Q 16: Poster: Quantum information, micromechanical oscillators, matter wave optics, precision measurements and metrology

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

Q 16.1 Mon 16:30 Spree-Palais

Quantum states with maximal memory effects — •Steffen Wissmann[1], Antti Karlsson[2], Elsi-Mari Laine[2], Jyrki Piilo[2], and Heinz-Peter Breuer[1] — [1]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [2]Turku Centre for Quantum Physics, University of Turku, Finland

Perfect isolation of any quantum system is almost impossible to realize since it is usually influenced by the coupling to an environment. The most prominent approach, which takes the interaction into account, resorts to an approximation of the open system dynamics in terms of a so-called Markovian master equation. Recently, there has been put much effort in completely classifying open system dynamics. One of the approaches to define non-Markovian evolutions is based on the exchange of information between the open system and its environment [1]. The associated measure relates the degree of memory effects to a certain pair of optimal initial state pairs featuring a maximal flow of information from the environment back to the open system. Here, we present the latest results on the non-Markovianity measure proposed in [1] regarding the mathematical and physical properties of optimal pairs maximizing this quantity [2]. In addition, we derive a new, convenient representation of the measure for finite-dimensional systems showing locality and universality of memory effects of the dynamical map.

[1] H.-P. Breuer, E.-M. Laine and J. Piilo, Phys. Rev. Lett. 103, 210401 (2009)

[2] S. Wißmann, A. Karlsson, E.-M. Laine, J. Piilo and H.-P. Breuer, Phys. Rev. A 86, 062108 (2012)

Q 16.2 Mon 16:30 Spree-Palais

Efficient Optimization of Quantum Gates for Rydberg Atoms and Transmon Qubits under Dissipative Evolution — •Michael H. Goerz, Daniel M. Reich, and Christiane P. Koch — Universität Kassel, Institut für Theoretische Physik

We consider two different physical systems to illustrate an efficient optimization of quantum gates under dissipative evolution, requiring the propagation of only three states, irrespective of the dimension of the Hilbert space. In the first example, two trapped neutral atoms are excited to a Rydberg state, via a decaying intermediary state. The interaction between both atoms in the $|rr\rangle$ state allows for the realization of a diagonal CPHASE gate. Optimal control theory finds a solution that uses a STIRAP-like mechanism to suppress population in the decaying intermediary state, while implementing the desired gate. As a second example, we consider two superconducting transmon qubits coupled via a shared transmission line resonator. The Hamiltonian in this case also allows for non-diagonal gates, and we optimize for a $\sqrt{iSWAP}$, taking into account energy relaxation and dephasing of the qubits. The system is driven at a frequency close to the center between both qubits, and the optimized gate exploits a near-resonance of the $|0\rangle \rightarrow |1\rangle$ transition on the left qubit and the $|1\rangle \rightarrow |2\rangle$ transition on the right qubit. For both examples, the gate fidelity reached by optimization is only limited by the decoherence.

Q 16.3 Mon 16:30 Spree-Palais

On the SLOCC-classification of multilevel tripartite entanglement — •Christina Ritz[1], Matthias Kleinmann[1,2], and Otfried Gühne[1] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Germany — [2]Departamento de Matematica, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

The classification of entanglement regarding their invariance under SLOCC-transformations for tripartite systems has been studied thoroughly for the case of qubits whereas when dealing with higher dimensions only the case of $2 \times 2 \times N$ has been studied in detail [1].

We present a classification for the qubit-qutrit-qutrit ($2 \times 3 \times 3$) case, based on a finite classification due to Lamata [2]. We discuss possible generalizations to the case of $2 \times N \times N$ and difficulties that occur in the case of three qutrits.

[1] A.Miyake and F.Verstraete, Phys. Rev. A 69, 012101 (2004)

[2] L.Lamata et al., Phys. Rev. A 75, 022318 (2007)

Q 16.4 Mon 16:30 Spree-Palais

Closed form solution of Lindblad master equations without gain — •Juan Mauricio Torres — Theoretische Physik, Universität des Saarlandes, D66123 Saarbrücken, Germany — Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Germany — Departamento de Investigación en Física, Universidad de Sonora, Hermosillo, México

We present a closed form solution of the eigenvalue problem of a class of master equations that describe open quantum systems with loss and dephasing but without gain. The method relies on the existence of a conserved number of excitations in the Hamiltonian part and on the fact that none of the Lindblad operators describes an excitation of the system. In the absence of dephasing Lindblad operators the eigensystem of the Liouville operators can be constructed from the eigenvalues and eigenvectors of the effective non-hermitian Hamiltonian used in the quantum jump approach. Open versions of spin chains, of the Tavis-Cummings model and of coupled harmonic oscillators without gain can be solved using this technique.

Q 16.5 Mon 16:30 Spree-Palais

Thermalization free interaction of two quantum systems governed by independent Markovian master equations — •József Zsolt Bernád[1], Juan Mauricio Torres[1,2], and Gernot Alber[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Germany — [2]Departamento de Investigación en Física, Universidad de Sonora, Hermosillo, México

The quantum Markovian master equation is the simplest but also the most used case of study for the dynamics of open quantum systems. An interesting issue arises when the system can be clearly decomposed into two interacting subparts, which are separately coupled to two independent environments. We show a class of interactions which leaves invariant one of the subsystems in a stationary state, i.e. only one of the reduced density matrices is sensitive to the interaction. We discuss a few models of which the best known is the optomechanical coupling model, an optical cavity coupled to a small mechanical resonator.

Q 16.6 Mon 16:30 Spree-Palais

Single-mode EPR-entanglement via narrowband filtering of multimode type-II parametric down-conversion — Andreas Christ[1], Cosmo Lupo[2], •Matthias Reichelt[3], Torsten Meier[3], and Christine Silberhorn[1] — [1]Applied Physics University of Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany — [2]Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge MA, USA — [3]University of Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

Entanglement is an essential key for quantum-information and communication applications. Here, we present a method to generate single-mode EPR-entanglement via narrowband spectral filtering of multimode type-II parametric down-conversion [1]. In the framework of continuous variables [2] we show that due to the filtering process all higher-order modes are effectively suppressed. Performing a subsequent mode optimization algorithm [3] reveals that the filtered output contains EPR-squeezing in a single optical mode indeed.

[1] A. Christ, B. Brecht, W. Mauerer, and C. Silberhorn, New Journal of Physics **15**, 053038 (May 2013)

[2] S.L. Braunstein and P. van Loock, Rev. Mod. Phys. **77** (2005).

[3] A. Walther, M. Reichelt, and T. Meier, Photonics and Nanostructures - Fundamentals and Applications **9**, 328 (2011).

Q 16.7 Mon 16:30 Spree-Palais

Stochastics in System-Environment Correlation Dynamics — •Franziska Peter and Walter Strunz — Institut für Theoretische Physik, Technische Universität Dresden, Germany

Considering small open quantum systems linearly coupled to a bosonic heat bath, we investigate the nature of system-environment correlations of these bipartite quantum systems at finite temperature. We thereby forge ahead into a wide area of decoherence processes, as in the limit of weak coupling the interaction with any environment can be mapped onto this model.

Taking advantage of some utile properties of the Glauber-Sudarshan Partial-P function, we were able to prove that e.g. a harmonic oscillator with zero initial correlation never entangles with its environment (which might suggest that in general there is no entanglement possible in the Lindblad regime) but in contrast, there are other systems with most interesting time and temperature dependence of separability and entanglement, which now is being further investigated using Itô-calculus.

Q 16.8 Mon 16:30 Spree-Palais

Maxwell's demon observing a scattering process: Quantum surplus of energy-transfer — •C. Aris C.-Dreismann[1], Tomasz P. Blach[2], and Alexander Dreismann[3] — [1]Institute of Chemistry, TU Berlin, Germany — [2]Queensland University of Technology, Brisbane, Australia — [3]Department of Physics, Cavendish Laboratory, University of Cambridge, UK

Quantum correlations and associated quantum information concepts (e.g. quantum discord, entanglement) provide novel insights in various quantum-information-processing tasks, quantum-thermodynamics processes, open-system dynamics, and general many-body physics [1]. We investigate a new effect of correlations accompanying collision of two quantum systems A and B, the latter being part of a larger (interacting) system B+M. In contrast to the usual case of a classical "environment" or "demon" M (which can have only classical correlations with A+B during and after the collision), the quantum case [1] may exhibit novel features. Here, in the frame of ultrafast neutron collisional processes (Compton and inelastic neutron scattering), we report experimental evidence of a new phenomenon: Quantum surplus of energy and momentum transfers. Results are reported from liquid 4-He, D2 [2], and of H2O molecules confined in sub-nanometer cavities. Theoretical analysis shows that the findings have no classical analogue.

[1] K. Modi et al., The classical-quantum boundary for correlations: Discord and related measures, Rev. Mod. Phys. 84 (2012) 1655. [2] C. A. C.-Dreismann, E. MacA. Gray, T. P. Blach, AIP Advances 1 (2011) 022118; Nucl. Instr. Meth. A 676 (2012) 120.

Q 16.9 Mon 16:30 Spree-Palais

Simulation des Trennens von Ionenkristallen und Messung von Heizraten in einer segmentierten Mikroionenfalle — •Claudia Warschburger, Henning Kaufmann, Thomas Ruster, Christian Schmiegelow, Ulrich Poschinger und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz

Um die Anforderungen eines zukünftigen Quantencomputer-Systems zu erfüllen, sind neben quantenlogischen Operationen auch der Transport von Ionen und das Trennen von Kristallen in segmentierten Mikroionenfallen essenzielle Voraussetzungen [1,2]. Das Auftrennen von Kristallen wird für unterschiedliche Fallengeometrien simuliert und optimiert. Mit diesen Berechnungen kann eine allgemein anwendbare Methode angegeben werden, um die exakten Spannungsrampen für das Trennen zu implementieren und um den Quantenzustand der Bewegung nach Transport -oder Trennoperationen zu bestimmen. Neben einer kohärenten Anregung ist bei solchen Experimenten ein limitierender Effekt die thermische Anregung der Ionen. Sogenanntes anomales Heizen tritt vor allem bei Ionenfallen mit kleinen Abmessungen auf. Wir studieren diese Heizeffekte, wobei wir die Position des Ions in der Falle variieren. Dadurch soll die Ursache von Heizeffekten verstanden und bei der zukünftigen Fallenherstellung vermieden werden.

[1] A. Walther et al., Phys. Rev. Lett. 109, 080501 (2012).
[2] R. Bowler et al., Phys. Rev. Lett. 109, 080502 (2012).

Q 16.10 Mon 16:30 Spree-Palais

Hybride Ionenfalle für Spin-Spin Wechselwirkungen — •Niels Kurz, Jens Welzel, Amado Bautista-Salvador und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz

Wir beschreiben den Aufbau einer Hybridfalle mit integrierten stromführenden Drähten (Ag/Pt) direkt unterhalb eines planaren Fallenchips. Das magnetische Quadrupolfeld am Ort des Ions wird einen Gradienten von $3\frac{\mathrm{T}}{\mathrm{m\,A}}$ erreichen um in $^{40}Ca^{+}$ Ionenkristallen eine 30kHz starke Spin-Spin-Wechselwirkung zu erzeugen [1]. Laserinduziertes Ätzen des Quarzglases (SiO_2) erlaubt Fallenstrukturen mit hohem Seitenverhältnis [2]. Die Oberfläche der Elektroden besteht aus einem Schichtsystem (Al/Cu/Al/Cu), das durch Bedampfung auf das bearbeitete SiO_2 aufgebracht wird. Dickfilm-Technologie ermöglicht das Drucken von 40μm-dicken Drähten auf ein thermisch gut leitendes Substrat (AlN), so dass hohe Stromdichten erzielt werden können. Die hohen magnetischen Gradienten verlangen einen geringen (100μm) Abstand des Ionenkristalls zur Oberfläche. Daher ist eine in-situ Reinigung durch Ar^{+} Ionen Beschuss vorgesehen [3].

[1] Welzel, J. et. al. Eur. Phys. J. D **65**, 285−297 (2011).
[2] Daniilidis, N. et. al. arXiv:1307.7194 (2013).
[3] Hite, D. et. al. Phys. Rev. Lett. **109**, 10, (2012).

Q 16.11 Mon 16:30 Spree-Palais

Thermalization, Error-Correction, and Memory Lifetime for Ising Anyon Systems — •Courtney Brell[1,2], Simon Burton[1], Guillaume Dauphinais[3], Steven Flammia[1], and David Poulin[3] — [1]Centre for Engineered Quantum Systems, School of Physics, The University of Sydney, Sydney, Australia — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [3]Département de Physique, Université de Sherbrooke, Sherbrooke, Québec, Canada

We consider two-dimensional lattice models that support Ising anyonic excitations and are coupled to a thermal bath. We propose a phenomenological model for the resulting short-time dynamics that includes pair-creation, hopping, braiding, and fusion of anyons. By explicitly constructing topological quantum error-correcting codes for this class of system, we use our thermalization model to estimate the lifetime of the quantum information stored in the encoded spaces. To decode and correct errors in these codes, we adapt several existing topological decoders to the non-Abelian setting. We perform large-scale numerical simulations of these two-dimensional Ising anyon systems and and that the thresholds of these models range between 13% to 25%. To our knowledge, these are the first numerical threshold estimates for quantum codes without explicit additive structure.

Q 16.12 Mon 16:30 Spree-Palais

Quantum Error Correction for Optical Continuous-Variable Cluster Computation — •Alexander Roth and Peter van Loock — Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Quantum computing with optical continuous variables (CV) [1] shows high potential and the creation of an ultra-large cluster state [2] has now been demonstrated. Logical Qubits encoded in physical CV states enables quantum error correction. The finite squeezing of the CV-states acts like an amplitude-damping channel during teleportation [3], and makes quantum error correction even more necessary.

This work looks at efficient quantum error correction codes to protect the logical Qubits against the amplitude-damping channel to lower the required squeezing, and to make CV cluster computing experimentally more viable.

[1] N. C. Menicucci et al., Phys.Rev.Lett. **97**, 110501 (2006)
[2] S. Yokoyama et al., arXiv 1306.3366 (2013)
[3] H. F. Hofmann et al., Phys.Rev.A **64**, 040301 (2001)

Q 16.13 Mon 16:30 Spree-Palais

A scanning probe quantum processor using NV centres — •Andreas Brunner, Rainer Stöhr, Friedemann Reinhard, and Jörg Wrachtrup — 3. Physikalisches Institut und Forschungszentrum SCoPE, Universität Stuttgart, Germany

The nitrogen-vacancy (NV) colour centre in diamond has shown to be a promising candidate for applications in quantum information [1]. This is due to its electron spin structure featuring long coherence times and allowing optical state readout.

We introduce a NV scanning-probe quantum processor architecture. It combines a scanning NV read/write head with an array of stationary solid state quits. This allows to benefit both from the straightforward NV manipulation and readout [2] and from the superb coherence properties of otherwise optically inactive qubits, e.g. fullerenes.

Our realisation of this configuration joins a commercial low temperature AFM with confocal microscope access and microwave addressing. We present this setup as well as first benchmark measurements of cryogenic NV manipulation.

[1] N. Mizuochi et al., Nature Photonics 6, 299-303 (2012)
[2] F. Jelezko et al., Phys. Rev. Lett. 93, 130501 (2004)

Q 16.14 Mon 16:30 Spree-Palais

Characterisation of ion heating in a cryogenic ion-trap system — •Michael Niedermayr[1], Kirill Lakhmanskiy[1], Muir Kumph[1], Stefan Partel[2], Johannes Edlinger[2], Michael Brownnutt[1], and Rainer Blatt[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria —

[2]Forschungszentrum Mikrotechnik, FH Vorarlberg, Hochschulstr. 1, Dornbirn, Austria

One promising approach to scalable quantum-information-processing architectures is based on miniaturised surface ion traps. At present, one significant limitation to miniaturisation is set by the rate at which ions are heated, which is predominately caused by electric-field noise at the ions' resonant frequencies and increases as the ions approach the trap surface. The mechanism of this heating is not yet fully understood, but various sources for the field noise have been identified, such as surface contamination and technical noise. We present heating-rate measurements performed on single $^{40}Ca^{+}$ ions confined in surface traps with an ion-electrode separation of 230 μm. The traps were operated at cryogenic temperatures to reduce the ion's heating rate and improve the trap's material properties. The heating was characterised for a number of configurations of the filtering electronics and for different trap fabrication methods. The results contribute to an improved understanding of electric-filed-noise sources in cryogenic ion traps.

Q 16.15 Mon 16:30 Spree-Palais

Radio-frequency spectroscopy of dark state polaritons — •Georg Enzian, Vladimir Djokic, Frank Vewinger, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, D-53115 Bonn

We study dark state polaritons using a multilevel-tripod scheme in atomic rubidium vapor. In this system, two dark states exist, and the dark polariton has an internal two-level structure, in which a photonic qubit can be encoded. We presently study the driving of transitions between the two internal states of the spinor polariton by means of radio-frequency spectroscopy. The status of the ongoing experiment will be reported.

Q 16.16 Mon 16:30 Spree-Palais

Charakterisierung eines mikrostrukturierten Paulfallen-Resonatorsystems für eine Licht-Ionen Schnittstelle — •Max Hettrich, Andreas Pfister, Marcel Salz und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz

Einzelne Photonen sind für die Übertragung von Quanteninformation über weite Strecken eine naheliegende Wahl. Um diese jedoch sinnvoll weiterverarbeiten zu können, ist es notwendig, die Photonen an ein dafür geeignetes System zu koppeln, zum Beispiel an einzelne Ionen in einer Paulfalle. Wir haben ein System in Betrieb genommen, welches nach diesen Anforderungen entworfen wurde: Eine mikrostrukturierte segmentierte Paulfalle mit einem integrierten Faserresonatormodul. Wir haben einzelne Ionen kontrolliert entlang der Fallenachse transportiert und dabei axiale Fallenfrequenzen von bis zu 1,8 MHz gemessen. Für die Herstellung der Faserresonatoren haben wir eine neuartiges Verfahren mit einem FIB untersucht und optimiert, welches unseren Anforderungen an die Abstände der Fasern von 100 μm bis 300 μm besonders entgegenkommt. Das Gesamtsystem stellt somit eine Licht-Ionen-Schmittstelle dar, wie sie beispielsweise in einem zukünftigem Quantenrepeater benötigt wird.

Q 16.17 Mon 16:30 Spree-Palais

Towards resonance fluorescence from single GaAs/AlGaAs quantum dots at 780nm — •Robert Keil, Bianca Höfer, Jiaxiang Zhang, Eugenio Zallo, Fei Ding, and Oliver G. Schmidt — Institute for Integrative Nanosciences, IFW-Dresden, Helmholtzstrasse 20, D-01069 Dresden, Germany

Resonant excitation of the semiconductor quantum dots allows to initialize, manipulate and read out their spin states with reduced dephasing and photon-time-emission jitter [Vamivakas, Nat.Phys. (2012)], offering a promising approach for quantum communication applications, e.g. quantum repeaters. However, distinguishing the scattered photons from the equichromatic laser light remains a challenge. We are working on the resonance fuorescence with GaAs/AlGaAs quantum dots emitting at around 780 nm, using a polarization based laser suppression setup [Moelbjerg, Phys.Rev.Lett. (2012)]. The quantum dots were grown by molecular beam epitaxy infilling self-assembled nanoholes fabricated in situ by droplet etching [Atkinson J.Appl.Phys. (2012)]. And the wavelength of single quantum dots can be tuned exactly to 780.2nm by electro-mechanical tuning. The aim is to realize a hybrid interface between the single photons and the rubidium D2 transition line.

Q 16.18 Mon 16:30 Spree-Palais

Temperature-dependent zero-phonon line shift and broadening in single silicon vacancy centres in diamond — •Jan Binder, Andreas Dietrich, Kay Jahnke, and Lachlan Rogers — Institute of Quantum Optics, Ulm University

The usability of single silicon vacancy centres in diamond as indistinguishable single photon emitters highly depends on the stability and width of their zero-phonon lines. At low temperatures, excellent stability and narrow linewidth of negatively charged silicon vacancies (SiV^{-}) zero phonon lines (ZPLs) in CVD diamond has been demonstrated, yet their temperature dependent behaviour has not been analyzed in depth. The measurements presented here show the spectral behaviour of the SiV^{-} from cryogenic to room temperatures. Furthermore, an attempt is made to identify the line broadening and shifting mechanisms by comparison to theoretical models of elastic spring softening of the excited state[1] and optical dephasing in defect-rich crystals[2].

[1] Hizhnyakov V, Kaasik H and Sildos I, 2002 *Phys. Status Solidi b* **234** 644
[2] Hizhnyakov V and Reineker P 1999 *J. Chem. Phys.* **111** 8131

Q 16.19 Mon 16:30 Spree-Palais

An ion-trap fiber-cavity apparatus as an efficient quantum interface — •Birgit Brandstätter[1], Klemens Schüppert[1], Bernardo Casabone[1], Konstantin Friebe[1], Jakob Reichel[2], Tracy Northup[1], and Rainer Blatt[1,3] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25/4, 6020 Innsbruck, Austria — [2]Laboratoire Kastler Brossel, ENS/UPMC-Paris 6/CNRS, 24 rue Lhomond, F-75005 Paris, France — [3]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria.

Optical cavities can be used as efficient quantum interfaces between photons and atoms to realize a quantum network. In such a network, photonic channels link quantum nodes composed of trapped atoms. However, the technical requirements for the building blocks of such a network are demanding because coherent effects should dominate the system's dynamics.

Here we present the development of an integrated ion-trap fiber-cavity setup, in which cavity parameters are designed for strong coupling to a single ion. Thus, coherent interaction provides high fidelities and efficiencies for network protocols. Simulations of protocols such as ion-photon state mapping and ion-photon entanglement demonstrate the advantage of a fiber-cavity system over existing ion-trap systems.

Q 16.20 Mon 16:30 Spree-Palais

Aufbau eines QKD-Setups mit passiver Zustandspräparation — •Stephanie Lehmann[1], Sabine Wenzel[1], Sabine Euler[1,2] und Thomas Walther[1,2] — [1]Institut für Angewandte Physik, AG Laser und Quantenoptik, TU Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt — [2]CASED, Mornewegstr. 32, 64293 Darmstadt

Über spontane parametrische Abwärtskonversion (PDC) in periodisch gepoltem Kaliumtitanylphosphat (PPKTP) mit Wellenleiterstruktur werden degenerierte Photonenpaare um 808 nm erzeugt. Als Pumplaser wird ein gitterstabilisierter Diodenlaser (404 nm) genutzt. Ein Photon des erzeugten Paares wird entsprechend dem BB84-Protokoll zum Quantenschlüsselaustausch in seiner Polarisation kodiert, das andere wird zur Ankündigung des übertragenen Photons verwendet. Die Präparation des Polarisationszustandes erfolgt ausschließlich unter Verwendung von passiven optischen Komponenten. Der aktuelle Stand des Projekts wird diskutiert.

Q 16.21 Mon 16:30 Spree-Palais

Parametric down-conversion sources for applications in quantum information — •Sabine Euler[1,2] and Thomas Walther[1,2] — [1]Institut für Angewandte Physik, AG Laser und Quantenoptik, TU Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt — [2]Cased, Mornewegstraße 32, 64293 Darmstadt

We present type-II parametric down-conversion (PDC) processes in different PPKTP waveguide-chips pumped by a cw diode laser @404nm.

By manipulating the temperature of the PPKTP chips and the coupling of the pump laser we are able to control the produced photon pairs and either prepare a separable two-photon state or an entangled one. The quantum state of the photon pairs is detected by a Hong-Ou-Mandel interference between signal and idler photon.

Two different applications are based on our single photon sources: In a first experiment the BB84 protocol for quantum key distribution is implemented only by the use of passive optical components.

The second experiment aims at implementing a source of two identical photons. One of the PDC photons is fed back into the chip where in a difference frequency generation (DFG) process between a pump photon @404nm and the single PDC photon @808nm two additional red photons are generated.

We will discuss the current state of the experiments.

Q 16.22 Mon 16:30 Spree-Palais

Towards strong coupling in an ion-trap fiber-cavity apparatus — •Klemens Schüppert[1], Birgit Brandstätter[1], Bernardo Casabone[1], Konstantin Friebe[1], Sebastien Garcia[2], Jakob Reichel[2], Tracy Northup[1], and Rainer Blatt[2,3] — [1]Institute of Experimental Physics, University Innsbruck, Austria — [2]Laboratoire Kastler Brossel ENS / UPMC-Paris 6 / CNRS, Paris, France — [3]Institute of Quantum Optics and Quantum Information, Innsbruck, Austrian Academy of Sciences

With atoms coupled to optical cavities it is possible to build up quantum interfaces between stationary and flying qubits. A quantum network based on these interfaces offers a compelling solution to the challenge of scalability in quantum computing. By using fiber-based cavities, we expect to reach the strong coupling regime of cavity quantum electrodynamics with single ions, which has not previously been accessed.

To that end, we are further developing and testing the laser ablation of fiber facets, which are then coated to produce high-finesse fiber mirrors. Specifically, we plan to produce cavities of about 8 μm mode waist and 500 μm in length for use in our integrated ion-trap cavity setup. In parallel, we are currently optimizing trapping parameters for calcium ions in our miniaturized trap.

Q 16.23 Mon 16:30 Spree-Palais

Key rates for practical quantum key distribution protocols — •Florian Köppen[1], Tobias Moroder[1], Norbert Lütkenhaus[2], and Otfried Gühne[1] — [1]Theoretische Quantenoptik, Department Physik, Universität Siegen — [2]Institute for Quantum Computing, Waterloo

Quantum key distribution, the method to provide secure communication, represents one of the cornerstone applications of quantum information and it has already evolved into its own research field. While the possible key rate of a generic quantum key distribution protocol is already fairly well known, its exact evaluation can often be quite tricky and cumbersome, in particular for practical implementations where one often needs to consider additional deviations between the ideal protocol and its realization. Moreover since these rates are often bounded analytically it is not clear whether one really evaluates the maximal possible rate or just a, possibly bad, lower bound of it.

In this work we develop a general method to overcome this drawback by using numerical techniques in the form of non-linear convex optimization. Via this powerful tool one can then start analyzing the exact predicted rates of various different protocols. As a primary application we investigate the behavior of implementations of the Bennett-Brassard protocol with asymmetric qubit error rates and the 2-state protocol.

Q 16.24 Mon 16:30 Spree-Palais

Enhanced state–mapping using ion crystals — •Konstantin Friebe[1], Bernardo Casabone[1], Birgit Brandstätter[1], Klemens Schüppert[1], Tracy Northup[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Österreich

We investigate the use of a trapped ion crystal in an optical cavity as a node for quantum networks. The electronic state of a single ion can be mapped onto the polarization state of a cavity photon [1]. To enhance the fidelity of this process, the logical qubit can be encoded across two or more ions. For an entangled two-ion crystal, an enhanced coupling of the logical qubit to the cavity mode by a factor of $\sqrt{2}$ is predicted. This protocol strongly relies on the control of the coupling of both ions to the cavity mode [2]. We describe an experimental implementation with trapped calcium ions and future plans, exploring the possibilities offered by ion crystals in cavities.

[1] Stute et al., Nat. Phot. 7, 219 (2013)
[2] Casabone et al., Phys. Rev. Lett. 111, 100505 (2013)

Q 16.25 Mon 16:30 Spree-Palais

High-fidelity quantum repeater using cavity-QED and bright coherent light — •Denis Gonta and Peter van Loock — Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz

In the framework of cavity QED, we propose a practical quantum repeater scheme that uses coherent light and chains of atoms coupled to optical cavities. In contrast to conventional schemes, we exploit solely the cavity QED evolution for the entire quantum repeater scheme and, thus, avoid the usage of two-qubit quantum logical gates. In our previous paper [1], we already proposed a dynamical quantum repeater scheme in which the entanglement between the two neighboring repeater nodes was distributed using weak pulses of coherent light, while the obtained entangled pairs were purified using ancillary entangled states. In this work, the entanglement distribution is realized with the help of bright coherent-light pulses which involve hundreds of photons, while the entanglement purification avoids the usage of ancillary entangled resources. Our repeater scheme exhibits high fidelities and reasonable probabilities of success providing an efficient and experimentally feasible platform for long-distance quantum communication.

[1] D. Gonta and P. van Loock, Phys. Rev. A 88, 052308 (2013).

Q 16.26 Mon 16:30 Spree-Palais

Practical Trojan-horse attacks on continuous-variable QKD — Imran Khan[1,2], •Nitin Jain[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University Erlangen-Nuremberg, 91058 Erlangen, Germany

The functionality of an optical component inside a quantum key distribution (QKD) system may be probed from the quantum channel by sending in bright pulses of light and analyzing suitable back-reflected pulses. This forms the basis of a Trojan-horse attack [1]. We review the feasibility of such an attack, previously demonstrated on a commercial discrete-variable QKD system from ID Quantique [2], on a home-built prepare-and-measure continuous-variable quantum communication system. The objective is to read the modulation $\phi_A = 0$ or π that is applied by the sender Alice to encode her secret bit into the quantum state $|\alpha\rangle$ or $|-\alpha\rangle$ respectively. By homodyning the back-reflected pulse, Eve can infer Alice's modulation and thus breach the security of the system. We show the first results obtained with our attack.

[1] N. Gisin et al., Phys. Rev. A 73, 022320 (2006); A. Vakhitov et al., J. Mod. Opt. 48 2023 (2001). [2] N. Jain et al., (in preparation).

Q 16.27 Mon 16:30 Spree-Palais

Realisation of a 7 qubit error correcting code with trapped ions — Daniel Nigg[1], Markus Müller[2], •Esteban Martinez[1], Philipp Schindler[1], Thomas Monz[1], Markus Hennrich[1], Miguel Angel Martin-Delgado[2], and Rainer Blatt[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Quantum Information and Computation Group, Universidad Complutense de Madrid, Spain

Every quantum processor is affected by noise from the environment and imperfections of the gate operations. The essential method to correct for these errors and therefore enabling fault tolerant quantum computation is known as quantum error correction. Here we report on the experimental realization of a quantum error correcting code, where a logical qubit is encoded within 7 ion qubits, the minimal instance of a topological stabilizer code. We demonstrate the capability of detecting arbitrary single qubit errors by measuring the full syndrome table. Additionally, we show the realization of unitary operations on the logical qubit, which is the basic requirement for fault tolerant quantum computation.

Q 16.28 Mon 16:30 Spree-Palais

Experimente mit gemischten Coulomb-Kristallen bestehend aus einfach und doppelt geladenen Kalzium Ionen — •Thomas Feldker[1], Matthias Stappel[1,2], Patrick Bachor[1,2], Lennart Pelzer[1,2], Jochen Walz[1,2] und Ferdinand Schmidt-Kaler[1] — [1]Institut für Physik, Universität Mainz, Deutschland — [2]Helmholtz-Institut Mainz, Deutschland

Lasergekühlte Ionen in Paulfallen sind vielversprechende Kandidaten für die Quanteninformationsverarbeitung, die Skalierung hin zu Experimenten mit vielen Ionen bleibt dabei jedoch eine zentrale Herausforderung. Die Anregung von Ionen in hoch angeregten Rydbergzuständen hat das Potential die Anzahl der nutzbaren qubits drastisch zu erhöhen. In einem solchen System können, durch Ausnutzung der hohen Polarisierbarkeit der Rydbergzustände, lokale Vibrationsmoden erzeugt und für Verschränkungsoperationen genutzt werden.

Wichtige Aspekte dieses Systems können bereits mit gemischten Coulomb-Kristallen untersucht werden. Dazu ionisieren wir $^{40}Ca^{+}$ Ionen mithilfe von kohärentem Licht mit 121,26nm Wellenlänge. Die $^{40}Ca^{2+}$ Ionen erfahren durch die doppelte Ladung ein stärkeres Potential, was zur Bildung modifizierter Vibrationsmoden führt. Wir präsentieren Experimente zur Konfiguration und zu lokalen Radialmoden gemischter Coulomb-Kristalle[1].

[1] T. Feldker, L. Pelzer, M. Stappel, P. Bachor, R. Steinborn, D. Kolbe, J. Walz, F. Schmidt-Kaler, Applied Physics B, DOI 10.1007/s00340-013-5673-1

Q 16.29 Mon 16:30 Spree-Palais

Laser Systems for Manipulation of $^{9}Be^{+}$ — •K. Voges[1], M. Kohnen[2,1], M. Carsjens[2,1], T. Dubielzig[1], S. Grondkowski[1], H. Hahn[1], M. Niemann[1], A.-G. Paschke[1], and C. Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST-Institute @ PTB, Braunschweig

Multi-qubit interactions for quantum information processing with trapped ions require a coupling between individual ion-qubits and a shared motional degree of freedom. Recent experiments have shown how such interactions can be realized using microwave near-fields rather than laser beams [1]. In one of the present projects in our group, we are developing advanced near-field trap designs with $^{9}Be^{+}$ hyperfine qubits. In our second project, we are developing quantum logic spectroscopy techniques for single (anti-)protons with the ultimate goal of a g-factor based test of CPT invariance [2]. For both projects, we discuss laser systems for trap loading, cooling, repumping and controlling of $^{9}Be^{+}$ qubit ions. For efficient trap loading through ablation, we are testing a pulsed laser system. Moreover, we are setting up a frequency quadrupled infrared laser to implement a multi-photon process for ionization of Beryllium atoms. The light for Doppler cooling, repumping and Raman transitions will be provided by three tunable infrared fiber lasers generating two beams via sum-frequency generation and second harmonic generation (similar to [3]).

[1] C. Ospelkaus et al., Nature 476, 181 (2011).
[2] D. J. Heinzen and D. J. Wineland, Phys. Rev. A 42, 2977 (1990).
[3] A.C. Wilson et al., Appl. Phys. B, 105: 741-748 (2011).

Q 16.30 Mon 16:30 Spree-Palais

Single-ion Faraday rotation and ion-ion entanglement by single-photon detection — •Gabriel Araneda Machuca[1], Lukas Slodicka[2], Nadia Röck[1], Gabriel Hétet[1], Markus Hennrich[1], Yves Colombe[1], and Rainer Blatt[1] — [1]Universität Innsbruck — [2]Palacky University, Olomuc

We present two recent experiments with one and two trapped Barium ions. In the first [1] we could observe Faraday rotation of a probed beam by a single trapped ion. In the second one [2] we were able to entangle two effectively distant ions by a single photon detection triggered process.

Furthermore, we present the development of our new ion trap, which is composed by four main tips and integrated with a hemispherical mirror and a high numerical aperture (0.7) aspheric lens. This new trap will allow us to more than triple our collection of fluorescence light, and to explore a regime where the spontaneous emission of the ion can be reduced drastically.

[1] Free-space read-out and control of single-ion dispersion using quantum interference, PRA 88, 041804(R) (2013)
[2] Atom-Atom Entanglement by Single-Photon Detection, PRL 110, 083603 (2013)

Q 16.31 Mon 16:30 Spree-Palais

Quantum control of $^{9}Be^{+}$ hyperfine qubits — •Sebastian Grondkowski[1], Martina Carsjens[1,2], Matthias Kohnen[1,2], Timko Dubielzig[1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We describe the necessary control infrastructure for experiments with integrated microwave near-field surface-electrode ion traps with applications in quantum simulation and quantum logic. A trap geometry recently developed in our group [1] requires a static bias magnetic field, microwave control fields for single-qubit rotations and sideband transitions, dc voltages for trapping fields and reconfigurable rf trapping potentials.

Transistor amplifiers with preceding control stages on three rf trap electrodes are used to generate a reconfigurable rf trapping potential. In order to realize a field-independent $^{9}Be^{+}$ qubit at 22.3 mT, we have designed a set of water-cooled magnetic field coils. The microwave currents are generated in FPGA controlled DDS-modules and pass a frequency multiplier and pulse shaping stage. We use fast DAC-modules [2] from NIST to generate arbitrary waveforms for the pulse shaper and also for the dc voltages in the trap.

[1] Applied Physics B - 10.1007/s00340-013-5689-6 (2013)
[2] Rev. Sci. Instrum. 84, 033108 (2013)

Q 16.32 Mon 16:30 Spree-Palais

Laser-machined optical cavities of high finesse — •Manuel Uphoff, Manuel Brekenfeld, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Single atoms strongly coupled to optical cavities have shown great potential for light-matter interfaces at the single excitation level. The strength of the coupling is inversely proportional to the square root of the mode volume of the cavity, which depends on the radius of curvature of the mirrors. For superpolished substrates the radius of curvature is limited by the polishing process. Laser ablation with a CO_2-laser offers a reduction of the radius of curvature by two orders of magnitude.

We report on the fabrication of near-spherical surfaces on the end facets of optical fibers with a CO_2-laser at 9.3 μm wavelength. This method enables concave structures with a diameter approaching the size of the fiber, which show a residual roughness below 0.3 nm rms. Cavities using two of these fibers with a highly reflective, dielectric coating show a finesse of up to 190000. We will discuss the effects of mirror ellipticity on cavity birefringence and the progress towards the fabrication of fiber-based cavities optimized for applications in quantum information processing.

Q 16.33 Mon 16:30 Spree-Palais

Single-atom electromagnetically induced transparency in a strongly coupled atom-cavity system — •Haytham Chibani, Christoph Hamsen, Ingmari Tietje, Paul A. Altin, Tatjana Wilk, and Gerhard Rempe — Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

The realization of controllable nonlinearities at the level of single quanta of matter and light is one of the main goals of quantum optics. A recent theoretical study [1] predicted that photon statistics of an incoming laser beam could be coherently controlled by means of a system which merges single-atom cavity quantum electrodynamics (QED) with electromagnetically induced transparency (EIT). Towards achieving this goal, we report on the latest experimental results obtained with our atom-cavity apparatus which has at its heart a single ^{87}Rb atom strongly coupled to a cavity mode. We present transmission measurements for a single atom showing for the first time both the EIT window and the normal mode structure which is the signature of a strongly coupled cavity QED system.

[1] Souza et al. Phys. Rev. Lett. 111, 113602 (2013)

Q 16.34 Mon 16:30 Spree-Palais

Generation of entangled atom-photon states via reflection off an optical cavity — •Bastian Hacker, Andreas Reiserer, Norbert Kalb, Mahmood Sabooni, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Entanglement is a key resource for quantum communication and quantum computing. We demonstrate a novel approach to generate entangled states between a single trapped atom and an impinging optical photon via an atom-photon quantum gate, which is based on reflection of a photon from a high-finesse optical cavity containing the single atom. In the strong coupling regime, entanglement between the spin of the atom and the polarization of the photon can be generated. The potential for the generation of entangled states between the atom and more than one photon and prospects to even mediate photon-photon interactions will be discussed.

Q 16.35 Mon 16:30 Spree-Palais

Auf dem Weg zu einer Einzel-Ionen-Wärmekraftmaschine — •Karl Nicolas Tolazzi[1], Johannes Rossnagel[1], Obinna Abah[2], Ferdinand Schmidt-Kaler[1], Eric Lutz[2] und Kilian Singer[1] — [1]QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz — [2]Department für Physik, Universität Erlangen-Nürnberg, 91058 Erlangen

Während thermodynamische Gesetze auf den kollektiven Eigenschaften von Systemen mit großen Teilchenzahlen beruhen, untersuchen wir das thermodynamische Verhalten einzelner Teilchen und deren Wechselwirkungen. Wir präsentieren die ersten Schritte zur experimentellen Realisierung einer Nano-Wärmekraftmaschine mit einem einzelnen Ion als Arbeitsmedium. Ein neuartiges Ionenfallen-Design ermöglicht die direkte Umsetzung von ungerichteter, thermischer Bewegung in eine gerichtete kohärente Bewegung, deren Energie mechanisch nutzbar gemacht werden kann. Wir zeigen verschiedene Möglichkeiten zur experimentellen Realisierung thermischer, sowie nicht-thermischer Bäder, mit denen eine solche Maschine angetrieben werden kann. Durch gezielte Modellierung nicht-klassischer Wärmebäder wird es möglich die Effizienz dieser Einzelionen-Wärmekraftmaschine zu steigern und bei maximaler Leistung operierend das klassische Carnot-Limit zu überschreiten[1]. Weiterhin ist geplant das einzelne Ion durch eine lineare Kette zu ersetzen, die es ermöglicht eine detaillierte Untersuchung des Wärmetransportes entlang dieser Kette unter verschiedenen experimentell kontrollierbaren Rahmenbedingungen vorzunehmen. [1] J.Rossnagel, O.Abah, F.Schmidt-Kaler et al., *arXiv:1308.5935 (2013).

Q 16.36 Mon 16:30 Spree-Palais

Dissipative Quantum State Engineering with Atoms and Molecules — •Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

While dissipation is generally thought to be an undesirable process for the observation of coherent dynamics, it is actually possible to turn controlled dissipation into a useful resource for the realization of strongly correlated quantum states. In this context, I will discuss the possibility for a novel dissipatively bound state between ultracold atoms or molecules [1], as well as recent results on the dissipative preparation of topologically ordered many-body states using polar molecules [2]. Finally, I will present a new mechanism for the quantum simulation of extended Hubbard models using Rydberg atoms [3].

[1] M. Lemeshko, H. Weimer, *Nature Communications* **4**, 2230 (2013).
[2] H. Weimer, *Molecular Physics* **111**, 1753 (2013).
[3] H. Weimer, *arXiv:1309.0514* (2013).

Q 16.37 Mon 16:30 Spree-Palais

Solid state laser system to studying topological defects in Coulomb crystals — •Philip Kiefer[1], Jonathan Brox[1], Haggai Landa[2], Manuel Mielenz[1], Benni Reznik[2], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel-Aviv University, Tel-Aviv 69978, Israel

We study structural defects (kinks) which are formed during the transition from a laser cooled cloud of Mg-Ions to a Coulomb crystal [1]. The formation of kink configurations and the transformations of kinks between different structures in dependence on the trapping parameters are investigated. We present configurations of pairs of interacting kinks stable for long times, offering the perspective for exploring and exploiting complex collective nonlinear excitations, controllable on the quantum level [2]. For further investigations we built-up an all solid state laser system to achieve several mW at 280 nm. The system is based on frequency quadrupoling a fibre laser operating at 1118 nm. The first second harmonic generation (SHG) has been realized by a single-pass periodically poled lithium niobate waveguide, which shows at some relevant wavelength an even higher conversion efficiency than LBO ring cavities, whereas the second SHG is based on resonant enhancement in a BBO ring cavity.

[1] M. Mielenz et al., Phys. Rev. Lett. **110**, 133004 (2013)
[2] H. Landa et al., New J. Phys. **15**, 093003 (2013)

Q 16.38 Mon 16:30 Spree-Palais

Quantum dynamics of an ion controlled bosonic Josephson junction — •Jannis Joger[1], Antonio Negretti[2], Ferdinand Schmidt-Kaler[1], and Rene Gerritsma[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, D-22761 Hamburg

We theoretically investigate the dynamics of an atomic Josephson junction formed by a double-well potential with a single trapped ion in the center. We found before that the ion can coherently control the atomic tunneling rate in the junction by its spin [1]. On this poster, we show that it should also be possible to control the tunneling using the motion of the ion. This can lead to large matterwave-ion entangled states in which the position of the matterwave is entangled with the ion. We analyze the effect of imperfections such as in residual thermal ion motion and Paul-trap induced micromotion. We aim to implement this scheme in a combined atom-ion microtrap that is currently being built. This setup will also allow studying atom-ion interactions in the 1-dimensional regime.

[1] R. Gerritsma et al. Phys. Rev. Letters 109, 080402 (2012).

Q 16.39 Mon 16:30 Spree-Palais

Controlled preparation of multiple atoms in an optical cavity — •Matthias Körber, Andreas Neuzner, Carolin Hahn, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Single neutral atoms trapped in an optical cavity are a powerful experimental system that allows for a high degree of control over light-matter interaction. Starting from a magneto-optical trap we transfer neutral ^{87}Rb atoms into a two-dimensional optical lattice at the center of a Fabry-Perot cavity. A high-numerical-aperture objective mounted transversally to the cavity axis allows us to observe and simultaneously address individual atoms. By impinging a resonant laser beam through the addressing system, unwanted atoms can be pushed out from the optical lattice. Subsequently, the atom pattern can be shifted along one axis by rotating a glass plate located in one of the lattice beams. This quasi-deterministic method allows us to prepare a predetermined pattern of atoms in the cavity. After this preparation, a series of operations with thousands of experimental iterations can be performed on one and the same array of atoms. Experimental progress towards the implementation of scalable protocols for quantum information processing will be discussed.

Q 16.40 Mon 16:30 Spree-Palais

Towards the simulation of the spin-boson model — •Jakob Pacer, Govinda Clos, Ulrich Warring und Tobias Schaetz — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

In our trapped-ion experiment, we aim to study the onset of the dynamics of the spin-boson model [1], a paradigmatic open-quantum system. We consider a linear chain of Mg^+ ions, their internal structure (two hyperfine ground states) representing a spin system while the motional modes stand for the bosons.

Different lasers and control protocols [2] can be used to explore the rich physics of the spin-boson model. In particular, two-photon stimulated Raman transitions enable coherent couplings between the hyperfine states as well as common motional modes of the ions. In our presentation, we will report about crucial techniques for our studies, including: isotope-selective loading, ion-chain reordering, and sympathetic cooling towards the ground state of motion.

[1] Porras, D., Marquardt, F., von Delft, J. and Cirac, J. I., Phys. Rev. A 78, 010101 (2008). [2] A. Friedenauer, H. Schmitz, J. Glueckert, D. Porras and T. Schaetz, Nat. Phys. 4, 757-761 (2008).

Q 16.41 Mon 16:30 Spree-Palais

An ion as a probe for focus characterization — •Marianne Bader[1,2], Martin Fischer[1,2], Paul Roth[1,2], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institute for the Science of Light, Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Erlangen, Germany

The strength of coupling between light and a single quantum system can be optimized by matching the incident light mode to the emission pattern of the quantum system. For atoms in free space, the emission is usually a dipole wave. We aim for mode-matching to this radiation pattern by placing a single ion in the focus of a parabolic mirror [1]. The mirror allows for illumination from 94% of the solid angle when weighted with the dipole pattern. In first experiments, the focusing geometry was restricted to half solid-angle. We have reached 7.2% coupling efficiency instead of the 50% maximum possible in this scenario. The missing factor is only 7.

In this contribution, we present attempts to investigate this discrepancy. Among them are first experiments with full solid-angle illumination. In other experiments we adress a different atomic transition than in the above mentioned experiments. This transition has a longer wavelength and is thus less sensitive to aberrations of the parabolic mirror.

[1] R. Maiwald et al., Phys. Rev. A **86**, 043431 (2012)
[2] M. Fischer et al., arXiv:1311.1982 (2013)

Q 16.42 Mon 16:30 Spree-Palais

Addressing of individual ions with RF radiation in a planar electrode ion trap with integrated current carrying electrodes — Peter Kunert, •Ivan Boldin, Daniel Georgen, Michael Johanning, and Christof Wunderlich — University of Siegen, Siegen, Germany

We present a planar electrode ion trap that is designed as a prototype of a future quantum processor with microwave control over the qubits using the magnetic gradient induced coupling (MAGIC) scheme. The electrodes of the trap can carry DC currents that create a spatially varying magnetic field in the region of ion trapping: This is used for addressing trapped ions in frequency space and to couple internal and motional degrees of freedom via MAGIC.

The planar trap is shown to be functional and trapping times of several hours are achieved for individual Yb+ ions. Up to 12 ions have been be trapped with storage times on the order of minutes. The magnetic field in the trapping region is mapped using radio frequency-optical double resonance spectroscopy. In addition, we apply and characterize a magnetic gradient and demonstrate individual addressing, that is, selective excitation on a Zeeman transition of the D3/2 state, in a string of three ions using RF radiation.

Q 16.43 Mon 16:30 Spree-Palais

Towards a loophole free test of Bell's inequality with atoms entangled over a large distance — •Daniel Burchardt[1], Norbert Ortegel[1], Kai Redeker[1], Julian Hofmann[1], Michael Krug[1], Markus Rau[1], Wenjamin Rosenfeld[1,2], and Harald Weinfurter[1,2] — [1]Ludwig-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching

Bell's inequality allows to exclude local hidden variable theories for physical description. Up to now all experiments suffered from at least one of the two loopholes resulting either from low detection efficiency or from lack of space-like separation of the measurements.

We present our progress towards a Bell experiment where the two sites are separated by 400 m. This long distance entanglement is obtained in two steps. First, ^{87}Rb atoms are entangled with spontaneously emitted photons and second, a Bell-measurement on the photons transfers the entanglement to the atoms. This scheme provides a heralding signal every time the atoms are entangled. To achieve space-like separation, the atomic states are read out within one microsecond using state selective ionization and a fast detection of the ionization fragments. This time already includes the random choice of the measurement basis which is obtained by a quantum random number generator. The short measurement time together with the large distance and the efficient state read-out of the atoms fulfills the requirements to close both the detection and the locality loophole in a single experiment.

Q 16.44 Mon 16:30 Spree-Palais

Quantum nonlinear optics with an ion crystal in a cavity — •Robert Johne and Thomas Pohl — Max-Planck-Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

Ion crystals represent a versatile platform to engineer spin-spin interactions, which can be induced by an optical force and by coupling of the ions to common vibrational modes in the crystal [1]. This spin-spin interaction has been demonstrated and gives rise to study quantum phase transitions in the framework of quantum simulations [2]. Furthermore, coupling of an ion crystal to a cavity mode has been realized [3]. Here, we theoretically investigate an ion crystal embedded in a cavity, driven by coherent laser pulses. The interplay of cavity-ion coupling and the spin-spin interaction can be used to generate nonclassical spin as well as nonclassical light states with high fidelity. Moreover, this system holds the potential for engineering photon-photon interactions and as a quantum light-matter interface.

[1] D. Porras and J. I. Cirac, Phys. Rev. Lett. 92, 207901 (2004) [2] R. Blatt and C. F. Roos, Nature Physics 8, 277 (2012) [3] P. F. Herskind et al. Nature Physics 5, 494 (2009)

Q 16.45 Mon 16:30 Spree-Palais

Towards an on-demand single photon source based on room temperature vapor cells — •Michael Zugenmaier, Jürgen Appel, Jörg Müller, and Eugene Polzik — Niels Bohr Institute, Copenhagen, Denmark

The DLCZ protocol for long distance quantum communication is based on the storage of single collective excitations, superposition quantum states where one of many indistinguishable atoms is excited.

We report on the progress of our experiment applying room temperature vapor cells to create and store a single collective excitation. A weak laser pulse excites one of the Cesium atoms inside the vapor, The single excitation will be heralded by the detection of a single forward-scattered photon. The paraffin-coated cell walls preserve coherence times over milliseconds. The readout of the single excitation deterministically creates a single photon with high efficiency.

Scaleability and fast reinitialization allow to combine such cells to create a quantum information network, opening the door for DLCZ-based entanglement and other interesting experiments.

Q 16.46 Mon 16:30 Spree-Palais

Cryogenic ion-trap system for quantum computing applications. — •Kirill Lakhmanskiy[1], Michael Niedermayr[1], Stefan Partel[3], Alexander Erhard[1], Johannes Edlinger[3], Michael Brownnutt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria — [3]FH Vorarlberg, Forschungszentrum Mikrotechnik, Hochschulstraße 1, 6850 Dornbirn, Austria

Trapped ions have demonstrated great promise for investigating and controlling quantum systems. Operating traps under cryogenic conditions provides a number of distinct benefits. These include reducing the rate at which the ion is heated (thereby increasing the coherence time of the motional state); allowing the use of new materials and components which would otherwise be unsuitable for use in vacuum; and facilitating a faster development cycle for testing different experimental configurations.

We report on the fabrication and operation of a cryogenic trapped-ion system which leverages each of these benefits. Surface ion traps which exhibit low and highly reproducible heating rates have been fabricated. Driving and filtering electronics are mounted on the 4 K stage of the cryostat, in close proximity to the trap and in ultra-high vacuum. This system has been used in conjunction with stabilised diode-laser systems to trap, cool and manipulate single $^{40}Ca^+$ ions.

Q 16.47 Mon 16:30 Spree-Palais

Light switching mediated by a single atom — •Michael Scheucher, Christian Junge, Jürgen Volz, and Arno Rauschenbeutel — Vienna Center for Quantum Science and Technology, TU Wien - Atominstitut, Stadionallee 2, 1020 Wien, Austria

We experimentally investigate the interaction between single rubidium atoms and whispering-gallery-mode (WGM) bottle microresonators. These resonators confine light by continuous total internal reflection and offer the advantage of very long photon lifetimes in conjunction with near lossless in- and out-coupling of light via tapered fiber couplers. Recently, we discovered that the occurrence of non-transversal polarization of the light guided in WGM fundamentally alters the physics of light-matter interaction [1]. In particular, this effect enables us to perform single-atom-controlled light switching between two distinct optical fibers. We experimentally characterize the light routing performance of two different implementations: The direct switching of light between two tapered fibers coupled to the resonator [2] and the single-atom-controlled polarization rotation of the fiber guided light. Owing to the excellent optical properties of our bottle microresonator and the non-transversal polarization of its modes, both schemes yield high switching fidelities and low losses.

[1] C. Junge et al., Phys. Rev. Lett. **110**, 213604 (2013)
[2] D. O'Shea et al., Phys. Rev. Lett. **111**, 193601 (2013)

Q 16.48 Mon 16:30 Spree-Palais

Entanglement of two trapped ions via an optical resonator — •Bernardo Casabone[1], Konstantin Friebe[1], Andreas Stute[1], Birgit Brandstätter[1], Klemens Schüppert[1], Tracy Northup[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria

We demonstrate precise control of the coupling of each of two trapped ions to the mode of an optical resonator. When both ions are coupled with near-maximum strength, we generate ion-ion entanglement heralded by the detection of two orthogonally polarized cavity photons. The entanglement fidelity with respect to the Bell state $|\Psi^+\rangle$ reaches $F \leq (91.9 \pm 2.5)\%$. We present numerical simulations of fidelity as a function of the interval between photon detection times, based on the quantum Monte Carlo method. The simulations agree with the measured data and provide insight into the coherent and incoherent effects that contribute to the reduction of the fidelity. This result represent an important step toward distributed quantum computing with cavities linking remote atom-based registers.

Q 16.49 Mon 16:30 Spree-Palais

Set-up of a hybrid quantum optomechanical system at 30 mK — •Hai Zhong, Gotthold Fläschner, Michael Nitschke, Alexander Schwarz, and Roland Wiesendanger — Institut für Angewandte Physik, Universität Hamburg, Hamburg, Deutschland

We are currently setting up a hybrid quantum optomechanical system in an ultrahigh vacuum (UHV) environment at 30 mK using a $^3He/^4He$ dilution refrigerator. The newly installed cryostat will be used to precool our mechanical oscillators. It has shown a base temperature of 30.6±2 mK and a cooling power of 560 μW at 100 mK with holding time of more than 12 hours without any device attached. A fiber cavity with a high-Q SiN membrane in the middle ('MIM') aligned by two sets of home-built five-axis piezo-motors has been constructed and tested at room temperature. The 'MIM' set-up will be used to indirectly (ex situ) couple to ^{87}Rb cold atoms or even to a BEC located in a separate vacuum chamber via optical fibers. The combined system is aiming to cool an ultralow mass membrane down to the quantum mechanical ground state using optomechanical as well as sympathetical cooling schemes. This work is supported by the ERC Advanced Grant 'FURORE'.

Q 16.50 Mon 16:30 Spree-Palais

Stabilization of an optomechanical system via Pyragas control — •Nicolas L. Naumann, Julia Kabuss, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Berlin, Germany

With a variety of possible applications (sensing devices, quantum information processing) and potentially revealing insights into the nature of quantum mechanics, optomechanical systems are currently subject to intense research. Our studies focus on the control of an optically pumped system, consisting of a cavity with one movable mirror. The moving mirror constitutes a source to nonlinearities, induced by radiation pressure [1]. To control the dynamics of this nonlinear system, we apply the widely used Pyragas control scheme [2] in oder to stabilize formerly unstable solutions.

[1] C.K. Law, Phys. Rev. A 51, 2537 (1995)
[2] K. Pyragas, Phys. Lett. A 170 421 (1992)

Q 16.51 Mon 16:30 Spree-Palais

Towards x-ray optomechanics — •Luling Jin[1], Yong Li[2], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Beijing Computational Science Research Centre, Beijing 100084, China, China

We propose a hybrid optomechanical system connecting light in the visible frequency range with hard x-rays. Our setup combines a standard cavity optomechanical setup [1] operating in the visible frequency range with an additional driving of the vibrating cavity mirror by x-ray light [2]. We find that the visible light can be used to detect properties of the x-ray light and its influence on the cavity mirror motion, and discuss the potential of hard x-rays provided by modern light sources for optomechanics.

[1] M. Aspelmeyer, T. J. Kippenberg, F. Marquardt, arXiv:1303.0733v1 [cond-mat.mes-hall]
[2] K. P. Heeg et al, Phys. Rev. Lett. 111, 073601 (2013)

Q 16.52 Mon 16:30 Spree-Palais

A Hybrid System in the Quantum Regime — •Christina Staarmann[1], Andreas Bick[1], Philipp Christoph[1], Ortwin Hellmig[1], Christoph Becker[1], Klaus Sengstock[1], Hai Zhong[2], Gotthold Fläschner[2], Alexander Schwarz[2], and Roland Wiesendanger[2] — [1]1Center for Optical Quantum Technologies, Hamburg, Germany — [2]Insitute for Applied Physics, Hamburg, Germany

In this poster we present work towards a new hybrid quantum system consisting of a Bose-Einstein condensate coupled to a mechanical oscillator. Our combined system offers the possibility to use the large toolbox available to control and manipulate ultracold atoms for the benefit of the hybrid device and will thus open completely new avenues for the manipulation, preparation and detection of the mechanical oscillator e.g. the development of new cooling schemes. By laser cooling the atoms it is possible via a suitable coupling mechanism to damp the motion of the mechanical oscillator. Vice versa the mechanical element can be utilized as a non-destructive sensor for the atomic system, giving rise to new prospects for the field of ultracold quantum gases.

We will employ an optical lattice to couple a Rubidium-BEC to a high-Q micromechanical membrane, which is situated inside a fiber Fabry-Perot cavity. As a convenient starting point to reach the ground state of the oscillator the membrane setup will be pre-cooled inside a dilution cryostat.

This work is supported by the Landesexzellenzinitiative Hamburg, the Joachim Herz Stiftung and the ERC Advanced Grant "FURORE".

Q 16.53 Mon 16:30 Spree-Palais

Sympathetic cooling of a micromechanical membrane via ultracold atoms — •Aline Faber, Andreas Jöckel, Maria Korppi, Thomas Lauber, Tobias Kampschulte, and Philipp Treutlein — Universität Basel, Departement Physik, CH-4056 Basel

In the last years hybrid quantum systems started to attract interest as potential interfaces in new quantum technologies. A mechanical element in such a system could act as a transducer between different quantum systems or might be used for metrology applications.

In our experiment we couple the motion of ultracold atoms to the vibrations of a Si_3N_4 membrane inside an optical cavity. The coupling is mediated by a laser beam that couples to the cavity and, at the same time, creates an optical lattice for the atoms. The motion of the membrane shifts the phase of the reflected light and thereby displaces the lattice potential for the atoms. Inversely, when the atoms oscillate in the lattice they modulate the radiation pressure and thereby act on the membrane. With this coupling we can sympathetically cool the fundamental mode of the membrane down to two Kelvin by laser cooling the atoms.

Here we present our experimental setup and recent results. Further we discuss limitations in the current system due to laser noise and present a new cavity design, which is more stable and compact. With cryogenic pre-cooling of this new, compact cavity and suppression of laser noise, cooling of the membrane to the quantum ground state should be feasible [1].

[1] B. Vogell et al., Phys. Rev. A **87**, 023816 (2013)

Q 16.54 Mon 16:30 Spree-Palais

Dynamics of hybrid optomechanical systems — •Timo Holz, Marc Bienert, and Ralf Betzholz — Universität des Saarlandes, Saarbrücken, Germany

We explore the quantum dynamics of a hybrid optomechanical system composed of a two-level atom and an optical cavity with a moveable end-mirror. The interaction between the atom and the cavity mode is described by the Jaynes-Cummings interaction. The standard Hamiltonian of optomechanics specifies the phonon-photon interaction. We investigate the coherent time evolution of quantum states of the composite system in different parameter regimes both numerically and analytically. We analyse how non-classical states can be prepared and seek for a description of effective interactions between the different components of the hybrid system. Moreover, we discuss the influence of decoherence on the time evolution.

Q 16.55 Mon 16:30 Spree-Palais

High-Q membrane mechanical oscillators made from $In_xGa_{1-x}P$ for cavity optomechanics experiments — Garrett D. Cole[1], •Witlef Wieczorek[1], Claus Gärtner[1], Ramon M. Nia[1,2], Karoline Siquans[1], Jason Hoelscher-Obermaier[1,2], and Markus Aspelmeyer[1] — [1]Vienna Center for Quantum Science and Technology, Faculty of Physics, University of Vienna, 1090 Vienna, Austria — [2]Max Planck Institute for Gravitational Physics, Callinstraße 38, 30167 Hannover, Germany

Quantum experiments performed with cavity optomechanical systems hinge on the availability of mechanical oscillators with both a low decoherence rate and large optomechanical coupling. Here we present membrane mechanical oscillators constructed from a novel material system that promises a route towards these goals. Our high-Q membranes are fabricated from a 30 nm thick, tensile strained $In_xGa_{1-x}P$ film and can be regarded as a convergence of two successful technologies: (i) high-Q membranes made from SiN and (ii) single-crystaline semiconductor GaAs membranes. In first measurements, we determine Q factors up to 10^6 at room temperature and a $Q \cdot f$ product of 10^{11}. At low temperatures we measure improvements by a factor of 10. In the future, we will impart larger tensile strain in the $In_xGa_{1-x}P$ layer to further increase the mechanical frequency. The $In_xGa_{1-x}P$ material system is promising for a wide range of experiments, such as fully monolithic cavity-optomechanical systems, stacked membranes and optoelectronically-active mechanical resonators.

Q 16.56 Mon 16:30 Spree-Palais

Cavity optomechanics with an optically levitated submicron particle — •Uroš Delić, Nikolai Kiesel, Florian Blaser, David Grass, Rainer Kaltenbaek, and Markus Aspelmeyer — Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, A-1090 Vienna, Austria

The center-of-mass motion of an optically levitated sub-micron dielectric particle, once decoupled from thermal environment, promises unprecedented high mechanical quality factors and a large force sensitivity [1]. Combined with an optical cavity this approach has been anticipated to allow room temperature quantum optomechanics [2]. We demonstrate experimentally the cavity-optomechanical control of a sub-wavelength sized particle and compare our results with a detailed theoretical description of the system. Current challenges and future extensions of the system towards high-Q operation are discussed.

[1] Li, T. et al. Nat Phys 7, 527 (2011), Gieseler, J. et al., PRL 109, 103603 (2012)

[2] Romero-Isart, O. et al. NJP 12, 33015 (2010), Chang D. et al. PNAS 107, 0912969107, (2009)

Q 16.57 Mon 16:30 Spree-Palais

Density profiles and contrast in open atom interferometers — •Wolfgang Zeller[1], Albert Roura[1], Wolfgang P. Schleich[1], and the QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenphysik, Universität Ulm — [2]Institut für Quantenoptik, LU Hannover — [3]ZARM, Universität Bremen — [4]Institut für Physik, HU Berlin — [5]Institut für Laser-Physik, Universität Hamburg — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham, UK — [8]FBH, Berlin — [9]MPQ, Garching

Light-pulse atom interferometers have become a valuable tool for precision measurements of inertial and gravitational forces as well as fundamental constants. Effects like gravity gradients can lead to open atom interferometers (OAI), where the interfering paths do not close in phase space. In this contribution, we present an elementary description of all the features of OAI. In particular, we analyze the loss of contrast of the integrated particle number and present a strategy how to recover the contrast necessary for interferometry. Moreover, our approach allows an intuitive understanding of the fringe patterns appearing in OAI, which were the basis of recent experiments [1,2]. The picture is completed with a phase-space representation of the state in the exit of the 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 50WM1136.

[1] H. Müntinga et al., Phys. Rev. Lett. 110, 093602 (2013)

[2] S. M. Dickerson et al., Phys. Rev. Lett. 111, 083001 (2013)

Q 16.58 Mon 16:30 Spree-Palais

Interferometry Experiments with Charged Matter Waves — •Georg Schütz, Alexander Rembold, Andreas Pooch, Andreas Günther, and Alexander Stibor — Physikalisches Institut, Universität Tübingen, 72076 Tübingen, Deutschland

Experiments with electron or ion matter waves require a coherent, monochromatic and long-term stable source with high brightness. These requirements are best fulfilled by single atom tip (SAT) field emitters. The performance of an iridium covered W(111) SAT is demonstrated and analyzed for electrons in a biprism interferometer [1]. Furthermore, we characterize the emission of the SAT in a separate field electron and field ion microscope and compare it with other emitter types. In contrast to other biprism interferometers the source and the biprism size are well defined within a few nanometers.

We also present a scheme to suppress the influence of dephasing mechanisms. By analyzing temporal and spatial particle correlations available in modern detectors, interference properties can be revealed that would otherwise be washed out due to perturbing external signals. In the case that the dephasing disturbance is a single frequency, the original spatial fringe pattern without the perturbation can be restored. The setup has direct applications in ion interferometry and Aharonov-Bohm physics. [1] F. Hasselbach and U. Maier, 1999 Quantum Coherence and Decoherence, Proc. ISQM, Tokyo 98, ed. by Y.A. Ono and K. Fujikawa (Amsterdam: Elsevier), 299 (1999)

Q 16.59 Mon 16:30 Spree-Palais

Simulating matter-wave interferometers with classical rays — •Mathias Schneider and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt

The development of quantum limited acceleration and rotation devices is a key research direction. In the context of ultra-cold matter-waves, whether thermal clouds or Bose-Einstein condensates, this is usually realized with interferometers [1]. The design of high precision optical devices, in particular optical interferometers, does not rely on Maxwell's equations but only on efficient semi-classical ray tracing methods. In the same spirit, we approximate the dynamics of thermal clouds or Bose-Einstein condensates with a ray tracing formalism. We employ the effective single-particle Wigner function as a phase space representation of the atom cloud [2], which is well suited for describing partially coherent matter-waves used for interferometry. When classical transport theory is valid, the Wigner function flows along the classical phase space trajectories. However, when the ensemble interacts with a coherence creating device, like a beam splitter or double slit, one has to use an appropriate map. We discuss advantages and shortcomings of the approach above and show some results of calculations simulating an realistic experimental setup.

References:

1. Conin, Schmiedmayer, and Pritchard, Rev. Mod. Phys. 81, 1051 (2009)

2. Schleich: "Quantum Optics in Phase Space", Wiley-VHC (2001)

Q 16.60 Mon 16:30 Spree-Palais

MAIUS - a rocket-based atom interferometer in space — •Maike Diana Lachmann[1], Dennis Becker[1], Stephan Tobias Seidel[1], Ernst Maria Rasel[1], and The QUANTUS Team[1,2,3,4,5,6,7] — [1]Institut für Quantenoptik, LU Hannover — [2]Zarm, Universität Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]FBH, Berlin

The development of space-qualified technologies for rocket-based missions would mark a major advancement towards a precise measurement of the equivalence principle with a space-born atom interferometer. With the launch of the rocket-based atom interferometer MAIUS in November 2014 we plan to create a Bose-Einstein condensate and to demonstrate atom interferometry in space for the first time. The poster shows the setup, the up to date progress and future prospects of this ambitious and technically challenging project.

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 50 WM 1131.

Q 16.61 Mon 16:30 Spree-Palais

Compact electronics for laser system in microgravity — •Manuel Popp, Thijs Wendrich, Wolfgang Ertmer, and Ernst Maria Rasel — Leibniz Universität Hannover, Institut für Quantenoptik

Applications of modern cold-atom physics in metrology and spaceborne research demand for both robust and compact scientific apparatus. The project LASUS focuses on the development of the needed technology, namely miniaturized and robust diode lasers, optical modules and electronics, sophisticated for application in microgravity environments. In this poster we present the modular FPGA-based electronics for a complete atom-optical experiment, fitting in a volume of less than a few liters. These electronics allow for a fully automated laser locking system to enable autonomous operation without human intervention. The LASUS project is a collaboration of FBH Berlin, HU Berlin, U Hamburg and LU Hanover supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM1239.

Q 16.62 Mon 16:30 Spree-Palais

Electron guiding on a surface-electrode microwave chip — •Jakob Hammer, Stephan Heinrich, Dominik Ehberger, Sebastian Thomas, and Peter Hommelhoff — Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 1, 91058 Erlangen

We study the guiding of free electrons in a planar microwave quadrupole guide [1]. The surface-electrode structure is driven at microwave frequencies, which allows tight radial confinement of $1-10\,\mathrm{eV}$ electrons with transverse trap frequencies of several 100 MHz. We experimentally and numerically study the dynamics of the electrons in the guiding potential. Upon coupling into the guide the electron trajectories show strong dependence on the microwave phase and fringing electric fields. We therefore have set up a pulsed electron source with pulse lengths of ∼ 100 ps to temporarily resolve fringing electric fields, oscillating at the microwave drive frequency. By synchronizing the electron pulses to a certain microwave phase we can increase the number of effectively guided electrons. Furthermore we present numerically optimized electrode structures where we significantly reduced the fringing fields at the coupling entrance of the guide. We also discuss more complex electrode structures like planar beam splitting elements for guided electrons.

Finally the combination of an electron guide with a single-atom tip electron source should allow the direct preparation of electrons in low-lying quantum states of the transverse guiding potential, enabling new matter-wave experiments with guided electrons.

[1] J. Hoffrogge, et al., *Phys. Rev. Lett.* **106**, 193001 (2011).

Q 16.63 Mon 16:30 Spree-Palais

Planar microwave structures for electron guiding — Jakob Hammer, Stephan Heinrich, •Philipp Weber, and Peter Hommelhoff — Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 1, 91058 Erlangen

We investigate electron guiding in a miniaturized planar AC-quadrupole guide (linear Paul trap) [1]. Here electrons propagate freely along the electrodes of a micro-fabricated chip and experience a tight transverse harmonic confinement. The surface electrode structure is driven at microwave frequencies, which results in trapping frequencies of several 100 MHz and enables precise control of slow electrons at 1-10 eV by means of purely electric fields.

Here we discuss ongoing experimental efforts to extend trapping frequencies of electron guiding into the GHz range. For this means we are developping a clean room process for the fabrication of smaller electrode designs. We also discuss electrically long electrode structures, where traveling wave effects have to be considered in the electrode layout [2]. For trapping frequencies on the order of ∼ 1 GHz the quantum mechanical ground state of the guiding potential is 100 nm in size which is resolvable by conventional electron optics. This encourages experiments to prepare electron matter-waves in the transverse motional ground state by matching the wavefunction of an incident electron with the ground state of the microwave guide.

[1] J. Hoffrogge, R. Fröhlich, M. Kasevich and P. Hommelhoff, *Phys. Rev. Lett.* **106**, 193001 (2011).
[2] J. Hoffrogge, et al., *Phys. Rev. Lett.* **106**, 193001 (2011).

Q 16.64 Mon 16:30 Spree-Palais

A compact gravimeter based on Bragg diffraction of a Bose-Einstein condensate — •Maral Sahelgozin[1], Jonas Matthias[1], Ernst Maria Rasel[1], and The QUANTUS-TEAM[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

We demonstrate a gravimeter using Bragg scattering in our atom-chip based QUANTUS-I apparatus in order to investigate new tools for atomic gravimeters. The low momentum spread of a BEC collimated by a magnetic lens is expected to reduce the systematic error arising from wavefront inhomogeneities of the beam splitting light fields, which is a major limitation to the precision of current generation atomic gravimeters. On this poster, we discuss the application of atom chip technology to atomic gravimetry under consideration of effective atomic flux, atomic sample temperature equivalent, and compactness of the experimental setup, which atom chips are capable to provide. Moreover, we study the application of multi-photon Bragg scattering and new interferometer schemes accessible with atomic samples of low momentum spread in order to increase the sensitivity while keeping the device size small.

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.

Q 16.65 Mon 16:30 Spree-Palais

Tomography of Dispersion forces — •Johannes Fiedler and Stefan Scheel — Universität Rostock, Institut für Physik, Rostock, Germany

Dispersion forces (DF), such as Casimir-Polder (CP) forces between atoms and macroscopic bodies, are all effective electromagnetic forces caused by ground-state fluctuations of the electromagnetic field [1]. Because of their short interaction range, they can play a major role in situations where two objects are brought close together. For example, in experiments with trapped ultracold atoms [2] and lead to unwanted losses. In molecular interferometry (MI), these CP interactions influence the intensity distribution in the interference pattern [3]. The exact quantative description of dispersion forces is typically very complicated as it requires exact knowledge of all optical properties of the involved objects. In particular, solid-state optical responses are usually not well known. In order to experimentally determine DF, we propose a tomographic reconstruction method. Specifically, we envisage using the tomographic MI [4] to reconstruct the interaction potential between a molecule and a solid grating. We show that it is possible to reconstruct physical quantities such as the geometry of the scatterer and molecular properties such as bond lengths [5] from the tomographic data.

[1] S. Scheel and S.Y. Buhmann. Acta Phys. Slov. 58, 675 (2008).
[2] Y.J. Lin et al. Phys. Rev. Lett. 92, 050404 (2004).
[3] B. Brezger et al. Phys. Rev. Lett. 88, 100404 (2002).
[4] T. Juffmann et al. Nature Nanotechnology 7, 297 (2012).
[5] Grisenti et al. Phys. Rev. Lett. 85, 2284 (2000).

Q 16.66 Mon 16:30 Spree-Palais

Laser system technology for quantum gas experiments aboard sounding rockets — •Vladimir Schkolnik[1], Markus Krutzik[1], Achim Peters[1,2], The QUANTUS Team[1,2,3,4,5,6,7,8,9], The LASUS Team[1,2,3,5], and The KALEXUS Team[1,2,3,4] — [1]HU Berlin — [2]FBH, Berlin — [3]U Hamburg — [4]JGU Mainz — [5]LU Hannover — [6]ZARM, U Bremen — [7]TU Darmstadt — [8]U Ulm — [9]DLR-RY, Bremen

We present a new generation of compact laser systems optimized for precision measurement applications with ultra-cold atoms aboard sounding rockets. Design, assembly and qualification of a system capable of atom interferometric experiments with degenerate ^{87}Rb in context of the MAIUS mission will be discussed. It combines micro-integrated, high power diode laser modules with a switching module based on zerodur optical bench technology and fiber optical splitter systems. All stringent qualification procedures and reliability issues imposed by a double-stage rocket mission launch have been passed on component and system level. Laser spectroscopy payloads for two other sounding rocket experiments, FOKUS and KALEXUS, are presented which demonstrate the technological readiness of complex laser system assemblies and key components for future space missions. All laser systems are to be launched within the next two years.

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 50WM 1131-1137, 1237-1240, and 1345.

Q 16.67 Mon 16:30 Spree-Palais

A miniaturized, high flux BEC source for precision interferometry — Alexander Grote[1], Klaus Sengstock[1], and •The QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Laserphysik, Universität Hamburg — [2]Institut für Quantenoptik, Universität Hannover — [3]ZARM, Universität Bremen — [4]Institut für Physik, HU Berlin — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]MURAC, University of Birmingham — [8]FBH, Berlin — [9]MPQ, Garching

Atom chips have proven to be excellent sources for the fast production of ultra-cold gases due to their outstanding performance in evaporative cooling. However, the total number of atoms has previously been limited by the small volume of their magnetic traps. To overcome this restriction, we have developed a novel loading scheme that allows us to produce Bose-Einstein condensates of 4x10^5 ^{87}Rb atoms every 1.6 seconds. Ensembles of 1x10^5 atoms can be produced with 1Hz repetition rate. The apparatus is designed to be operated under microgravity at the drop tower in Bremen, where even higher numbers of atoms can be achieved due to the absence of any gravitational sag.
Using the drop tower's catapult mode, our setup will perform atom interferometry during nine seconds in free fall. Thus, the fast loading scheme allows for interferometer sequences of up to seven seconds – interrogation times which are inaccessible for ground based devices.
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.

Q 16.68 Mon 16:30 Spree-Palais

Satellite-borne laser system for $^{87/85}$Rb dual-species interferometry — •Markus Krutzik[1], Achim Peters[1,2], and the STE-QUEST team[3] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [3]European Consortium

The search for unification of general relativity (GR) with quantum mechanics is an enormously active research field and several attempts or extended theories addressing this problem predict violations of the basic principles of GR. ESA's STE-QUEST is a M3 satellite mission candidate dedicated to conceive different aspects of Einstein's equivalence principle (EEP), such as testing the universality of the free propagation of matter waves with a dual-species atom interferometer. In this poster, we present the overall architecture and technological details of a laser system for two-species BEC operation including simultaneous Raman double-diffraction interferometry with ^{87}Rb and ^{85}Rb. It combines an all-fibered telecom technology based reference and optical dipole trap laser with ultra-compact, micro-integrated ECDL-based MOPA systems for laser cooling and coherent manipulation. Precise switching of all laser beams, frequency shifts, monitoring and laser pulse generation are realized in advanced zerodur optical bench technology featuring free-space optics and active components.

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 50OY 1304 and 50WM 1141.

Q 16.69 Mon 16:30 Spree-Palais

The AEI-SAS: Seismic isolation for the 10 m Prototype Interferometer — •Gerald Bergmann — for the AEI 10 m Prototype Team

A 10 m arm length prototype interferometer is currently being set up 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 very good isolation from seismic motion is required. The first stage of seismic isolation for the 10 m prototype interferometer is a set of passively isolated optical tables. Geometric anti-spring filters provide vertical attenuation, and the tables are mounted on inverted pendulum legs which provide isolation in horizontal direction. Purely mechanically passive attenuation of more than 60 dB below 10 Hz was shown in first experiments. The table motion agrees very well with the predicted performance. Several sensors and a Suspension Platform Interferometer measure the residual table motion. These signals are used for actively controling the tables. This even improve the passive table's performance around its fundamental resonances. Currently two out of three tables are installed in the vacuum envelope.

Q 16.70 Mon 16:30 Spree-Palais

The Frequency Reference Cavity for the AEI 10 m Prototype Interferometer — •Manuela Hanke — AEI Hannover

The 10 m Prototype facility, currently being set up at the AEI Hannover, will provide a testbed for very sensitive 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 stabilized. The laser source is a AEI-LZH 35 W Nd:YAG laser also used to drive the km-scale gravitational wave observatories, LIGO and GEO 600. A 23 m long fully suspended triangular ring cavity of finesse ca. 3000 will be used as a frequency reference for the stabilization of the laser. The aim of this project, the frequency reference cavity, is to reach a level of laser frequency fluctuations of better than $10^{-5}/\sqrt{\mathrm{Hz}}$ in the detection band, centered around 200 Hz. Therefore we need to reduce the frequency noise of the free running laser by a factor of a million. The most important goal is to make a sufficiently stabilized 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.

Q 16.71 Mon 16:30 Spree-Palais

Progress Report Towards an Al$^+$ Quantum Logic Optical Clock — •Stephan Hannig[1], Sana Amairi[1], Jannes B. Wübbena[1], Nils Scharnhorst[1], Ian D. Leroux[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, PTB, 38116 Braunschweig, Germany — [2]LUH, 30167 Hannover, Germany

We present the status of our aluminium ion optical clock using quantum logic techniques for cooling and reading out the clock ion. The design goals for the frequency standard are an inaccuracy below 10^{-17} and relative instability better than 10^{-15} in one second. ^{27}Al$^+$ provides a narrow (8 mHz) clock transition at 267 nm which exhibits no electric quadrupole shift and a low sensitivity to black-body radiation. A single ^{27}Al$^+$ ion will be confined in a linear Paul Trap together with a ^{40}Ca$^+$ logic ion. The latter is used for sympathetic cooling and internal state detection of the clock ion via Coulomb interaction.

The high stability will be achieved through a 39.5 cm long clock cavity with reduced thermal noise. Preliminary results on the thermal characteristics and the sensitivity to vibrations will be presented. Moreover, we show a setup to quadruple the output frequency of the clock laser locked to the cavity. We present the status of the experiment and recent results. Currently, a second generation, new vacuum chamber including a segmented multi-layer linear paul trap is designed. The new system paves the way towards multi-ion clocks, combining the high accuracy of single-ion clocks with high stability.

Q 16.72 Mon 16:30 Spree-Palais

Accuracy bounds for gradient metrology with PI atomic ensembles — •Iagoba Apellaniz[1], Iñigo Urizar-Lanz[1], Zoltán Zimboras[1], and Géza Toth[1,2,3] — [1]Dept. of Theoretical Physics, University of the Basque Country, Leioa, Spain. — [2]IKERBASQUE, Basque Foundation for Science, Bilbao, Spain — [3]Wigner Research Center for Physics, Hungarian Academy of Science, Budapest, Hungary

We study gradient magnetometry with atomic ensembles. The accuracy bounds for the estimation of the gradient for a single atomic ensemble is determined, assuming that the state of the ensemble is permutationally invariant. Our bounds are obtained from calculations based on the multi-parametric quantum Fisher information, and they are generally valid for all possible measurements.

A setup with a single atomic ensemble has several advantages: (i) the spatial resolution can be better and the experimental requirements are smaller since they are globally prepared, and (ii) single ensemble states insensitive to homogeneous fields, for instance singlet states, can also be used and they make it possible to measure the gradient without the need to measure the homogeneous field.

Q 16.73 Mon 16:30 Spree-Palais

Ultra-low frequency-noise laser for reducing the instability of an optical lattice clock — •S. Häfner[1], St. Falke[1], M. Merimaa[2], Ch. Grebing[1], Th. Legero[1], Ch. Lisdat[1], and U. Sterr[1] — [1]Physikalisch-Technische Bundesanstalt (PTB); Bundesallee 100; 38116 Braunschweig — [2]Centre for Metrology and Accreditation (MIKES); P.O. Box 9; FI-02151 Espoo; Finland

Ultra-stable lasers are key instruments of many experiments in physics, e.g. optical clocks use low-noise lasers to interrogate narrow atomic reference transitions. State-of-the-art lasers reach a relative frequency instability of just below 10^{-16} at a few seconds averaging time by frequency locking to an external reference cavity. The frequency noise of reference cavities is limited by Brownian motion in the mirror coatings and substrates and scales inversely proportional to the length of the cavity. In the presented work, we have used a 48-cm long spacer with an estimated thermal noise limited instability of 4×10^{-17}. This ultrastable laser was evaluated in a three-cornered-hat comparison and in PTB's strontium lattice clock. We observed a minimum laser instability of 7×10^{-17} at 300 s and an improved stability of the optical clock down to an estimated $4 \times 10^{-16}\sqrt{s/\tau}$. This reduces averaging times in studies of systematic shifts of the clock transition frequency and places our clock among the most stable clocks worldwide.

This work was supported by QUEST, DFG (RTG 1729), and the European Metrology Research Programme (EMRP) in IND14, ITOC, and QESOCAS. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

Q 16.74 Mon 16:30 Spree-Palais

Ultrastable clock laser for a magnesium frequency standard — •Steffen Rühmann, André Kulosa, Dominika Fim, Klaus Zipfel, Steffen Sauer, Birte Lampmann, Leonie Theis, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

State-of-the-art frequency standards based on ultranarrow optical transitions enable new applications, i.e. in geodesy, navigation and fundamental physics. Here timescales of applications are mainly limited due to the short term stability of the frequency standard which is

mainly given by the interrogation oszillator.
At the IQ Hannover we are currently setting up a frequency standard based on neutral magnesium atoms trapped in an optical lattice at the predicted magic wavelength which promises to be a good candidate as a clock element due to its low sensitivity to black body radiation. For interrogation we built up a laser system based on an 10 cm long ULE-spacer contacted with fused silica mirrors at room temperature. This resonator is housed in a vacuum chamber which ist isolated from thermal and acoustic fluctuations. We reach an instability of 5×10^{-16} in 1 s with a calculated thermal noise limit of 3×10^{-16}. We give details in the performance of the clock laser system and the main contributions to its limits.

Q 16.75 Mon 16:30 Spree-Palais

Compact mode-locked diode laser system for highly accurate frequency comparisons in microgravity — •Heike Christopher[1,2], Evgeny Kovalchuk[1,2], Andreas Wicht[1,2], Götz Erbert[2], Günther Tränkle[2], Achim Peters[1,2], and The LASUS Team[1,2,3,4] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut, 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 to generate an optical frequency comb spanning the wavelength range from 767 nm to 780 nm. Hence it will allow highly accurate frequency comparisons in microgravity experiments testing the Einstein Equivalence Principle (EEP) for potassium and rubidium quantum gases.

The extended-cavity passively mode-locked diode laser contains an external dielectric mirror for high flexibility in optimizing performance parameters to match the required specifications. The ridge-waveguide (RW) laser diode consists of a short saturable absorber and a long gain section. Selecting the appropriate group velocity dispersion (GVD) of the external mirror provides optimal pulse performance at a repetition rate of about 4 GHz. Thus a free running timing jitter of less than 2 ps (bandwidth 20 kHz to 80 MHz) was achieved. We present the current status of our work and discuss options for further improvements.

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Q 16.76 Mon 16:30 Spree-Palais

Sisyphus cooling of magnesium in an optical dipole trap — •Steffen Sauer, André Kulosa, Steffen Rühmann, Dominika Fim, Klaus Zipfel, Birte Lampmann, Leonie Theis, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

We present a novel scheme of Sisyphus cooling of bosonic ^{24}Mg. It consists of exploiting the differential AC-Stark shift which makes excited atoms interact with a steeper potential than those being in the ground state. This induces on average a net loss of kinetic energy by spontaneous decay. The theoretically achievable temperature limit given by this method is located at 1.9 μK which is the recoil temperature [1].

We cool 10^9 magnesium atoms in a first-stage magneto-optical trap (singlet-MOT) at 285 nm down to a final temperature of 3 mK. The $^1S_0 \rightarrow {}^3P_1$ transition posseses a natural linewidth of 36 Hz only, prohibiting further cooling in a MOT. For this reason, the atoms are just pumped to the triplet manifold allowing for further cooling in a second-stage MOT (triplet MOT) at 383 nm to temperatures of 1 mK. Recently, we succeeded in beating the density limit of the triplet MOT by continuously loading an optical dipole trap at 1064 nm [2]. 10^5 atoms with a temperature of 100 μK in the $^3P_0$ state are now optically pumped back to the $^1S_0$ state where they are objected to the proposed innovation.

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[2] M. Riedmann, et al., *Phys. Rev. A* **86**, 043416 (2012)

Q 16.77 Mon 16:30 Spree-Palais

Micro-integrated extended cavity diode lasers for precision quantum sensors — •Christian Kürbis[1], Erdenetsetseg Luvsandamdin[1], Max Schiemangk[1,2], Andreas Wicht[1,2], Götz Erbert[1], Achim Peters[1,2], and Günther Tränkle[1] — [1]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin, Germany

Portable cold atom based quantum sensors like atom interferometers for inertial navigation sensors, geophysics and resource exploration as well as precision quantum optics experiments in space put stringent requirements on the performance and the compactness of the corresponding laser sources. Beside narrow linewidth emission and single-mode operation at a specific wavelength the lasers have to be compact, robust, lightweight and energy efficient.

We report on the electro-optical characterization of micro-integrated extended cavity diode lasers (ECDLs) as well as on the results of mechanical stress tests carried out for future sounding rocket experiments on rubidium and potassium.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM0940 and 50WM1240, and by the Future and Emerging Technologies (FET) programme within the Seventh Framework programme for Research of the European Commission, under FET Open grant number 250072.

Q 16.78 Mon 16:30 Spree-Palais

Comparison of balanced homodyne detection for different wavelengths using noise-equivalent power — •Imran Khan[1,2], Andreas Leitherer[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University Erlangen-Nuremberg, 91058 Erlangen, Germany

Balanced homodyne detection is a well-established and important technique in quantum optics. In recent years homodyne detection has been utilized for both discrete- and continuous-variable experiments, making it an attractive technique for a range of physical systems. In this work, we compare balanced homodyne detection for different wavelengths (ultraviolet to long-wave infrared) using the noise-equivalent power as a figure of merit.

In balanced homodyne detection, a strong coherent reference beam is used to measure the electric field quadrature of a weak signal beam. When using this method, one wants the local oscillator beam strong enough to have a good signal-to-noise ratio, but weak enough to still be in the linear regime of the detector. We will investigate the suitable parameter ranges of different detector technologies.

Q 16.79 Mon 16:30 Spree-Palais

The ^{87}Sr Strontium Lattice Clock at PTB — •A. Al-Masoudi, St. Falke, S. Häfner, St. Vogt, U. Sterr, and C. Lisdat — Physikalisch-Technische Bundesanstalt (PTB); Bundesallee 100; 38116 Braunschweig

Optical clocks have been quickly moving to the forefront of the frequency standards due to high spectral resolution, and therefore high potential stability and accuracy. One envisioned application of optical clocks is to perform tests fundamental physics with high accuracy. Sr optical clocks have a significant frequency shift due to blackbody radiation. We will control this effect by interrogating the ^{87}Sr atoms in an environment of well controlled temperature. This produces a well characterized BBR field that allows together with a precisely known atomic reaction to the field for a high accuracy correction of the BBR shift. Another effect, which can play a significant role in the lattice clock accuracy budget, is the dc Stark shift due to stray or patch fields. We measured the residual electric field by measuring the shift of the transition frequency as a function of an additional electric field. The dc Stark shift is proportional to the total electric field squared and the stray field can be inferred from the parabola offset. Applying three different fields, the total dc electric field was derived, which corresponded to a fractional shift of 3×10^{-19}. By field compensation, this approach allows for control of this effect at a level of 10^{-19}. This work is supported by QUEST, DFG (RTG 1729), and the EMRP in IND14, ITOC, and QESOCAS. The EMRP is jointly funded by the EMRP participating countries within EURAMET and European Union.

Q 16.80 Mon 16:30 Spree-Palais

Quantum interferometry with spinor BECs — •Daniel Linnemann, Wolfgang Müssel, Helmut Strobel, Jonas Schulz, Jiri Tomkovic, Eike Nicklas, Ion Stroescu, David B. Hume, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Heidelberg, Germany

Atom interferometry is a powerful technique for precision measurements in gravimetry, inertial sensing and atomic clocks. Improved precision can be obtained either with spin squeezed states at the input of a linear interferometer or by employing nonlinear beam splitters. We present a systematic experimental study of squeezing generation in a spinor BEC. The use of parallelized nonlinear evolution in an optical lattice allows for obtaining spin squeezing for more than 10000 atoms. Furthermore, we implement an SU(1,1) interferometer which allows for precise phase estimation even with a small average number of atoms in each arm. Its phase sensitivity, which is predicted to be at the Heisenberg limit, is experimentally characterized.

Q 16.81 Mon 16:30 Spree-Palais

Iodine frequency reference for space applications using a multipass absorption cell — •Klaus Döringshoff[1], Julia Pahl[1], Moritz Nagel[1], Evgeny V. Kovalchuk[1], Johannes Stühler[2], Thilo Schuldt[3], Claus Braxmaier[3,4], and Achim Peters[1] — [1]Humboldt-Universität zu Berlin, Institut für Physik — [2]University of Applied SciencesKonstanz (HTWG), Institute of Optical Systems — [3]DLR Institute for Space Systems (Bremen) — [4]University Bremen, Center for Applied SpaceTechnology and Microgravity (ZARM)

We present a compact iodine frequency reference developed with respect to space applications, which is realized on a fused silica baseplate using an adhesive bonding method and a special designed multipass absorbtion cell.

A Nd:YAG laser system featuring waveguide SHG modules is stabilized to hyperfine transitions in I_2 at 532 nm by means of the modulation transfer spectroscopy technique with a relative stability of 10^{-15} at several seconds of averaging time. This system can be a useful optical frequency reference for future space missions related to fundamental science, earth observation, and navigation and ranging using 1064 nm laser technology.

We report on environmental tests of the setup including thermal cycling and vibrational test required for space qualification.

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Q 16.82 Mon 16:30 Spree-Palais

An inertial sensitive matter wave interferometer based on ^{39}K — •Logan Richardson, Henning Albers, Dennis Schlippert, Christian Meiners, Jonas Hartwig, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

As part of an ongoing experiment that utilizes dual species matter-wave inteferometry to test Einstein's equivalence principle, we have developed inertially sensitive matter-wave interferometers employing the atomic species ^{39}K and ^{87}Rb. In comparison to ^{87}Rb, the significantly lower mass and lower excited state hyperfine splitting result in ^{39}K being much harder to cool, thus making achievable temperatures the prime obstacle when realizing an interferometer with ^{39}K. We report on our potassium double-MOT system and techniques to overcome the inherent cooling problems, e.g. dark molasses cooling and an optical dipole trap for evaporative and/or sympathetic cooling. We show the first inertial sensitive ^{39}K matter wave interferometer allowing for determination of absolute local gravitational acceleration with pulse separation times of up to T=20ms in a Mach-Zehnder configuration. Moreover, we discuss prospects of simultaneous dual species interferometry.

Q 16.83 Mon 16:30 Spree-Palais

The Suspension Platform Interferometer for the AEI 10 m Prototype — •Sina Köhlenbeck for the AEI 10m Prototype Team — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationspyhsik und Institut für Gravitationsphysik der Universität Hannover

The AEI 10m-Prototype facility is an environment for interferometry at the Standard Quantum Limit and a place to test new techniques for the next generation of gravitational wave detectors. Such experiments require extreme isolation from external vibrations. To this end, a variety of subsystems have been developed. Three in-vacuum optical tables are each supported by a seismic attenuation system (SAS), which provides passive isolation down to 100-400 mHz and additional isolation via active feedback control. To operate the three optical tables as one stable 'virtual platform' and to provide stabilization at very low frequencies (10 to 100 mHz), a Suspension Platform Interferometer (SPI) is implemented. Using heterodyne Mach-Zehnder interferometry, the SPI measures the relative displacement of the optical tables with a precision as good as $100\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ at 10 mHz. A feedback control system then stabilizes the distance between the tables. We report initial results from the control of two tables.

Q 16.84 Mon 16:30 Spree-Palais

Determination of the magic wavelength of magnesium — •Birte Lampmann, André Kulosa, Steffen Rühmann, Dominika Fim, Klaus Zipfel, Steffen Sauer, Leonie Theis, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Universität Hannover

Optical clocks with neutral atoms are based on atoms trapped in an optical lattice at the magic wavelength, where the differential AC-Stark shift vanishes. The predicted magic wavelength for magnesium is in the range of $460 - 480$ nm. The latest and most accurate calculation estimates $469\,\mathrm{nm} \pm 3\,\mathrm{nm}$.

Here we report on the status of the magnesium optical clock experiment. We trap 10^4 atoms in an optical lattice at the predicted magic wavelength. To remove the hottest atoms from the lattice, the power is ramped down thus only the coldest atoms at approximately $2\,\mu$K remain trapped.

We perform spectroscopy of the $^1\mathrm{S}_0 \rightarrow {}^3\mathrm{P}_0$ clock transition and by variation of the lattice power and wavelength the magic wavelength can be measured. So far, we narrowed the possible range to be 467.664 nm to 468.957 nm and we will report on the latest results.

Q 16.85 Mon 16:30 Spree-Palais

Spectroscopy of the clock transition in ^{171}Yb in a transportable setup — •Gregor Mura, Tobias Franzen, Daria Ziguleva, Julian Schmitt, Charbel Abou Jaoudeh, 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 our recent results of the 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.

Q 16.86 Mon 16:30 Spree-Palais

Postcorrection of Vibrational Noise in an Atomic Gravimeter — •Christian Meiners, Henning Albers, Logan Richardson, Dennis Schlippert, Jonas Hartwig, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik and Centre for Quantum Engineering and Space-Time Research - QUEST, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

We present a study of the performance of a gravimeter based on free falling atoms, correlated with classical seismometers to correct for vibrational noise. This is of particular interest in regard to future mobile applications.

The source consists of a combined 2D- and 3D MOT setup for Rb^{87}, delivering clouds of 10^9 atoms within 1 second at 3 μK. With a $\frac{\pi}{2} - \pi - \frac{\pi}{2}$ combination of raman pulses seperated by equal time intervals T, a Mach-Zehnder-type interferometer is realised, which is sensitive to the acceleration of the atoms relative to the retro reflection mirror for the raman pulses. Even though the retro reflector is mounted on a commercial vibration isolation platform, the short term stability is limited to $6 \cdot 10^{-7}\ g/\sqrt{Hz}$ due to residual vibrational noise. To circumvent this limitation, we employ a postcorrection algorithm to correct the signal of the atom interferometer for the AC-acceleration of the mirror using a classical seismometer. For optimal correlation, the frequency response of the seismometer has to be taken into account and digital filter routines are investigated. Finally we present a comparative study of different seismometers used to measure the correction phase.

Q 16.87 Mon 16:30 Spree-Palais

Gravitational Wave Polarization and the Antenna Pattern — •Tobin Fricke — Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

The most commonly used depictions of the antenna pattern of a laser-interferometric gravitational wave detector can lead to some misconceptions about the sensitivity to the plus and cross polarizations, and, indeed, the nature of the decomposition into two polarizations in the first place. I will discuss gravitational wave polarization with respect to the detector's antenna pattern, suggesting more pedagogical approaches to be used in the future.