics that are relevant for obtaining and detecting quantum magnetism in optical lattices.

It is shown that mixtures with both imbalances present can have easy-axis antiferromagnetic, ferrimagnetic, charge-density wave, canted-antiferromagnetic order or be unordered depending on parameters of the system. We study the resulting phase diagram in detail and investigate the stability of the phases to thermal fluctuations. We also perform a quantitative analysis for a gas confined in a harmonic trap, by applying the local density approximation and a real-space generalization of DMFT.

A 29.10 Wed 16:00 Empore Lichthof

Single Ions Trapped in a One-Dimensional Optical lattice — •Thomas Huber, Martin Enderlein, Christian Schneider, Alexander Lambrecht, Michael Zugenmaier, Julian Schmidt, and Tobias Schaetz — Albert-Ludwigs Universität Freiburg

In 2010 we trapped a Mg+ ion in an optical dipole trap [1]. Compared to conventional ion traps optically trapped ions permit novel prospects in several ways: For example to study ultra-cold atom-ion collisions, not suffering from micromotion-induced heating [2] and as potentially scalable systems in optical lattices with long-range interaction for quantum simulations based on ions or ions and atoms.

We report on three-dimensional optical trapping of single ions in a one-dimensional optical lattice formed by two counterpropagating laser beams [3]. We characterize the trapping parameters of the standing-wave using the ion as a sensor stored in a hybrid trap consisting of a radio-frequency (rf), a dc, and the optical potential. When loading ions directly from the rf into the standing-wave trap, we observe a domi-nant heating rate. Monte Carlo simulations confirm rf-induced para-metric excitations within the deep optical lattice as the main source. We demonstrate a way around this effect by an alternative transfer protocol which involves an intermediate step of optical confinement in a single-beam trap avoiding the temporal overlap of the standing-wave and the rf field. We discuss potential applications.

[1]Schneider et al., Nat. Photonics 4(2010)
[2]Cormick et al., New J. Phys. 13 (2011)
[3]M. Enderlein et al., Phys. Rev. Lett. 109 (2012)

A 29.11 Wed 16:00 Empore Lichthof

Laser stabilisation techniques for cooling of Barium ions — •Julian Schmidt, Thomas Huber, Alexander Lambrecht, Michael Zugenmaier, and Tobias Schaetz — Universität Freiburg

In ion trapping experiments, the frequency of the lasers required for cooling, repumping and photoionisation needs to be just as stable as for neutral atom experiments, that is on the order of a fraction of the natural linewidth. However, since the gas is composed of neutral atoms and molecules, one cannot, in general, use established locking techniques on a gas cell filled with the chemical element in question.

For Ba^+, the repumping transition at 650nm is in the vicinity of an Iodine line; however, in typical gas cells, there are no established transitions to lock the Doppler cooling laser at 493nm (which is frequency-doubled from 987nm) or the two-photon photoionisation laser at 413nm. In our experiment, we therefore implement temperature stabilised optical cavities suited to fulfill our requirements at 987nm and 413nm with sub-MHz (sub-Hz stabilisation is not required) linewidth and excellent long-term stability to produce a useful error signal.

For the future, we are investigating several options, e.g. locking the 493nm laser to a transition in the H_2O molecule which is, to our knowledge, not being exploited in other Ba^+-trapping experiments, or to an improved version of our current optical cavity.

A 29.12 Wed 16:00 Empore Lichthof

Structural and dynamical properties of quasi-1D dipolar crystals — •Florian Cartarius[1,2], Anna Minguzzi[1], and Giovanna Morigi[2] — [1]Université de Grenoble 1/CNRS, LPMMC UMR 5493, B.P. 166, 38042 Grenoble, France — [2]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany

We study the ground state of classical dipolar particles in quasi-1D geometries, which can be realized in highly anisotropic traps. Here, the dipolar interaction between the particles can be made repulsive by confining the particles on a plane in presence of an external field perpendicular to it. We study the equilibrium configurations which are obtained for decreasing values of the trap aspect ratio by means of a Basin-Hopping Monte Carlo method and of analytical calculations of the motional spectra, and determine the structural phase diagram.

A 29.13 Wed 16:00 Empore Lichthof

An ultracold ytterbium quantum gas for lattice many-body physics — •C. Hofrichter, P. C. De Groot, F. Scazza, M. Höfer, C. Schweizer, E. Davis, I. Bloch, and S. Fölling — MPI für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching and Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München, Germany

Alkaline-earth-type atoms (AEA) like ytterbium differ in their internal structure from the more widely used alkali atomic species. Their electronic structure is responsible for specific properties that can be exploited in the field of quantum simulation with ultracold atoms in optical lattices.

AEAs possess a metastable excited state useful for implementing state-dependent optical potentials necessary for certain novel types of many-body Hamiltonians. In addition, the high nuclear spin of fermionic isotopes gives rise to an enlarged SU(N) symmetry of the hamiltonian. A significant theoretical effort has been already committed to the understanding of the physics of systems that could be realized with an ytterbium quantum gas trapped in an optical lattice, such as the Kondo lattice model or higher-symmetry Heisenberg models.

We present our setup for the production of an Yb degenerate gas of bosonic or fermionic atoms with control over nuclear and electronic spin state populations in a 3D optical lattice.

A 29.14 Wed 16:00 Empore Lichthof

Detection of Single Flux Quanta with Ultracold Atoms — •Patrizia Weiss, Simon Bernon, Helge Hattermann, Martin Knufinke, Daniel Bothner, 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

We report on the interaction of an atomic cloud with a superconducting ring. When such a structure is cooled through the superconducting transition ($T_c = 9.2\,\mathrm{K}$) in an external field, persistent currents will conserve the magnetic flux inside the ring. The trapped flux is quantized and will be an integer multiple of the magnetic flux quantum $\Phi_0 = 2.067 \times 10^{-15}\,\mathrm{Tm}^2$.

We trap atomic clouds of ^{87}Rb in a superconducting magnetic microtrap at 4.2 K and bring the atoms in the vicinity of the ring structure ($R = 10\,\mu$m). The atomic cloud is sensitive to the 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 depth. The results pave the way towards coupling cold atoms to SQUIDS and the generation of periodic magnetic micropotentials based on persistent currents.

A 29.15 Wed 16:00 Empore Lichthof

Operation of a cold atom setup in a delution refrigerator — •Florian Jessen, Martin Knufinke, Petra Vergien, Malte Reinschmidt, Helge Hattermann, Simon Bernon, Simon Bell, Daniel Cano, Dieter Kölle, Reinhold Kleiner, and József Fortágh — Center for Collective Quantum Phenomena, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

We describe the operation and technical details of a cold atom setup in a delution refrigerator. The setup contains a magneto optical trap, which is loaded from a Zeeman slower, magnetic traps and optical dipole traps.

A 29.16 Wed 16:00 Empore Lichthof

Towards probing of fermionic quantum many body systems on the single atom level — •Ahmed Omran[1], Martin Boll[1], Timon Hilker[1], Michael Lohse[1], Thomas Reimann[1,2], Thomas Gantner[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, Fakultät für Physik, Schellingstraße 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.

We are using mixtures of Li-6 and Li-7 atoms to achieve a degenerate bosonic or fermionic many body system trapped in a 3D optical lattice. With a high resolution imaging system, we will be able to resolve single sites in a 2D plane of the lattice and image single atoms. Superimposing an additional small-scale pinning lattice onto the larger-scale physics lattice in order to freeze out the distribution of atoms during imaging, we separate the detector from the physical system under study. This will allow for the investigation of different lattice geometries with single atom sensitivity.

We present the current status of our experimental realization and a method for in-situ thermometry in magnetic traps.

A 29.17 Wed 16:00 Empore Lichthof

Interfacing Cold Atoms and Carbon Nanotubes — •Simon Bell, Peter Federsel, Hannah Schefzyk, Markus Stecker, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Deutschland

Hybrid systems of ultracold atoms and nano-devices have attracted considerable attention within the last years. In future, such systems might allow the realization of novel nano-devices and nano-sensors with sensitivities only limited by quantum effects. In our system we routinely interface ultracold atoms with single carbon nanotubes. We show how this system might be used to demonstrate a novel quantum galvanometer, and summarize our results on the first cold-atom scanning probe microscope [1, 2].

While efficient single-atom detection will become more and more important for hybrid systems and for quantum atom optics in general, we also show our latest attempts towards in-situ single-atom detection of trapped quantum gases. Currently we are investigating two different schemes, both based on ionization of individual atoms and subsequent ion-detection. The first scheme uses optical ionization and allows highly resolved spatial imaging. The second scheme uses field ionization at the tip of a charged nanotube/nanowire to limit the ionization region to the nm length scale. We will expand on both of these detection schemes and show our first results.

[1] Schneeweiß et al., *Nature Nanotechnology* **7**, 515-519 (2012)
[2] Gierling et al., *Nature Nanotechnology* **6**; 446-451 (2011)

A 29.18 Wed 16:00 Empore Lichthof

Crossover from a crystalline to a cluster phase for a confined finite chain of ions — •Alexandra Zampetaki[1], Fotios Diakonos[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Department of Physics, University of Athens, GR-15874, Athens, Greece

Employing Monte-Carlo simulation techniques we investigate the statistical properties of equally charged particles confined in a one-dimensional box trap. We detect a crossover from a crystalline to a cluster phase with increasing temperature. The corresponding transition temperature depends separately on the number of particles N and the box size L, implying non-extensivity due to the long-range character of the interactions. The probability density of the spacing between the particles exhibits at low temperatures an accumulation of discrete peaks with an overall asymmetric shape. Around the transition temperature it is of a Gaussian form whereas in the high temperature regime it obeys an exponential decay. The high temperature behaviour shows a cluster phase with a mean cluster size that first increases with the temperature but finally saturates.The crossover is clearly identifiable also in the non-linear behaviour of the heat capacity with varying the temperature.

A 29.19 Wed 16:00 Empore Lichthof

Topological Insulators in Optical Lattices: interaction and trapping — •Daniel Cocks[1], Peter Orth[2], Michael Buchhold[1], Stephan Rachel[3], Karyn Le Hur[4], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe Universität, Frankfurt — [2]Institut für Theorie der Kondensierten Materie, Karlsruhe Institut für Technologie — [3]Institut für Theoretische Physik, Technische Universität Dreseden — [4]Center for Theoretical Physics, École Polytechnique, Palaiseau

We investigate effects of interaction and trapping in a 2D system to be realised in experiment (Goldman et al. PRL **105**, 255302, 2010) that exhibits topologically insulating phases in an optical square lattice, using both real-space dynamical mean-field theory (R-DMFT) and analytical techniques. This system includes a flux term, which emulates a spin-dependent magnetic field, a Rashba/Dresselhaus-like spin-orbit term, which introduces non-Abelian behavior, and a staggered super-lattice potential, which introduces non-trivial topology at half-filling.

We investigate with R-DMFT the robustness of the topological phases for weak interaction, and transitions to magnetic order at strong interaction. We demonstrate a critical dependence on the number of Dirac points. As well, we derive and analyze the corresponding spin-Hamiltonian and show that the competition of flux and Rashba-like spin-orbit couplings produce non-trivial spiral-like orders. We also consider the effects of trapping on the visibility of edge states, and show that new interesting features arise when smooth trapping is present.

A 29.20 Wed 16:00 Empore Lichthof

Millisecond Dynamics of Ultracold Rydberg Gases — •Tobias Weber, Thomas Niederprüm, Torsten Manthey, Giovanni

Barontini, Vera Guarrera, and Herwig Ott — TU Kaiserslautern

We observe ultracold atoms continuously coupled to Rydberg states on a timescale exceeding the vastly investigated so called frozen Rydberg regime. A scanning electron microscope technique is exploited to prepare distributions of mesoscopic ensemples with dipole-dipole interactions induced by resonant and off-resonant excitation. Characterisations of correlations between Rydberg atoms and of ionization processes are derived from the analysis of the ion signal.

A 29.21 Wed 16:00 Empore Lichthof

Investigation of two ultra-cold dipolar particles in a trap — •Bruno Schulz, Philipp-Immanuel Schneider, Simon Sala, and Alejandro Saenz — Institut für Physik, Humboldt Universität zu Berlin, Germany

Ultra-cold dipolar gases have lead to novel phenomena in the regime of degenerate many-body quantum systems. The interaction strength of such systems can easily be varied by external homogeneous electric or magnetic fields depending on the type of dipoles. Therefore, a high degree of control can be achieved on the quantum states of such systems. Those dipolar quantum gases are interesting candidates for applications like quantum computation due to their strong dipole-dipole interaction that often acts on a longer distance than the standard atom-atom interaction. Despite the large interest in ultra-cold dipolar quantum gases, a fully theoretical description of two dipolar particles interacting via a short-range contact interaction and the dipole-dipole interaction in a trap is not known. Therefore, our group developed an approach to solve the time-independent Schrödinger equation with a realistic full Born-Oppenheimer interatomic interaction potential and the long-range anisotropic dipole-dipole interaction in three dimensions in a finite optical lattice. The understanding of the pair interaction of two particles interacting via dipole-dipole interaction could help to understand general properties of such systems and to obtain improved parameters for Ising-type models. As a first step towards the understanding we present and discuss the energy spectra and pair densities of two ultra-cold dipolar particles in a harmonic trap.

A 29.22 Wed 16:00 Empore Lichthof

Towards Ultracold Mixtures on an Atom Chip — •Jonathan Nute, Matthew Jones, Asaf Paris Mandoki, Sonali Warriar, Peter Krüger, and Lucia Hackermüller — University of Nottingham, UK

Ultracold mixtures hold the promise of understanding new phases of matter and collisions at very low energies. 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. We plan to introduce a micro-chip, which in conjunction with optical dipole trapping, will make it possible to trap these mixtures in low dimensions and tune their scattering lengths via Feshbach resonances. In this way it will also be possible to realise experiments with additional magnetic potentials, position dependent interactions or impurity dynamics. Here we present the current status of our experiment. We detail the cooling schemes for the two atom species and include the recent development of implementing an optical dipole trap. We discuss plans for introducing a glass cell to our caesium setup in preparation for our contribution to the Quantum Integrated Light and Matter Interface (QuILMI) European collaboration.

A 29.23 Wed 16:00 Empore Lichthof

An Ultracold Fermi Gas in an Optical Lattice — •Puneet Murthy, Mathias Neidig, Martin Ries, Andre Wenz, Thomas Lompe, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Heidelberg

Ultracold Fermi gases confined in optical lattices hold great promise in understanding interesting many-body phenomenon. Recent studies have demonstrated single site resolution in a system of bosonic quantum gases. Our objective is to employ similar techniques in the study of an ultracold quantum degenerate Fermi gas of ^{6}Li atoms. This poster presents our recent experimental progress towards attaining such a system.

At present we are able to transfer a quantum degenerate two component gas of ^{6}Li atoms from an optical dipole trap into a stack of several 'pancake'-shaped potentials, which are formed by the interference pattern of two off-resonant laser beams. We use a radio-frequency tomographic method to probe the occupation of individual pancakes and find that we can load atoms into less than five pancakes. In the next step, we aim to transfer the atoms into a single pancake potential. By having additional lattice beams creating standing waves in the perpendicular direction, we will be able to produce a two-dimensional optical lattice containing an ultracold degenerate Fermi gas, and perform in-situ studies on it.

A 29.24 Wed 16:00 Empore Lichthof

Low-noise absorption detection for sub-shot-noise atom interferometry — •Bernd Lücke, Jan Peise, Wolfgang Ertmer, and Carsten Klempt — Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Atom interferometers are extremely precise measurement tools in a wide field of metrological applications. An interferometer maps the quantity of interest on the number of atoms in its output ports. Therefore a low noise detection of the atoms is crucial. Moreover new entangled states of matter will push the precision of atom interferometers to new limits and thus require even more precise atom detection. In our experiment we create entangled twin Fock states for interferometry beyond the shot noise limit. The measurement of the interferometric sensitivity of this state sets high requirements on our absorption detection. We show how we were able to increase its precision and discuss the effect of photon shot noise as a fundamental limitation for absorption detection.

A 29.25 Wed 16:00 Empore Lichthof

Evidence for a quantum-to-classical transition in a system of two coupled quantum rotors — •Bryce Gadway[1,2], Jeremy Reeves[1], Ludwig Krinner[1], and Dominik Schneble[1] — [1]Dept. of Physics and Astronomy, Stony Brook University, Stony Brook, NY, USA — [2]present address: JILA, University of Colorado, Boulder, CO, USA

We experimentally realize a pair of two coupled quantum kicked rotors, by subjecting a coherent atomic matter wave to two periodically pulsed, incommensurate optical lattices. Momentum transport in this system is found to be radically different from the well-known behavior of a single kicked rotor, with a breakdown of dynamical localization and the emergence of classical diffusion. Our observations confirm a long-standing prediction for many-dimensional quantum-chaotic systems, and shed new light on how classical behavior can emerge in isolated, periodically driven quantum systems.

A 29.26 Wed 16:00 Empore Lichthof

Progress at the Munich ultracold polar molecules project — •Nikolaus Buchheim, Zhenkai Lu, Diana Amaro, Tobias Schneider, Immanuel Bloch, and Christoph Gohle — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching

Ultra cold quantum gases with large dipolar interaction or large polarizability that are recently becoming available promise exciting new possibilities. Self assembled lattices of polarized particles supporting phonon modes will provide opportunities to simulate an even broader range of solid state physics phenomena [1]. 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.

Among other systems like Rydberg atoms or Atoms with exceptionally large magnetic dipole moments, simple polar molecules are a viable alternative due to their good balance between dipole length and scattering length as well as their potential long levity. We present the latest news on our experiment to create ultracold NaK molecules. In this system the instability due to inelastic two body collisions known from pioneering experiments [2] does not exist and chances are good to reach far into the interesting parameter space.

[1] Pupillo, G., Micheli, A., Büchler, H. P., & Zoller, P. (2008). Condensed Matter Physics with Cold Polar Molecules. arxiv:0805.1896.

[2] Ni, K.-K., Ospelkaus, S., et al. A high phase-space-density gas of polar molecules. Science, 322, 231-5 (2008).

A 29.27 Wed 16:00 Empore Lichthof

Stable Heteronuclear Few-Atom Bound States in Mixed Dimensions — •Tao Yin[1,2], Peng Zhang[2], and Wei Zhang[2] — [1]Institut für Theoretische physik, Goethe-Universität, 60438 Frankfurt/Main, Germany — [2]Department of Physics, Renmin University of China, Beijing 100872, People's Republic of China

We study few-body problems in mixed dimensions with two or three heavy atoms trapped individually in parallel one-dimensional tubes or two-dimensional disks, and a single light atom travels freely in three dimensions. By using the Born-Oppenheimer approximation, we find three- and four-body bound states for a broad parameter region. Specifically, the existence of trimer and tetramer states persist to negative scattering lengths regime, where no two-body bound state is present. As pointed out by Nishida in an earlier work [Phys. Rev. A **82**, 011605(R) (2010)], these few-body bound states are stable against three-body recombination due to geometric separation. In addition, we find that the binding energy of the ground trimer and tetramer state reaches its maximum value when the scattering lengths are comparable to the separation between the low-dimensional traps.

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

Time: Wednesday 16:00–18:30 Location: Empore Lichthof

A 30.1 Wed 16:00 Empore Lichthof

Temporal Dynamics of Stimulated Emission — •Andreas Reichegger and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

We study the temporal dynamics of stimulated emission. Stimulated emission is a fundamental quantum mechanical process of light-matter interaction, which plays a key role, e.g. in the theory of Lasers. For these purposes, we use a quantum optical model, where a single-photon-pulse will interact with an excited two-level atom. We develop signatures to assess the temporal evolution of stimulated emission in this model. Possible applications for nuclear X-ray Lasers are discussed.

A 30.2 Wed 16:00 Empore Lichthof

Time-dependent theory of resonance fluorescence for ultrafast and ultraintense x rays — •Stefano M. Cavaletto[1], Christian Buth[2], Zoltán Harman[1,3], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Argonne National Laboratory, Argonne, IL, USA — [3]ExtreMe Matter Institute (EMMI), Darmstadt, Germany

The recent development of intense sources of coherent x-ray radiation such as the Linac Coherent Light Source (LCLS) in Menlo Park, California, USA, provides one with an unprecedented way to study nonlinear physics at short wavelengths. In this regard, resonance fluorescence, i.e. the spectrum of photons scattered off atoms and molecules driven by a near-resonant electric field, is expected to play a decisive role. We compute the time-dependent spectrum of resonance fluorescence of a two-level system excited by an ultrashort pulse. We allow for inner-shell hole decay widths and destruction of the system by further photoionization. This two-level description is employed to model neon cations strongly driven by LCLS light tuned to the $1s\,2p^{-1} \to 1s^{-1}\,2p$ transition at 848 eV: x rays induce Rabi oscillations which are so fast that they compete with Ne $1s$-hole decay. First, we predict resonance fluorescence spectra for chaotic pulses generated at present-day LCLS; second, we explore the exciting novel opportunities offered by Gaussian pulses which will become available in the foreseeable future with self-seeding techniques. In the latter case, we predict a clear signature of Rabi flopping in the spectrum of resonance fluorescence.

A 30.3 Wed 16:00 Empore Lichthof

THz-XUV Pump-Probe Experiment Using a REMI at FLASH — •Jakob Kunz[1], Georg Schmid[1], Kirsten Schnorr[1], Nikola Stojanovic[2], Artem Rudenko[3], Lutz Foucar[4], Arne Senftleben[1], Shaofeng Zhang[1], Thomas Pfeifer[1], Joachim Ullrich[5], Yuhai Jiang[6], Alexander Broska[1], Michael Gensch[7], Alaa Al-Shemmary[2], Matthias Kuebel[8], Claus-Dieter Schroeter[1], and Robert Moshammer[1] — [1]MPIK Heidelberg — [2]DESY Hamburg — [3]Kansas State University Manhattan — [4]ASG Hamburg — [5]PTB Braunschweig — [6]Shanghai Advanced Research Institute — [7]Hemholtz-Zentrum Dresden-Rossendorf — [8]MPQ Garching

Using a Reaction Microscope (REMI) we study the fragmentation dynamics of atoms and molecules in a pump-probe scheme with a fs XUV-pulse at 58 eV and a fully synchronized strong THz-pulse at a wavelength of 150 μm. The three dimensional momenta of all charged particles are reconstructed which allows in particular the investigation of angular distributions and energies as a function of the time delay.
Streaking of ions and electrons originating from ionization of atoms and molecules is demonstrated. We map the shape of the THz pulse via emission of photoelectrons created by the XUV-pulse into the THz field. Furthermore streaking as a tool to trace atomic processes, such as Auger decay in real time is discussed.

A 30.4 Wed 16:00 Empore Lichthof

Photofragmentation of Molecular Iodine studied by VIS/XUV- and XUV/XUV-Pump-Probe Measurements at FLASH — •Georg Schmid[1], Kirsten Schnorr[1], Jakob Kunz[1], Arne Senftleben[1], Artem Rudenko[2], Thomas Pfeifer[1], Kristina Meyer[1], Theo Zouros[3], Joachim Ullrich[4], Yuhai Jiang[5], Stefan Düsterer[6], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Kansas State University, Manhattan — [3]University of Crete, Heraklion — [4]PTB, Braunschweig — [5]Shanghai Advanced Research Institute, Shanghai — [6]DESY, Hamburg

In a pump-probe experiment the photofragmentation of molecular iodine using an ultrashort XUV pulse at $\approx$ 14 nm delivered by the free-electron-laser facility FLASH and a femtosecond IR laser pulse at $\approx$ 800 nm was performed. In order to trace the photoionization dynamics as a function of the internuclear distance, the delay between XUV- and IR-pulse is varied. A preceding IR-pulse removes valence electrons and the I_2 molecule starts to dissociate which is then probed via the inner-shell absorption of multiple XUV photons. At 14 nm the FEL creates dominantly 4d core holes followed by Auger cascades which results in charge states up to I_2^{15+}. Thus the interplay between valence- and core-electrons as a function of time is studied. A second time resolved experiment with XUV-pump and XUV-probe allows to investigate core/core electron dynamics.With both schemes we analyze the charge-up behaviour of molecular ions and ionic fragments applying coincident detection of all ion species in a reaction microscope.

A 30.5 Wed 16:00 Empore Lichthof

Isomer depletion via photons and electrons generated by an XFEL pulse — •Jonas Gunst, Adriana Pálffy, and Christoph H. Keitel — Max-Planck Institut für Kernphysik, Heidelberg

Long-lived nuclear excited states also known as isomers can store large amounts of energy over long periods of time. Much interest arises from a number of fascinating potential applications related to the controlled release of nuclear energy on demand, such as nuclear batteries. Here we investigate the controlled depletion of the 2.4 MeV ^{93m}Mo isomer via the excitation of a 4.8 keV transition to an above lying triggering level that then decays via a fast cascade to the ground state.

As excitation mechanisms we consider the competition between photoexcitation and the coupling to the atomic shell in the process of nuclear excitation by electron capture (NEEC). A brilliant x-ray free electron laser (XFEL) source delivers the resonant photons for photoexcitation and simultaneously produces the electron plasma [1] which provides the free electrons and charged ions necessary for NEEC. Based on the semi–classical Maxwell–Bloch equations and perturbation theory we present numerical results for reaction rates of isomer depletion. While the photoexcitation cross section is typically two orders of magnitude smaller than the NEEC one for the 4.8 keV transition [2], we show that the efficiency of the NEEC process is in our case limited by the available charge states and the electron temperature in the plasma.

[1] S. M. Vinko *et al.*, Nature 482, 59 (2012).
[2] A. Pálffy, J. Evers and C. H. Keitel, Phys. Rev. Lett. 99, 172502 (2007).

A 30.6 Wed 16:00 Empore Lichthof

Conditions for orientation recovery using diffusion map — •Martin Winter, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Dresden

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 apply diffusion map to ensembles of unorientated diffraction patterns and to coordinates of points in three dimensional space and quantify when orientation recovery breaks down. For a better understanding we investigate the metric underlying the mappings from orientations to diffraction patterns and coordinates, respectively.

[1] Optics Express, Vol. 20, Issue 12, pp. 12799-12826 (2012)

A 30.7 Wed 16:00 Empore Lichthof

Nonlinear X-Ray Optics: A Numerical Study Based on the Maxwell-Schrödinger Equations — •Paolo Longo and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The interaction of intense X-ray light (e.g., from a free-electron laser) with condensed matter does not only provide a versatile tool for the study of various material properties. It also allows for the investigation of coherent quantum optical effects in the X-ray domain [1]. In this work, we address questions from nonlinear X-ray optics based on a Maxwell-Schrödinger solver for quantum optical few-level systems [2].

[1] B. W. Adams *et al.*, J. Mod. Optic. *(in press)*.
[2] R. Fleischhaker and J. Evers, Comput. Phys. Commun. **182**, 739 (2011).

A 30.8 Wed 16:00 Empore Lichthof

XUV/IR pump-probe and single XUV photon dissociative ionization of H_2 — •Alexander Sperl[1], Andreas Fischer[1], Philipp Cörlin[1], Michael Schönwald[1], Arne Senftleben[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Using a pump-probe scheme of an XUV-pump and IR-probe pulse, we investigated the nuclear wave packet dynamics of the high vibrational states in the $H_2^+(X\,^2\Sigma_g)$ potential. We observed the beating of the nuclear wave-packet as well as the de-phasing and re-phasing of the wave packet caused by the anharmonicity of the potential. By Fourier-transforming the time signal, we obtained the frequency spacings of the different vibrational states. We further studied the dissociative ionization induced by a single XUV photon. Here the doubly excited states Q_1 were mainly under investigation. In an ion-electron-correlation measurement we observed an oscillatory molecular frame asymmetry in the dissociation, similar to [1]. The asymmetry is caused by the interference of two paths.

Both measurements were performed using a reaction microscope, enabling the kinematically complete reconstruction of all momenta in a reaction.

[1] F. Martín, J. Fernández, T. Havermeier, L. Foucar, T. Weber, K. Kreidi, M. Schöffler, L. Schmidt, T. Jahnke, O. Jagutzki, et al., Science 315, 629 (2007)

A 30.9 Wed 16:00 Empore Lichthof

Towards Non-Linear X-ray Quantum Optics with Thin Film Cavities — •Kilian Heeg and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Thin film cavities with resonant iron-57 Mößbauer nuclei have proven to be a powerful system to study coherent light-matter interaction in the x-ray regime. Superradiance and the collective Lamb shift [1], electromagnetically induced transparency [2] and spontaneously generated coherences could be observed recently. In order to provide a full interpretation of the processes in the cavity, we establish a general quantum optical theory. This also opens the door to study quantum effects and the non-linear regime in such cavities. We discuss approaches and possible applications of this framework with the aim to determine if non-classical light states can be created in thin film cavities.

[1] R. Röhlsberger et al., Science 328, 1248-1251 (2010)
[2] R. Röhlsberger et al., Nature 482, 199 (2012)

A 30.10 Wed 16:00 Empore Lichthof

Dynamics of heteronuclear clusters in 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

We study the fragmentation dynamics of various molecular clusters (like CH_4, NH_3, H_2O) following multiple ionization with short and intense X-ray pulses. Whereas the photons are preferentially absorbed by the core electrons of the heavy species in the cluster, fast intramolecular charge transfer results in the formation of bare protons. We observe low final charge states of the heavy atoms and an intensity-dependent segregation of the proton and heavy-atom component leading to an inhibited expansion of the latter. Such findings could be relevant to approach the damage processes of large organic molecules as they occur during coherent diffractive imaging with intense X-ray pulses.

A 30.11 Wed 16:00 Empore Lichthof

Circular polarimetry of gamma-rays - a possible tool for observation of bulk antimatter in the Universe — •Stanislav Tashenov — Physics Institute, Heidelberg University, Germany

A significant body of observations points out that the Universe is composed of matter rather than antimatter. This baryon asymmetry for a long time remains an unsolved problem of physics. The current explanations include a possible CP-symmetry violation or a perfect separation between the bulks of matter and antimatter in the Universe. In the latter case this separation would preclude an observation of annihilation radiation at the border regions. This radiation is currently the only probe for bulk antimatter and it may fail if no bulk matter is present in the vicinity. Another possible method which is free from this limitation is based on circular polarimetry of gamma-rays, in particular on the circular polarization of gamma-ray continuum afterglow which follows a supernova explosion. However, so far no technique to measure circular polarization of cosmic gamma-rays was available. I propose the first such technique which can be naturally integrated into the concept of a gamma-ray Compton telescope. It is based on the transfer of the gamma-ray spin to the recoiled electron in Compton scattering and subsequent detection of the electron spin polarization by means of bremsstrahlung of these electrons. The physics phenomena needed by this technique were recently confirmed and the necessary algorithm for polarization reconstruction was developed.

A 30.12 Wed 16:00 Empore Lichthof

A high precision experimental benchmark of Fe M-shell unresolved-transition-array (UTA) inter-shell absorption lines — C. Beilmann[1], M. Leutenegger[2], R. Steinbrügge[1], J. Rudolph[1,3], S. Eberle[1], M.C. Simon[1], S.W. Epp[1], A. Graf[4], G.V. Brown[4], P. Beiersdorfer[4], T.M. Baumann[1], F.R. Brunner[1], S. Bernitt[1], Z. Harman[1,5], N.S. Oreshkina[1], C.H. Keitel[1], R. Follath[6], G. Reichardt[6], J. Ullrich[1], and •J.R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]NASA/GSFC, Greenbelt MD, USA — [3]Universität Gießen, Germany — [4]LLNL, Livermore CA, USA — [5]EMMI, Darmnstadt, Germany — [6]HZB/BESSY, Berlin, Germany

Measurements of inner-shell absorption lines in highly charged ions have been performed with the portable electron beam ion trap FLASH-EBIT. It was coupled to a high-resolution monochromator at the synchrotron X-ray source BESSY II [1] to measure the resonant excitation energies of states decaying by autoionization or photon emission, which are measured by counting photoions and fluorescence photons in dependence of the X-ray energy. We compared the results with those of our own state-of-the-art relativistic configuration-interaction and multiconfiguration Dirac-Fock calculations, as well as with other recent calculations. The experimentally determined resonance energies typically have absolute precisions of about 70 meV, stringently benchmarking theory.

[1] M.C. Simon et al., Phys. Rev. Lett. **105**, 183001 (2010)

A 30.13 Wed 16:00 Empore Lichthof

X-ray spectroscopy of chemical systems in liquids phase — •Zhong Yin[1,2], Simone Techert[1], Ivan Rajkovic[1], Katharina Kubicek[1,2], Alexander Föhlisch[3,4], Philippe Wernet[3], and Wilson Quevedo[3] — [1]Max Planck Institute for Biophysical Chemistry, Am Faßberg 11, 37077 Göttingen, Germany — [2]Deutsches-Elektron Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [3]Helmholtz Zentrum Berlin, Albert-Einstein-Strasse 15, 12489 Berlin, Germany — [4]University of Potsdam, Karl-Liebknecht-Strasse 24-25, 14476 Potsdam, Germany

Based on their ability to salt in or salt out macromolecules salt ions are classified according to the Hofmeister series. While the macroscopic effect is known for over 100 years, the origin of the effect on the molecular level is still not understood. We present X-ray emission spectroscopy (XES) on the oxygen K-edge of water in aqueous solutions of inorganic salts using BESSY II synchrotron (Berlin, Germany) X-rays. The FlexRIXS end station utilized a liquid micro jet for sample delivery. The element- and site-specific XES method contains information about occupied and unoccupied molecular orbitals and is therefore sensitive to the chemical environment. The aim of our measurements was to reveal the influence of the water-ion interactions on the local water structure further elucidating the understanding of the structure maker and structure breaker concept. Structural changes while utilizing different salts were expected to show as spectral changes in the oxygen K-edge spectra, e.g. of peak shapes or intensities.

A 31: Interatomic and Intermolecular Coulombic Decay

Time: Thursday 11:00–13:00 Location: E 415

Invited Talk A 31.1 Thu 11:00 E 415

Ultralong range ICD in the He dimer, resonant Auger - ICD cascade processes — •Till Jahnke — IKF, Goethe Universität, Max-von-Laue-Str.1, 60438 Frankfurt

Interatomic (or intermolecular) Coulombic Decay (ICD) has become an extensively studied atomic decay process during the last 10 years. The talk will show examples of different systems in which ICD has been examined. In particular helium molecules (so called helium dimers) are presented in which ICD occurs over longest internuclear distances.

In ICD electrons of low energy are created as a typical decay product. Such electrons are known to effectively cause DNA double strand breakups suggesting ICD as a possible origin for radiation damage of living tissue. The group of L. Cederbaum recently suggested that ICD can be triggered efficiently and site-selectively by resonant excitation of molecules. They realized that this provides a unique tool to create low energy electrons at a specific site inside a biological system for example in order to damage malignant cells that are tagged using specific marker molecules.

Here we show experimentally that resonant Auger induced ICD can indeed be observed in model systems of small nitrogen and carbon monoxide clusters and - as expected - produces low energy electrons. Furthermore our simple model systems are able to prove the efficiency of ICD: it occurs before the individual molecule is able to undergo dissociation, i.e on a timescale <10 fs. Our findings therefore strongly support the idea of resonant Auger-ICD being a promising process to induce radiation damage at a specific site inside a high-Z-tagged cell.

Invited Talk A 31.2 Thu 11:30 E 415

Inter-atomic Coulombic decay in endohedral fullerenes — Narges Bahmanpour and •Vitali Averbukh — Department of Physics, Imperial College London, Prince Consort Rd, SW7 2AZ, London, UK

Interatomic Coulombic decay (ICD) in endohedral fullerene complexes presents a special interest due to its ultrafast and possibly non-destructive character [1]. Here we consider for the first time the variation of the decay width of the endohedral inner-valence vacancy with the displacement of the endohedral atom from the fullerene centre. Excitation of multipole fullerene plasmons by ICD in the off-centre geometry is predicted [2]. Distinction is made between averaging over classical ensemble of random displacements and over coherent vibrational state of the endohedral ion inside the cage. Finally, orbital overlap effect is considered within the lowest-order Wigner-Wesskopf theory.

[1] V. Averbukh and L. S. Cederbaum, Phys. Rev. Lett. 96, 053401 (2006).

[2] N. Bahmanpour and V. Averbukh, in preparation.

Invited Talk A 31.3 Thu 12:00 E 415

ICD-like decays in aqueous electrolytes — •Gunnar Öhrwall[1], Niklas Ottosson[2,3], and Olle Björneholm[2] — [1]MAX-lab, Univ. of Lund, Box 118, 22100 Lund, Sweden — [2]Dept. of Physics and Astronomy, Univ. of Uppsala, Box 516, 75120 Uppsala, Sweden — [3]FOM-institute AMOLF, Science Park 102, 1098 XG Amsterdam, The Netherlands

The first systems where it was predicted that inner valence-ionized states of condensed matter should relax efficiently to delocalized two-hole final states - Interatomic or Intermolecular Coulombic Decay (ICD), were hydrogen-bonded clusters, and recently the phenomenon has been observed following inner-valence ionization in hydrogen-bonded water clusters [1]. In 2005, Öhrwall et al. showed the existence of an ICD-like mechanism following O1s ionization of large water-clusters: In the de-excitation spectrum, features originating from final states delocalized over the ionized molecule and a neighboring molecule were observed, in addition to the normal Auger final states localized on the ionized species [2]. This has later also been observed in O1s ionization of liquid water.

Here, I will show examples of ICD-like decays in core-ionized aqueous ions, and in water molecules in aqueous electrolytes. I will also discuss how the efficiency for such decays depends on factors such as charge, polarizability, and solvated radius of the ionic solutes [3].

References [1] M. Mucke et al., Nat. Phys. 6 (2010) 143. [2] G. Öhrwall et al., J. Chem. Phys. 123 (2005) 054310. [3] N. Ottosson, G. Öhrwall, and O. Björneholm, Chem. Phys. Lett. 543 (2012) 1.

Invited Talk A 31.4 Thu 12:30 E 415

Intermolecular Coulomb decay at heterogeneous interfaces — •Thomas Orlando[1,2] and Gregory Grieves[1] — [1]School of Chemisty and Biochemistry, Georgia Institute of Technology, Atlanta, Georgia-USA — [2]School of Physics, Georgia Institute of Technology, Atlanta, Georgia-USA

We investigate low-energy (1-250 eV) electron interactions with complex targets with a particular emphasis on understanding correlated electron interactions and energy exchange in the deep valence and shallow core regions of the collision targets. Specifically, we demonstrate that ejection of $H^+(H_2O)_{n=1-8}$ from low energy electron irradiated water clusters adsorbed on graphite and graphite overlayers of Ar, Kr or Xe results from intermolecular Coulomb decay (ICD). Inner valence holes in water ($2a_1^{-1}$), Ar ($3s^{-1}$), Kr ($4s^{-1}$) and Xe ($5s^{-1}$) levels correlate with the cluster appearance thresholds and initiate ICD. Proton transfer occurs during or immediately after ICD and the resultant Coulomb explosion leads to $H^+(H_2O)_{n=1-8}$ desorption with kinetic energies that vary with initiating state, final state and inter-atomic/molecular distances. Since ICD can create reactive protons and low energy electrons locally, this process may contribute to radiation-induced damage of hydrated DNA.

A 32: Ultra-cold atoms, ions and BEC VI (with Q)

Time: Thursday 11:00–12:30 Location: B 305

A 32.1 Thu 11:00 B 305

Experimental observation of universal scaling at a quantum phase transition — •Eike Nicklas, Moritz Höfer, Wolfgang Müssel, Helmut Strobel, Ion Stroescu, Jiri Tomkovic, Maxime Joos, Daniel Linnemann, David B Hume, and Markus K Oberthaler — Kirchhoff-Institut für Physik, Heidelberg, Germany

A prominent feature of phase transitions is a universal scaling in the divergence of characteristic length and time scales when approaching a critical point. Here we report on the experimental observation of such scaling close to a quantum phase transition in a one-dimensional binary condensate of Rubidium. The quantum phase transition is realized by a microwave dressing field transforming the system from immiscible to miscible, where the distance to the critical point can be well controlled via the amplitude of the dressing field. We investigate the dynamics of in-situ spin-spin correlations and observe scaling behaviour of the correlation length. Both the deduced critical coupling strength and the power law exponent are consistent with theoretical predictions.

A 32.2 Thu 11:15 B 305

Coupled l-wave confinement-induced resonances in cylindrically symmetric waveguides — •Panagiotis Giannakeas[1], Fotios Diakonos[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149,

22761 Hamburg, Germany — [2]Department of Physics, University of Athens, GR-15771 Athens, Greece

A semi-analytical approach to atomic waveguide scattering for harmonic confinement is developed taking into account all partial waves. As a consequence l-wave confinement-induced resonances are formed being coupled to each other due to the confinement. The corresponding resonance condition is obtained analytically using the K-matrix formalism. Atomic scattering is described by transition diagrams which depict all relevant processes the atoms undergo during the collision. Our analytical results are compared to corresponding numerical data and show very good agreement.

A 32.3 Thu 11:30 B 305

Evaporative cooling and thermalization in one-dimensional Bose gases — •Bernhard Rauer, Tim Langen, Michael Gring, Max Kuhnert, David Adu Smith, Remi Geiger, and Jörg Schmiedmayer — Vienna Center for Quantum Science and Technology, Atominstitut, Technische Universität (TU) Wien, Stadionallee 2, 1020 Vienna, Austria.

We experimentally study the process of evaporative cooling for a one-dimensional (1D) Bose gas in the quasi-condensate regime. While this process is well understood for 3D systems, evaporative cooling in 1D is strongly affected by the discrete level structure of the trap and the strongly inhibited thermalization. Consequently, the exact mechanism is still the subject of theoretical debate. The problem is closely related to our ongoing effort to understand relaxation and thermalization in a 1D quantum gases. The current status of this investigation will be presented.

A 32.4 Thu 11:45 B 305

Hermitian four-well potential as a realization of a $\mathcal{PT}$ symmetric system — •Manuel Kreibich, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

A $\mathcal{PT}$ symmetric Bose-Einstein condensate can be theoretically described using a complex optical potential, however, the experimental realization of such an optical potential describing the coherent in- and outcoupling of particles is a nontrivial task.

As an alternative, we propose an experiment for a quantum mechanical realization of a $\mathcal{PT}$ symmetric system. The $\mathcal{PT}$ symmetric currents of a two-well system are implemented by coupling two additional wells to the system, which act as particle reservoirs. In terms of a simple four-mode model we derive conditions under which the two middle wells of the Hermitian four-well system behave *exactly* as the two wells of the $\mathcal{PT}$ symmetric system. We apply these conditions to calculate stationary solutions and oscillatory dynamics. By means of frozen Gaussian wave packets we relate the Gross-Pitaevskii equation to the four-mode model and give parameters required for the external potential, which provides approximate conditions for a realistic experimental setup.

A 32.5 Thu 12:00 B 305

The impact of spatial correlation on the tunneling dynamics of few-boson mixtures — •Lushuai Cao, Ioannis Brouzos, Budhaditya Chatterjee, and Peter Schmelcher — Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany

We investigate the tunneling properties of a two-species few-boson mixture in a one dimensional triple well and harmonic trap. The mixture is prepared in an initial state with a strong spatial correlation for one species and a complete localization for the other species. We observe a correlation induced tunneling process in the weak interspecies interaction regime. The onset of the interspecies interaction disturbs the spatial correlation of one species and induces tunneling among the correlated wells. The corresponding tunneling properties can be controlled by the spatial correlations with an underlying mechanism which is inherently different from the well known resonant tunneling process. We also observe the correlated tunneling of both species in the intermediate interspecies interaction regime and the tunneling via higher band states for strong interactions.

A 32.6 Thu 12:15 B 305

Thermally induced coherent collapse of dipolar Bose-Einstein condensates — •Andrej Junginger[1], Jörg Main[1], Günter Wunner[1], and Thomas Bartsch[2] — [1]1. Institut für Theoretische Physik, Universität Stuttgart, Germany — [2]Department of Mathematical Sciences, Loughborough University, UK

We investigate Bose-Einstein condensates (BECs) with additional anisotropic and long-range dipolar interaction at finite temperature. The ground state of such a system is metastable and one decay mechanism is the BEC's coherent collapse due to collective thermal excitations. With focus on the latter and as an alternative to solving the Hartree-Fock-Bogoliubov equations, we make use of a variational approach to calculate the corresponding decay rates at temperatures small compared to the critical temperature. Within this variational approach, the collectively excited states of the condensates which form the "activated complex" are accessible. Using a normal form expansion of the equations of motion and the energy functional, the variational parameters can be mapped to classical phase space which allows for the application of transition-state theory. We show that the collapse dynamics of the dipolar BEC breaks the symmetry of the external trap if it is confined cylindrically symmetrical and present thermal decay rates for different temperatures of the quantum gas obtained from a variational ansatz using coupled Gaussian orbitals.

A 33: Interaction with strong or short laser pulses III

Time: Thursday 11:00–12:30 Location: B 302

A 33.1 Thu 11:00 B 302

Minicharged particles in a strong laser field — •Villalba-Chavez Selym and Müller Carsten — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf, Germany

Absorption of photons due to the production of pairs of minicharged particles are investigated in the presence of a high intensity laser. This hypothetical process would induce a tiny rotation of the polarization plane in a linearly polarized probe beam after travelling through the external wave (vacuum dichroism).

The optical theorem is applied to determine the rate and the corresponding rotation angle in terms of the imaginary part of the vacuum polarization tensor. A similar method has been recently applied in the calculation of the photo-production rate of scalar particles in a circularly polarized wave [S. Villalba-Chavez and C. Müller, Phys. Lett. B, in press; arXiv:1208.3595]

High-precision optical experiments would allow to impose bounds on the charge and mass of these hypothetical particles.

A 33.2 Thu 11:15 B 302

Interference Effects in Electron-Positron Pair Creation by the Interaction of a Bichromatic Laser Field and a Nucleus — •Sven Augustin and Carsten Müller — Heinrich-Heine Universität, Düsseldorf

We investigate quantum interferences in electron-positron pair creation in the collision of a relativistic nuclear beam and an intense laser pulse.

In particular, we consider a laser field consisting of two modes with commensurate frequencies. In this situation, quantum path interference may arise which can lead to an increase or a decrease of the total pair production rate. The interference is also visible in angular differential rates which are discussed both in the nuclear rest frame and the laboratory frame.

A 33.3 Thu 11:30 B 302

Decay of autoionizing states in time-dependent density functional and reduced density matrix functional theory — •Varun Kapoor, Martins Brics, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

Autoionizing states are inaccessible to time-dependent density functional theory (TDDFT) using known, adiabatic Kohn-Sham (KS) potentials. We determine the exact KS potential for a numerically exactly solvable model Helium atom interacting with a laser field that is populating an autoionizing state. The exact single-particle density of the population in the autoionizing state corresponds to that of the energetically lowest quasi-stationary state in the exact KS potential. We describe how this exact potential controls the decay by a barrier whose height and width allows for the density to tunnel out and decay with the same rate as in the ab initio time-dependent Schrödinger calculation. However, devising a useful exchange-correlation potential that is capable of governing such a scenario in general and in more complex systems is hopeless. As an improvement over TDDFT, time-dependent reduced density matrix functional theory has been proposed. We are able to obtain for the above described autoionization process the exact time-dependent natural orbitals (i.e., the eigenfunctions of the exact, time-dependent one-body reduced density matrix) and study the potentials that appear in the equations of motion for the natural orbitals and the structure of the two-body density matrix expanded in them.

A 33.4 Thu 11:45 B 302

Near-zero energy electron emission in strong field ionization at long wavelength — •Camus Nicolas[1], Dura Judith[2], Biegert Jens[2], Britz Alexander[2], Thai Alexandre[2], Hemmer Michael[2], Baudish Matthias[2], Ullrich Joachim[1,3], Senftleben Arne[1], and Moshammer Robert[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]ICFO-Institut de Ciences Fotoniques, 08860 Barcelona, Spain — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

The discovery of surprisingly high yields of low energy electrons in single ionization of atoms and molecules with intense near infra-red laser pulses [1] triggered theoretical [2-4] as well as experimental activities [5,6] in order to complete our understanding of the photo-ionization process. The important role of electron rescattering in the Coulomb potential is a common ingredient of all existing explanations, but a comprehensive description is still missing. Here we report on high-resolution measurements with a Reaction Microscope on ionization of atoms and small molecules using few-cycle long wavelength (3100 nm) laser pulses at high intensity, well in the tunneling regime. Results will be presented and discussed in the framework of already existing measurements and available theoretical models.

[1] Blaga et al, Nature Physics, 2009, 5, 335-338 [2] Liu et al Phys. Rev. Lett., 2010, 105, 113003 [3] Yan et al Phys. Rev. Lett., 2010, 105, 253002 [4] Kastner et al Phys. Rev. Lett., 2012, 108, 033201 [5] Quan, W. et al Phys. Rev. Lett., 2009, 103, 093001 [6] Wu et al Phys. Rev. Lett., 2012, 109, 043001

A 33.5 Thu 12:00 B 302

Emergence of sub-1.5-cycle pulses from a single filament — •Martin Kretschmar[1,2], Daniel S. Steingrube[1,2], Dominik Hoff[3], Emilia Schulz[1,2], Peter Hansinger[3], Thomas Binhammer[4], Gerhard G. Paulus[3], Uwe Morgner[1,2], and Milutin Kovacev[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, D-30167 Hannover, Germany — [2]QUEST, Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, D-30167 Hannover, Germany — [3]Friedrich-Schiller-Universität Jena, Institut für Optik und Quantenelektronik, Max-Wien-Platz 1, D-07743 Jena, Germany — [4]VENTEON Laser Technologies GmbH, D-30827 Garbsen, Germany

Filamentation has become a versatile tool for pulse shortening, making it applicable in attosecond science. Complex spatio-temporal dynamics taking place during the filamentation process strongly influence the propagating pulse, leading to few-cycle pulse generation as well as high-order harmonic generation directly inside the filament. Temporal dynamics of ultrashort laser pulses undergoing filamentary propagation are determined with a stereographic above-threshold ionization (ATI) phasemeter. The setup is capable of measuring the pulse duration as well as CEO-phase contributions of pulses originating from a fs-filament. We observe the formation of few-cycle pulses as well as temporal pulse splitting dynamics along the propagation direction of the filament. We demonstrate a pulse measurement of 3.8 fs duration, corresponding to sub-1.5 cycles of the electric field, emerging from a single fully propagated filament.

A 33.6 Thu 12:15 B 302

Measurement of the Gouy phase shift in two-color laser pulses — •Robert Irsig, Johannes Passig, Josef Tiggesbäumker, Thomas Fennel, and Karl-Heinz Meiwes-Broer — Insitut für Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock

The Gouy effect is well known as a phase shift of π of the electric field passing a focus region. In recent years, the Gouy effect was investigated using few cycle laser pulses to ionise rare gas atoms, taking benefit of the strong asymetric field distribution [1,2]. Depending on the phase of the laser pulses, electron spectra show a characteristic behaviour in energy distribution and emission direction. That allows for an absolute phase reconstruction. In contrast to few cycle experiments, we present first phase-depending measurements using intense two-color laser pulses of 150 fs (FWHM). By varying the phase-shift in between first and second harmonic, one can synthesise asymetric light fields which enables to controll electron emission. A home-build stereo-time-of-flight-spectrometer is used to simultaneous detect the electrons emitted in opposite directions with respect to the laser polarisation axis. By applying a focus scan, we can directly map the Gouy phase shift along the propagation direction in the electron spectra.

[1] Lindner et. al., Phys. Rev. Lett 92, 113001 (2004)
[2] Shivaram et. al., Optics Letters 35, 3312 (2010)

A 34: SYCD Interatomic and intermolecular Coulombic decay (contributed for SYCD in A, MO)

Time: Thursday 14:00–15:30 Location: B 302

Invited Talk A 34.1 Thu 14:00 B 302

Interatomic Coulombic decay following electronic excitations — •Kirill Gokhberg — Physikalisch-Chemisches Institut, Heidelberg University, Germany

Ultrafast non-radiative decay of excited electronic states embedded into an environment by interatomic Coulombic decay or ICD mechanism has been a topic of extensive theoretical and experimental work. An interesting and comparatively unexplored area of the ICD research is the role of an environment in the decay of resonantly excited atoms and molecules. Theoretical calculations show that the ICD lifetimes of such states range from a few hundred to a few tens femtoseconds. These large ICD rates imply that the excited state dynamics observed in isolated system will be drastically modified by the environment. We illustrate this on examples of molecular photodissociation, and multiple ionisation of rare gas clusters in strong fields.

A 34.2 Thu 14:30 B 302

The role of the partner atom and resonant excitation energy in ICD in rare gas dimers — •Patrick O'Keeffe[1], Paola Bolognesi[1], Marcello Coreno[1], Enrico Ripani[1], Lorenzo Avaldi[1], Michele Devetta[2], Robert Richter[3], Michele Di Fraia[3], Carlo Callegari[3], Kevin Prince[3], Antti Kivimaki[4], and Michele Alagia[4] — [1]CNR-IMIP, Area della Ricerca di Roma 1, Italy — [2]Dipartimento di Fisica, Università degli Studi di Milano, Milan, Italy — [3]Sincrotrone Trieste, Area Science Park, 34149 Trieste, Italy — [4]CNR-IOM, 34149 Trieste, Italy

This work shows experimental evidence for Interatomic Coulombic Decay (ICD) in mixed rare gas dimers following resonant Auger decay. A modified velocity map imaging apparatus together with a cooled supersonic beam containing Ar_2, ArNe and ArKr dimers was used to record electron VMI images in coincidence with either one or two mass selected ions following excitation of the species on five resonances converging to the Ar^+ $2p^{-1}_{1/2}$ and $2p^{-1}_{3/2}$ thresholds using the synchrotron radiation of Elettra. The results show that the kinetic energy distribution of the ICD electrons observed in coincidence with the ions from Coulomb explosion of the dimers depends on the partner ion and resonant excitation photon energy.

A 34.3 Thu 14:45 B 302

Competition of ICD pathways in mixed neon-argon clusters — •Marko Förstel and Uwe Hergenhahn — Max-Planck-Institut für Plasmaphysik, c/o HZB-Bessy II, Albert-Einstein Str. 15, 12489 Berlin

Interatomic (or -molecular) coulombic decay (ICD) is an electronic de-excitation mediated by an energy transfer to the surrounding of the initially excited site.

Ne 2s excited, mixed Ne-Ar clusters exhibit both, Ne-Ar and Ne-Ne ICD. We measured both decay pathways simultaneously in mixed clusters of varying size and composition using electron-electron coincidence spectroscopy.

The decay rate of ICD is strongly dependent on the number and the distance to the neighbors of the initially excited atom. Additionally, the kinetic energy of the ICD electron allows for a direct assignment of the ICD pathway. Consequentially the structure of the mixed cluster can be probed by measuring the competition of Ne-Ne and Ne-Ar ICD.

I will present outer valence and inner valence spectra of Ne-Ar clusters of different sizes and composition. I will present electron-electron coincidence spectra of the same species. Both results will be used to discuss the composition and the structure of the clusters.

A 34.4 Thu 15:00 B 302

Investigation of ICD via fluorescence spectroscopy — •Andreas Hans[1], André Knie[1], Benjamin Kambs[1], Daniel Metz[2], Jörg Voigtsberger[2], Florian Trinter[2], Till Jahnke[2], Reinhard Dörner[2], and Arno Ehresmann[1] — [1]Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology, Universität Kassel, Heinrich-Plett-Straße 40, D-34132 Kassel, Germany — [2]Institut für Kernphysik, Goethe-Universität Frankfurt am Main, Max-von-Laue-Straße 1, D-60438 Frankfurt, Germany

Interatomic Coulombic Decay (ICD) has recently been subject of many experiments. It is a new decay path for excited atoms in weakly bound systems. Here we introduce fluorescence as an as yet not considered tool to investigate ICD. In noble gas clusters fluorescence decay paths should be observable due to ICD, that are not possible in the atomic case. A more elegant possibility offer mixed clusters. After excitation of one kind of atom fluorescence of the cluster partner can be measured. We introduce the planned spectroscopy experiments to proof and investigate the ICD-process and we present results of preliminary experiments on fluorescence spectroscopy of noble gas atoms and clusters.

A 34.5 Thu 15:15 B 302

Interatomic Coulombic Electron Capture in Double Quantum Dots — •Federico M. Pont, Annika Bande, Kirill Gokhberg, and Lorenz S. Cederbaum — Theoretische Chemie, Physikalisch-Chemisches Institut, Im Neuenheimer Feld 229, 69120 Heidelberg, Germany

We demonstrate that Interatomic Coulombic Electron Capture (ICEC) is possible in double quantum dots. It was first proposed for atomic dimers and is a process were one electron is captured by one of the atoms and the released energy is used to ionize the neighboring atom. ICEC is related to the Inter Coulombic Decay (ICD) processes, and it can be conceptualized using a virtual photon mechanism as well, but it is not a resonant process. The model used consists of two aligned dots separated by a distance R in a quasi-onedimensional nanowire. We are interested in a regime where the dots are not identical, they have only one bound state each, and the separation R is long enough to prevent electrons from tunneling between them. Since ICEC is not a resonant process, it can be in principle accessible in a wide range of energies. However we have found that in the quasi-onedimensional regime, the process shows enhancements for some definite values of the incoming electron momentum. In this case the reaction probability for ICEC was estimated to be of the order of 1%. Another ICEC related process was analyzed by allowing one of the dots to have one more bound state. In this setup a delocalized resonance between dots, which can decay through ICD, aids the process and a huge increase in the reaction probability is found reaching values up to 35%.

A 35: Ultra-cold atoms, ions and BEC VII (with Q)

Time: Thursday 14:00–16:00 Location: B 305

A 35.1 Thu 14:00 B 305

Magneto-optical trapping of dysprosium — •Thomas Maier, Holger Kadau, Matthias Schmitt, Michaela Nickel, 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 such quantum gases. Recent generation of degenerated bosonic [1] and fermionic dysprosium [2] and bosonic erbium [3], both elements with large magnetic dipole moment, are promising candidates to observe these mentioned effects.

We report on progress in our experiment to achieve degenerate dysprosium quantum gases. Dysprosium is the element with the highest magnetic moment and offers a non-spherical symmetric groundstate $^5\mathrm{I}_8$. In the present stage, we realized a magneto-optical trap (MOT) for dysprosium on a broad cooling transition at 421 nm. Future perspectives are to implement a narrow-line MOT on the 626 nm cooling transition, similar to the work in [3].

[1] M. Lu *et al.*, Phys. Rev. Lett. **107**, 190401 (2011)
[2] M. Lu *et al.*, Phys. Rev. Lett. **108**, 215301 (2012)
[3] K. Aikawa *et al.*, Phys. Rev. Lett. **108**, 210401 (2012)

A 35.2 Thu 14:15 B 305

Dissipative Binding of Lattice Bosons through Distance-Selective Pair Loss — Cenap Ates, Beatriz Olmos, •Weibin Li, and Igor Lesanovsky — School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, United Kingdom

We show that in a gas of ultracold atoms distance selective two-body loss can be engineered via the resonant laser excitation of atom pairs to interacting electronic states. In an optical lattice this leads to a dissipative master equation dynamics with Lindblad jump operators that annihilate atom pairs with a specific interparticle distance. In conjunction with coherent hopping between lattice sites this unusual dissipation mechanism leads to the formation of coherent long-lived complexes that can even exhibit an internal level structure which is strongly coupled to their external motion. We analyze this counterintuitive phenomenon in detail in a system of hard-core bosons. While current research has established that dissipation in general can lead to the emergence of coherent features in many-body systems our work shows that strong nonlocal dissipation can effectuate a binding mechanism for particles.

A 35.3 Thu 14:30 B 305

Atomic Coherence in a Superconducting Coplanar Resonator — •Patrizia Weiss, Helge Hattermann, Simon Bernon, Daniel Bothner, Martin Knufinke, 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 devices have proved suitable for fast qubit operations and quantum gates. However, their coherence times are still limited to a few μs. Therefore hybrid quantum systems have attracted considerable interest. One promising system is composed of superconductors and cold atoms, in which the atomic ensemble takes the role of a quantum memory and is coupled to a superconducting resonator that acts as a quantum bus.

Here we report on the preparation and coherence times of atomic ensembles in a superconducting coplanar resonator on an atom chip. The superconducting structures are based on niobium thin films at 4.2 K. Atoms are trapped by persistent currents in the resonator ground planes. We are able to produce large BECs of up to 10^6 atoms. The coherence of atomic superposition states is investigated by means of Ramsey interferometry. We find atomic coherence times on the order of $T_2 \sim 10\,\mathrm{s}$. We report on progress towards coupling of the atoms to the mode of a cavity.

A 35.4 Thu 14:45 B 305

Millikelvin System for Cold Atom Superconductor Hybrid Quantum Devices — •Florian Jessen, Martin Knufinke, Petra Vergien, Malte Reinschmidt, Helge Hattermann, Simon Bernon, Simon Bell, Daniel Cano, Dieter Kölle, Reinhold Kleiner, and József Fortágh — Center for Collective Quantum Phenomena, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

Hybrid quantum systems based on ultracold atoms and superconducting devices are promising candidates for fundamental physics as well as quantum information especially superconducting quantum circuits require millikelvin temperatures for their operation and sufficiently long coherence time. Towards realisation of the cold atom/superconductor quantum interface we installed cold atoms setup into a delution refrigerator reaching a base temperature of 50mK. We report on the operation of this system.

A 35.5 Thu 15:00 B 305

Semiclassical dynamics of ultracold Bosons in multiple wells — •Lena Simon and Walter Strunz — Institut für theoretische Physik, TU Dresden

We aim to shed light on the transition from a nonequilibrium to an equilibrium state of an interacting bosonic manybody system. We investigate the dynamics of an ensemble of Bosons in a multiple well potential, which has been initially set up in a nonequilibrium state. The Bosons display interesting dynamics, gouverned by the interplay of tunneling and the interaction amongst the particles. The dynamics are investigated by solving the full Schroedinger equation for a Bose-Hubbard-model, and by means of the so called (semiclassical) Herman-Kluk propagator. The results are also compared to the often applied mean-field approximation.

A 35.6 Thu 15:15 B 305

Noise correlations of two-dimensional Bose gases — •Vijay Pal Singh and Ludwig Mathey — Zentrum fuer Optische Quantentechnologien and Institut fuer Laserphysik, Universitaet Hamburg, D-22761 Hamburg, Germany

We analyze the density-density correlations of the expanding clouds of weakly interacting two-dimensional (2D) Bose gases below and above the Berezinskii-Kosterlitz-Thouless (BKT) transition. Such a system has two thermal phases in equilibrium, defined through the long-range order of the two-point correlation function. In the course of a time-of-flight expansion, both thermal and quantum fluctuations present in the trapped system transform into density fluctuations. The spectrum of density distributions shows an oscillatory shape controlled only by the scaling exponent of the quasi-condensed phase (below the transition) and by the correlation length (above the transition). This exponent can be extracted by analyzing the evolution of the spectrum of density distributions as a function of the expansion time. The positions of the spectral peaks show a scaling behavior with the expansion time. How these features can be extracted in experiment will be discussed as well.

A 35.7 Thu 15:30 B 305

Quasi-particle excitation spectra of general quantum lattice systems via the 1/Z expansion — •Patrick Navez, Konstantin Krutitsky, Friedemann Queisser, and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany

We investigate general quantum lattice systems such as the Bose and Fermi Hubbard models or the Heisenberg spin model using the 1/Z expansion method [1,2] where Z is the coordination number. This method provides a general framework for deriving linearized equations of motion for quasi-particle excitation operators, which yield the excitation spectra, for example. Their solutions determine the one-site reduced density matrix and the two-sites reduced correlation density matrix, which are given in terms of bilinear expectation values of the quasi-particle excitation operators (displaying the quantum fluctuations). We illustrate the powerfulness of these general concepts for several examples such as particle-hole operators in the Mott phase of the Bose and Fermi Hubbard models (which lower the ground state energy by virtual tunneling) or the Heisenberg model (where virtual magnon excitations of opposite spin reduce antiferromagnetism) and compare our findings with the results found in the literature.

1 P. Navez, R. Schützhold, Phys. Rev. A 82, 063603 (2010)

2 F. Queisser, K. Krutitsky, P. Navez, R. Schützhold, arXiv:1203.2164

A 35.8 Thu 15:45 B 305

Local Detection of Quantum Gases in Real Time — •Peter Federsel, Markus Stecker, Simon Bell, Hannah Schefzyk, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Deutschland

In this talk, we describe a novel scheme for local single-atom detection in trapped clouds of ultracold atoms. The scheme is based on local field ionization of atoms and subsequent ion detection. The ionization takes place in the locally enhanced near-field at the tip of a charged nanowire. Field strengths of up to 10^{10} V/m can be achieved, sufficient for field ionization of nearby rubidium atoms. The detection scheme is fully compatible to state-of-the-art atomchip experiments and includes ion-optics for extracting and guiding the ions to the sensitive single ion detector. We will show first results on this new detection scheme, including measurements on the tips field enhancement, characterization of the ion optics and field-ionization of thermal atoms.

A 36: Atomic clusters II (with MO)

Time: Thursday 14:00–15:30 Location: F 428

Invited Talk A 36.1 Thu 14:00 F 428

Size selective vibrational spectroscopy of strongly bound neutral clusters — •Andre Fielicke — Institut für Optik und atomare Physik, TU Berlin

Properties of small clusters are often not only strongly dependent on their size but also on their charge state. A prominent example for this is the transition from 2D to 3D structures for gold clusters which is observed to occur at n=8 for the cations and at n=12 for the anions. While such ionic clusters are susceptible to common mass spectrometric techniques for size selection and storage similar manipulations are more difficult for neutral species and, hence, different experimental techniques need to be applied to obtain cluster size specific information. Recently, different methods have been developed that apply resonant vibrational excitation of strongly bound neutral clusters in molecular beams with infrared Free Electron Lasers. These IR sources provide intense and tunable radiation even in the far-IR region where the vibrational fundamentals of metal or semi-metal clusters are located. Size selectivity is obtained by coupling the IR excitation with a subsequent soft ionization step, i.e. avoiding fragmentation, and mass spectrometric analysis of the ionic distribution. Examples of such action spectroscopic IR studies on neutral clusters are the dissociation of messenger complexes of metal clusters,[1] IR-UV two color ionization of semi-metal and oxide clusters [2] and IR resonant enhanced multiple photon ionization of clusters of refractory materials. [1] P. Gruene et al., Science 321, 674 (2008); [2] M. Haertelt et al., Phys. Chem. Chem. Phys. 14, 2849 (2012).

A 36.2 Thu 14:30 F 428

Time resolved ionization dynamics of Xe clusters investigated with XUV-NIR pump-probe experiments at the FLASH free-electron laser — •M Sauppe[1], M Adolph[1], L Flückiger[1], T Gorkhover[1], D Rupp[1], S Schorb[2], S Düsterer[3], M Harmand[3], R Treusch[3], C Bostedt[2], M Krikunova[1], and T Möller[1] — [1]IOAP, TUB — [2]LCLS, SLAC — [3]HASYLAB, DESY

Clusters irradiated by intense femtosecond extreme ultraviolet (XUV) light pulses from the FLASH free-electron laser are transformed into a highly excited non-equilibrium state resulting in complex electron and expansion dynamics. We used XUV and near infrared (NIR) pulses with pump-probe technique in order to get insight into the dynamics. The XUV pump pulse creates a nanoplasma of quasi-free electrons and initiates the expansion process of the cluster. The dynamics is probed with the time delayed NIR pulse.

Xenon clusters were produced by supersonic expansion of Xe gas. Ions and scattered photons from large single xenon clusters were recorded in coincidence. The scattering pattern gives us the possibility to determine and sort for cluster size. With the expansion of the clusters, the density of the generated quasi-free electrons of the produced nano plasma decreases. At well defined delay after the first pulse, the resonant frequency of the nanoplasma meets the frequency of the NIR-probe pulse, known as plasma resonance. These optimal conditions for energy absorption from the NIR pulse into the cluster lead to a simultaneous increase of the ion yield as observed in our experiment. The relationship between cluster size and ion yield will be discussed.

A 36.3 Thu 14:45 F 428

Spin Coupling and Orbital Angular Momentum Quenching in Free Iron, Cobalt, and Nickel Clusters — Andreas Langenberg[1,2], Konstantin Hirsch[1,2], Arkadiusz Ławicki[1], Vicente Zamudio-Bayer[1,2], Markus Niemeyer[1,2], Patrick Chmiela[1,2], Bruno Langbehn[1,2], Akira Terasaki[3,4], Thomas Möller[2], Bernd von Issendorff[5], and •Tobias Lau[1] — [1]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin — [2]Institut für Optik und Atomare Physik, Technische Universität Berlin, 10623 Berlin — [3]Cluster Research Laboratory, Toyota Technological Institute, Chiba, Japan — [4]Department of Chemistry, Kyushu University, Fukuoka, Japan — [5]Fakultät für Physik, Universität Freiburg, 79104 Freiburg

The peculiar magnetic behavior of the cationic thirteen iron atom icosahedron [1] is investigated in a comparative x-ray magnetic circular dichroism study of size-selected free iron, cobalt, and nickel clusters in the size range of 10–15 atoms per cluster. While the magnetic spin moment of cationic Fe_{13}^+ is quenched significantly, no such quenching was observed for Co_{13}^+ or Ni_{13}^+. This can most likely be correlated to the high symmetry in the case of iron.
[1] M. Niemeyer *et al.*, Phys. Rev. Lett. **108**, 057201 (2012).

A 36.4 Thu 15:00 F 428

XUV-Fluorescence spectroscopy of Argon clusters excited by intense XUV pulses and high kinetic electrons — •T Oelze[1], M Adolph[1], L Flückiger[1], T Gorkhover[1], M Krikunova[1], M Müller[1], L Nösel[1], Y Ovcharenko[1], R Richter[1], D Rupp[1], M Sauppe[1], S Schorb[1,3], D Wolter[1], A Przystawik[2], L Schrödter[2], C Bostedt[1,3], T Laarmann[2], and T Möller[1] — [1]TU-Berlin — [2]HASYLAB@DESY — [3]LCLS@SLAC

Free-electron lasers (FELs) in the short wavelength regime, such as FLASH, combine a high photon flux with fs pulse length, thus enabling us to study the interaction between intense light and matter in new ways. Rare gas clusters as size scalable nano-objects are used as model systems to study this interaction. When the clusters get hit by an FEL pulse, a nanoplasma is created within the cluster. Finally the clusters disintegrate into highly charged ions while emitting electrons and photons. The residues, yielding information of mechanisms and time scales, can be analyzed. Fluorescence spectra of rare gas clusters taken at FLASH at an excitation energy of 90 eV revealed a large number of lines between 10 and 75 nm. To further investigate the cluster size dependent development of those lines, a subsequent experiment using high kinetic electrons for excitation, has been realized. A corresponding dependency of the fluorescence spectra on the electron energy was found, which points to strong influence of the nanoplasma in the fluorescence process. The setup will be discussed and results will be shown.

A 36.5 Thu 15:15 F 428

Impact of electron-ion recombination on the ionization dynamics of Xenon clusters under XUV pump-probe excitation — •Mathias Arbeiter and Thomas Fennel — Institute of Physics, University of Rostock

A theoretical analysis of the ionization dynamics of Xenon clusters under XUV pump-probe excitation is presented for the parameter range studied in a recent experiment at $\hbar\omega = 92$eV [1]. In this scenario, the nanoplasma evolution in the pump-induced cluster expansion is probed by a delayed second pulse that further ionizes the target. The pump-probe experiments have shown that the average charge state of the fragment ions increases with delay [2]. This enhancement was interpreted as direct photoemission due to global cluster potential lowering within cluster expansion. The theoretical analysis verifies the presence of this effect. However, our simulations show that the contribution of the direct emission is too weak to explain the observations. Our simulations predict that the decrease of electron-ion recombination for longer delays is the dominant process. The theory results are in good agreement with the experiment for both absolute charge states and timescales.

[1] M. Arbeiter, Th. Fennel, to be submitted

[2] M. Krikunova, M. Adolph, T. Gorkhover, D. Rupp, S. Schorb, C. Bostedt, S. Roling, B. Siemer, R. Mitzner, H. Zacharias and T. Möller, J. Phys. B: At. Mol. Opt. Phys. 45, 105101 (2012)

A 37: Precision measurements and metrology IV (with Q)

Time: Thursday 14:00–16:00 Location: F 128

Group Report A 37.1 Thu 14:00 F 128

A prototype optical bench for the Laser Interferometer Space Antenna — •Michael Tröbs and the LISA Optical Bench Team — Albert Einstein Institute, Callinstrasse 38, 30167 Hannover, Germany

The Laser Interferometer Space Antenna (LISA), aims to detect gravitational-waves at mHz frequencies. It consists of three spacecraft forming an equilateral triangle in an Earth-like orbit around the sun. Drag-free test masses define the arms of a Michelson interferometer that is implemented by mutual laser links between the satellites in a transponder configuration. Each LISA satellite carries optical benches, one for each test mass, that measure the distance to the local test mass and to the remote optical bench on the distant satellite. In addition, the optical bench includes an acquisition sensor and mechanisms for laser redundancy switching.

Currently, an elegant bread board of the optical bench is developed and will be characterized. This requires to complete externally the two interferometers mentioned above by simulators – a test mass simulator and a telescope simulator. We will give an overview of the test infrastructure including the simulators, the interferometer readout, the laser systems and the data acquisition.

A 37.2 Thu 14:30 F 128

Micro-Newton thruster and test facility development — •Franz Georg Hey[1,2], Andreas Keller[1], Ulrich Johann[1], Claus Braxmaier[1,3,4], Martin Tajmar[2], and Dennis Weise[1] — [1]Astrium GmbH - Satellites — [2]Technische Universität Dresden — [3]Universität Bremen — [4]Deutsches Zentrum für Luft- und Raumfahrt

For future space missions especially with multi satellite configuration like the New Gravitational Wave Observatory, a highly precise attitude control system is required. The High Efficiency Multistage Plasma Thruster (HEMP-T) could be an adequate attitude actuator for these mission scenarios. In parallel to the development of suitable thrusters, also the setup of suitable test infrastructure for measurement of μN thrust noise levels is of crucial importance to understand such systems.

We present the development status of the micro-Newton HEMP-T as well as the status of the developed micro-Newton thrust balance. The developed, integrated and tested thrust balance consists of an optical read out, a calibration device, and the measurement pendulum itself. A heterodyne interferometer is used as optical read out. To measure the tilt of the pendulum, differential wave front sensing is used. The whole interferometer- and the mechanical balance setup is in a total symmetric configuration to enable a common-mode rejection of different noise sources. The calibration was accomplished with an electro static comb. The developed thrust balance has a resolution of $10\,\mu\mathrm{N}/\sqrt{Hz}$ by a measured pendulum translation of few nanometers. Moreover we present the results of an experimental comparison of different HEMP-T configurations.

A 37.3 Thu 14:45 F 128

Ground-based characterisation of the LISA Pathfinder optical measurement system — •Andreas Wittchen, Martin Hewitson, Heather Audley, Natalia Korsakova, Gerhard Heinzel, and Karsten Danzmann — Max-Planck Institut/AEI Hannover

A space-based gravitational wave detector, the laser interferometer space antenna (LISA), is currently being developed. LISA consists of three identical satellites, forming an equilateral triangle with million kilometre armlengths. To develop and test key technologies required, a test satellite, LISA Pathfinder, will be launched. This satellite contains a pair of free-floating test masses. The distance between the test masses will be precisely measured interferometrically. One of the key components of the measurement system is the optical bench, consisting of four interferometers. An engineering model optical bench is available at the Albert Einstein Institute, Hannover. It is currently used for system characterisation experiments, and will be integrated in a ground based test bed for use during in-flight operations. In this contribution the optical bench will be introduced and the current preparations for the mission are explained.

A 37.4 Thu 15:00 F 128

MAIUS - a rocket-based matter-wave interferometer — •Stephan Tobias Seidel[1], Ernst Maria Rasel[1], and The Quantus-Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Universität Bremen — [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 — [9]MPQ, Garching

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. With the QUANTUS experiments operating in the drop tower Bremen we were able to realize the first BEC based interferometer in microgravity. As a next step towards the transfer of such a system in space, either on board the ISS or as a dedicated satellite mission, a chip-based atom interferometer operating on a sounding rocket is currently being built. The success of this project would mark a major advancement towards a precise measurement of the equivalence principle with a space-born atom interferometer.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM1131.

A 37.5 Thu 15:15 F 128

Breadboard model of the LISA Phasemeter — •Oliver Gerberding, Simon Barke, Joachim Kullmann, Ioury Bykov, Juan Josè Esteban Degaldo, Gerhard Heinzel, and Karsten Danzmann — Max-Planck-Institute for Gravitational Physics (Albert-Einstein-Institute) and Leibniz University of Hannover, Callinstraße 38, 30167 Hannover, Germany

The detection of gravitational waves in the sub-Hz regime will allow insight into the dynamics of galactic objects, like mergers of ultramassiv black holes. For this purpose the space-born gravitational wave detector LISA is planned, which uses precision heterodyne laser interferometry as main measurement technology.

A breadboard model for the phase readout system of these interferometers (Phasemeter) is currently under development as an ESA project by a collaboration between the Albert-Einstein Institute, the Technical University of Denmark and 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 current status of testing and development of the breadboard. This includes phase readout with $1\mu\text{cycle}/\sqrt{\text{Hz}}$ performance, clock noise transfer, inter-satellite ranging and communication, laser frequency control and acquisition.

A 37.6 Thu 15:30 F 128

Laser frequency stabilisation for the AEI 10m Prototype Interferometer — •Manuela Hanke for the AEI 10 m Prototype team — Leibniz Universität Hannover und MPG für Gravitationsphysik (AEI)

The 10 m Prototype facility, currently being set up at the AEI Hannover, will provide a testbed for very sensitve interferometric experiments. One ambitious goal of this project is to reach and subsequently even surpass the standard quantum limit in a detection band around 200 Hz with a 10 m arm length Michelson interferometer. In order to pursue such an avenue, the laser source must be extremely well stabilised. The laser source was chosen to be one of the 35 W lasers used to drive the km-scale gravitational wave observatories, LIGO and GEO 600. A fully suspended triangular ring cavity of finesse ca. 5000 will be used as a frequency reference for the stabilisation of the laser. The aim of this project, the so-called frequency reference cavity, is to reach a level of laser frequency fluctuations of better than 10^{-5} Hz/sqrt(Hz) in the detection band, centered around 200 Hz. Therefore we need to reduce the frequency noise by a factor of 10^7. The main goal is to make a sufficiently stabilised laser beam available for the AEI 10 m Prototype Interferometer, with a duty cycle that is not limiting the operation of the core instrument by any means. In this talk I will show the motivation for a frequency stabilisation and present the layout and the status of the reference cavity.

A 37.7 Thu 15:45 F 128

Development of photoreceivers for space-based interferometry — •Germán Fernández, Gerhard Heinzel, and Karsten Danzmann — Max Planck Institute for Gravitational Physics/AEI, Hannover

The photoreceiver is a basic element in laser interferometry systems presented in space-based missions such as Lisa Pathfinder or GRACE. The special requirements demaded 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 38: Poster: Atomic clusters (with MO)

Time: Thursday 16:00–18:30 Location: Empore Lichthof

A 38.1 Thu 16:00 Empore Lichthof

Auftrittshäufigkeit größenselektierter, polyanionischer Cluster — •Franklin Martinez, Steffi Bandelow, Gerrit Marx und Lutz Schweikhard — Institut für Physik, Ernst-Moritz-Arndt Universität, 17487 Greifswald, Deutschland

Die Stabilität mehrfach negativ geladener Cluster ist von der Anzahl der Atome im Cluster abhängig. Insbesondere benötigt der Cluster eine Mindestgröße, um eine gegebene Anzahl von Zusatzelektronen zu tragen. Im Bereich direkt oberhalb dieser Auftrittsgröße ist der polyanionische Cluster metastabil, da das Zusatzelektron eine negative Bindungsenergie aufweist und lediglich durch das Coulomb-Potential gebunden wird. Folglich führt Tunneln nach endlicher Zeit zur Elektronenemission. In Ionenfallen-Experimenten zeigt sich die Polyanionen-Stabilität in Form clustergrößenabhängiger Auftrittshäufigkeiten. Neben Tunneleffekten muss zur Beschreibung der experimentellen Daten auch die thermionische Elektronenemission berücksichtigt werden. Entsprechende Modellansätze basierend auf der Richardson-Dushman-Formel und dem Weisskopf-Formalismus werden am Beispiel polyanionischer Aluminiumcluster vorgestellt.

A 38.2 Thu 16:00 Empore Lichthof

Untersuchung mehrfach negativ geladener Goldcluster in einer linearen Paulfalle — •Steffi Bandelow, Franklin Martinez, Gerrit Marx und Lutz Schweikhard — Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Deutschland

Die Erzeugung mehrfach negativ geladener Cluster wurde erstmals auch in einer linearen Paulfalle realisiert. Grundlage hierfür ist der räumliche Überlapp zwischen einfach negativ geladenen Clustern und Elektronen. Dazu wird ein niederenergetischer Elektronenstrahl durch das Fallenvolumen einer sogenannten Digitalen Ionenfalle geleitet. In Digitalen Ionenfallen gelingt die Clusterspeicherung mittels rechteckigen Wechselspannungssignalen als Zwei- [1,2] bzw. 3-Zustands-Falle [3]. Letztere ermöglicht einen vom Radiofrequenzfeld ungestörten Elektronendurchschuss in den potentialfreien Zeiten im Verlauf der Wechselspannungssignale. Im Beitrag werden vorläufige Daten zu der Erzeugung mehrfach negativ geladener Cluster zu Wechselwirkungsstudien präsentiert.

[1] J.A. Richards et al., Int. J. Mass Spectrom. Ion Phys. 12 (1973) 317. [2] S. Bandelow et al., Int. J. Mass Spectrom., eingereicht (2012). [3] S. Bandelow et al., Int. J. Mass Spectrom., in Vorbereitung.

A 38.3 Thu 16:00 Empore Lichthof

Multiply charged sodium cluster anions in density functional theory — •Franziska Reimann, Thomas Keil, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

Multiply charged cluster anions are prime examples of highly correlated finite systems that can be studied as a function of the cluster size. The subject of this work is to investigate the "existence" of multiply negatively charged sodium clusters at various levels of density functional theory. It is well known that the exchange-only local spin-density approximation does not allow for, e.g., Na^-. However, we find that cluster anions exist even in that simplest of all approximations to the exchange-correlation potential, although for overestimated cluster sizes only. Taking self-interaction into account improves the results. We compare with previous theoretical work [1] and, where available, with experiments. The ultimate goal is to simulate the correlated emission of the surplus electrons after photoexcitation [2], using time-dependent density functional theory.

[1] C. Yannouleas and Uzi Landman, Phys. Rev. B 48, 8376 (1993).
[2] A. Herlert and L. Schweikhard, New J. Phys. 14, 055015 (2012).

A 38.4 Thu 16:00 Empore Lichthof

Experimente mit der Greifswald EBIT — •Birgit Schabinger[1], Christoph Biedermann[2], Stephan Gierke[1], Gerrit Marx[1] und Lutz Schweikhard[1] — [1]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald — [2]Max-Planck-Institut für Plasmaphysik, Wendelsteinstr. 1, 17491 Greifswald

Die Wirkung starker elektrischer Felder auf atomare Cluster soll mithilfe einer Elektronenstrahl-Ionenfalle (EBIT) untersucht werden. In dieser werden hochgeladene Ionen (HCIs) erzeugt, die bei Wechselwirkung mit Clustern Feldstärken in der Größenordnung von 10^{12} V/m (z.B. für Xe^{44+} in 2 Å Abstand) bewirken. In Vorbereitung dieser Experimente wurde in Greifswald die ehemalige Berlin EBIT [1] aufgebaut. Die Erzeugung definierter, hoher Ladungszustände erfolgt durch Elektronenstoßionisation mit einem monoenergetischen Elektronenstrahl und ihre nichtdestruktive Detektion mit einem Röntgendetektor. Anschließend werden die Ionen extrahiert und durch eine "Beamline" in eine Reaktionskammer überführt. Dort sollen sie zukünftig zum Beispiel mit einem Strahl neutraler Fullerene kollidieren. Für die Analyse der Reaktionsprodukte - hoch geladene Fullerene und Kohlenstoffatome verschiedener Ladungszustände [2] - wurde ein Flugzeit-Massenspektrometer installiert. Im Beitrag werden charakterisierende Messungen zur EBIT selbst und der Extraktion der HCIs präsentiert.

[1] C. Biedermann *et.* al, Phys. Scr. T. 73 (1997) 360
[2] S. Martin *et.* al, Phys. Rew. A. 62 (2000) 022707

A 38.5 Thu 16:00 Empore Lichthof

Temporally controlled two-electron wavepackets — •Zhaohe Liang — Noethnitzer str.38, Dresden,Germany

Temporally controlled two-electron wavepackets

Most research on correlated two-electron motion has been based on single or multiple photon absorption in the energy domain. The availability of ultrashort light pulses offers the opportunity to probe electron dynamics in an atom or molecule on its intrinsic time scale. Then we intend to investigate the dynamics and interactions of two wavepackets from two different electrons, which can be generated in various ways: 1) double ionization (DI) in Helium with a single short XUV pulse such that two photon absorption is necessary but one photon cannot ionize He+. [1] 2) DI in Helium with two attoseconds laser pulses of variable time delay. 3) Ionizing an inner shell electron of an atom with the Auger electron generating a second, time delayed wavepacket. This investigation will aim at characteristic features in the cross-section, angular and energy distributions, associated with each mechanism.

Reference: [1] Nabekawa Y.; Hasegawa H.; Takahashi E. and Midorikawa k. 2005 Phys. Rev. Lett. 94,043001

A 38.6 Thu 16:00 Empore Lichthof

Molecular superfluidity in helium clusters studied using impulsive alignment — Gediminas Galinis[1], Luis Mendoza Guillermo Luna[1], •Lev Kazak[2], Sebastian Göde[2], Russell Minns[4], Mark Watkins[1], Slawomir Skruszewicz[2], Robert Irsig[2], Andrew Ellis[3], Edmon Turcu[5], Cephise Cacho[5], Emma Springate[5], Josef Tiggesbäumker[2], Karl-Heinz Meiwes-Broer[2], and Klaus von Haeften[1] — [1]Department of Physics and Astronomy, University of Leicester, UK — [2]Institut für Physik, Universität Rostock, Deutschland — [3]Department of Chemistry, University of Leicester, UK — [4]Department of Chemistry, University of Southampton, UK — [5]CLF, STFC, Rutherford Appleton Laboratories, UK

Superfluidity is an intriguing phenomenon commonly associated with frictionless flow. Although this macroscopic effect is well understood, our understanding of how superfluidity evolves on the nanoscale is less extensive.We apply new approach to study superfluidity as a function of the number of helium atoms involved. A femtosecond pump-probe laser setup is used to excite a rotational wavepacket and to follow its propagation in time. The periodically recurring molecular alignment is probed by analyzing the emission characteristics in delayed Coulomb explosion with a velocity map imaging (VMI) spectrometer. First results show CO attached to five helium atoms and rotational features of HCCH-He corresponding to a linear configuration. To maximize the molecular beam intensity and to cope with the associated high gas load we developed a unique, differentially pumped VMI spectrometer.

A 38.7 Thu 16:00 Empore Lichthof

Untersuchung der Ionisation von H_2^+ in starken Laserfeldern — •Kevin Pahl, Max Schütt, Lothar Schmidt, Maksim Kunitski, Markus Waitz, Florian Trinter, Robert Wallauer, Hong-Keun Kim, Markus Schöffler, Horst Schmidt-Böcking und Reinhard Dörner — Institut für Kernphysik, Frankfurt a.M., Deutschland

H2+ ist das einfachste mögliche Molekül. Sein Verhalten in starken Laserfeldern wurde bereits in zahlreichen theoretischen und experimentellen Abhandlungen thematisiert. Bei diesem Versuch gelingt es unter der Verwendung eines Ionenstrahls aus H2+ Ionen neben den, durch Ionisation oder Dissotiation fragmentierten, Atomkernen auch das bei der Ionisation ausgelöste Elektron zu detektieren. Die daraus resultierenden Messergebnisse bei einer Laserlichtwellenlänge von 400 nm sollen hier vorgestellt werden.

A 38.8 Thu 16:00 Empore Lichthof

Core-level photoemission from free SiO_2 and Fe_3O_4 nanoparticles (3-10 nm) — •Burkhard Langer[1], Markus Eritt[2], Denis Duft[2], Thomas Leisner[2,3], and Eckart Rühl[1] — [1]Physikalische Chemie, Freie Universität Berlin — [2]Institut für Umweltphysik, Universität Heidelberg — [3]IMK, Karlsruher Institut für Technologie - KIT

We studied inner-shell photoelectron and near-edge spectra of 5-10 nm nanoparticles which are created in a microwave discharge source from gaseous precursors using a magnetic bottle electron spectrometer. Ferrocene vapor from heated powder as well as silane diluted in helium as a carrier gas (>99%) were being mixed under controlled conditions. Nanoparticles are formed in a microwave excited plasma. The nanoparticles were transferred into the interaction region, where they were excited by the synchrotron radiation from BESSY II, using a newly optimized transfer system containing an aerodynamic lens combined with a quadrupole guide / storage trap. The experiments were carried out in the energy regimes of the 2p absorption edges of Si (100-125 eV) and Fe (700-730 eV), respectively. In addition to SiO_2 nanoparticles, which have been studied before, we verified the presence of iron and iron oxide in free 5-10 nm particles formed from ferrocene and silane precursors using near-edge spectra. The analysis in the Fe 2p regime reveals that magnetite structures (Fe_3O_4) are present. Further, SiO_4 moieties are identified, but there is no evidence for fayalite (Fe_2SiO_4).

A 39: Poster: Atomic systems in external fields

Time: Thursday 16:00–18:30 Location: Empore Lichthof

A 39.1 Thu 16:00 Empore Lichthof

Energy levels, oscillator strengths and transition probabilities for Si-like Zn XVII, Ga XVIII, Ge XIX and As XX — •Ahmed Abou El-Maaref[1], Mohamed A Uosif[1], Sami H Allam[2], and Tharwat M El-Sherbini[2] — [1]Physics Department, Al-Azhar University, Assuit, Egypt — [2]Laboratory of Lasers and New Materials, Physics Department, Faculty of Science, Cairo University, Giza, Egypt

Fine-structure calculations of energy levels, oscillator strengths, and transition probabilities for transitions among the terms belonging to 3s23p2, 3s3p3, 3s23p3d, 3s23p4s, 3s23p4p, 3s23p4d, 3s23p5s and 3s23p5p configurations of silicon-like ions Zn XVII, Ga XVIII, Ge XIX and As XX have been calculated using configuration-interaction version 3 (CIV3). We have also carried out calculations in the intermediate coupling scheme using the Breit-Pauli Hamiltonian. We compared our data with the available experimental data and other theoretical calculations. Most of our calculations of energy levels and oscillator strengths (in length form) show good agreement with both experimental and theoretical data. Lifetimes of the excited levels are also given

A 39.2 Thu 16:00 Empore Lichthof

Laser-induced tunneling in the relativistic regime — •Enderalp Yakaboylu, Michael Klaiber, Heiko Bauke, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

A novel physical picture of laser driven tunneling at ions in the relativistic regime is presented. In the quasi-static approximation of the process, it can be shown that the tunneling barrier is identical to the one in the non-relativistic case via the dipole-approximation and that only the energy level on which the electron tunnels through the barrier is altered by the magnetic field component. This leads to a shift of the momentum distribution of the ionized electron with a maximum at a value that compensates the action of the laser magnetic field during tunneling. Further, the total tunneling rate is increased compared to the non-relativistic case by the relativistic mass correction, that changes the energy-momentum dispersion relation. Other relativistic correction terms are playing no role. Finally, it is shown that the electron experiences no drift in laser propagation direction under the barrier in the quasi-classical approximation, i.e., solely moves along the laser polarization direction [1].

[1] Michael Klaiber, Enderalp Yakaboylu, Heiko Bauke, Karen Z. Hatsagortsyan, and Christoph H. Keitel, preprint arXiv:1205.2004

A 39.3 Thu 16:00 Empore Lichthof

Testing the Jarzynski equality with single trapped neutral atoms — •Noomen Belmechri[1], Andrea Alberti[1], Andreas Steffen[1], Wolfgang Alt[1], Artur Widera[2], and Dieter Meschede[1] — [1]Institut für Angewandte Physik, Universität Bonn, Germany — [2]Fachbereich Physik und Forschungszentrum OPTIMAS, Universität Kaiserslautern, Germany

The Jarzynski equation complements the thermodynamics inequality $\Delta F \leqslant \overline{W}$ by the more general equality $\Delta F = -\beta^{-1} \ln \overline{\exp(-\beta W)}$. Both equations relate the free energy difference between two equilibrium states of a system to the average work performed when switching it from one state to another. The Jarzynski equality is valid regardless of the way the switching process is performed. This allows one to infer exact equilibrium state information from measurements where the system may be driven far away from equilibrium. This surprising result has already been verified with mesoscopic systems, i.e. large molecules or colloidal particles in optical tweezers, as well as with microscopic systems such as effective two-level systems formed by defect centres in diamond. Here, we present recent results in which we use a spin-dependent optical lattice to perform and measure work exerted on individual trapped atoms which promises a direct verification of the Jarzynski equality with a multi-level quantum system consisting of single neutral atoms.

A 39.4 Thu 16:00 Empore Lichthof

Quantum breathing mode of trapped dipolar bosons — •Jan Willem Abraham, Alexei Filinov, Tim Schoof, David Hochstuhl, and Michael Bonitz — Christian-Albrechts-Universität zu Kiel, ITAP

We study the quantum breathing mode (monopole mode) of finite systems at low temperature from weak to strong coupling. Using an improved version of the quantum mechanical sum rule formula of Stringari et al. [1], we perform ab-initio Quantum Monte Carlo simulations to obtain the mode frequencies for dipole-interacting bosons in a harmonic trap. [1] We compare our results to those from other methods and present additional results for fermions. [3]

[1] C. Menotti, and S. Stringari, Phys. Rev. A **66**, 043610 (2002)
[2] A. Filinov et al., Phys. Rev. Lett. **105**, 070401 (2010)
[3] T. Schoof et al., Contrib. Plasma Phys. **51**, No. 8, 687-697 (2011)

A 39.5 Thu 16:00 Empore Lichthof

Quantum breathing mode of charged fermions in a 2D harmonic trap — Chris McDonald[2], G. Orlando[2], •Jan Willem Abraham[1], David Hochstuhl[1], Michael Bonitz[1], and Thomas Brabec[2] — [1]Christian-Albrechts-Universität zu Kiel, ITAP — [2]Department of Physics, University of Ottawa, Ottawa, Canada

The N-particle time-dependent Schrödinger equation is solved to investigate the quantum breathing mode of Coulomb-interacting fermions confined in two-dimensional quantum dots. [1] The Multi-Configurational Time-Dependent Hartree-Fock method allows us to obtain the mode frequencies for up to 6 particles in the whole range of coupling parameters, from the ideal quantum gas to Wigner crystallization. Furthermore, a new approximate analytical approach to the quantum breathing mode is presented.

[1] C. McDonald et al., submitted to Phys. Rev. Lett. (2012)

A 39.6 Thu 16:00 Empore Lichthof

Radiation-assisted relativistic electron vortex beams — •Armen Hayrapetyan[1], Oliver Matula[1,2], Andrey Surzhykov[1,2], and Stephan Fritzsche[2,3] — [1]Physikalisches Institut, Universität Heidelberg, D-69120 Heidelberg, Germany — [2]Gesellschaft für Schwerionenforschung (GSI), D-64291, Darmstadt, Germany — [3]Department of Physics, P.O., Box 3000, Fin-90014 University of Oulu, Finland

We study relativistic electron vortex beams under the impact of the field of a plane electromagnetic wave. We construct exact Bessel-beam solutions by making use of Volkov solutions for the Dirac equation. When switching off the field we show that these solutions contain the new type of free electron-Bessel beams, reported by Bliokh et al. [Phys. Rev. Lett. 107, 174802 (2011)]. We study total-angular-momentum-dependent distribution of probability density and current for nonparaxial Bessel beams as a dependence on electromagnetic field parameters, such as frequency and amplitude of vector potential. Moreover, we show that the kinetic momentum density in the Bessel-state implies that the effective mass of the twisted electron coupled to the field acquires a shift. Such beams may be of interest for experiments relating to the Compton and electron-electron scattering under impact of external fields, as well as radiative electron capture in relativistic ion-atom collisions and photoelectric effects in atomic systems.

A 39.7 Thu 16:00 Empore Lichthof

On the response of electromagnetically-induced transparency to laser phase changes — Carl Basler, •Katrin Reininger, Stephan Welte, and Jannis Seyfried — Universität Freiburg

We study the transient response of the refractive index to changes of the phase of the laser field under conditions of electromagnetically induced transparency. This is an extension of recent work in our group, FM et al. PR A 85, 013820 (2012) where the dynamic response to frequency changes was explored. Under EIT conditions the quantum superposition state $\Psi = |1\rangle - \mathrm{e}^{\mathrm{i}\eta}\,|2\rangle$, called dark state, develops by spontaneous emission in the presence of two phase-stable laser fields $E_j(\omega_j, \varphi_j)$. The dark state phase fulfills the requirement $\eta = \varphi_1 - \varphi_2$ and is thus sensitive to the laser phase. If under EIT conditions the relative phase of the laser fields is changed by π the dark state superposition instantly becomes bright. More intricate is the behavior under conditions near EIT resonance. Here the dynamic response shows instant as well as slow components which mirror the interplay between rapid and slow coherences in the density matrix. With phase jumps of short duration we can determine the relative phase between the dark state and the laser field in a minimally destructive way, we can measure the absolute depth of the dark resonance and the absolute detuning from EIT resonance without detuning the lasers.

A 39.8 Thu 16:00 Empore Lichthof

Vibrational Mechanics in an Optical Lattice: Controlling Transport via Potential Renormalization — •Arne Wickenbrock[1], Philip C. Holz[1], Nihal A. Abdul Wahab[1], David Cubero[2], and Ferruccio Renzoni[1] — [1]University College London, London, UK — [2]Universidad de Sevilla, Sevilla, Spain

We demonstrate theoretically and experimentally the phenomenon of vibrational resonance in a periodic potential, using cold atoms in an optical lattice as a model system. A high-frequency (HF) drive, with a frequency much larger than any characteristic frequency of the system, is applied by phase modulating one of the lattice beams. We show that the HF drive leads to the renormalization of the potential. We used transport measurements as a probe of the potential renormalization. The very same experiments also demonstrate that transport can be controlled by the HF drive via potential renormalization.

A 39.9 Thu 16:00 Empore Lichthof

Time-dependent reduced density matrix functional theory applied to laser-driven, correlated two-electron dynamics — •Martins Brics, Varun Kapoor, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

Time-dependent density functional theory (TDDFT) with known and practicable exchange-correlation potentials does not capture highly correlated electron dynamics such as single-photon double ionization, autoionization, or nonsequential ionization. Time-dependent reduced density matrix functional theory (TDRDMFT) may remedy these problems. The key ingredients in TDRDMFT are the natural orbitals (NOs), i.e., the eigenfunctions of the one-body reduced density matrix (1-RDM), and the occupation numbers (OCs), i.e., the respective eigenvalues. The two-body reduced density matrix (2-RDM) is then expanded in NOs, and equations of motion for the NOs can be derived. If the expansion coefficients of the 2-RDM were known exactly, the problem at hand would be solved. In practice, approximations have to be made. We study the prospects of TDRDMFT following a top-down approach. We solve the exact two-electron time-dependent Schrödinger equation for a model Helium atom in intense laser fields in order to study highly correlated phenomena such as the population of autoionizing states or single-photon double ionization. From the exact wave function we calculate the exact NOs, OCs, the exact expansion coefficients of the 2-RDM, and the exact potentials in the equations of motion. In that way we can identify how many NOs and which level of approximations are necessary to capture such phenomena.

A 39.10 Thu 16:00 Empore Lichthof

Dynamic phase studies at EIT conditions in thermal rubidium — •Stephan Welte — Physikalisches Institut Uni Freiburg

We investigate the response of an EIT medium to changes of the magnetic field vector. Employing two phase locked external cavity diode lasers, we prepare the atoms in a dark superposition of two Rb ground states, (F=1, mF=-1) and (F=2, mF=1). During preparation of the dark state a constant magnetic field is employed as quantization axis. Its magnitude is chosen as the magic 3.2 Gauss where ground state transition is magnetic-field insensitive in the first-order Zeeman effect. Applying a second magnetic field in the same direction as the quantization field results in a small Zeeman shift of the two mF states. When returning to the original field, the two states of the superposition have picked up unequal dynamical phases due to the quadratic Zeeman effect. As a result, there is a relative phase change in the superposition state which manifests itself in a rise of the absorption signal. We compare our findings with numerical simulations using a realistic eight-level density matrix. A further experiment in progress concerns the detection of a Berry phase imposed in a thermal EIT medium. By rotating an additonal magnetic field in a cone and returning to the original field, the two mF levels of the dark state will acquire different Berry phases which depend on the cone angle. As in the dynamic phase experiment, a relative phase difference should manifest itself in a rise of the absorption signal. This feature is also predicted in our numerical simulation.

A 39.11 Thu 16:00 Empore Lichthof

Temporal dynamics in strong-field processes subjected to Coulomb correlations — •Maximilian Hollstein and Daniela Pfannkuche — Jungiusstraße 9, 20355 Hamburg

Common theoretical approaches for studying atomic strong-field processes such as tunnel and multiphoton ionization of atoms or atom-like systems (e.g. quantum dots) rely on an (effective) one-particle description as for example the single-active-electron approach or the time-dependent configuration-interaction singles (TD-CIS) method. Within these methods, Coulomb correlations are usually neglected. In contrast to these approaches we are investigating the temporal dynamics in strong-field processes subjected to Coulomb correlations on a model system by solving the time-dependent Schrödinger Equation numerically. We consider the time evolution of pair-correlation functions and investigate two-particle excitations which are exceeding the configuration-interaction singles approximation.

A 39.12 Thu 16:00 Empore Lichthof

Mass Effects on the Entanglement Features of an Exactly Soluble Quantum Few-Body System — •Peter Alexander Bouvrie[1], Malte Christopher Tichy[2], Ana Paula Majtey[1], Angel Ricardo Plastino[1], and Jesús Sánchez-Dehesa[1] — [1]Instituto *Carlos I* de Física Teórica y Computacional and Departamento de Física Atómica, Molecular y Nuclear, Universidad de Granada, 18071-Granada, Spain — [2]Lundbeck Foundation Theoretical Center for Quantum System Research, Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark

We explore the entanglement features [1] of the eigenstates of an exactly soluble many-particle model consisting of N_n "nuclei" and N_e "electrons" which interact harmonically in a confining harmonic trap. We investigate its dependence upon the different parameters characterizing the system such as the relative strength between the two-particle interaction and the confining harmonic force, the number of particles and their masses. Particular attention is paid to the dependence of the entanglement on the ratio of the masses of the constituent particles; we have found that the entanglement vanishes when the subsystems have very different masses. Since the validity of the Born-Oppenheimer approach is closely related to the mass of the particles, we have studied the validity region of this approach depending on the parameters of the model; so, shedding new light on the understanding of the vanishing bipartite entanglement with the different subsystems mass.

[1] Bouvrie P A, Majtey A P, Plastino A R, Sanchez-Moreno P and Dehesa J S 2012 Eur. Phys. J. D **66** 15.

A 39.13 Thu 16:00 Empore Lichthof

Electron dynamics in atoms and clusters driven by twisted light — •Koray Köksal[1,2], Yaroslav Pavlyukh[2], and Jamal Berakdar[2] — [1]Faculty of Arts and Science, Physics Department, Bitlis Eren University, 13000 Bitlis, Turkey — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Str. 4, 06120 Halle, Germany

We study the electron dynamics in atoms and clusters triggered by light carrying orbital angular momentum (or twisted light). It is shown that charge currents can be generated [1] in the system that may be utilized as a source for localized magnetic pulses. For a sizable current it is advantageous to have the system's size on the scale of the waist size of the laser. Hence, we are investigating the electron dynamics in metal clusters under the action of twisted light with analytical and numerical methods as we developed and presented in [1, 2].

[1] K. Köksal and J. Berakdar, Phys. Rev. A, **86**, 063812 (2012).
[2] Y. Pavlyukh and J. Berakdar, K. Köksal, Phys. Rev. B **85**, 195418 (2012).

A 40: Poster: Ultra-cold plasmas and Rydberg systems (with Q)

Time: Thursday 16:00–18:30 Location: Empore Lichthof

A 40.1 Thu 16:00 Empore Lichthof

An optically resolvable Schrödinger's cat from Rydberg dressed cold atom clouds — Sebastian Möbius, Michael Genkin, Alexander Eisfeld, •Sebastian Wuester, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, D-01187 Dresden, Germany

In Rydberg dressed ultra-cold gases, ground state atoms inherit properties of a weakly admixed Rydberg state, such as sensitivity to long-range interactions. We show that through hyperfine-state dependent interactions, a pair of atom clouds can evolve into a spin and subsequently into a spatial Schroedinger's cat state: The pair, containing 40 atoms in total, is in a coherent superposition of two configurations, with cloud locations separated by micrometers. The mesoscopic nature of the superposition state can be proven with absorption imaging, while the coherence can be revealed though recombination and interference of the split wave packets.

A 40.2 Thu 16:00 Empore Lichthof

Spin Squeezing in ultracold Strontium lattices — •Laura I.R. Gil[1], Rick Mukherjee[1], Liz Bridge[2], Matthew P.A. Jones[2], and Thomas Pohl[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]Department of Physics, Durham University, United Kingdom

Squeezed many-body states of atoms are a valuable resource for high precision frequency metrology and could tremendously boost the performance of atomic lattice clocks. Here, we study the dynamics of Strontium atoms confined in an optical lattice, where strong interactions are induced by exciting one valence electron to a high-lying Rydberg state. Making use of the extra valence electron, we demonstrate how to control the motional dynamics of the atoms and analyze the performance of the proposed setting. Finally, we present a simple protocol to prepare spin squeezed states in such a Strontium-Rydberg clock, and discuss the achievable amount of squeezing for different geometries and experimentally relevant parameters.

A 40.3 Thu 16:00 Empore Lichthof

Equilibration heating of Rydberg atoms — •Yaroslav Lutsyshyn and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

We investigate the equilibration heating in clouds of Rydberg atoms which are interacting with a van der Waals potential. The released energy depends only on the initial and final states, allowing a simple analysis in terms of the excitation parameters and the effective interaction constant. The control of heating is useful both if one wants to increase the motion of the Rydberg atoms, for example to enhance collisional ionization, or, to the opposite, in attempts to achieve an ordered state with an equilibrated or partially equilibrated cloud. Knowing the amount of heating maps the excitation conditions directly to the equilibrium phase diagram of the vdW gas, which we reported previously [1].

[1] O. N. Osychenko, G. E. Astrakharchik, Y. Lutsyshyn, Yu. E. Lozovik, J. Boronat, Phys. Rev. A **84**, 063621, (2011).

A 40.4 Thu 16:00 Empore Lichthof

Line shifts of Rydberg atoms near surfaces due to adsorbate fields — •Florian Karlewski, Markus Mack, Jens Grimmel, Helge Hattermann, Simone Höckh, Florian Jessen, Daniel Cano, and József Fortágh — Physikalisches Institut der Universität Tübingen

Interfacing Rydberg atoms to solid state devices like atom chips is a promising concept for novel quantum systems. However, before attempting to understand and exploit the interactions between solid state quantum circuits and Rydberg atoms, one first needs to investigate the interactions between these atoms and the solid state surface.

The main effect on the Rydberg atoms is a line shift due to the electric field of atoms adsorbed to the surface. We show the accumulation of these adsorbates over time in a cold atom experiment, using electromagnetically induced transparency to detect the line shifts with high accuracy.

In future projects, we plan to study how adsorbates can be reduced, manipulated or avoided.

A 40.5 Thu 16:00 Empore Lichthof

Creation of GHZ-states in optical lattices of alkaline-earth atoms — •Rick Mukherjee, Arnab Das, Frank Pollmann, and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We present a scheme for the production of many-body GHZ states in an optical lattice of Strontium atoms via optical excitation to strongly interacting atomic states. We identify magic wavelengths that permit strong lattice confinement for both internal states, and yield an effective Ising spin model with controllable external fields. For the considered case, the interactions are attractive such that this system features a quantum phase transition between para- and ferromagnetic phases. We identify suitable field ramps across the transition that permit the controlled creation of GHZ-states for large system sizes and with high fidelity.

A 40.6 Thu 16:00 Empore Lichthof

Microwave Electrometry with Rydberg Atoms in a Vapor Cell using Bright Atomic Resonances — Jonathon A. Sedlacek[2], Harald Kübler[1,2], Renate Daschner[1], Arne Schwettmann[2], •Anita Gaj[1], Robert Löw[1], Tilman Pfau[1], and James P. Shaffer[2] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57 D-70550 Stuttgart, Germany — [2]Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, 440 W. Brooks St. Norman, Oklahoma 73019, USA

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 cw 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 $\sim 30\mu\text{Vcm}^{-1}\text{Hz}^{-1/2}$ in a thermal vapor cell[1]. In addition, our approach can be used to detect an arbitrary microwave electric field polarizations and offers a sub-wavelength spatial resolution. The method can serve as a new atom based traceable standard for vector microwave electrometry. The reproducibility, accuracy and stability of using an atom for measuring microwave electric fields promises to advance traceable microwave electrometry to the current levels of magnetometry.

[1] J. A. Sedlacek et al., Nature Physics **8**, 819-824 (2012)

A 40.7 Thu 16:00 Empore Lichthof

Static and dynamical properties of two-dimensional Rydberg lattices — •Sebnem Günes Söyler[1], Tommaso Macri[1], Thomas Pohl[1], Peter Schauss[2], Marc Cheneau[2], Manuel Endres[2], Takeshi Fukuhara[2], Sebastian Hild[2], Ahmed Omran[2], Christian Gross[2], Stefan Kuhr[2,3], and Immanuel Bloch[2,4] — [1]Max Planck Institut für Physik Komplexer Systeme, Dresden, Germany — [2]Max Planck Institut für Quantenoptik, Garching, Germany — [3]University of Strathclyde, Glasgow, UK — [4]Ludwig Maximilians Universität, München, Germany

Recent experimental efforts to manipulate long range interactions in cold atomic setups offer a unique way to study strongly correlated quantum systems. Among them Rydberg atoms are particularly interesting due to their extremely large dipole moments that result in enormous interactions acting over micrometer distances. We investigate the ground state phase diagram of Rydberg-excited atoms in a two-dimensional optical lattice by large-scale quantum Monte Carlo simulations. In addition, we explore suitable schemes for the dynamical preparation of the resulting quantum phases in the presence of imperfections and de-coherence under realistic experimental conditions.

A 40.8 Thu 16:00 Empore Lichthof

Rydberg Dressing in the Super Atom Picture — •Alexander Krupp, Jonathan Balewski, Anita Gaj, Sebastian Hofferberth, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

Highly excited Rydberg atoms show strong interaction over a mesoscopic range, which can be controlled using external electric and magnetic fields [1]. Such an interaction can block the excitation in the range of the blockade radius around the Rydberg atom. In case of coherently driven samples one can think about one excitation shared by all the atoms within a sphere. These N atoms then effectively behave like one atom driven with a $\sqrt{N}$ enhanced collective Rabi frequency, therefore forming a so called superatom. By exciting a sample of atoms at large detunings from the Rydberg state one can generate a coherent collective state with long lifetime [2], which would allow to observe mechanical effects of the Rydberg-Rydberg interaction potential on the whole sample. By tuning the excitation laser parameters and external fields one can therefore tailor the atomic interaction potential. This ability permits one to achieve interesting and novel many-body phases ranging from superfluid to supersolid crystals. We show that the interaction potential of weakly Rydberg dressed atoms can be understood within the super atom picture. This description allows us to calculate the effect on a BEC under realistic experimental conditions.

[1] J. Nipper et al., *Phys. Rev. X* ***2***, 031011 (2012)
[2] J. Honer et al., *Phys. Rev. Lett.* ***105***, 160404 (2010)

A 40.9 Thu 16:00 Empore Lichthof

Measurement of ion - ion collisions in strongly coupled plasmas — •Georg Bannasch[1], Thomas Pohl[1], Jose Castro[2], Patrick McQuillen[2], and Thomas Killian[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden — [2]Physics & Astronomy Department, Rice University, Houston, USA

Relaxation processes in weakly coupled plasmas are well described within the framework of the famous Spitzer theory [1]. As the theory relies on a Debye screening length λ_D that is much larger than the mean interparticle distance a, the resulting relaxation rates diverge in the strongly coupled domain, where the two length scales can become comparable. Here, we present a joint experimental theoretical study of ion - ion collisions in an ultracold plasma, created at the onset of strong plasma coupling, beyond the validity of the Spitzer theory. Velocity-selective optical pumping combined with fluorescence measurements permits to observe the dynamics of velocity relaxation [2]. We find excellent agreement between measured rates and theoretical results obtained from molecular dynamics simulations as well as from generalized kinetic theory. The presented framework permits direct access to the velocity dependence of the relaxation rate.

[1] Jr. L. Spitzer. Physics of Fully Ionized Gases. Wiley, New York, 1962
[2] G. Bannasch, J. Castro, P. McQuillen, T. Pohl, and T. C. Killian, Phys. Rev. Lett. 109, 185008 (2012)

A 40.10 Thu 16:00 Empore Lichthof

Second-generation apparatus for Ryberg-atoms in an ultracold gas — •Huan Nguyen, Michael Schlagmüller, Thomas Schmid, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Phys. Institut, Universität Stuttgart

The giant size and large polarizibility of Rydberg-atoms, resulting in strong long-range Rydberg-Rydberg interactions, make them ideal for studying many-body cooperative effects. In particular, the investigation of dense, ultracold Rydberg-gases in a magnetic trap has opened the door to novel effects such as Rydberg-molecules.

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, 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.

A 41: Poster: Electron scattering and recombination

Time: Thursday 16:00–18:30 Location: Empore Lichthof

A 41.1 Thu 16:00 Empore Lichthof

Coupling Nuclei to the Atomic Shells in Stellar Environments — •Stephan Helmrich[1,2] and Adriana Pálffy[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

The role of processes coupling nuclear transitions to the atomic shells has been investigated in dense stellar plasma conditions. In particular addressed was the process of nuclear excitation by electron capture (NEEC) [1], in which the recombination of a free electron into a highly charged ion leads to the simultaneous excitation of the nucleus. In the context of isomer depletion, the role of NEEC in populating low-lying nuclear excited states under dense stellar plasma conditions has been previously investigated [2].

Here we study a different scenario, in which NEEC occurs not from the nuclear ground state but instead from highly excited states close to the neutron threshold. Such states are reached in dense astrophysical plasmas via neutron capture. The impact of such additional nuclear excitations on the neutron capture and gamma decay sequence which is relevant for s-process nucleosynthesis is investigated. Our results show that for electron fluxes typical for the s-process, NEEC does not influence the nucleosynthesis sequence. Higher plasma temperatures as typical for r-process nucleosynthesis also do not favor the coupling to the atomic shells, but rather processes like photoabsorption.

[1] A. Pálffy, W. Scheid and Z. Harman, Phys. Rev. A 73, 012715 (2006)
[2] G. Gosselin, P. Morel and P. Mohr, Phys. Rev. C 81, 055808 (2010)

A 41.2 Thu 16:00 Empore Lichthof

Electron-atom collisions studied in a MOTReMi apparatus — •Elisabeth Brühl, Natalia Ferreira, Johannes Goullon, Renate Hubele, Hannes Lindenblatt, Michael Schuricke, Alexander Dorn, and Daniel Fischer — Max-Planck Institut für Kernphysik, Heidelberg

Studying the dynamics of atomic collisions, reaction microscopes (ReMi) have been used as a powerful experimental tool for nearly two decades. ReMis make the momentum information of all collision products over the full solid angle accessible. In our experiment we combine a ReMi with a magneto-optically trapped (MOT) target of lithium atoms (MOTReMi). Due to its electronic structure with its two strongly correlated inner electrons and a single valence electron, lithium is an ideal candidate to examine electronic correlation and collision dynamics of simple few-body systems. In addition, this element has the advantage that it can be relatively easily cooled down to temperatures well below mK. One of the main technical challenges for the combination in a MOTReMi is the superposition of two magnetic fields. The inhomogeneous magnetic field of the MOT has to be switched off very fast allowing for the momentum reconstruction of the ejected electrons. The MOTReMi is currently integrated into the test storage ring (TSR) of the MPIK in Heidelberg and ion-atom collisions are observed in unprecedented details. In future experiments, an electron beam will be used as a projectile to study electron impact ionization for collision energies between 70 and 500 eV. The technical realization and the setup will be shown.

A 41.3 Thu 16:00 Empore Lichthof

Absolute Recombination Rate Coefficients Of Highly Charged Tungsten Ions — •Kaija Spruck[1], Arno Becker[2], Dietrich Bernhardt[1], Manfred Grieser[2], Michael Hahn[3], Claude Krantz[2], Michael Lestinsky[4], Alfred Müller[1], Oldřich Novotný[3], Roland Repnow[2], Daniel Wolf Savin[3], Andreas Wolf[2], and Stefan Schippers[1] — [1]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Giessen, 35392 Giessen, Germany — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [3]Columbia Astrophysics Laboratory, Columbia University, New York, NY 10027, USA — [4]GSI Helmholtzzentrum, 64291 Darmstadt, Germany

Tungsten is commonly used as a material for plasma facing walls in nuclear fusion reactors as it can resist the typical high-temperatures and high neutron irradiation levels. As a result, impurities of highly charged tungsten ions in the plasma are inevitable. Radiation from these excited tungsten ions leads to plasma cooling. Modeling this cooling requires reliable ionization and recombination cross sections for tungsten ions. To date, most of the needed atomic data come from theory. Previously large discrepancies were found between experimental and theoretical values.

Here, we report electron-ion recombination experiments for highly charged tungsten ions, performed at the TSR storage ring in Heidelberg, Germany. Absolute experimental rate coefficients of W^{q+} ions with $18 \leq q \leq 21$ will be presented.

A 41.4 Thu 16:00 Empore Lichthof

Untersuchung von Ionen-Lithium Dynamik mit einem in-Ring MOTReMi — •Hannes Lindenblatt[1], Elisabeth Bruehl[1], Natalia Ferreira[1], Johannes Goullon[1], Renate Hubele[1], Aaron LaForge[2] und Daniel Fischer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisches Institut, Universität Freiburg

Seit der Entwicklung der Rückstoßionen-Impulspektroskopie (engl. abgekürzt COLTRIMS) sowie von Reaktions-Mikroskopen (ReMi) kann die Dynamik von atomaren Viel-Teilchen-Coulomb-Systemen z.B. bei der stoßinduzierten Fragmentation atomarer oder molekularer Targets, experimentell mit großer Akzeptanz und mit hervorragender Genauigkeit untersucht werden. Bei dieser Technik kamen bisher größtenteils Überschall-Gasjet-Targets zum Einsatz. Das einfachste atomare Target, das hierbei zu den notwendigen Temperaturen gekühlt werden kann, ist Helium, das deshalb bereits in vielen Experimenten untersucht wurde. Das nächst-komplexere Atom, Lithium, war für solche Untersuchungen bisher nicht zugänglich. In unserem Experiment haben wir ein ReMi mit einer magneto-optischen Lithium Falle (MOT) kombiniert. Dieses MOTReMi ist zur kinematisch vollständigen Untersuchung von Ion-Atom-Stößen in einen Ionenspeicherring implemetiert. Aufgrund der optischen Anregung, die in der MOT induziert wird, können erstmals auch angeregte und sogar polarisierte Targets für Stoßexperimente benutzt werden. Auf diesem Poster werden die Ergebnisse der ersten Experimente mit dem MOTReMi vorgestellt.

A 41.5 Thu 16:00 Empore Lichthof

Spectroscopic investigation of resonant recombination processes on highly charged silicon — •Thomas M. Baumann, Zoltan Harman, Christian Beilmann, Julian Stark, Paul H. Mokler, Joachim Ullrich, and Jose R. Crespo Lopez-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Spectroscopic studies of inter-shell (K-L) resonant electronic recombination processes for He-like to O-like Si ions (Si^{12+} to Si^{6+}) are presented and compared to theoretical predictions obtained from MCDF and FAC calculations. These measurements were performed at the HYPER-EBIT, the new cryogenic electron beam ion trap of the MPIK. The charge state evolution and charge-breeding process in this machine was further studied using the time resolved evolution of the resonant recombination spectra. Strong contributions of higher-order recombination processes (trielectronic recombination, TR) are compared to lines resulting from first order dielectronic recombination (DR) using the strength ratio S^{TR}/S^{DR}. For electronic recombination into B-like Si ions this ratio is in agreement with theory. For C-like Si, the measured value of $S^{TR}/S^{DR} = 1,2 \pm 0,1$ is about half the theoretical value. This deviation can be explained by barely resolvable contributions from long-lived metastable states in the recombining C-like ions.

A 41.6 Thu 16:00 Empore Lichthof

The spin-orbit interaction in bremsstrahlung and its application for electron beam polarimetry — •Stanislav Tashenov[1], Torbjörn Bäck[2], Bo Cederwall[2], Anton Khaplanov[2], Kai-Uwe Schässburger[2], Roman Barday[3], Joachim Enders[3], Yulia Fritzsche[3], Andrey Surzhykov[1,4], Vladimir Yerokhin[1,4,5], and Doris Jakubassa-Amundsen[6] — [1]Physics Institute, Heidelberg University, Heidelberg, Germany — [2]Royal Institute of Technology, Stockholm, Sweden — [3]Institut für Kernphysik, Technische Universität Darmstadt, Germany — [4]GSI Helmholtzzentrum, Darmstadt, Germany — [5]Center for Advanced Studies, St. Petersburg State Polytechnical University, St. Petersburg, Russia — [6]Mathematics Institute, University of Munich, Munich, Germany

Linear polarization of hard x-rays emitted in the process of the atomic field electron bremsstrahlung was measured with a polarized electron beam. The correlation between the initial orientation of the electron spin and the angle of photon polarization has been systematically studied by means of Compton and Rayleigh polarimetry techniques applied to a segmented germanium detector. The results are in a good agreement with the fully-relativistic calculations based on Dirac theory. They are also explained classically and in a unique way manifest that due to the spin-orbit interaction the electron scattering trajectory is not confined to a single scattering plane. Bremsstrahlung polarization correlations lead to a new method of polarimetry of electron beams which is sensitive to all three components of the electron spin.

A 41.7 Thu 16:00 Empore Lichthof

First observation of correlated photons emitted by a heavy highly charged ion — •Stanislav Tashenov[1], Dariusz Banas[2], Heinrich Beier[3], Karl-Heinz Blumenhagen[3], Carsten Brandau[3,5], Alexandre Gumberidze[3,5], Tobias Habermann[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], and Andrey Surzhykov[1,3] — [1]Physics Institute, Heidelberg University, Heidelberg, Germany — [2]Institute of Physics, Jan Kochanowski University, Kielce, Poland — [3]GSI Helmholtzzentrum, Darmstadt, Germany — [4]Helmholtz-Institut Jena, Germany — [5]ExtreMe Matter Institute EMMI, GSI, Darmstadt, Germany

Two correlated photons emitted in the process of Radiative Electron Capture (REC) into an excited state $2p_{3/2}$ of an initially bare uranium ion followed by its radiative decay were detected in coincidence. For this a relativistic beam of bare uranium ions, stored in the GSI storage ring ESR, collided with a gas target of N_2 atoms. The photons were detected by a setup of segmented large area germanium detectors. This experiment for the first time allows to determine the alignment of the states produced by REC where the recombination photon is observed. It represents a significant step towards the complete experiment of REC as well as of the photoelectric effect in time reversal.

A 41.8 Thu 16:00 Empore Lichthof

Measurement of the angular distribution of Dielectronic Recombination into highly charged Krypton ions — •Pedro Amaro[1], Christian Beilmann[1,2], René Steinbrügge[2], Chintan Shah[1], Jan K. Rudolph[2], Sven Bernitt[2], Oleksiy Kovtun[1], José R. Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Ruprecht-Karls-Universität Heidelberg, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We report studies of the angular distribution of X-rays produced by dielectronic recombination (DR) of highly charged ions. Krypton ions in He-like through N-like charge states were generated in an electron beam ion trap, and the electron-ion collision energy scanned over a range of DR resonances exciting K-shell electrons. The subsequent photon emission was recorded both along and perpendicular to the electron beam axis. The asymmetries observed indicate an alignment of the total angular momentum vector of the intermediate excited state with respect to the electron beam propagation axis. This alignment probes the dynamics of the DR process due to the electron-electron interaction in the strong electromagnetic field of the target ion.

A 41.9 Thu 16:00 Empore Lichthof

Unexpected high strength of inter-shell trielectronic recombination — C. Beilmann[1], P.H. Mokler[1], T.M. Baumann[1], S. Bernitt[1], C.H. Keitel[1], J. Ullrich[1], Z. Harman[1,2], and •J.R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]ExtreMe Matter Institute (EMMI), Darmnstadt, Germany

Intershell KL-LLL trielectronic recombination (TR) in highly charged ions, where a K-shell and a L-shell electron are simultaneously excited by the capture of a free one, was studied at electron beam ion traps. In our experiments and accompanying MCDF calculations, we show that these higher-order contributions to the total recombination yield grow to an unexpected strength in light and mid-heavy ions. The experimental results of TR measurements in Ar, Fe and Kr allow for the deduction of a scaling law for the TR strength in dependence of Z. In C-like ions with $Z \leq 20$, TR even dominates over the first-order dielectronic process (DR) [1]. The strong sensitivity of the TR process to eletron-electron interaction gives new experimental access to the study of inner-atomic electron correlation effects. Therefore, the importance of Breit interaction becomes measurable already for lighter ions around Fe ($Z = 26$) focussing on TR resonances. Beside this, considering the strong selection rules for TR, the measurements can be used as a proof for the importance of configuration interaction. We present theoretical considerations using the flexible atomic code as well as experimental investigations of C-like TR in iron.

[1] C. Beilmann et al., Phys. Rev. Lett. 107, 143201 (2011)

A 42: Poster: Attosecond physics

Time: Thursday 16:00–18:30 Location: Empore Lichthof

A 42.1 Thu 16:00 Empore Lichthof

Correlated Few-Electron Dynamics on the Attosecond Timescale — •Thomas Ding, Christian Ott, Andreas Kaldun, Alexander Blättermann, Difa Ye, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

The concerted motion of two or more electrons is the fundamental cause of virtually any chemical reaction. With attosecond laser pulses, a time-resolved investigation of the correlated electron dynamics on their natural timescales is possible. In a recent experiment we induced a coherent wavepacket beating of several doubly-excited states (DES) in helium with weak broadband attosecond-pulsed light in the extreme ultraviolet (XUV) energy range. We studied the behavior of the DES under the influence of a strong few-cycle near-infrared (NIR) dressing field allowing the coherent coupling of the DES with the N = 2 threshold. The time-delay of the XUV pulse with respect to the NIR dressing field as well as the laser intensity of the latter are varied and serve as control parameters in this setup. In more recent experiments other rare gas species such as neon are investigated, which will be presented here. In addition, for a better understanding of the role of electron correlation, we reproduce our experimental conditions theoretically in a one-dimensional two-electron model system that interacts with the corresponding laser pulses. By numerically solving the time-dependent Schrödinger equation we calculate the XUV absorption cross section and obtain results that are qualitatively consistent with our experiments. The simulations allow a direct visualization of the induced and controlled correlated two-electron wavefunction dynamics.

A 42.2 Thu 16:00 Empore Lichthof

Spatial contribution of electron trajectories to HHG in a semi-infinite gas cell — •Martin Kretschmar[1,2], Carlos-Hernandes Garcia[3], Daniel S. Steingrube[1,2], Luis Plaja[3], Uwe Morgner[1,2], and Milutin Kovacev[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, D-30167 Hannover, Germany — [2]QUEST, Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, D-30167 Hannover, Germany — [3]Grupo de Investigacion en Optica Extrema, Universidad de Salamanca, E-37008 Salamanca, Spain

We present an analysis of the spatial beam profile of high-order harmonic radiation generated in xenon in a semi-infinite gas cell (SIGC). The observed spatial profiles consist of a central, less divergent part surrounded by a conical structure. We were able to assign contributions of two electron trajectories to different regions of the beam by experimental observations as well as simulations. Furthermore we examine the influence of phase-matching parameters, such as the focusing position inside the SIGC and the pressure of the generating medium on the different electron trajectory contributions and their spatial separation. Simulations, based on the discrete dipole approximation, confirm the experimental observations and give further insight on the generation process.

A 42.3 Thu 16:00 Empore Lichthof

Yield-Control of High-Order Harmonic Generation from Water Droplets — Heiko G. Kurz[1,2], •Melanie Barth[1], Martin Kretschmar[1,2], Tamas Nagy[1], Daniel S. Steingrube[1,2], Detlev Ristau[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 use a pump-probe setup in order to investigate the properties of high-order harmonic radiation generated from liquid water droplets. Using a commercial CPA-laser system, the influence of the time delay onto the emission of harmonic radiation is systematically studied and optimum parameters for the conversion process are determined. We control the spatiotemporal dynamics of the droplet, such as the expansion of the droplet and plasma formation during interaction with intense laser pulses by variation of the intensity of the pump pulse and observe its influence onto high-order harmonic generation (HHG). Moreover, the coherent build-up of the generated radiation field (Phase-matching) is studied by controlling the focal position and the intensity of the probe pulse. We find transient phase-matching conditions and the spatio-temporal dynamics of the target to be of major influence on the harmonic yield. The experiments represent a fundamental analysis of phase matching during HHG from liquid droplets.

A 42.4 Thu 16:00 Empore Lichthof

Generation of few-femtosecond monochromatized XUV-pulses for ultrafast pump-probe studies in gas and liquid phase — •Markus Kubin[1], Martin Eckstein[1], Fabio Frassetto[2], Johan Hummert[1], Kathrin Lange[1], Luca Poletto[2], Chung-Hsin Yang[1], Julius Zielinski[1], Marc Vrakking[1], and Oleg Kornilov[1] — [1]Max-Born-Institut, Berlin — [2]LUXOR, Padova, Italy

High harmonic generation (HHG) driven by femtosecond (fs) lasers provides ultrashort XUV pulses with a comb-like spectrum with photon energies reaching several keV. In combination with pump-probe VIS/XUV photoelectron and photoion spectroscopy it helps to follow chemical reactions in real time on fs- to attosecond-scales. However, the broad spectrum of HHG often launches dynamics on many potential energy surfaces and poses challenges for retrieving useful information from the spectra. In grating-based monochromators - used to narrow the spectrum of HHG sources - dispersion stretches the XUV pulses in time. Here we report on the implementation of a two-stage time-compensating monochromator to deliver XUV pulses with photon energies up to 50 eV and pulse durations around 10 fs. The setup allows for VIS/XUV pump-probe photoelectron and photoion spectroscopy in gas phase and condensed phase (employing the liquid micro-jet technique). The spectral and temporal performance of the system will be discussed in the context of IR-assisted ionization of rare gas atomic samples.

A 43: Precision spectroscopy of atoms and ions VI (with Q)

Time: Friday 11:00–12:30 Location: B 305

Invited Talk A 43.1 Fri 11:00 B 305

Accurate, stable, transportable: lattice clocks at PTB — •Christian Lisdat, Stephan Falke, Nathan Lemke, Thomas Middelmann, Stefan Vogt, Sebastian Häfner, and Uwe Sterr — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

After an introduction to the ideas of optical clocks in general and lattice clocks in particular we will present recent improvements on the strontium lattice clocks of PTB. The typical benchmarks of clocks are their accuracy and stability – where substantial improvements have been achieved by the highly accurate evaluation of the dominating source of uncertainty of Sr lattice clocks [1] and the application of an extremely coherent laser [2] for the interrogation of the atomic clock transition in strontium. Now, PTB's laboratory lattice clock is expected to achieve its uncertainty of 4×10^{-17} after an averaging time of less than 200 s. We will use our clock for measurements aiming at posing improved limits on the time variation of fundamental constants. So far these formidable measurement devices are only available in few laboratories in the world. By building a transportable lattice clock we want to develop an instrument for frequency comparisons, tests of e.g. the gravitational redshift or applications like relativistic geodesy with high temporal resolution.

[1] T. Middelmann *et al.*: High accuracy correction of blackbody radiation shift in an optical lattice clock; Phys. Rev. Lett in press (2012).
[2] T. Kessler *et al.*: A sub-40 mHz linewidth laser based on a silicon single-crystal optical cavity; Nature Photonics **6**, 687–692 (2012).

A 43.2 Fri 11:30 B 305

Development of Scalable Ion Traps for Optical Clocks — •Tobias Burgermeister[1], Karsten Pyka[1], Jonas Keller[1], Heather L. Partner[1], Kestutis Kurselis[2], Roman Kiyan[2], Carsten Reinhardt[2], Daniel Hagedorn[1], Rudolf Meess[1], and Tanja E. Mehlstäubler[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Our work focuses on the realization of an optical clock with a fractional frequency inaccuracy as low as 10^{-18} and improved short-term stability. It is based on multiple $^{115}In^{+}$ ions which are sympathetically cooled by $^{172}Yb^{+}$ ions.

Within a new European joint research project we develop chip-based linear ion traps for quantum metrology. Using an operating prototype trap [1,2] we characterize excess micromotion and demonstrate sympathetic cooling of In^{+}/Yb^{+}-crystals. We show that our trap design provides a highly controllable environment for precision spectroscopy and experiments with ion Coulomb crystals.

An advanced next generation ion trap, will be based on gold coated aluminum nitride wafers, which are laser machined at LZH and PTB. For this new trap design we perform theoretical and experimental thermal studies at MIKES (Finland) and CMI (Czech Republic), which will characterize the influence of trap heating on the clock measurement.

[1] Pyka *et al.*, *arXiv*:1206.5111v1 (2012)
[2] Herschbach *et al.*, *Appl. Phys. B* **107**, 891 (2012)

A 43.3 Fri 11:45 B 305

Optical Clock with a Generalized Ramsey Scheme — •Nils Huntemann, Burghard Lipphard, Christian Tamm, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

We experimentally investigate a recently proposed optical excitation scheme [1] that is a generalization of Ramsey's method of separated oscillatory fields. The excitation pulse sequence is tailored to produce a resonance signal that is immune to the light shift and other shifts of the transition frequency that are correlated with the interaction of the atomic system with the probe light field. We investigate the scheme using a single trapped $^{171}Yb^{+}$ ion and perform spectroscopy on the highly forbidden $^2S_{1/2} - {}^2F_{7/2}$ electric-octupole transition that exhibits a strong light shift. This transition serves as a reference in an optical clock, whose accuracy critically depends on the degree of light shift suppression [2]. Our experiments on the new excitation method clearly show a suppression of the light shift by four orders of magnitude and an immunity against its fluctuations [3]. The superior performance of the new technique is demonstrated in a frequency ratio measurement with another optical clock.

[1] V. I. Yudin et al., PRA **82**, 011804 (2010)
[2] N. Huntemann et al., PRL **108**, 090801 (2012)
[3] N. Huntemann et al., PRL **109**, 213002 (2012)

A 43.4 Fri 12:00 B 305

Optical spectroscopy on Ir^{17+} for the determination of transitions extremly sensitive on a variation of the fine-structure constant — •Alexander Windberger[1], Hendrik Bekker[1], Christian Beilmann[2], Renee Klawitter[3], Piet O. Schmidt[4,5], Oscar O. Versolato[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik — [2]Karlsruher Institut für Technologie — [3]Tri University Meson Facility — [4]Physikalisch-Technische Bundesanstalt — [5]Leibniz Universität Hannover

The fine-structure constant α is closely related to fundamental physics. Thus, a temporal variation would point towards physics beyond the Standard Model. Evidence for a variation $\dot{\alpha}/\alpha \approx 10^{-19}$/year has been claimed by [1] based on astronomical observations. In order to test this claim in a laboratory experiment, two accurate ion clocks can be compared to search for a drift in $\dot{\alpha}$-sensitive clock transitions. Moving from singly charged to highly charged ions can enhance, both, the clock accuracy, and the $\dot{\alpha}$-sensitivity to meet the requirements. Particularly, the highest sensitivity for $\dot{\alpha}$ ever predicted for a stable atomic system is found in Ir^{17+} by [2]. To determine the wavelength of the predicted transitions accurately, optical spectroscopy on Ir^{17+} is performed inside the Heidelberg electron beam ion trap (EBIT) at a ppm accuracy level. This will allow for future precision experiments, where Ir^{17+} will be transfered from an EBIT into the Cryogenic Paul Trap Experiment (CryPTEx).

[1] J. K. Webb *et al.*, *Phys. Rev. Lett.* **107**, 191101 (2011).
[2]J. C. Berengut *et al.*, *Phys. Rev. Lett.* **106**, 210802 (2011).

A 43.5 Fri 12:15 B 305

Towards Laser Cooling of Negative Ions — •Elena Jordan, Sophia Haude, Anke Heilmann, and Alban Kellerbauer — MPI für Kernphysik, Heidelberg

Ultra-cold negative ions could be used in a wide field of applications. We intend to demonstrate the first laser cooling of atomic anions. In order to identify suitable laser cooling transitions, we study negative ions by high-resolution laser spectroscopy. Previously the transition frequencies and transition cross-sections of various Os^{-} isotopes were determined [1]. The isotope shift and the hyperfine structure (where applicable) were resolved [2,3], and the Zeeman splitting in a magnetic field was measured [4]. These measurements have shown that laser cooling of Os^{-} is possible in principle, but is hampered by a low cooling transition rate. Presently we are pursuing high-resolution spectroscopy on La^{-}, which has been identified as another potential candidate for anion laser cooling [5].

[1] U. Warring et al., Phys. Rev. Lett. 102 (2008) 043001.
[2] A. Fischer et al., Phys. Rev. Lett. 104 (2010) 073004.
[3] A. Kellerbauer et al., Phys. Rev. A 84 (2011) 062510.
[4] A. Kellerbauer et al., submitted to Phys. Rev. Lett.
[5] S. M. O'Malley & D. R. Beck, Phys. Rev. A 81 (2010) 032503.

A 44: 100 Years of Mass Spectrometry 1

Time: Friday 11:00–13:00 Location: E 415

Invited Talk A 44.1 Fri 11:00 E 415

MS for environmental and radiochemical applications — •Clemens Walther — Institut für Radioökologie und Strahlenschutz, Leibniz Universität Hannover Herrenhäuser Str. 2, 30419 Hannover

MS is applied frequently for investigating environmental questions, making use of the techniques' superior sensitivity and selectivity. A particular interesting field is the detection and speciation of radionuclides. The talk will revisit historical developments and will give an overview of recent applications for both, chemical speciation of radionuclides and trace detection in the environment.

Invited Talk A 44.2 Fri 11:30 E 415

Modern nuclear mass models — •Stephane Goriely — Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, CP226, 1050 Brussels, Belgium

The nuclear mass remains a property of fundamental importance not only for various aspects of nuclear physics, but also for some physics applications, such as nuclear astrophysics. We review the various mass models that have been developed in recent years and critically compare their predictions of experimentally known nuclear structure properties as well as their extrapolation towards the exotic neutron-rich nuclei. Special attention is devoted to recent microscopic mass models based on the mean-field Hartree-Fock-Bogolyuobov method with effective nucleon-nucleon interactions.

Invited Talk A 44.3 Fri 12:00 E 415

High-accuracy mass measurements for nuclear astrophysics — •Susanne Kreim — CERN, Genf, Schweiz — Max-Planck- Institut für Kernphysik, Heidelberg, Deutschland

The mass of a nucleus delivers the binding energy giving insight into structural effects throughout the nuclear chart from the lightest to the heaviest element. Precision measurements of masses far away from the valley of stability are also important to understand nuclear stability. Both notions are crucial for a correct description of astrophysical processes.

The so-called rapid neutron-capture process (r-process) of stellar nucleosynthesis is held responsible for the production of the heavy elements. However, the astrophysical site for a successful r-process has not been identified yet. A possible theory, alternative to the supernova-induced r-process, is the decompression of neutron-star matter by its merger with another neutron star. In the neutron-star crust, exotic rare isotopes become so-called equilibrium nuclei and can contribute to the elemental abundance. Another mechanism of stellar nucleosynthesis is the rp-process, rapid proton-capture process, which takes place on the proton-rich side of the valley of stability and originates in x-ray bursts.

Precise mass values are input parameters that constrain the models for the stellar creation of elements. Whenever masses are not (yet) available, one has to rely on mass models for the nuclei participating in astrophysical processes. New masses offer the required test bench for the predictive power of models. In this contribution, recently performed mass measurements as well as still desired ones will be discussed.

Invited Talk A 44.4 Fri 12:30 E 415

Storage ring mass and lifetime measurements — •Fritz Bosch — GSI Helmholtzzentrum, Darmstadt, Germany

The Experimental Storage Ring ESR provided the first opportunity for addressing precision masurements of masses and beta-decay characteristics of stored and cooled unstable highly-charged ions. This talk will focus on the first observations of the orbital electron-capture decay of H-like and He-like ions in well-defined quantum states. The ESR is for this purpose a unique tool, since the only, but unambiguous signature for these two-body decays is a sudden tiny jump of the revolution frequency. If only a few parent ions are injected and subsequently cooled, this extremely small change of the revolution frequency can be observed and clearly resolved. The first results of this "single-ion decay spectroscopy" will be reported and discussed.

A 45: Atomic systems in external fields I

Time: Friday 11:00–12:30 Location: B 302

Invited Talk A 45.1 Fri 11:00 B 302

Attosecond time-resolved high-resolution spectroscopy of two-electron dynamics in helium, and impulsive control of light — •Thomas Pfeifer — MPI für Kernphysik, Heidelberg

The dynamical motion of electrons governs the physics of processes as fundamental as the absorption of visible light (e.g. creating color) and the making and breaking of molecular bonds (e.g. chemical reactions). In almost all atoms or molecules, electronic excitations are based on the concerted, quantum-correlated, motion of two or more electrons, due to the strong and long-range electron–electron Coulomb interaction and the fermionic exchange symmetry (Pauli principle). It has thus been a long-standing dream to temporally resolve, understand, and control the correlated quantum-mechanical wave function of two or more electrons. Here, we present an experimental spectroscopy method to measure this correlated motion of two electrons bound to a Helium atom. By using tunable laser intensity, we directly observe the continuous transition from weak and perturbative to strong coupling with Rabi cycling (Autler–Townes doublet formation) among autoionizing states. We also use our measurement scheme and its sensitivity to the quantum phase of the excited states to reconstruct a two-electron wavepacket, which can be shaped by the visible laser field, with corresponding implications for the control of covalent molecular bonds, typically consisting of two electrons. We also find a mechanism to variably tune the Fano absorption profiles (inversion and Lorentz-profile conversion), which has far-reaching consequences for the control of absorption of radiation throughout the entire spectrum in general.

A 45.2 Fri 11:30 B 302

Strong-field response of a system with resonance in the continuum. — •Maria Tudorovskaya and Manfred Lein — Institut für Theoretische Physik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

If an atom is subject to a strong oscillating field, it can emit high-harmonic radiation due to the ionization and the following recombination. We consider high-harmonic generation (HHG) in a system with a metastable resonance state in the continuum.

We solve the time-dependent Schrödinger equation numerically in 1D and 2D. We consider a model system describing ions in a Mn plasma [1]. In the system, noticeable increase of HHG at frequencies around the resonance is found. For few-cycle driving pulses, emission takes the form of a short burst.

With an additional XUV driving field, Rabi oscillations can be induced between the ground state and the resonance, affecting the resulting spectrum. Because the decay of the resonance, the oscillation amplitude is damped. Due to the combined effect of the fields, the intensity of the harmonics in the plateau region can be significantly increased.

[1] R. A. Ganeev, et al., Opt. Express 20, 25239 (2012).

A 45.3 Fri 11:45 B 302

Phase-controlled electron acceleration from dielectric nanoparticles in intense few-cycle laser pulses — •Lennart Seiffert[1], Frederik Süssmann[2], Sergey Zherebtsov[2], Jürgen Plenge[3], Eckart Rühl[3], Matthias Kling[2], and Thomas Fennel[1] — [1]Universität Rostock, 18051 Rostock, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Freie Universität Berlin, 14195 Berlin, Germany

The electron emission from atoms and molecules in intense few-cycle laser pulses can be precisely controlled (with sub-fs resolution) by the carrier-envelope-phase [1]. Recently, it has been shown that such pulses also allow us to unravel and control ionization processes in more complex many particle systems, such as silica nanoparticles [2]. Here, we investigate the electron acceleration from laser driven dielectric nanoparticles, where near-field enhancement at the surface leads to the emission of high energy electrons. The electron dynamics is modelled using a quasi-classical trajectory-based mean field Monte-Carlo approach [3], which is extended to account for propagation effects of the near-fields. The size-dependent structure of the near-fields results in strong changes of the angular resolved electron spectra for particle diameters in the range $100 - 400\,\mathrm{nm}$. A detailed understanding of the contributing emission procceses, such as direct, thermal, and field enhanced emission can be deduced from the electron trajectory analysis.

[1] G. G. Paulus et al., Phys. Rev. Lett. 91:253004 (2003)
[2] S. Zherebtsov et al., Nature Phys. 7:656 (2011)
[3] S. Zherebtsov et al., New J. Phys. 14:075010 (2012)

A 45.4 Fri 12:00 B 302

High-n Rydberg states in strontium — •Moritz Hiller[1], Shuhei Yoshida[1], Joachim Burgdörfer[1], Shuzhen Ye[2], and F. Barry Dunning[2] — [1]Institute for Theoretical Physics, Vienna University of Technology, Austria — [2]Rice University, Houston, Texas, USA

We study the photoexcitation of strontium to high-n Rydberg states, in the presence of a weak DC electric field. The two-photon excitation process is analyzed by means of single- and two-electron models which yield marked differences in the oscillator strengths. We compare our theoretical predictions to measured data at $n \approx 300$ and analyze the observed propensity in the excitation of D states as compared to S states. A possibility to generate polarized Rydberg states is discussed.

A 45.5 Fri 12:15 B 302

Bessel beams of laser-driven two-level atoms — •Armen Hayrapetyan[1], Oliver Matula[1,2], Andrey Surzhykov[1,2], and Stephan Fritzsche[2,3] — [1]Physikalisches Institut, Universität Heidelberg, D-69120 Heidelberg, Germany — [2]Gesellschaft für Schwerionenforschung (GSI), D-64291, Darmstadt, Germany — [3]Department of Physics, P.O., Box 3000, Fin-90014 University of Oulu, Finland

We study Bessel beams of two-level atoms that are driven by the linearly polarized laser field. For such laser-driven two-level atoms, we obtain exact, Bessel-type solutions of the time-dependent Schrödinger equation that describes the dynamics of the atom-laser system beyond the typical paraxial approximation. We show that the probability density and the current of these atomic beams obtain non-trivial, Bessel-type behavior and can be tuned under the special choice of the atom and laser parameters, such as the nuclear charge, atom velocity, laser frequency and the propagation geometry of the atom and laser beams. In crossed-beam scenario, moreover, we show that both the probability density and the current of Bessel beams of different atoms acquire different time-dependency. Whereas, in collinear-beam scenario, the probability density and current of these atomic beams do not depend on time. Bessel beams of atoms are of interest to re-investigate atomic collisions, recombination processes or the generation of entanglement in atomic beams.

A 46: Ultra-cold plasmas and Rydberg systems (with Q)

Time: Friday 11:00–12:30 Location: F 428

A 46.1 Fri 11:00 F 428

Periodic emission of entangled Rydberg atoms from superatomic Rydberg clouds — •Michael Genkin, Sebastian Wüster, Sebastian Möbius, Alexander Eisfeld, and Jan Michael Rost — MPI für Physik komplexer Systeme, 01187 Dresden, Germany

We consider a scheme in which dipole-dipole interactions between coherently Rydberg-excited atom clouds (superatoms) are used to generate periodic emission of entangled atom pairs. As demonstrated in earlier work [1], the dipole-dipole interactions between two such clouds can lead to their break up by emission of a single atom pair. In this scenario, the entire, initially coherently shared Rydberg excitation, is eventually localized on the emitted atoms. We propose a setup in which this feature is employed to generate a source for entangled atoms pairs, by periodically re-exciting the remaining ground state atoms to a superatomic state. Depending on the prepared initial state, the entanglement can be encoded either in the motion of the atoms or in the angular quantum number of the Rydberg excitation. Our preliminary findings suggest that above-kHz emission rates can be reached.

[1] S. Möbius *et al*, arXiv:1212.1267 [physics.atom-ph]

A 46.2 Fri 11:15 F 428

The Role of Conical Intersections in flexible Rydberg aggregates — •Karsten Leonhardt, Sebastian Wüster, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems

Transport of electronic excitation is a very important mechanism in nature, e.g. Photosynthesis [1]. It was shown that in linear flexible Rydberg aggregates [2] localized excitons connects the electronic excitation and entanglement transport with atomic motion [3,4]. Here we study linear Rydberg chains perpendicular to each other in a 2D plane. Conical intersections then become relevant for the dynamics, without the need of a ring confinement [5]. We show that this feature leads to a highly nonadiabatic dynamic and an entanglement of motion.

References

[1] R. van Grondelle,V.I. Novoderezhkin, *Phys. Chem. Chem. Phys.* **8**, 793 (2006).
[2] C. Ates, A. Eisfeld, J-M. Rost, *New. J. Phys.* **10**, 045030 (2008).
[3] S. Wüster, C. Ates, A. Eisfeld, J-M. Rost, *Phys. Rev. Lett.* **105**, 195392 (2010).
[4] S. Möbius, S. Wüster, C. Ates, A. Eisfeld, J-M. Rost, *J. Phys. B.* **44**, 184011 (2011).
[5] S. Wüster, A. Eisfeld, J-M. Rost, *Phys. Rev. Lett.* **106**, 153002 (2011).

A 46.3 Fri 11:30 F 428

Electrical read out for coherent phenomena involving Rydberg atoms in thermal vapor cells — •Daniel Barredo, Harald Kübler, Renate Daschner, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

In Rydberg ensembles, coherent excitation, control and detection of highly excited states are key requisites for proposed applications in quantum information processing. For room temperature applications, Electromagnetically Induced Transparency (EIT) has been, to date, the standard tool for coherent detection of highly excited Rydberg states [1].

Here we report on a very sensitive and scalable method to measure coherent phenomena involving Rydberg atoms in vapor cells [2]. We demonstrate that the detection of the Rydberg ionization current in a vapor cell provides a direct measure of Rydberg state populations (in contrast to coherences probed by EIT) with superior signal-to-noise ratios compared to purely optical techniques. This opens up new and alternative routes to study interacting Rydberg ensembles in thermal vapor cells. We will discuss some possible applications of this new technique and future directions.

[1] A. K. Mohapatra, T. R. Jackson, and C. S. Adams. *Phys. Rev. Lett.* **98** 113003 (2007).
[2] D. Barredo, H. Kübler, R. Daschner, R. Löw, and T. Pfau. *arXiv:1209.6550* (2012).

A 46.4 Fri 11:45 F 428

Observation of spatially ordered structures in a two-dimensional Rydberg gas — •Peter Schauss[1], Marc Cheneau[1], Manuel Endres[1], Takeshi Fukuhara[1], Sebastian Hild[1], Ahmed Omran[1], Thomas Pohl[2], Christian Gross[1], Stefan Kuhr[1,3], and Immanuel Bloch[1,4] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden — [3]University of Strathclyde, SUPA, Glasgow G4 0NG, UK — [4]Ludwig-Maximilians-Universität, 80799 München

The ability to control and tune interactions in ultra-cold atomic gases has paved the way for the realization of new phases of matter with short-range interactions. Rydberg atoms are highly suited to extend the scope to long-range interacting systems due to the much stronger van der Waals forces between them.

Here we report on the experimental observation of strong correlations between laser-excited Rydberg atoms using a high-resolution optical detection scheme.

The measurements reveal the emergence of spatially ordered excitation patterns with random orientation, but well-defined geometry in the high-density components of the prepared many-body state. In combination with single-site addressing the developed Rydberg atom imaging techniques will enable further well-controlled experiments with Rydberg gases on the single-atom level.

[1] P. Schauß et al., Nature 491, 87 (2012)

A 46.5 Fri 12:00 F 428

Generating Lévy stable disorder from a random enviroment — •Sebastian Möbius[1], Sebastiaan M. Vlaming[1,2], Victor A. Malyshev[2], Jasper Knoester[2], and Alexander Eisfeld[1] — [1]Max Planck Institute for Physics of Complex Systems, Nöthnitzer Strasse 38, D-01187 Dresden, Germany — [2]Centre for Theoretical Physics and Zernike Institute for Advanced Materials, University of Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands

Assemblies of molecules or atoms, that are coupled via long range resonant transition dipole-dipole interaction, exhibit extraordinary absorption properties. In the presence of an environment, that leads to static Gaussian energy fluctuations of the individual constituents, a narrowing of the absorptions band is observed. Recent studies [1] have shown, that Levy stable distributions (LSD), a generalization of the Gaussian case, may also lead to a broadening of the absorption band.

Assemblies of Rydberg exited atoms are an ideal system, to experimentally study the proposed effects of the LSD. The large polarizability of Rydberg atoms allow for a strong interaction with an environment, e.g. polar background gas. The resulting energy fluctuations, due to Stark shifts, will be distributed according to a LSD.

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

A 46.6 Fri 12:15 F 428

Coherent molecule formation in anharmonic waveguides due to inelastic confinement-induced resonances — •Simon Sala[1], Gerhard Zürn[2], Thomas Lompe[2], Andre N. Wenz[2], Simon Murmann[2], Friedhelm Serwane[2], Selim Jochim[2], and Alejandro Saenz[1] — [1]AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstrasse 15, 12489 Berlin, Germany — [2]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Germany

Ultracold atomic systems of reduced dimensionality show intriguing phenomena like fermionization of bosons in the Tonks-Girardeau gas or confinement-induced resonances (CIR). The latter allow for a manipulation of the effective 1D interaction strength in a 3D system of large anisotropy. It was proposed [1] that inelastic CIR, which originate from a coupling of center-of-mass and relative motion due an anharmonicity of the trapping potential, lead to losses in a recent experiment. However, also other mechanism were proposed to explain the losses. Here, it is demonstrated that the coupling of center-of-mass and relative motion leads to a coherent coupling of a state of an unbound atom pair and a molecule in agreement with the theory predicting inelastic CIR. Performing an experiment with exactly two particles allows for a direct observation of molecules under exclusion of three-body losses. Moreover, it is shown that molecule formation is absent at an elastic CIR. This has consequences for the interpretation of loss experiments in low dimensional systems.

[1] S. Sala et al., Phys. Rev. Lett. 109, 073201 (2012).

A 47: Precision measurements and metrology V (with Q)

Time: Friday 11:00–12:30 Location: E 001

A 47.1 Fri 11:00 E 001

Spektroskopie des optischen $^1S_0$-$^3P_0$ Uhrenübergangs von Magnesium nahe der magischen Wellenlänge — •Steffen Rühmann, André Kulosa, Dominika Fim, Klaus Zipfel, Temmo Wübbena, André Pape, Wolfgang Ertmer und Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Magnesium ist ein interessanter Kandidat für die Präzisionsspektroskopie in optischen Gittern [Katori, Nature 435, 321-324, 2005]. Es besitzt eine der geringsten Sensitivitäten auf die Schwarzkörperstrahlung, welche die Performance aktueller Neutralatomuhren limitiert. Wir berichten über die Speicherung von Magnesium in einem optischen Gitter bei der sogenannten magischen Wellenlänge, bei der die differentielle Frequenzverschiebung durch den AC-Stark-Effekt des stark verbotenen Uhrenübergangs $^1S_0$-$^3P_0$ in erster Ordnung unterdrückt wird. Dies erlaubt es erstmalig diesen Übergang direkt anzuregen. Erste Ergebnisse zur Spektroskopie werden präsentiert.

A 47.2 Fri 11:15 E 001

Ultra-stable Cryogenic Optical Sapphire Cavities – Towards a Thermal Noise Limited Frequency Stability $< 3 \cdot 10^{-17}$ — •Moritz Nagel, Katharina Möhle, Klaus Döringshoff, Sylvia Schikora, Evgeny Kovalchuk, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

Many experimental and technical applications, e.g. optical atomic clocks, demand ultra-stable cavity systems for laser frequency stabilization. Nowadays, the main limiting factor in frequency stability for room temperature resonators has been identified to be the displacement noise within the resonator substrates and mirror coatings due to thermal noise. A rather straightforward method to reduce the influence of thermal noise is to cool down the resonators to cryogenic temperatures. Following this approach, we present a design and first measurements for an ultra-stable cryogenically cooled sapphire optical cavity system, with a prospective thermal noise limited frequency stability better than $3 \cdot 10^{-17}$.

A 47.3 Fri 11:30 E 001

Coherence transfer for the generation of x-ray frequency combs — •Stefano M. Cavaletto[1], Zoltán Harman[1,2], Christian Buth[3], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]ExtreMe Matter Institute (EMMI), Darmstadt, Germany — [3]Argonne National Laboratory, Argonne, IL, USA

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 in a femtosecond-enhancement cavity [1]. We propose an optical scheme to transfer the coherence of a driving, optical frequency comb to the radiation emitted by transitions of higher frequencies. The comb structure we predict in the emitted x-ray spectrum might eventually represent an alternative scheme for x-ray-comb generation, able to overcome the frequency limitations of present HHG-based methods.

[1] A. Cingöz et al., Nature 482, 68 (2012).

A 47.4 Fri 11:45 E 001

Coherence-Enhanced Optical Determination of the ^{229}Th Isomeric Transition — •Sumanta Das, Wen-Te Liao, Christoph H. Keitel, and Adriana Pálffy — Max Planck Institute for Nuclear Physics, Heidelberg

The 7.8 eV isomeric transition in ^{229}Th [1] is a promising candidate for next generation frequency standards. The advantages of this nuclear transition are its very narrow width, the stability with respect to external perturbations and an accessible frequency within the VUV region. However, a direct measurement of the transition energy has not yet been possible, due to the weak fluorescence signal and the lack of an unmistakable signature for the nuclear excitation.

Here we investigate the effect of coherent light propagation on the excitation and fluorescence signal of the isomeric transition [2]. The transient superradiant behaviour for the nuclear fluorescence in a crystal lattice environment in the forward direction can be exploited to enhance the signal and reduce data collecting time. Furthermore, we put forward a quantum optics scheme based on quantum interference induced by two coherent fields coupling three nuclear levels as a novel way to identify the isomeric transition energy [2]. The proposed setup provides a clear signature for the nuclear excitation and an enhanced precision in the optical determination of the transition frequency compared to a direct fluorescence experiment using only one field.

[1] B. R. Beck *et al.*, Phys. Rev. Lett. 98, 142501 (2007).
[2] W.-T. Liao, S. Das, C. H. Keitel and A. Pálffy, Phys. Rev. Lett., in press (2012).

A 47.5 Fri 12:00 E 001

An optical feedback frequency stabilized laser tuned by single-sideband modulation — •Johannes Burkart and Samir Kassi — Laboratoire Interdisciplinaire de Physique (LIPhy), UMR5588 CNRS/Université Joseph Fourier Grenoble, 38402 Saint Martin d'Hères, France

Stable, narrow and tunable laser sources are indispensable for molecular lineshape metrology.

Our novel approach consists in stabilizing a distributed feedback diode laser to an ultrastable V-shaped reference cavity by optical feedback self-locking. This limits the laser's frequency drifts to the order of a few hertz per second and reduces its linewidth by several orders of magnitude.

The second key innovation consists in shifting the laser frequency with millihertz precision using an integrated electro-optic Mach-Zehnder modulator. By successive laser locking to adjacent reference cavity modes this technique allows continuous frequency tuning over more than one terahertz.

Combined with cavity ring-down spectroscopy, this new setup will pave the way to an accurate determination of the Boltzmann constant as well as optical precision measurements of isotopic ratios for atmospheric and climate sciences.

A 47.6 Fri 12:15 E 001

Optical Frequency Transfer over 1840 km Fiber Link - Bridging Continental Distances — •Stefan Droste[1], Katharina Predehl[1], Thomas Udem[1], Theodor W. Hänsch[1], Ronald Holzwarth[1], Sebastian Raupach[2], Filip Ozimek[2], Harald Schnatz[2], and Gesine Grosche[2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

The increasing performance of optical 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. Doppler shifts introduced by the fiber link lead to a degradation of the optical signal. After applying a correction signal to compensate for the fiber noise we could demonstrate that optical frequencies can be transferred over nearly 2000 km with a stability and accuracy that surpasses the requirements for comparing modern optical frequency standards by more than one order of magnitude.

A 48: Ultracold atoms: Manipulation and detection (with Q)

Time: Friday 11:00–12:30 Location: F 142

A 48.1 Fri 11:00 F 142

Direct synthesis of light polarization for state-dependent transport of atoms — •Carsten Robens, Andreas Steffen, Anna Hambitzer, Noomen Belmechri, Andrea Alberti, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn,Wegelerstr. 8,53115 Bonn

Coherent control of individual atoms in optical lattices have recently proven to be a key asset in simulating physical phenomena, spanning from quantum transport effects typical of solid state physics to artificial gauge fields.
We report on a new approach to transport neutral atoms state-dependently in a spin-dependent optical lattice. The scheme is based on direct synthesis of light polarization by employing RF sources integrated with acousto-optic modulators for phase control.
The optical lattice is formed by superimposing two circularly polarized lattices. An optical phase-locked loop allows us to control with interferometric precision the phase difference between the two lattices. The phase directly corresponds to the relative displacement of the two lattices.
Applying this method to a digital atom interferometer [1], we envisage macroscopic splitting over spatial distances up to 10mm, about a million times larger than the size of each component of the split atom.

[1] A. Steffen, A. Alberti, W. Alt, N. Belmechri, S. Hild, M. Karski, A. Widera and D. Meschede, PNAS109, 9770 (2012)

A 48.2 Fri 11:15 F 142

Coherent manipulation of cold cesium atoms in a nanofiber-based two-color dipole trap — •Daniel Reitz, Rudolf Mitsch, Clement Sayrin, Philipp Schneeweiss, and Arno Rauschenbeutel — Vienna Center for Quantum Science and Technology, TU Wien, Atominstitut, Stadionallee 2, A-1020 Wien, Austria

We have recently demonstrated a new experimental platform for trapping and optically interfacing laser-cooled cesium atoms. The scheme uses a two-color evanescent field surrounding an optical nanofiber to localize the atoms in a one-dimensional optical lattice 200 nm above the nanofiber surface. In order to use this fiber-coupled ensemble of trapped atoms for applications in the context of quantum communication and quantum information processing, non-classical states of the atomic spins have to be prepared and should live long enough to allow one to apply successive quantum gates. The close proximity of the trapped atoms to the nanofiber surface and the strong polarization gradients of nanofiber-guided light fields are potentially important sources of decoherence. Here, we present our latest experimental results on the coherence properties of atomic spins in our nanofiber-based trap. Using a microwave field to drive the clock transition, we determine inhomogeneous and homogeneous dephasing times by Ramsey and spin echo techniques, respectively. Our results constitute the first measurement of the coherence properties of atoms trapped in the vicinity of a nanofiber and represent a fundamental step towards establishing nanofiber-based traps for cold atoms as a building block in a quantum network.

A 48.3 Fri 11:30 F 142

Atom lens without chromatic aberrations — •Maxim A. Efremov[1], Polina V. Mironova[2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, 89081 Ulm, Germany — [2]Theoretische Quantendynamik, Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt

We propose a lens for atoms with reduced chromatic aberrations and calculate its focal length and spot size. In our scheme a two-level atom interacts with a near-resonant standing light wave formed by two running waves of slightly different wave vectors, and a far-detuned running wave propagating perpendicular to the standing wave. We show that within the Raman-Nath approximation and for an adiabatically slow atom-light interaction, the phase acquired by the atom is independent of the incident atomic velocity.

A 48.4 Fri 11:45 F 142

Optomechanics with an atomic array in a cavity — •Oxana Mishina and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany

Cold atomic ensembles inside an optical cavities are good candidates for exploring quantum aspects of optomechanical coupling. An interesting perspective emerges in the configuration when the atoms are confined by an external periodic potential inside a high-finesse resonator. We present a theoretical model describing the optomechanical coupling of the atomic array with a single mode light in a cavity and investigate cooling of the atomic motion to the ground state of the individual wells. We reproduce the dynamics observed in [1]. Moreover, we investigate further experimental regimes and find that arrays with tens of atoms can be cooled down to the ground state within few milliseconds for accessible experimental parameters. These results set the starting point for the exploration of the light-phonon interface and possibly novel quantum states of motion.
[1] Optomechanical Cavity Cooling of an Atomic Ensemble M.H., Schleier-Smith, I.D. Leroux, H. Zhang, M.A. Van Camp, and V. Vuletić, Phys. Rev. Lett. 107, 143005 (2011)

A 48.5 Fri 12:00 F 142

Heterodyne spectroscopy of single atom motional states inside a high-finesse cavity — •René Reimann, Wolfgang Alt, Tobias Kampschulte, Sebastian Manz, Natalie Thau, 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 experiments connected to the field of quantum information. In our system insight to the motional states of single atoms coupled to a high finesse optical resonator is gained by the means of optical heterodyne detection. Measuring the beat signal between a fixed-frequency local oscillator beam and the light interacting with the coupled atoms, we are able to map the atomic motional state to the frequency domain in a non-destructive way. Analysing the spectra we discuss different experimental imperfections and estimate the intra-cavity atomic temperature within the frame of a simple model.

A 48.6 Fri 12:15 F 142

Optimal control of effective Hamiltonians — •Albert Verdeny Vilalta[1], Cord A. Müller[2], and Florian Mintert[1] — [1]Freiburg Institute for Advanced Studies, Albert-Ludwigs University of Freiburg, Freiburg 79104, Germany — [2]Centre for Quantum Technologies, National University of Singapore, Singapore 117543, Singapore

Periodically driven Hamiltonians can be approximately described by a time-independent effective Hamiltonian if the driving is sufficiently fast. There exist, however, many different drivings that result in the same effective Hamiltonian. Using optimal control techniques, we investigate which driving yields the best approximation to the dynamics induced by a desired effective Hamiltonian. The viability of our approach is proven for the simplest example of a driven three-level Lambda system, and shall ultimately help to improve the precision of quantum simulations.

A 49: 100 Years of Mass Spectrometry 2

Time: Friday 14:00–16:30 Location: E 415

Invited Talk A 49.1 Fri 14:00 E 415

Search for resonant double-electron capture — •Sergey Eliseev[1], Klaus Blaum[1], Michael Block[2], Christian Droese[3], Dmitriy Nesterenko[4], Yuri Novikov[4], Enrique Minaya Ramirez[2], Christian Roux[1], Lutz Schweikhard[3], and Kay Zuber[5] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [3]Institut für Physik, Ernst-Moritz-Arndt-Universität, Greifswald, Germany — [4]PNPI, St. Petersburg, Russia — [5]Institut für Kern- und Teilchenphysik, Technische Universität, Dresden, Germany

It is still unknown whether neutrinos are Dirac or Majorana particles. An answer to this question can be obtained from neutrinoless double-electron capture. An observation of this process would prove that the neutrino is a Majorana particle. A measurement of the half-life of this process would allow a determination of the effective Majorana neutrino mass.

In the search for the nuclide with the largest probability for neutrinoless double-electron capture, we have determined the Q-values of several potentially suitable nuclides with SHIPTRAP by Penning-trap mass-ratio measurements. The ECEC-transition in ^{152}Gd has been determined to have the smallest half-life of 10^{26} years for a 1 eV neutrino mass among all known 0νECEC-transitions, which makes ^{152}Gd the most promising candidate for the search for neutrino-less double electron capture. This contribution will summarize the recent experimental results.

Invited Talk A 49.2 Fri 14:30 E 415

Towards accurate T-3He Q-value — •Tommi Eronen[1], Martin Höcker[1], Jochen Ketter[1], Sebastian Streubel[1], Robert S. Van Dyck[2], and Klaus Blaum[1] — [1]Max-Planck Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Department of Physics, University of Washington, Seattle, WA 98195-1560, USA

Great efforts have been put forward to determine the neutrino mass from tritium β decay. The most prominent experimental setup, KATRIN [1], is expected to deliver an upper limit to the neutrino mass that is one order of magnitude more stringent than the current value by measuring the endpoint and the shape of the β spectrum of the tritium decay.

The endpoint energy (assuming zero neutrino mass) can also be deduced from the Q-value of the decay by measuring the mass difference of tritium and the daughter ^{3}He using high-resolution mass spectrometry. Such a measurement would give an excellent, independent calibration point for the KATRIN experiment to deduce its systematics.

Our mass-difference measurement utilizes the **T**ritium-**He**lium double Penning trap (THe-Trap) setup [2]. Based on the anharmonic cyclotron frequency determination method pioneered at the University of Washington, Seattle, precision at the level of 1 part in 10^{11} in the T/^{3}He mass ratio is expected. In this contribution, I will describe the motivation, the principle, current status, and expectations of the experiment.

[1] Wolf J., Nucl. Instr. Meth., Sect. A **623**, 442 (2010).
[2] Diehl C. *et al.*, Hyperfine Interact. **199**, 291 (2011).

Invited Talk A 49.3 Fri 15:00 E 415

The Avogadro constant and a new definition of the kilogram — •Peter Becker — PTB, Bundesallee 100, 38116 Braunschweig

The Avogadro constant, the number of entities in the amount of substance of one mole, links the atomic and the macroscopic properties of matter. Since the molar Planck constant is very well known via the measurement of the Rydberg constant, the Avogadro constant is also closely related to the Planck constant. In addition, its accurate determination is of paramount importance for a new definition of the kilogram in terms of a fundamental constant. The talk describes a new and unique approach for the determination of the Avogadro constant by *counting* the atoms in 1 kg single-crystal spheres, which are highly enriched with the 28Si isotope. This approach has enabled us to apply isotope dilution mass spectroscopy to determine the molar mass of the silicon crystal with unprecedented accuracy. The value obtained, NA = 6.022 140 84(18) x 1023 mol-1, is now the most accurate input datum for a new definition of the kilogram.

Invited Talk A 49.4 Fri 15:30 E 415

Dating human DNA with the 14C bomb peak — •Walter Kutschera, Jakob Liebl, and Peter Steier — VERA Laboratory, University of Vienna, Vienna, Austria

In 1963 the limited nuclear test ban treaty stopped nuclear weapons testing in the atmosphere. By then the addition from bomb-produced 14C had doubled the 14C content of the atmosphere. Through the CO2 cycle this excess exchanged with the hydrosphere and biosphere leading to a rapidly decreasing 14C level in the atmosphere. Today we are almost back to the pre-nuclear level. As a consequence all people on Earth who lived during the second half of the 20th century were exposed to this rapidly changing 14C signal.

A few years ago, a group at the Department of Cell and Molecular Biology of the Karolinska Institute in Stockholm started to use the 14C bomb peak signal in DNA to determine retrospectively the age of cells from various parts of the human body (brain, heart, fat). In a collaboration with this group, we have studied the age of olfactory bulb neurons in the human brain. For this investigation, 14C AMS measurements were developed at VERA for very small carbon samples in the range from 2 to 4 micrograms.

In the presentation the general concept of 14C bomb peak dating of human DNA and several applications will be discussed.

Invited Talk A 49.5 Fri 16:00 E 415

Resonance ionization mass spectrometry — •Klaus Wendt — Institut für Physik, Johannes Gutenberg-Universität Mainz

The second key issue of elemental mass spectrometry - apart from its overall sensitivity - is the achievable selectivity in respect to any kind of contamination within the sample or ion beam, which defines the significance of results. While the suppression of neighbouring masses is usually high and primarily governed by the resolution of the mass spectrometer in use, isobaric interferences cause the dominant limitation for conventional mass spectrometers.

The implementation of element-specific ion sources which employ resonant excitation processes and subsequent ionization by powerful and properly tuned laser light, has drastically altered this situation. Resonance ionization mass spectrometry adds optical selectivities of many orders of magnitude in respect to isobars and even isotopes of the same element within such a laser ion source to the performance of a well adapted mass spectrometer. Applications focus on the selective production of radioactive ion beams of exotic species at on-line facilities as well as the ultra trace analysis of radioisotopes at lowest concentration levels. The presentation gives an overview of the state of the art of this challenging technique.

A 50: Atomic systems in external fields II

Time: Friday 14:00–15:45 Location: B 302

A 50.1 Fri 14:00 B 302

Ultra-long-range Rydberg molecules exposed to external electric fields — •Markus Kurz[1], Michael Mayle[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]JILA, University of Colorado and National Institute of Standards and Technology, Boulder, Colorado 80309-0440, USA

We investigate the impact of an external electric field on ultra-long-range Rydberg molecules in the ultra-cold regime. The theoretical framework of the considered problem is based on the Fermi pseudopotential approximation, where we include p-wave contributions in the electron-perturber interaction. Hereafter, we study the rich topology of the Born-Oppenheimer potential surfaces for several field strengths. Furthermore, we analyze the rovibrational dynamics for different electronically excited states. Finally, we present a preparation scheme for high-ℓ molecular electronic states via a two photon excitation process.

A 50.2 Fri 14:15 B 302

Measurements of the dynamic and Berry phases in Rb superposition states — •Carl Basler — Department of Molecular and Optical Physics, Universität Freiburg

We study the transient response of the refractive index to changes of the magnetic field vector under conditions of electromagnetically-induced transparency. This is an extension of our recent work, FM et al. PR A 85, 013820 (2012) where the dynamic response to frequency changes was explored. Under EIT conditions the superposition state $\Psi = (|1\rangle - e^{i\eta}|2\rangle)/\sqrt{2}$ is called dark state and is barred from fluorescence. This state develops by spontaneous emission in the presence of two phase-stable laser fields $E_j(\omega_j, \phi_j)$. The dark state phase fulfils the requirement $\eta = \phi_1 - \phi_2$ and is thus sensitive to the laser phases. When the dark state has formed and the lasers are suddenly detuned from EIT resonance the atoms undergo Rabi floppings between dark and bright state.

When changing the magnetic field, the lasers are also detuned from resonance due to Zeeman shifts and the dark state atoms pick up a dynamic phase. When the magnetic field is not changed in strength but rotated in space the system acquires a Berry phase. We show measurements of the dynamic phase and the Berry phase of Rb-atoms in a buffered gas cell at room temperature.

A 50.3 Fri 14:30 B 302

Doppler-free Magnetically Induced Dichroism Signals of the deep UV 6^1S_0 - 6^3P_1 Transition in Neutral Mercury Atoms — •Martin Fertl — Paul Scherrer Institut, Villigen, Switzerland — on behalf of the nEDM Collaboration: nedm.web.psi.ch

We report on the observation of Doppler-free magnetically induced dichroism signals of the deep UV 6^1S_0 - 6^3P_1 transition in neutral mercury atoms of all naturally abundant isotopes. The signals are used to frequency stabilize a UV frequency-quadrupled diode laser system (FHG) to sub-MHz stability without frequency modulation and with sub-mW light power (sub-Doppler DAVLL). The FHG is part of a free induction decay magnetometer based on spin polarized ^{199}Hg atoms. Polarized ^{199}Hg atoms precess freely in a magnetic field after a $\pi/2$ flip. This precession is detected as amplitude modulation of a circularly polarized UV light beam traversing the Hg storage volume in the spin precession plane (ODMR). Present techniques, using off-resonant light (e.g. ^{204}Hg discharge lamp) can induce vector light shifts and induce systematic frequency shifts. The FHG will be locked to the frequency where this vector light shift effect is absent. The magnetometer is employed to extract and survey the time stability ($\approx 10^{-8}$ over 100s) of the magnetic field ($\approx 1\mu$T) in the neutron electric dipole moment (nEDM) experiment at the Paul Scherrer Institute, Switzerland (PSI). The frequency locking scheme might also be applied to laser cooling of mercury atoms for magneto optical traps. This project is supported by the Swiss National Science Foundation under contract number 200021-126562.

A 50.4 Fri 14:45 B 302

Nuclear recollisions in laser-assisted α decay — •Héctor Mauricio Castañeda Cortés[1], Carsten Müller[1,2], Christoph H. Keitel[1], and Adriana Pálffy[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Laser-driven recollisions have come to play a crucial part in atomic strong-field physics. In this work we investigate theoretically the nuclear physics counterpart involving a repulsive potential, namely laser-driven recollisions following α decay. The effects of the intense laser field on the α particle tunneling and dynamics after emission were accounted for in the framework of a laser-assisted decay of quasistationary states formalism [1]. We find that under the action of a strong laser field, the α particle may change its trajectory after emission and be driven back to recollide with the daughter nucleus at energies sufficient to produce nuclear reactions and on time scales currently not available in experiments [2]. Fast recollisions can even allow probing short-lived excited nuclear states reached via α decay. Thus, laser-driven nuclear recollisions open the exciting possibility to investigate a new energy regime at the interplay between the electromagnetic and strong forces. We show here that such recollisions are rare but detectable already at presently available laser intensities of $10^{22} - 10^{23}$ W/cm^2 [2].

[1] H. M. Castañeda Cortés, S. V. Popruzhenko, D. Bauer and A. Pálffy, New J. Phys. 13, 063007 (2011).
[2] H. M. Castañeda Cortés, C. Müller, C. H. Keitel and A. Pálffy, arXiv:1207.2395

A 50.5 Fri 15:00 B 302

Recent Improvements of a mobile polarizer system for ^{129}Xe — •Vanessa Stahl[1], Werner Heil[1], Sergei Karpuk[1], Peter Blümler[1], Maricel Repetto[1], Benjamin Niederländer[1], Manuel Braun[1], Martin Fuchs[1], Kerstin Münnemann[2], and Hans Spiess[2] — [1]Institut für Physik, Universität Mainz — [2]Max Planck Institute for Polymer Research Mainz

(HP) ^{129}Xe has numerous applications both in fundamental physics like nuclear spin clocks [1] and in medical research, e.g. in lung MRI [2,3]. We report on a compact mobile ^{129}Xe polarizer built in order to achieve high polarization degrees operating in counter flow. The optical pumping scheme is optimized in terms of magnetic field homogeneity, rubidium saturation, freeze-thaw method [4], gas-transport and its storage in special vessels with low wall relaxation. This talk will cover different aspects of HP gas production, manipulation and minimization of losses due to relaxation.

[1] C. Gemmel, Phys. Rev. D 82, 111901(R) (2010)
[2] Driehuys, Radiology 262, 1 (2012)
[3] H. E. Möller, Jour. of Magn. Res. in Med. 41, 1058-1064 (1999)
[4] I. C. Ruset and F.W. Hersman, PRL 96, 053002 (2006)

A 50.6 Fri 15:15 B 302

Spin dynamics in the relativistic Kapitza-Dirac effect — •Sven Ahrens[1], Heiko Bauke[1], Christoph H. Keitel[1], and Carsten Müller[1,2] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

The Kapitza-Dirac effect [1], which is the diffraction of electrons at a standing wave of light, has been observed experimentally in the last decade [2]. The availability of novel high intensity X-ray laser sources calls for a relativistic description of this electron scattering process.

We discuss the quantum dynamics of the electron diffraction by solving the Dirac equation in momentum space [3]. We demonstrate that generalized 3-photon Kapitza-Dirac scattering of the electron with the laser beam occurs if the energy and the momentum of corresponding classical kinematics are conserved. This 3-photon Kapitza-Dirac effect features a tunable electron spin-flip probability. We emphasize the significance of the electron's spin-degree of freedom by a comparison with corresponding quantum dynamics of the Klein-Gordon equation.

[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 50.7 Fri 15:30 B 302

Angular distribution effects in multi-photon ionization — •Gregor Hartmann[1,2], Markus Braune[3], Toralf Lischke[1,2], André Meissner[1], André Knie[4], Arno Ehresmann[4], Markus Ilchen[3], Omar Al-Dossary[5,6], and Uwe Becker[1,2,5] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [3]DESY Notkestraße 85, 22067 Hamburg, Germany — [4]Institut für Physik and CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [5]Physics Department, College of Science, King Saud University, Riyadh 11451, Saudi Arabia — [6]National Center for Mathematics and Physics, KACST, Saudi Arabia

The angular distribution of emitted photoelectrons is determined by the transfer of the angular momentum of the ionizing photon to the ejected electron. In the case of two-photon ionization another angular momentum of one comes into play giving rise to a Legendre polynomial of fourth order, the so called β_4 term. Interestingly this additional term does not only effect the electrons emitted by two photons but also the one being ejected by one photon only. This shows that both processes are coherently coupled. We show this effect for the first time for the two-photon ionization of the rare gases measured at FLASH. Even more interesting is the fact that this phenomenon is even observed for the case of He although 1s-shell photoionization should exhibit no β_4 term at all because the remaining hole is isotropic. We interpret this unexpected result as due to autoionizing doubly excited resonances in He.

A 51: Precision measurements and metrology VI (with Q)

Time: Friday 14:00–15:45 Location: E 001

A 51.1 Fri 14:00 E 001

A long reference cavity with contribution from thermal noise to frequency instability of below 10^{-16} — •Sebastian Häfner, Stefan Vogt, Stephan Falke, Christian Lisdat, and Uwe Sterr — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

The stability of current optical clocks is limited through the short-term stability of the interrogation laser. Here, we will focus on the reference cavity of the clock laser system, whose mechanical length stability provides the frequency stability of the clock laser. The length stability of well designed and operated cavities is limited by the Brownian motion of the materials, especially of the mirrors. This influence can be reduced by using longer cavities at the cost of a higher sensitivity to vibrations and more difficult thermal control.

Our laser system uses a 47.7 cm long ULE high finesse cavity which is to our knowledge the longest cavity ever used for frequency stabilization of a laser, with expected frequency instability from thermal noise of $\Delta\nu/\nu = 8 \cdot 10^{-17}$. We have designed a new cavity mounting which shows a measured acceleration sensitivity of $\Delta l/l = 4 \cdot 10^{-11}/g$ and a precision temperature control system with expected temperature instability of below 10 μK. To fully benefit from the cavities stability, we are planing to control all fluctuations of the optical path length from the end mirror of the cavity to the experiment. This work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and EU through the Space Optical Clocks (SOC2) project.

A 51.2 Fri 14:15 E 001

Laser ranging for GRACE follow-on — •Daniel Schütze, Gunnar Stede, Vitali Müller, Alexander Görth, Oliver Gerberding, Christoph Mahrdt, Benjamin Sheard, Gerhard Heinzel, and Karsten Danzmann — Max Planck Institute for Gravitational Physics / Albert Einstein Institute Hanover

The joint NASA/DLR mission GRACE (Gravity Recovery and Climate Experiment) successfully collects data about spatial and temporal variations in the gravity field of the earth using satellite-to-satellite tracking via microwave ranging. A GRACE follow-on mission will be launched in 2017. In addition to the conventional microwave ranging system, the GRACE follow-on satellites will also contain a laser ranging instrument to improve the inter-satellite distance measurements. This laser ranging instrument employs heterodyne interferometry with a receiver-transponder principle and phasemeter readout making use of LISA technologies. Essential parts of the laser ranging instrument are a triple mirror assembly to establish an off-axis roundtrip path between the satellites and a steering mirror setup to account for satellite pointing. A laboratory test setup of the GRACE follow-on interferometer is presented with which these key components are tested.

A 51.3 Fri 14:30 E 001

General Astigmatic Gaussian Beam Model — •Evgenia Kochkina, Dennis Schmelzer, Gudrun Wanner, Gerhard Heinzel, and Karsten Danzmann — Albert Einstein Institute, Hannover

Optical simulations for space interferometers require accurate beam models in order to predict all interesting effects. In many cases circular or elliptical (simple astigmatic) Gaussian beams are sufficient. When a beam is transformed (reflected or refracted) at a curved interface the plane of incidence is defined by the beam direction and the local normal vector to the interface at the point of incidence. This definition is purely geometrical and doesn't account for physical beam properties, such as intensity or phase distribution. If we assume that the transformed beam is elliptical, we need one of it's semi-axes to lie in plane of incidence in order to use simple astigmatic beam model. In a general 3D case it's not necessarily true. When both semi-axes of the beam ellipse do not lie in the plane of incidence, beam transformations can be described using the general astigmatic Gaussian beam model. Such beams have been described in the literature. To our knowledge however there is no available software implementation or a complete general astigmatic Gaussian model description. We will report on our investigations of the general astigmatic Gaussian beam model, it's implementation in the software and the experiments to verify the simulation results.

A 51.4 Fri 14:45 E 001

Ultra-stable 39.5 cm long optical cavity with reduced thermal noise — •Sana Amairi and Piet O. Schmidt — QUEST, PTB, Braunschweig , Germany

We are currently setting up an aluminium quantum logic optical clock. $^{27}Al^{+}$ has been chosen as the clock ion since it has a narrow 8 mHz clock transition at 267 nm which exhibits no electric quadruple shift and a low sensitivity to black-body radiation. The $^{27}Al^{+}$ clock ion is be trapped together with a $^{40}Ca^{+}$ ion which is used for sympathetic cooling and internal state detection of the clock ion. The quantum projection noise limited stability $\sigma_y(\tau)$ for Al$^+$ is in the order of $1 \times 10^{-16}/\sqrt{\tau}$. This stability can only be achieved with an interrogation laser with a sufficiently small linewidth, thermal noise-limited instability and drift. The dominant thermal noise contribution to relative frequency instability in state-of-the art optical cavities comes from the mirror coatings. It scales with the inverse length of the cavity and the inverse square of the laser beam radius on the mirrors, which also increases with the length. Therefore, we have set up a long (39.5 cm) ultra-stable optical cavity made of a ULE spacer and fused silica mirrors. We have performed finite element simulations to estimate a thermal noise limited instability of 7×10^{-17} for such a cavity [1]. Furthermore, we have performed numerical simulations to find optimum support points together with allowed machining tolerances and required force balancing. Besides theoretical estimates, we present first experiments towards the characterization of the cavity. Ref[1]:ArXiv:submit/0614173

A 51.5 Fri 15:00 E 001

Digital unterstützte heterodyn Interferometrie — •Katharina-Sophie Isleif, Sina Köhlenbeck, Oliver Gerberding, Stefan Gossler, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationspyhsik und Institut für Gravitationsphysik der Universität Hannover, Callinstraße 38, 30167 Hannover, Deutschland

Heterodyne Laserinterferometrie ist eine der wichtigsten Technologien für präzise Längenänderungsmessungen, die bereits bei den Missionen LISA und LISA Pathfinder zur Anwendung kommt. Digital unterstützte heterodyne Interferometrie ist eine Erweiterung hiervon. Hier wird eine digital erzeugte binäre Pseudozufallszahlenfolge auf die Phase des Lichts in einem Interferometerarm mit Hilfe eines EOM's moduliert. Durch anschließende digitale Decodierung mit derselben Pseudozufallszahlenfolge mit unterschiedlichen Verzögerungen können die Laufwege mehrerer Laserstrahlen eines Strahlenganges separiert werden. Dadurch wird es möglich, mehrere Interferometer gemeinsam auszulesen und die Messempfindlichkeit durch Unterdrückung gemeinsamer Rauschquellen signifikant zu verbessern. Momentan wird am Albert Einstein Institut in Hannover an einem bestehenden Aufbau geforscht, der diese Technologie bereits verwendet.

In diesem Vortrag wird der aktuelle Stand des Interferometers vorgestellt. Die bisher erreichte Messempfindlichkeit beträgt 3pm/$\sqrt{\text{Hz}}$ bei 10Hz. Indem der bisher verwendete Laser auf einen frequenzstabileren iodstabilisierten Laser gelockt wird, erwarten wir eine Verbesserung der Sensitivität unterhalb 10Hz.

A 51.6 Fri 15:15 E 001

Coating thermal noise interferometer — •Tobias Westphal and the AEI 10m Prototype team — Max-Planck-Institute for Gravitational Physics (Albert-Einstein-Institut) and Leibniz University Hannover

Coating thermal noise (CTN) is getting a more and more significant noise source for high precision experiments and metrology. It arises from mechanical losses in the dielectric coatings applied to mirrors to achieve high reflectivity. Deeper understanding and verification of its theory 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. A pre-isolated platform shows three to four orders of magnitude attenuated seismic noise inside ultra-high vacuum. Up to 10 W highly stabilized (frequency as well as amplitude) laser power at 1064 nm will be available for experiments.

In this talk the CTN- interferometer being at the transition from design to construction phase will be presented. The range 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.

A 51.7 Fri 15:30 E 001

Control of optical cavities in light-shining-through-a-wall experiments — •Robin Baehre — Max-Planck-Institute for Gravitational Physics (Albert-Einstein-Institute), Callinstr. 38, 30167 Hannover, Germany

Light-shining-through-a-wall (LSW) experiments are a straightforward approach to laboratory searches for weakly interacting sub-eV particles (WISPs), which are considered as a viable candidate for cold dark matter. WISPs, which exhibit coupling to a photon field, can be produced from a laser beam, which is shone on a solid wall. Due to their weak coupling to ordinary matter, WISPs can transverse the wall, which is opaque to photons, and can reconvert into photons afterwards and consequently be detected by a photon detector. LSW experiments often suffer from the fact that WISP fluxes produced in the laboratory are much smaller than those from astronomical sources. However, LSW searches can be considerably improved by fully exploiting the benefits of using coherent laser light to the production and regeneration process. Using optical resonators on the production and regeneration side helps to probe for very small WISP-photon couplings and to explore the parameter space that can be deduced from observations of anomalous white dwarf cooling and transparency of the universe to TeV photons. I will focus my tak on the optical design of ALPS-II with the implementation of production and regeneration resonator and explain how the demanding requirements on spatial and spectral stability can be fulfilled by application of optical precision measurement and control with picometer accuracy.