Q 59: Poster IV

Time: Thursday 16:30–19:00 Location: Empore Lichthof

Q 59.1 Thu 16:30 Empore Lichthof

State-dependent force spectroscopy for trapped ions — •Stefan Walser, Zhenlin Wu, René Nardi, Guanqun Mu, Brandon Furey, and Philipp Schindler — Institut für Experimentalphysik, Universität Innsbruck, Austria

Optical trapping and laser cooling are techniques that founded a revolution of quantum experiments in which atoms and molecules are manipulated using optical forces induced by laser light. A particularly useful technique are optical tweezers which are routinely used in many scientific disciplines. Certain trapped ions are an excellent basis for high precision spectroscopic experiments due to the available electronic structure for state preparation and read-out at the single atom level. Within this project we aim to combine state-dependent optical tweezers to manipulate the motional modes of an ion crystal with quantum logic spectroscopy. We plan to co-trap a well controllable $^{40}Ca^+$ logic ion with a molecular ion of interest which is inaccessible to the standard spectroscopic techniques in ion traps. Applying a state-dependent force on the molecular ion using an optical tweezer, the overall trapping potential is modified. This consequently changes the frequency of the ion's common motional mode. That frequency shift can be measured via the logic ion. Thereby we realize a quantum non-demolition measurement of the molecule's internal vibrational and rotational states. We hope that this project will facilitate the non-destructive state detection of molecules with the outlook of providing a basis for a compact spectrometer for atomic and molecular systems.

Q 59.2 Thu 16:30 Empore Lichthof

Decoherence of Rigid Rotors due to Emission of Thermal Radiation — •Jonas Schäfer, Benjamin A. Stickler, and Klaus Hornberger — Faculty of Physics, University of Duisburg-Essen, Duisburg

Recent advances in the control of levitated nanoparticles open the door for fundamental tests and sensing applications exploiting their rotational degrees of freedom [1]. This poster presents the quantum master equation of rotational and translational decoherence of internally hot dielectric particles of arbitrary size and shape emitting thermal radiation. We find that even highly symmetric objects, such as spheres, exhibit orientational decoherence since the internal excitations sourcing the emitted fields break the symmetry of the particle. We quantify the resulting decoherence rates for upcoming experiments with nanoscale to microscale objects.

[1] Stickler, Hornberger, and Kim, Nat. Rev. Phys. 3, 589-597 (2021)

Q 59.3 Thu 16:30 Empore Lichthof

Dynamics of superconducting microscale rotors — •Fynn Köller, Klaus Hornberger, and Benjamin A. Stickler — University of Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

The rotation dynamics of magnetizable objects can be affected strongly by spin-rotational coupling since their internal magnetization field contributes to their total angular momentum. Starting from the classical equations of motion, this poster will derive the Hamiltonian of a superconducting rotor of ellipsoidal shape levitated diamagnetically in a magnetostatic quadrupole field. We will discuss how signatures of strong spin-rotational coupling might become observable in upcoming experiments in the field of levitated nanomechanics and discuss the prospects for magnetic-field sensing.

Q 59.4 Thu 16:30 Empore Lichthof

Quantum interference of electrically trapped particles — •Eric van den Bosch, Lukas Martinetz, Klaus Hornberger, and Benjamin A. Stickler — University Duisburg-Essen, Duisburg, Germany

Orientational quantum revivals are a pronounced quantum interference effect caused by the fundamental quantization of angular momentum [1]. This poster will show how this quantum effect can be observed with electrically charged nanorotors suspended in the time-dependent fields of quadrupole ion traps. We will propose a concrete setup and discuss under what conditions coherence times on the order of a few seconds are realistically achievable.

[1] Stickler, Hornberger, and Kim, Nat. Rev. Phys. 3, 589 (2021)

Q 59.5 Thu 16:30 Empore Lichthof

Navigation via a Gimbal-Stabilized Quantum Accelerometer — •Mouine Abidi[1], Philipp Barbey[1], Yueyang Zou[1], Ann Sabu[1], Dennis Schlippert[1], Christian Schubert[2,1], Ernst. M Rasel[1], and Sven Abend[1] — [1]Institut für Quantenoptik - Leibniz Universität, Hannover, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Satellitengeodäsie und Inertialsensorik, Germany

Inertial navigation and positioning systems are the basis for controlling vehicles such as aircraft, ships, or satellites. However classical inertial sensors suffer from device-dependent drifts and require GNSS corrections.

Satellite navigation (GNSS) possesses inherent limitations. Its signals are prone to natural or human-made interference. Besides no GNSS signal in some areas.

Hybrid quantum navigation, based on the combination of classical Inertial Measurement Units with quantum sensors based on atom interferometry are a serious candidate for a new technology that meets today's requirements for inertial navigation.

We present our latest activities to transfer a complex laboratory-based device to a robust and compact measurement unit that can be used in a dynamic environment to subtract the drifts of classical devices. Using a new laser system design with the latest developed electronics along with the implementation of new optics schemes and commercial compact vacuum system.

Q 59.6 Thu 16:30 Empore Lichthof

T^4-Atom Interferometer Sensitive to Angular Acceleration — •Bernd Konrad and Maxim Efremov — German Aerospace Center (DLR), Institute of Quantum Technologies, 89081 Ulm, Germany

Nowadays, matter-wave interferometry has become a powerful technique for measuring acceleration, gravity gradient, and constant rotation with enormous precision [1]. Here, we explore atom interferometer which is highly sensitive to unknown constant angular acceleration $\dot{\Omega}$. By modeling rotation with fixed axis and constant angular acceleration with time-dependent angular velocity $\vec{\Omega}(t) = (\Omega_0 + \dot{\Omega}t)\vec{e}_\Omega$, where Ω_0 is its initial value, we employ atom-interferometric scheme based on a sequence $\pi/2 - \pi - \pi - \pi - \pi/2$ of five Raman laser pulses [2]. For a small enough Ω_0, we have found that the interferometer has a very high contrast, $C \approx 1$, more precisely it is reduced only by a correction scaling with the sixth order of Ω_0, that is $C = 1 + \mathcal{O}\left(\Omega_0^6\right)$. On the other hand, the leading term of the interferometer phase is linearly proportional to the angular acceleration $\dot{\Omega}$ and scales as T^4, namely $\varphi \propto \dot{\Omega}T^4 + \mathcal{O}\left(\Omega_0^3\right)$, where T is the total interferometer time. In addition, we have investigated the feasibility of the proposed scheme for the typical ground- and space-based configurations, such as a rotating platform on earth and satellites.

[1] G.M. Tino and M.A. Kasevich (Eds.), Atom Interferometry (IOS Press, Amsterdam, 2014)
[2] K.-P. Marzlin and J. Audretsch, Phys. Rev. A **53**, 312 (1996)

Q 59.7 Thu 16:30 Empore Lichthof

The Very Long Baseline Atom Interferometry facility for high precision gravity measurement — •Ali Lezeik[1], Mario Montero[1], Constantin Stojkovic[1], Klaus Zipfel[1], Dorothee Tell[1], Vishu Gupta[1], Henning Albers[1], Sebastian Bode[1], Jonas Klussmeyer[1], Ernst Rasel[1], Christian Schubert[1,2], and Dennis Schlippert[1] — [1]Leibniz Universität Hannover- Insititut für Quantenoptik — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodäsie und Inertialsensorik

Matter-wave interferometry is a sequence of light pulses used to manipulate an ensemble of ultracold atoms and let them interfere. This interference pattern contains rich information about the intertial forces acting on the atoms like the gravitational acceleration, making atom interferometers useful devices for metrological applications and testing fundamental physics. Their sensitivity depends on several factors one of which being the freefall time. A second-long free fall of the atoms allows to reach acceleration sensitivities of 1 nm/s^2, comparable to the best classical gravimeters. In addition, excellent control over the environment and a high number of atoms in the ensemble is necessary to reduce systematic effects and enhance the signal to noise ratio. The 15 m high Very Long Baseline Atom Interferometry facility (VLBAI) aims for sub nm/s^2 gravity measurement sensitivities. We present the current status of the VLBAI and outline the distinguishing aspects of the facility that includes a dual source chamber of ytterbium and rubidium, a 10 m long UHV baseline magnetically shielded to below 1.5 nT/m, and a seismic attentuation system for intertial referencing.

Q 59.8 Thu 16:30 Empore Lichthof

Dark Energy search using atom interferometry in microgravity — •Sukhjovan S Gill[1], Magdalena Misslisch[1], Baptist Piest[1], Ioannis Papadakis[2], Vladimir Schkolnik[2], Sheng-wey Chiow[3], Nan Yu[3], and Ernst M Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität, Hannover, Germany 30167 — [2]Institut für Physik, Humboldt Universität zu Berlin, Berlin, Germany 12489 — [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA 91109

The nature of Dark energy is one of the biggest quests of modern physics. It is needed to explain the accelerated expansion of the universe. In the chameleon theory, a hypothetical scalar field is proposed, which might affect small test masses like dilute atomic gases. In the vicinity of bulk masses, the chameleon field is hidden due to a screening effect making the model in concordance with observations. Dark Energy Search using Interferometry in the Einstein-Elevator(DESIRE) studies the chameleon field model for dark energy using Bose-Einstein Condensate of ^{87}Rb atoms as a source in a microgravity environment. Einstein-Elevator provides 4 seconds of microgravity time for multiloop atom interferometry to search for phase contributions induced by chameleon scalar fields shaped by a changing mass density in their vicinity. This method suppresses the influence of vibrations, gravity gradients and rotations via common mode rejection. The specially designed test mass suppresses gravitational effects from self-mass and its environment. This work will further constrain thin-shell models for dark energy by several orders of magnitude.

Q 59.9 Thu 16:30 Empore Lichthof

Experimental platform for multi-axis inertial quantum sensing — •Matthias Gersemann[1], Sven Abend[1], Mouine Abidi[1], Philipp Barbey[1], Mikhail Cheredinov[1], Ashwin Rajagopalan[1], Ann Sabu[1], Yueyang Zou[1], Christian Schubert[2], Ekim T. Hanimeli[3], Sven Herrmann[3], Simon Kanthak[4], Ernst M. Rasel[1], and the QUANTUS team[1,3,4,5,6,7] — [1]Institut für Quantenoptik, LU Hannover — [2]DLR-SI, Hannover — [3]ZARM, Uni Bremen — [4]Institut für Physik, HU zu Berlin — [5]Institut für Quantenphysik, Uni Ulm — [6]Institut für Angewandte Physik, TU Darmstadt — [7]Institut für Physik, JGU Mainz

In light pulse atom interferometry, ultracold atoms open the prospect of developing new techniques and concepts, in particular to increase the sensitivity of inertial measurements.

The possibility of precise motion control combined with large momentum transfer through double Bragg diffraction and Bloch oscillations contributed to the development of a new concept to create two simultaneous interferometers from a single BEC, as employed for the differentiation between rotations and accelerations. Thanks to the symmetry of this geometry, its extension can form the basis for a compact six-axis quantum inertial measurement unit based on atom-chip technology.

The underlying concepts, the system design used for this purpose, and the technical realization are presented in this contribution.

Q 59.10 Thu 16:30 Empore Lichthof

The Very Long Baseline Atom Interferometry facility for high precision gravity measurement — •Ali Lezeik[1], Mario Montero[1], Klaus Zipfel[1], Dorothee Tell[1], Vishu Gupta[1], Christian Meiners[1], Henning Albers[1], Sebastian Bode[1], Ernst Rasel[1], Christian Schubert[1,2], and Dennis Schlippert[1] — [1]Leibniz Universität Hannover- Insititut für Quantenoptik — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodäsie und Inertialsensorik

Matter-wave interferometry is a sequence of light pulses used to manipulate an ensemble of ultracold atoms and let them interfere. This interference pattern provides information about the intertial forces acting on the atoms, making atom interferometers useful devices for metrological applications and testing fundamental physics. As their sensitivity scales quadratically with the freefall time, a second-long free fall of the atoms allows to reach acceleration sensitivities of 1 nm/s^2, comparable to the best classical gravimeters. Excellent control over the environment and a high number of atoms in the ensemble is also necessary to reduce systematic effects and enhance the signal to noise ratio. The 15 m high Very Long Baseline Atom Interferometry facility (VLBAI) aims for sub nm/s^2 gravity measurement sensitivities.

We present the current status of the VLBAI and outline the distinguishing aspects of the facility that includes a dual source chamber of ytterbium and rubidium, a 10 m long UHV baseline magnetically shielded to below 1.5 nT/m, and a seismic attentuation system for intertial referencing.

Q 59.11 Thu 16:30 Empore Lichthof

Absolute light-shift compensated laser system for a twin-lattice atom interferometry — •Mikhail Cheredinov[1], Matthias Gersemann[1], Ekim T. Hanimeli[2], Simon Kanthak[3], Sven Abend[1], Ernst M. Rasel[1], and the QUANTUS team[1,2,3,4,5,6] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU zu Berlin — [4]Institut für Quantenphysik, Uni Ulm — [5]Institut für Angewandte Physik, TU Darmstadt — [6]Institut für Physik, JGU Mainz

Twin-lattice atom interferometry is a method for forming symmetric interferometers with matter waves of large relative momentum by using two optical lattices propagating in opposite directions. A limiting factor is the loss of contrast associated with the AC Stark shift of far detuned light fields. This contribution presents the realization of a high power laser system for absolute light shift compensation and its potential for enhancing the interferometric contrast. The optical setup relies on two independent frequency doubling stages. One cavity produces the needed light fields for twin-lattice interferometry and another one produces one light field for AC Stark compensation.
Key features are the beam overlap on an interference filter with low power loss and coupling of high optical power in a photonic crystal fiber and further collimation of the output profile with flat-top beamshaper. The final beam contains the three linearly polarized light fields. Thanks to the flat-top shaped beam with more uniform intensity distribution it can be passed through our apertures with significantly less diffraction effects.

Q 59.12 Thu 16:30 Empore Lichthof

Multi-axis quantum gyroscope with multi-loop atomic Sagnac interferometry — •Ann Sabu[1], Yueyang Zou[1], Mouine Abidi[1], Philipp Barbey[1], Ashwin Rajagopalan[1], Christian Schubert[1,2], Matthias Gersemann[1], Dennis Schlippert[1], Ernst Rasel[1], and Sven Abend[1] — [1]Institut für Quantenoptik - Leibniz Universität, Welfgarten 1, 30167 Hannover — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Satellitengeodäsie und Inertialsensorik, Germany

Large area enclosed atom interferometers are potential devices for rotation measurements in inertial navigation. We aim at developing a compact and portable demonstrator capable of multi-axis inertial sensing, enabling precise measurement of rotations and accelerations. In future, an experimental realization of multi-loop atomic interferometry using such a portable gyrosope is also possible.

We present a brief theory of multi-loop atomic Sagnac interferometry, the current status of the preliminary system design of the demonstrator using the Bose-Einstein condensates (BECs) of ^{87}Rb atoms. We also present the design of the laser system for beamsplitter, cooling and detection sequence.

We acknowledge financial support from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC-2123 QuantumFrontiers - 390837967 and through the CRC 1227 (DQ-mat), as well as support from DLR with funds provided by the BMWi under grant no. DLR 50RK1957 (QGyro) and DLR 50NA2106 (QGyro+).

Q 59.13 Thu 16:30 Empore Lichthof

A state-of-the-art suppression of seismic noise. The Seismic attenuation for Very Long Baseline Atom Interferometry — •Jonas Klussmeyer, Sebastian Bode, Klaus Zipfel, Christian Schubert, Ernst M. Rasel, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

The increased separation time of atomic ensembles in a Very Long Baseline Atom Interferometer (VLBAI) allows one to scale up the sensitivity to inertial effects. Likewise, however this also increase the sensitivity to seismic noise introduced by the retro reflection mirror, which acts as an inertial reference. This noise source limits State-of-the-art atom interferometers (AI).

Here we present the VLBAI Seismic Attenuation System (SAS), which combines passive seismic attenuation in all degrees of freedom via an inverted pendulum hanging on geometric anti-springs with a vertical resonance frequency of 320 mHz. In order to suppress residual motion at the resonance, we aim for an active feedback utilizing various inertial sensors and actuators. The estimated instability using the SAS as an inertial reference has been calculated to around $10^{-6}\,\frac{\mathrm{m}}{\mathrm{s}^2}$ per shot (drop: $2T = 0.8\,\mathrm{s}$, launch: $2T = 2.8\,\mathrm{s}$). Measuring the residual motion using an out-of-loop low-noise seismometer opens the path for either a direct feedback on the laser phase or a post-correction of the AI signal for reaching a $10^{-9}\,\frac{\mathrm{m}}{\mathrm{s}^2}$ per shot instability, close to the shot noise limit for our 10^6 atoms.

Q 59.14 Thu 16:30 Empore Lichthof

Moving towards high precision classical sensor hybridization with atom interferometers — •Ashwin Rajagopalan, Ernst Rasel, Sven Abend, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

Vibrational noise is one amongst the most dominant noise sources that hinders the measurement sensitivity of an atom interferometer. Although correlation with commercial accelerometers can be a solution, there are limitations in terms of compatibility, dimensions, sensitivity and correlation efficiency with the atom interferometer. The perspective is to measure the inertial reference mirror motion with utmost precision, which in turn enhances the measurement sensitivity of the atom interferometer. For this purpose, the accelerometer should be placed as close as possible to the mirror or even better if fully integrated with it. We have already demonstrated using a compact Opto-mechanical resonator directly on the inertial reference mirror to measure its motion and suppress the effects of vibrational noise on a T = 10 ms atom interferometer without any vibration isolation. The next step is to fully integrate the Opto-mechanical motion sensor with the inertial reference mirror such that the same test mass serves as the inertial reference mirror as well as one of the mirrors for the optical interferometer measuring motion. This eradicates the existence of a mechanical transfer function between the mirror and the motion sensor. Funded by the DFG EXC2123 QuantumFrontiers - 390837967 supported by the DLR with funds provided by BMWK under Grant No. DLR 50RK1957 (QGyro) and DLR 50NA2106 (QGyro+).

Q 59.15 Thu 16:30 Empore Lichthof

Large-momentum-transfer atom interferometers with µrad-accuracy using Bragg diffraction — •Jan-Niclas Siemss[1,2], Florian Fitzek[1,2], Christian Schubert[2,3], Ernst M. Rasel[2], Naceur Gaaloul[2], and Klemens Hammerer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover — [2]Institut für Quantenoptik, Leibniz Universität Hannover — [3]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Satellitengeodäsie und Inertialsensorik

Large-momentum-transfer atom interferometers that employ elastic Bragg scattering from light waves are among the most precise quantum sensors available. To increase their accuracy from the mrad to the µrad regime, it is necessary to understand the rich phenomenology of Bragg interferometers, which can be quite different from that of a standard two-mode interferometer. We develop an analytic model for the interferometer signal and demonstrate its accuracy using extensive numerical simulations. Our analytic treatment enables the determination of the atomic projection noise limit of an LMT Bragg interferometer and provides the means to saturate this limit. It allows suppression of systematic phase errors by two orders of magnitude down to a few µrad using appropriate pulse parameters.

This work is supported through the DFG via QuantumFrontiers (EXC 2123), and DQ-mat (CRC1227) within Projects No. A05, No. B07, and No. B09.

Q 59.16 Thu 16:30 Empore Lichthof

Noise Description in Bragg Atom Interferometer Using Squeezed States — •Julian Günther[1,2], Naceur Gaaloul[2], and Klemens Hammerer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Using entanglement for N-particle states in matter wave interferometers allows one to outperformthe standard quantum limit of $\frac{1}{\sqrt{N}}$ and approach the Heisenberg scaling of $\frac{1}{N}$ for the uncertainty inthe phase measurement $\Delta\phi$. We consider specifically the use of one-axis twisted, spin squeezed atomicstates in a Bragg Mach-Zehnder interferometer. We evaluate the phase uncertainty $\Delta\phi$ in the phasemeasurement taking into account the multi-port and multi-path nature of the Bragg Mach-Zehnderinterferometer, and determine optimally squeezed states for a given interferometer.

This project was funded within the QuantERA II Programme that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101017733 with funding origanisation DFG (project number 499225223).

Q 59.17 Thu 16:30 Empore Lichthof

Raman and Bragg diffractions in a combined system — •Ekim T. Hanimeli[1], Simon Kanthak[2,3], Matthias Gersemann[4], Mikhail Cheredinov[4], Sven Herrmann[1], Claus Lämmerzahl[1], Sven Abend[4], Ernst M. Rasel[4], and the QUANTUS team[1,2,3,4,5,6] — [1]ZARM, Universität Bremen — [2]Institut für Physik, HU Berlin — [3]Ferdinand-Braun-Institut, Berlin — [4]Institut für Quantenoptik, LU Hannover — [5]Universität Ulm — [6]Technische Universität Darmstadt

Combining Bragg and Raman processes allow for manipulation of both internal and external states of atoms in matter-wave interferometry. This enables novel interferometry topologies with the inclusion of techniques such as blow-away pulses, and clock interferometry. In order to investigate the possibilities arising from their combined use, we have realized a system capable of implementing both interrogation techniques, as well as single, double or higher order diffractions in a single setup. Here, we present some preliminary results from the implementation of this system for BEC interferometry.

The project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) under grant number DLR 50WM2250C (QUANTUS+).

Q 59.18 Thu 16:30 Empore Lichthof

Momentum entanglement for atom interferometry — •Christophe Cassens[1], Fabian Anders[1], Alexander Idel[1], Polina Feldman[2], Dmitry Bondarenko[2], Sina Loriani[1], Karsten Lange[1], Jan Peise[1], Mathias Gersemann[1], Bernd Meyer-Hoppe[1], Sven Abend[1], Naceur Gaaloul[1], Christian Schubert[1,3], Dennis Schlippert[1], Luis Santos[2], Ernst Rasel[1], and Carsten Klempt[1,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Deutschland — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, 30167 Hannover, Deutschland — [3]Deutsches Zentrum fur Luft- und Raumfahrt e.V. (DLR), Institut für Satellitengeodäsie und Inertialsensorik, c/o Leibniz Universität Hannover, DLR-SI, 30167 Hannover

Compared to light interferometers, the flux in cold-atom interferometers is low and the shot noise large. Sensitivities beyond this limitation require the preparation of entangled atoms in different momentum modes.

Here entangled twin-Fock states are deterministically created in the internal spin-degree of freedom of a Bose-Einstein condensate. Hereupon, the entanglement is transferred to distinct momentum-modes using two-photon Raman transitions and verified by measurement of a squeezing parameter.

The observed mode quality and the residual expansion demonstrate that this entangled source is well-suited to the application in light-pulse atom interferometers and opens up a path towards gravimetry beyond the standard quantum limit.

Q 59.19 Thu 16:30 Empore Lichthof

BECCAL - The Bose-Einstein Condensate and Cold Atom Laboratory — •Christian Deppner[1], Holger Ahlers[1], Patrick Brunssen[2], Marcel Eichelmann[1], Kai Frye-Arndt[1,3], Caroline Lösch[2], Arne Wacker[1], Meike List[2], Ernst M. Rasel[3], Waldemar Herr[1], Christian Schubert[1], and The BECCAL Team[1,2,3,4,5,6,7,8,9,10] — [1]DLR-SI, Callinstr. 30B 30167 Hannover, Germany — [2]DLR-SI, Am Fallturm 9, 28359 Bremen, Germany — [3]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, 30167 Hannover, Germany — [4]DLR-QT — [5]DLR-SC — [6]Inst. für Quantenphysik, UUlm — [7]Inst. für Physik, JGU — [8]Inst. für Physik, HUB — [9]ZARM, Bremen — [10]FBH, Berlin

The Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) is a NASA-DLR collaboration which will be a facility for conducting experiments with ultra-cold atoms and Bose-Einstein Condensates (BECs) aboard the International Space Station (ISS). BECCAL will enable the development of future quantum sensors based on matter-wave interferometry. The long term microgravity conditions on the ISS offer a unique environment for precision measurements as well as for fundamental research. We report on experimental opportunities

and possible measurements with BECCAL. A detailed insight into the physics-package, where the ultra-cold atomic ensembles will be created and manipulated to perform these measurements will be given. Additionally, we show the microgravity and space heritage BECCAL is based on.

Q 59.20 Thu 16:30 Empore Lichthof

Utilizing Bose-Einstein condensates for atom interferometry in the transportable Quantum Gravimeter QG-1 — •Pablo Nuñez von Voigt[1], Nina Heine[1], Waldemar Herr[2], Christian Schubert[2], Ludger Timmen[3], Jürgen Müller[3], and Ernst M. Rasel[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Hannover, Germany — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodäsie und Inertialsensorik, Hannover, Germany — [3]Leibniz Universität Hannover, Institut für Erdmessung, Hannover, Germany

The transportable Quantum Gravimeter QG-1 is designed to determine local gravity to the low nm/s^2 level of uncertainty. It relies on the interferometric interrogation of magnetically collimated Bose-Einstein condensates (BEC) in a transportable setup. An atom-chip plays a major role in creating the BEC, allowing high controllability of the atomic cloud. In connection with the absorption detection a better characterization of uncertainties of the motional degrees of freedom is possible. For our current setup, we also discuss methods for operating the gravimeter in seismically noisy environments.

We acknowledge financial funding by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 434617780 - SFB 1464 and under Germany's Excellence Strategy - EXC 2123 QuantumFrontiers, Project-ID 390837967.

Q 59.21 Thu 16:30 Empore Lichthof

A compact setup for optically guided BEC interferometry at a single wavelength — •Simon Kanthak[1,2], Ekim Hanimeli[3], Matthias Gersemann[4], Mikhail Cheredinov[4], Sven Abend[4], Ernst M. Rasel[4], Markus Krutzik[1,2], and the QUANTUS team[1,2,3,4,5,6] — [1]Institut für Physik, HU Berlin — [2]Ferdinand--Braun-Institut, Berlin — [3]ZARM, Universität Bremen — [4]Institut für Quantenoptik, LU Hannover — [5]Institut für Angewandte Physik, TU Darmstadt — [6]Institut für Quantenphysik, Universität Ulm

Precision sensing with Bose-Einstein condensates (BECs) has been achieved in macroscopic free-space atom interferometers with underlying large scale enclosed space-time areas. As an alternative approach, trapped atom systems offer the opportunity for BEC sensors in more compact packages. For this purpose, atoms can be Bose condensed, delta-kick collimated, guided, split and recombined in optical potentials, which requires an optical guide, crossed beams and beam splitters usually at different wavelengths.

We report on our design and results with a linear setup for optically guided BEC interferometry at a single wavelength. Here, an atom chip serves to initially generate and delta-kick collimate a BEC inside a horizontally aligned atomic waveguide. A far-detuned focused beam in a retro-reflector configuration provides both tools to levitate and symmetrically split the wave packets via double Bragg diffraction.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Climate Action (BMWK) under Grant No. 50WM2250B (QUANTUS+).

Q 59.22 Thu 16:30 Empore Lichthof

Designing high precision electronics for atom interferometers in space applications — •Alexandros Papakonstantinou, Isabell Imwalle, Christian Reichelt, Matthias Koch, Thijs Wendrich, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Atom interferometers are a powerful tool for precision measurements. Their sensitivity scales with the free fall time, which on ground is limited by the size of the vacuum chamber. In microgravity this limitation disappears, enabling higher sensitivities. However, typical microgravity platforms like sounding rockets or the ISS have restrictions on size, weight and power. Also, the apparatus needs to be robust enough to survive the trip into space. In addition it should be fully remote controlled with a high degree of automation. For our microgravity experiments QUANTUS-1/-2 (drop tower), MAIUS-1/-2 (sounding rocket) and BECCAL (ISS), we have developed such components, including laser current drivers, atom-chip current drivers, RF and microwave generators, photodiode and temperature monitoring, power supplies and many more. This poster will show the progress and latest results of our developments.

Q 59.23 Thu 16:30 Empore Lichthof

Atom interferometry in microgravity on long time scales — •Dorthe Leopoldt[1], Anurag Bhadane[2], Merle Cornelius[3], Laura Pätzold[3], Julia Pahl[4], Ernst Rasel[1], and Quantus Team[1,2,3,4,5,6] — [1]LU Hannover — [2]JGU Mainz — [3]U Bremen — [4]HU Berlin — [5]U Ulm — [6]TU Darmstadt

Atom interferometry allows for precise quantum sensors, which can e.g. be used to perform a quantum test of Einstein's equivalence principle. The QUANTUS-2 experiment enables rapid BEC production of Rb-87 with over 1e5 atoms and performs atom interferometry under extended free fall at the ZARM drop tower in Bremen. With that it serves as a testbed for future space-based missions. By applying a quadrupole mode enhanced magnetic lens, we are able to reduce the total kinetic energy of the BEC down to 3/2*k_B*38 pK in three dimensions in order to increase the ensemble's density. Here, we present the latest results on single species atom interferometry in QUANTUS-2 and our next steps, including the implementation of potassium.

The QUANTUS project is supported by the DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action under grant number DLR 50WM1952-1957.

Q 59.24 Thu 16:30 Empore Lichthof

Matter-Wave optics with time-averaged potentials and tunable interactions — •Henning Albers[1], Alexander Herbst[1], Wei Liu[1], Dorothee Tell[1], Ernst M. Rasel[1], Dennis Schlippert[1], and The PRIMUS-Team[2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik — [2]ZARM, Universität Bremen

The performance of matter-wave sensors highly depends on the center-of-mass motion and the expansion rate of the atomic ensemble. Time-averaged optical dipole traps give rise to nearly arbitrary dynamic potentials. Alongside with magnetic traps, such as those used in atom chip traps, they can provide fast Bose-Einstein condensate production. Here time-averaged potentials overcome the limitations of typical dipole traps by conserving the trap frequencies during evaporative cooling. The all-optical approach additionally allows to tune the atomic interactions by means of magnetic Feshbach resonances. We discuss our latest results of combining dynamic optical potentials with tunable interactions when performing evaporative cooling [1] as well as applying all-optical matter-wave lenses [2].

[1] A. Herbst et al., PRA (2022): Rapid generation of all-optical ^{39}K Bose-Einstein condensates using a low-field Feshbach resonance
[2] H. Albers et al., CommPhys (2022): All-optical matter-wave lens using time-averaged potentials

Q 59.25 Thu 16:30 Empore Lichthof

Effective theory for Bloch-oscillation-based LMT atom interferometry — •Florian Fitzek[1,2], Jan-Niclas Siemss[1,2], Naceur Gaaloul[2], and Klemens Hammerer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Light-pulse atom interferometers are quantum sensors that enable a wide range of high-precision measurements such as the determination of inertial and electromagnetic forces or the fine-structure constant. Increased sensitivities can be achieved by implementing large momentum transfer (LMT) techniques. A well-known method to increase the momentum of the arms of an interferometer are sequential Bloch oscillations.

We present an accurate description for Bloch pulses based on Wannier-Stark states [Glück et al., Physics Reports 366, 6 (2002)] and the adiabatic theorem for non-hermitian Hamiltonians and verify our model by comparing to an exact numerical integration of the Schrödinger equation [Fitzek et al., Sci Rep 10, 22120 (2020)]. Based on this model, we characterize losses as well as phase uncertainties induced by lattice depth fluctuations in the context of LMT atom interferometry.

This work is supported through the Deutsche Forschungsgemeinschaft (DFG) under EXC 2123 QuantumFrontiers, Project-ID 390837967 and under the CRC1227 within Project No. A05 as well as by the VDI with funds provided by the BMBF under Grant No. VDI 13N14838 (TAIOL).

Q 59.26 Thu 16:30 Empore Lichthof

Quantum-clock interferometry — •Mario Montero[1], Ali Lezeik[1], Klaus Zipfel[1], Ernst M. Rasel[1], Christian Schubert[1,2], and Dennis Schlippert[1] — [1]Leibniz Universität Hannover- Insititut für Quantenoptik — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodäsie und Inertialsensorik

Universality of Gravitational Redshift (UGR) states that the time dilation measured by two objects in a gravitational field is independent of their composition. Testing the validity of UGR can be achieved through Quantum-Clock Interferometry (QCI), where a sequence of light pulses is used to split, redirected and recombined wave packets and drive transitions between internal states of the atom to measure a phase shift between the interferometer arms. However only certain space-time geometries are sensitive to gravitational time dilation effects [1].

We discuss proposals for QCI geometries that are sensitive to the gravitational redshift, and our approach for an experimental implementation in the Very Long Baseline Atom Interferometry (VLBAI) facility in Hannover [2]. Due to its long lived clock state, ytterbium (Yb) is an appealing candidate to measure differences in proper time. We present the current status of our high-flux source of laser-cooled Yb-174 atoms [3].

[1] C. Ufrecht et al, Phys. Rev. Research 2, 043240 (2020).

[2] D. Schlippert et al, arXiv:1909.08524 (2019).

[3] E. Wodey et al, J. Phys. B: At. Mol. Opt. Phys. 54 035301 (2021).

Q 59.27 Thu 16:30 Empore Lichthof

Principal Component Analysis for Image processing in Atom Interferometry — •Stefan Seckmeyer[1], Holger Ahlers[1,2], Sven Abend[1], Ernst M. Rasel[1], and Naceur Gaaloul[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt (DLR) Institut für Satellitengeodäsie und Inertialsensorik,, Hannover, Germany

Image analysis plays an important role in several current state-of-the-art atom interferometry experiments. We investigate the extraction of physical quantities from absorption images of atom interferometers using principal component analysis (PCA).

As a starting point we take a simple mathematical model for the images of the output ports of a two-port atom interferometer which is using a Bose-Einstein condensate as an atom source.

We show an analytic prediction of the PCA results for a subset of parameters which allows us to ascribe physical quantities to the output of a PCA analysis. Using this method we are not only able to extract the interferometer phase for each image but also a spatial phase aberration map shared by all images, here introduced at the final beam splitter.

We acknowledge financial support from the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under Grant No. 50WM2253A.

Q 59.28 Thu 16:30 Empore Lichthof

Towards a three axes quantum hybrid inertial sensor for mobile applications — •David Latorre Bastidas[1], Dennis Knoop[2], André Wenzlawski[1], Jens Grosse[2], Sven Herrmann[2], and Patrick Windpassinger[1] — [1]Institute of Physics, JGU Mainz — [2]ZARM, University of Bremen

Quantum hybrid inertial sensors based on cold atoms have been proposed as an accurate acceleration tracking alternative to current classical accelerometers. Such hybrid sensors allow a higher repetition rate and dynamic range than pure quantum atom interferometers. In this project, we plan to build a combination of an atom interferometer based on stimulated Raman transitions in a Mach-Zehnder configuration using Rubidium-87 with opto-mechanical sensors. For applications such as navigation or missions in space, optimization of the sensor in terms of size, weight and power are necessary, making it inevitable to find the optimal operating parameters.

This poster will give an overview of the current design and of the simulations that were used to optimize the measurement sequence. Further, an outlook is given on future on-site measurements and intermediate goals of the project.

Q 59.29 Thu 16:30 Empore Lichthof

Simulating space-borne atom interferometers for Earth Observation and tests of General Relativity — •Christian Struckmann[1], Ernst M. Rasel[1], Peter Wolf[2], and Naceur Gaaloul[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany — [2]LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université 61 avenue de l'Observatoire, 75014 Paris, France

Quantum sensors based on the interference of matter waves provide an exceptional performance to test the postulates of General Relativity by comparing the free-fall acceleration of matter waves of different composition. Space-borne quantum tests of the universality of free fall (UFF) promise to exploit the full potential of these sensors due to long free-fall times, and to reach unprecedented sensitivity beyond current limits.

In this contribution, we present a simulator for satellite-based atom interferometry and demonstrate its functionality in designing the STE-QUEST mission scenario, a satellite test of the UFF with ultra-cold atoms to 10^-17 as proposed to the ESA Medium mission frame [https://arxiv.org/abs/2211.15412]. Moreover, we will highlight the possibility of this simulator to design Earth Observation missions going beyond state of the art such as the CARIOQA concept [https://arxiv.org/abs/2211.01215].

This work is supported by DLR funds from the BMWi (50WM2263A-CARIOQA-GE and 50WM2253A-(AI)^2).

Q 59.30 Thu 16:30 Empore Lichthof

The Hannover Torsion Balance - a test platform for novel inertial sensing concepts — •Carolin Cordes, Christoph Gentemann, Gerald Bergmann, Moritz Mehmet, Gerhard Heinzel, and Karsten Danzmann — AEI Hannover

Gravity satellite missions require sensors that are sensitive to extremely small displacement changes of macroscopic test masses down to the millihertz regime. For the development of such novel sensors an environment is needed that resembles the conditions in space. Torsion pendulums can be used to simulate free-falling test masses in at least one degree of freedom in the lab on earth. For this reason, they are suitable testbeds for low frequency motion sensors. At the Albert Einstein Institute, we develop and construct such a test facility: the Hannover Torsion Balance, in which four dummy test masses are suspended as a torsion pendulum. A precise readout and control of the test mass motion is essential. To this end, an optical lever readout system and a capacitive readout and control system are implemented. A first interferometric readout will improve the test mass readout and control. To this aim, a Michelson interferometer will be added to the Torsion Balance. It will furthermore be an integral step towards testing novel optical satellite motion sensor readout techniques, such as Deep Frequency Modulation Interferometry. The poster will present the current status of the Torsion Balance and the latest results of the interferometric readout.

Q 59.31 Thu 16:30 Empore Lichthof

GRACE Follow-On and the Laser Ranging Interferometer: Measuring Earth Gravity from Space — •Malte Misfeldt[1,2], Vitali Müller[1,2], and Gerhard Heinel[1,2] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover — [2]Max-Planck Institut für Gravitationsphysik

The GRACE (Gravity Recovery And Climate Experiment) Follow-On twin satellites were launched in mid 2018 for continuity of the Earth gravity field measurements from GRACE (2002-2017). Formerly, the ranging measurement was performed using microwave interference. However, GRACE-FO hosts the novel Laser Ranging Interferometer (LRI), a technology-demonstrator for proving the feasibility of laser interferometry for precise inter-satellite ranging. The LRI surpasses the accuracy of the conventional microwave by a factor of 500 at high frequencies, which possibly enables new analysis techniques and insights into hydrological processes on Earth's surface.

This presentation discusses the design and working principle of the LRI are discussed. Furthermore, an outlook toward the next generation of gravity missions with an improved version of the LRI as the primary ranging instrument is given.

Q 59.32 Thu 16:30 Empore Lichthof

Balanced homodyne detection design and application at the AEI 10m Prototype facility — •Matteo Carlassara[1,2], Firoz Khan[1,2], Philip Koch[1,2], Johannes Lehmann[1,2], Harald Lück[1,2], Juliane von Wrangel[1,2], Janis Wöhler[1,2], and David S. Wu[1,2] — [1]Leibniz Universität Hannover, Hannover, DE — [2]Max Planck Institute for Gravitational Physics, Hannover, DE

Fundamental sources of quantum noise currently limit the performance of ground-based interferometric gravitational wave detectors (GWD), but ongoing technical improvements offer opportunities pushing past this limit. To further upgrade GWD sensitivity, as in the planned Einstein Telescope and Cosmic Explorer, the interferometer readout is planned to be a Balanced Homodyne Detection scheme (BHD) with suspended components to allow the interferometer to operate at a true dark fringe. This also allows the interferometer to be read out at arbitrary quadratures, which will be required by some advanced techniques to suppress quantum noise. The implementation of BHD involves overcoming a number of technical difficulties, including the creation of a very stable local oscillator (LO) and its active stabilisation. This poster focuses on an overview of the relevant issues and obstacles to implementing a BHD using the Albert Einstein Institute (AEI) 10m Prototype, an optimal facility to study novel technologies for reaching and surpassing the interferometric standard quantum limit (SQL). A report will be made on the current progress in the application of BHD with the construction of one of the triple mirror suspensions required for the LO's path.

Q 59.33 Thu 16:30 Empore Lichthof

Compact Optical Test Mass Sensing — •Victor Huarcaya — Albert-Einstein-Institut Hannover / Max-Planck-Institut für Gravitationsphysik, Hannover, Germany

High-precision measurement of all six degrees of freedom of freely floating test masses is necessary for gravitational space missions like GRACE (Gravity Recovery and Climate Experiment), its follow-on mission GRACE-FO, and GOCE (Gravity Field and steady-state Ocean Circulation Explorer). When aiming for sensing multiple degrees of freedom, typically, capacitive sensing is used, which facilitates a compact setup but does not provide competitive precision. In opposition, laser interferometers have been established as one of the tools of choice for high-precision measurement schemes. However, these measurements were restricted to the length changes in one degree of freedom. Here, we report on Deep Frequency Modulation (DFM). This novel interferometric readout technique is a promising candidate for improving the sensitivity beyond capacitance readout systems and reducing the complexity of the setup. Initial experimental results show optical zero measurements performance levels better than $250\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ at 1 mHz and electronic readout noise levels below $1\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ at 1 mHz. Based on DFM, we also report a novel sensor topology, the self-referenced single-element dual-interferometer (SEDI) inertial sensor, which takes simplification one step further by accommodating two interferometers in one optic which makes the SEDI sensor a promising approach for applications in high precision inertial sensing for both next-generation space-based gravity missions.

Q 59.34 Thu 16:30 Empore Lichthof

Scaling a robust Lorentz Symmetry test to multiple Yb^+ ions — •Kai C. Grensemann[1], Chih-Han Yeh[1], Laura S. Dreissen[1], and Tanja E. Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

We recently completed a test of local Lorentz invariance (LLI) in the electron-photon sector using a single trapped $^{172}Yb^+$ ion [1]. With a novel approach based on composite pulse Ramsey spectroscopy [2] we fully exploited the ion's high sensitivity to Lorentz violation (LV) [3] and reached second long coherence times. We extracted improved bounds on LV coefficients in the 10^{-21} region. Scaling the used method to a linear Coulomb crystal of N ions would further increase the sensitivity by $\sqrt{N}$. Here, we report on our ongoing efforts to test LLI on a 10 ion crystal. We show that the composite pulse sequence is highly robust against inhomogeneities of the magnetic and interaction fields, enabling easy upscaling to a 100 μm ion crystal. We also report on the progress of coherent multi-ion octupole excitation for efficient population of the F-state. The AC-Stark shift of several 100 Hz compared to a linewidth of 10 Hz [4] demands intensity deviations below $\pm 4\%$, which we achieve by shaping the beam with a holographic phaseplate.

[1] L.S. Dreissen et al., *Nat. Commun.* **13**, 7314 (2022). [2] R. Shaniv et al., *Phys. Rev. Lett.* **120**, 103202 (2018). [3] V.A. Dzuba et al., *Nature Physics* **12**, 465-468 (2016). [4] H. A. Fürst et al., *Phys. Rev. Lett.* **125**, 163001 (2020).

Q 59.35 Thu 16:30 Empore Lichthof

Progress on PTB's transportable Al^+ ion clock — •Constantin Nauk[1], Benjamin Kraus[1,2], Joost Hinrichs[1,3], Simone Callegari[1], Stephan Hannig[1,2], and Piet O. Schmidt[1,2,3] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]DLR-Institute for Satellite Geodesy and Inertial Sensing, 30167 Hannover, Germany — [3]Leibniz Universität Hannover, Institut für Quantenoptik, 30167 Hannover, Germany

Optical atomic clocks achieve fractional systematic and statistical frequency uncertainties on the order of 10^{-18}. This enables novel applications, such as height measurements in relativistic geodesy with ~ 1 cm resolution for earth monitoring. Towards this goal, we set up a transportable clock based on the $^1S_0 \rightarrow {}^3P_0$ transition in $^{27}Al^+$. A co-trapped $^{40}Ca^+$ ion allows state detection and cooling via quantum logic spectroscopy and sympathetic cooling.
We present the design and the current status of the transportable apparatus, review the recent development of the laser systems and show particularly the performance of the UV clock laser setup operating at 267.4 nm with a fractional frequency uncertainty of 10^{-16} at 1 second.

Q 59.36 Thu 16:30 Empore Lichthof

Compact rack-integrated UV laser system for a transportable Al^+ quantum logic optical clock — •Joost Hinrichs[1,2], Stephan Hannig[1,3], Benjamin Kraus[1,3], Constantin Nauk[1], and Piet O. Schmidt[1,2,3] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, 30167 Hannover, Germany — [3]DLR-Institute for Satellite Geodesy and Inertial Sensing, 30167 Hannover, Germany

Optical atomic clocks currently provide the most precise frequency standards. For side-by-side comparisons or applications in relativistic geodesy, transportable and robust setups with lowest possible uncertainties are necessary. The feature of transportability requires a highly-stable, compact and automatized implementation.
For our transportable $^{27}Al^+$ clock all components, including optics and the vacuum chamber, will be integrated into conventional 19 in-racks. As one part of the clock apparatus we present a compact design of the Al^+ logic laser emitting at 267 nm to drive the $^1S_0 \leftrightarrow {}^3P_1$ transition. The system consists of a fibre laser operating at 1068 nm and two frequency doubling cavities to generate the required UV output for the logic transition. The complete optical setup is housed in one rack-integrated aluminium drawer. We present the setup and characterize its efficiency and long-term stability.

Q 59.37 Thu 16:30 Empore Lichthof

Variational Clock Protocols — •Timm Kielinski — Institute for theoretical physics, Hannover, Germany

Enhancement of clock stability beyond the classical limit can be accomplished by introducing entanglement between the atoms. In particular, one-axis-twisting (OAT) interactions receive much attention since they give enhanced sensitivity by generating squeezed spin states or echo protocols and can be reliably implemented in several experimental setups. In local (frequentist) phase estimation, the sensitivity is characterized using tools as the Fisher information and is limited by the Cramér Rao bound. However, laser noise limits the clock stability and therefore frequency fluctuations during the clock operation have to be considered. To accomplish for the finite prior information, Bayesian phase estimation is applied representing the trade-off between reduction in quantum projection noise (QPN) and the coherence time limit (CTL) of the laser. This work aims to optimize the stability of ion clocks building on a variational class of Ramsey protocols. Theoretical predictions are validated by numerical simulations of the full feedback loop of an atomic clock. The main limitation is imposed by fringe hops, especially in the presence of dead time.

Q 59.38 Thu 16:30 Empore Lichthof

A compact strontium optical clock based on Ramsey-Bordé spectroscopy — •Oliver Fartmann[1], Ingmari C. Tietje[1], Amir Mahdian[1], Marc Christ[1,2], Conrad L. Zimmermann[2], Martin Jutisz[1], Vladimir Schkolnik[1,2], and Markus Krutzik[1,2] — [1]Humboldt-Universität zu Berlin, Inst. f. Physik — [2]Ferdinand-Braun-Institut GmbH, Leibniz-Institut für Höchstfrequenztechnik, Berlin

We present the status of our optical clock based on Ramsey-Bordé spectroscopy using the $^1S_0 \rightarrow {}^3P_1$ intercombination line at 689 nm in strontium. We give an overview of the underlying spectroscopy principle and a clock instability and uncertainty budget. Further, we present the current status in the laboratory including the design of a new compact and high-flux atomic oven and our work on the spectroscopy setup. Lastly, we show our progress towards micro-integrating the setup.

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Q 59.39 Thu 16:30 Empore Lichthof

Development of Two Laboratory Two-Photon Frequency References — •Moritz Eisebitt[1,2], Julien Kluge[1,3], Daniel Emanuel Kohl[1,3], Klaus Döringshoff[1,3], and Markus Krutzik[1,3] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]II. Physikalisches Institut, RWTH Aachen University — [3]Ferdinand-Braun-Insitut, Leibniz-Institut für Höchstfrequenztechnik

We present two laboratory monochromatic two-photon frequency references operating on the $5S_{1/2} \to 5D_{5/2}$ transition in Rubidium utilising frequency modulation spectroscopy. Two-photon references with Rubidium have the benefit of a narrow linewidth and being inherently Doppler-free. The references have a combined fractional instability below $3{\cdot}10^{-13}/\sqrt{\tau}$ up to 1000s. Efforts to stabilise the residual amplitude modulation are discussed as well as the performance and limits of the frequency reference induced by environmental effects. Measurements of the dipole, quadrupole and octupole hyperfine structure constants of Rb $5D_{5/2}$ are presented which surpass the precision of the current state of art values by an order of magnitude.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) due to an enactment of the German Bundestag under grant numbers 50RK19711, 50WM2164.

Q 59.40 Thu 16:30 Empore Lichthof

Recent Progress of a miniaturized all diode laser based strontium lattice clock — •Max Schlösinger[1], Henri Zimmermann[1], Christoph Pyrlik[1], Vladimir Schkolnik[1], Ronald Holzwarth[2], Robert Jördens[3], Enrico Vogt[4], Andreas Wicht[5], and Markus Krutzik[1,5] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin — [2]Menlo Systems GmbH, Bunsenstr. 5, 82152 Martinsried — [3]QUARTIQ GmbH, Rudower Chaussee 29, 12489 Berlin — [4]Qubig GmbH, Balanstr. 57, 81541 München — [5]Ferdinand Braun Institut GmbH, Gustav-Kirchhoffstraße 4, 12489 Berlin

The joint SOLIS-1G project aims to develop a size weight and power (SWaP) optimized, all diode-laser based strontium lattice clock demonstrator, thereby exploring and enabling essential technologies for future space-borne optical lattice clocks.

We report on the current state of the SOLIS-1G subsystems with a focus on the physics package, micro-integrated laser systems and compact control electronics.

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 DLR50WM2151 and DLR50RP2190B.

Q 59.41 Thu 16:30 Empore Lichthof

A multi-ion indium clock — •Ingrid M. Dippel[1], Moritz von Boehn[1], H. Nimrod Hausser[1], Jonas Keller[1], Jan Kiethe[1], Tabea Nordmann[1], and Tanja E. Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Leibniz Universität Hannover, Hannover, Germany

Currently, single-ion optical clocks represent some of the most accurate experiments and are used in high-precision spectroscopy, metrology and geodesy [1]. Though very precise, the statistical uncertainty of these optical clocks is fundamentally limited by the low signal-to-noise ratios and require averaging times on the order of days to resolve frequencies at the limit of their systematic uncertainties at the 10^{-18} level. This motivates the approach to develop multi-ion systems, leading to reduced quantum projection noise (QPN) by a factor of $1/\sqrt{N_{\text{ion}}}$, which is limiting the statistical uncertainty of a clock. Thereby, the averaging times can be decreased by factor of N_{ion} for a given level of statistical uncertainty.

We present an experimental set-up based on $^{115}\text{In}^+$ ions sympathetically cooled by $^{172}\text{Yb}^+$ ions, aiming for multi-ion operation and at the same reaching frequency unertainties on the level of 10^{-19} [2]. Furthermore, we discuss future plans and methods for improving robustness, reducing systematic uncertainties and extending automation of basic lab routines and measurement processes.

[1] T. E. Mehlstäubler et al., *Rep. Prog. Phys.* **81**, 064401 (2018)
[2] J. Keller et al., *Phys. Rev. A* **99**, 013405 (2019)

Q 59.42 Thu 16:30 Empore Lichthof

Development of a Miniaturized Two-photon Frequency Reference Towards Application on a Small Satellite Mission — •Daniel Emanuel Kohl[1,2], Julien Kluge[1,2], Moritz Eisebitt[2,3], Klaus Döringshoff[1,2], Sten Wenzel[2], Andrea Knigge[2], Andreas Wicht[2], and Markus Krutzik[1,2] — [1]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik — [2]Institut für Physik, Humboldt-Universität zu Berlin — [3]II. Physikalisches Institut, RWTH Aachen University

Global navigation satellite systems require precise clocks with stringent constraints on size, weight and power budget. Two-photon spectroscopy of the rubidium 5S-5D transition in conjunction with optical frequency combs can provide compact, high precision clocks for next generation GNSS systems. We present a two-photon rubidium frequency reference set-up, achieving fractional frequency instabilities in the regime of $10^{-13}/\sqrt{\tau}$.

Furthermore, we present a prototype of a compact set-up, featuring a monolithically integrated extended cavity diode laser and a miniaturized, heated and magnetically shielded 1 cm long vapor cell. Details of the vapor cell assembly and the lasers system will be shown. This work, in combination with advanced micro-integration techniques, may lead to ultra-compact, low power but high performant optical frequency references.

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 50RK1971, 50WM2164.

Q 59.43 Thu 16:30 Empore Lichthof

A strontium lattice clock with 3×10^{-18} uncertainty — •Kilian Stahl, Joshua Klose, Roman Schwarz, Ingo Nosske, Uwe Sterr, Sören Dörscher, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We present a strontium optical lattice clock, PTB-Sr3, that is equipped with in-vacuum heat shields providing a highly homogeneous thermal environment. Initial characterisation of systematic effects yields a fractional frequency uncertainty of about 3×10^{-18}. The clock has similar frequency instability as its predecessor, *i.e.*, below $2\times10^{-16}/\sqrt{\tau/\text{s}}$, and improved availability due to automated monitoring and recovery of laser frequency locks. We also report on a revisiting analysis of the atomic response to blackbody radiation (BBR), which reveals a previously unrecognised error in the dynamic correction coefficient corresponding to a 4×10^{-18} clock offset and improves the uncertainty of the atomic response near room temperature to about 1×10^{-18}. To improve the uncertainty of the BBR-induced frequency shift further, a closed-cycle cryocooler allows reducing the temperature of the heat shields to below 80 K. We discuss the prospects for improving the fractional frequency uncertainty of this clock into the 10^{-19} regime.

This project has been supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC-2123 QuantumFrontiers – Project-ID 390837967, SFB 1464 TerraQ – Project-ID 434617780 – within project A04, and SFB 1227 DQ-*mat* – Project-ID 274200144 – within project B02.

Q 59.44 Thu 16:30 Empore Lichthof

Towards a continuous wave superradiant Calcium Laser — •David Nak and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg, Hamburg, Deutschland

Superradiant Lasers are suitable as narrow light sources with ultralow bandwidth, as their emission frequency is only weakly dependent on an eigenfrequency of the laser cavity. They can be used as a read-out tool for precise optical atomic clocks. Currently, our experiment loads cold Calcium-40 atoms from a magneto optical trap into a one-dimensional optical lattice prepared inside a cavity. By incoherent population of the metastable triplet state, pulsed superradiant emission on the intercombination line was realized [1].

At present, the setup is being extended by an incoherent repumping mechanism, which will allow continuous wave operation.

[1] T. Laske, H. Winter, and A. Hemmerich, Pulse Delay Time Statistics in a Superradiant Laser with Calcium Atoms, Phys. Rev. Lett. 123, 103601 (2019).

Q 59.45 Thu 16:30 Empore Lichthof

Improving frequency superresolution with a resonant quantum pulse gate — •Dana Echeverría-Oviedo, Michael Stefszky, Jano Gil-López, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS).

The application of temporal mode selective measurements for time-frequency quantum metrology has been shown to reach the ultimate precision limit imposed by quantum mechanics and therefore saturate the quantum Cramér-Rao lower bound. These measurements can be implemented with a quantum pulse gate (QPG), a dispersion engineered device based on sum frequency generation between shaped pulses. In practice, the QPG finite phasematching (PM) bandwidth (BW) limits the achievable resolution of such measurements. Increasing the QPG length reduces its PM BW. However, building longer QPGs is not a trivial task since nonlinear crystals cannot be arbitrarily long and longer samples are more sensitive to fabrication imperfections degrading its PM spectrum. To alleviate this limitation, it is of paramount importance to tailor narrower PM BW, pushing the QPG to its performance limit. We propose a resonant QPG, which is composed of two coupled waveguide cavities. One of them is a nonlinear cavity in which the interaction occurs, while the other acts as a coherent filter to obtain a single resonance mode. Our design reduces the PM BW by 3 orders of magnitude for the same nonlinear interaction length of the corresponding QPG, yielding a 5.9 better resolution in superresolved metrology measurements.

Q 59.46 Thu 16:30 Empore Lichthof

The role of frequency stability in measurements of the coefficient of thermal expansion — •Nina Meyer, Tobias Ohlendorf, Uwe Sterr, and Thomas Legero — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

Materials with small coefficients of thermal expansions (CTEs) of about $10^{-8}\,\mathrm{K}^{-1}$ at room temperature are needed for extreme-ultraviolet lithography, in space and ground-based telescopes or ultra-stable resonators. Those small CTEs are usually accurately measured by two-beam Michelson interferometers [1] or by multiple-beam interference based on Fabry-Pérot resonators [2].
Our approach is based on a Fabry-Pérot resonator, consisting of the test material as spacer and two mirrors in a temperature-controlled vacuum chamber. To measure the small thermal expansion, we stabilize a transfer laser onto the TEM_{00} mode of the optical resonator and observe the beat frequency of the transfer laser and a frequency standard.
In this poster, we compare the stability of different types of transfer lasers to iodine-stabilized lasers and ultra-stable lasers via a frequency comb and discuss its influence on the CTE accuracy. We also provide an outlook to setups with lasers operating at $1.5\,\mu$m wavelength.

[1] R. Schödel, Meas. Sci. Technol. **19**, 084003 (2008).
[2] F. Riehle, Meas. Sci. Technol. **9**, 1042−1048 (1998).

Q 59.47 Thu 16:30 Empore Lichthof

En Route to hour long spin manipulation established via constantly driven Rabi nutation measurements — •Tianhao Liu, Jens Voigt, Silvia Knappe-Grüneberg, and Wolfgang Kilian — Physikalisch-Technische Bundesanstalt, 10587 Berlin, Germany

We describe a method for estimating the Larmor frequency of polarized nuclear spins by utilising Rabi nutation that is driven by an applied near-resonant magnetic field. Two data analysis methods for retrieving the Larmor frequency from the precession signals recorded by magnetometers on top of the cell are proposed and further verified with numerical simulations. Compared to the commonly used free decay method, the proposed method has distinct advantages on smaller polarisation loss and shorter measurement time. Main systematic sources on the estimated Lamour frequency by this method are identified and quantitively analysed with a forward analytic model. A series of experiments, where a cell of 3He polarised via spin-exchange optical pumping is placed under a SQUID system in a magnetically shielded room, have been performed to validate this method. A preliminary analysis shows that the relative uncertainty of less than 10-6 on the Lamour frequency could be achieved with data taken within few hundred seconds. This method could be used for traceable weak magnetic field measurements. Moreover, it provides a basis for coherently manipulating the nuclear spins for over an hour-long interval. To the end, we will present a slow Rabi nutation of 3He driven by near-resonance magnetic field over 1 hour.

Q 59.48 Thu 16:30 Empore Lichthof

Testing novel high-reflectivity mirror coatings from room temperature to 4 K — •Mona Kempkes, Jialiang Yu, Sofia Herbers, Thomas Legero, Uwe Sterr, and Daniele Nicolodi — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Brownian thermal noise of highly reflective mirror coatings is the fundamental limit to the performance of many precision laser experiments. Very high reflectivity mirrors with significantly lower mechanical losses than traditional Ta_2O_5/SiO_2 multilayers are needed to improve the stability of optical resonators. Few promising alternatives have been developed so far. However, direct coating noise measurements in representative setups are required to validate their performance, as demonstrated by our experiments with $Al_{0.92}Ga_{0.08}As/GaAs$ crystalline coatings [J. Yu et al., arXiv:2210.15671 (2022) and D. Kedar et al., arXiv:2210.14881 (2022)]. We will present our setup for the characterization of mirror coatings performance and direct Brownian thermal noise measurements from room-temperature to 4 K in a cryogenic optical resonator. This facility will be used to test novel mirror solutions as meta-mirrors and amorphous-Si based coatings.

We acknowledge support by the Project 20FUN08 NEXTLASERS, which has received funding from the EMPIR programme cofinanced by the Participating States and from the European Union's Horizon 2020 Research and Innovation Programme and by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy EXC-2123 QuantumFrontiers, Project-ID 390837967.

Q 59.49 Thu 16:30 Empore Lichthof

Vacuum-integration of a double-tip fiber microscope — •Florian Giefer, Lukas Tenbrake, Sebastian Hofferberth, and Hannes Pfeifer — Institute of Applied Physics, University of Bonn, Germany

Multi-mode cavity optomechanical systems are a promising platform for investigating many body dynamics, for distributed sensing, and optomechanical circuits. A prominent implementation of optomechanical experiments is the membrane-in-the-middle setup, where a thin suspended film is placed inside of an optical fiber Fabry-Perot cavity. To extend this platform towards multiple mechanical resonators with tailored properties we envisage employing 3D direct laser written membrane structures that are placed on a DBR substrate and interfaced using multiple fiber-tip integrated mirrors. To reduce mechanical dampening by surrounding air, our structures need to be placed in a vacuum environment. Based on the concept of "scanning cavity microscopes" introduced by Mader et al., we develop an experimental setup capable of interfacing optomechanical structures on DBR substrates in vacuum using two fiber mirrors with complete position control. We present the design, implementation challenges and future prospects of our experimental setup.

Q 59.50 Thu 16:30 Empore Lichthof

Programmable trap array of optically levitated nanoparticles — •Livia Egyed[1], Manuel Reisenbauer[1], Iurie Coroli[1], Murad Abuzarli[1], Uroš Delić[1], and Markus Aspelmeyer[1,2] — [1]University of Vienna, Faculty of Physics, Vienna Center for Quantum Science and Technology (VCQ), Boltzmanngasse 5, A-1090 Vienna, Austria — [2]Institute for Quantum Optics and Quantum Information (IQOQI) Vienna, Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria

Arrays of coupled mechanical oscillators have been proposed for studies of collective effects such as non-reciprocal phonon transport, investigation of topological phases or multipartite entanglement. Existing experimental architectures are usually either based on fabricated structures or use an optical cavity to mediate the interaction between multiple mechanical modes, thereby limiting the maximal number of elements and the versatility of the created interaction, as well as prohibiting individual detection of the oscillators.

Here, we present a novel platform for studying collective dynamics based on a tunable trap array of levitated nanoparticles which allows for independent control and readout of the particles motions. In addition to standard cavity-mediated setups, we exploit the light-induced dipole-dipole interactions between the particles to introduce direct coupling between them. The ability to control non-reciprocal particle interaction paves the way towards exploring many particle phenomena with massive objects. We will present this platform as well as first results on the collective dynamics of two interacting particles.

Q 59.51 Thu 16:30 Empore Lichthof

Optimal Control of Quantum Squeezed States — •Anton Halaski, Matthias G. Krauss, Daniel Basilewitsch, and Christiane P. Koch — Freie Universität Berlin, Berlin, Germany

Squeezed states are interesting for various tasks, including applications in quantum sensing or quantum information processing. We demonstrate how a mechanical resonator in an optomechanical setup can be brought into a squeezed state using optimal control theory. Using Krotov's method [Reich et al. *J. Chem. Phys.* **136**, 104103 (2012)], we show how optimal control theory can reduce the time needed for squeezed state generation by several orders of magnitude compared to protocols with constant driving. Further, we derive a general protocol for acquiring squeezed states, which not only allows us to simplify the general pulse shapes but also to understand the physical processes during the time evolution of the system.

Q 59.52 Thu 16:30 Empore Lichthof

Quantum state tomography of a nanomechanical resonator in a pulsed measurement protocol — •Felix Klein[1], Jakob Butlewski[1], Alexander Schwarz[2], Klaus Sengstock[1], Roland Wiesendanger[2], and Christoph Becker[1] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institute for Applied Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

Pulsed optomechanical experiments have received growing interest in recent years as they promise a convenient path to full state tomography of quantum objects. Instantaneous snapshots and squeezing of one motional quadrature project the measurement induced noise into the perpendicular quadrature enabling quantum limited high precision measurements.
We realize high fidelity quantum state tomography of a nanomechanical SiN trampoline resonator in a fiber fabry pérot cavity achieving a position uncertainty of 2 pm using light pulses much shorter than the resonators oscillation period.
Here we give an overview of the current experimental setup and discuss ongoing modifications that will allow resolving the resonators zero-point motion.

Q 59.53 Thu 16:30 Empore Lichthof

Levitated nanoparticles in microgravity — •Govindarajan Prakash, Vincent Hock, Marian Woltmann, Sven Hermann, Claus Lämmerzahl, and Christian Vogt — University of Bremen, ZARM (Centre for Applied Space Technology and Microgravity)

Optomechanical levitation of nanoparticles provides a promising platform to perform tests with macroscopic particles on the interface between quantum and classical regimes. Schemes of such tests involve optical trapping, feedback cooling, and release and retrapping of nanoparticles. Here, we aim to discuss how this allows us to perform force sensing of the order of attonewtons in microgravity conditions at the drop towers of ZARM in Bremen using silica nanoparticles. We present the progress thus far in our preliminary aim of building a force sensor that might be suitable for usage in space-based environments for dark matter searches and the like

Q 59.54 Thu 16:30 Empore Lichthof

Nonlinear Oscillator with a Single Trapped Ion — •Moritz Göb, Bo Deng, Max Masuhr, Kilian Singer, and Daqing Wang — Experimentalphysik I, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel

Nonlinear oscillators are interesting test systems for realizing thermal machines in the quantum regime. In our experiment, we investigate a single, laser-cooled $^{40}Ca^{+}$ ion confined in a funnel-shaped Paul trap. This trap geometry leads to an interaction of the axial and radial phonons, which resembles the optomechanical interaction described by the radiation pressure Hamiltonian. Based on this system, we measure and characterize this nonlinear interaction and the resulted mechanical bistability. In this poster, I will detail the technical implementation of this experiment.

Q 59.55 Thu 16:30 Empore Lichthof

Ultrastrong coupling in levitated optomechanics — •Iurie Coroli[1], Kahan Dare[1,2], Jannek Hansen[1], Aisling Johnson[1], Markus Aspelmeyer[1,2], and Uros Delic[1] — [1]University of Vienna, Faculty of Physics, Vienna Center for Quantum Science and Technology (VCQ), Boltzmanngasse 5, A-1090 Vienna, Austria — [2]Institute for Quantum Optics and Quantum Information (IQOQI) Vienna, Austrian Academy of Sciences, A-1090 Vienna, Austria

Levitated nanoparticles have long been heralded as an excellent platform for quantum sensing. Recent proposals have sought to utilize instability due to ultra-strong coupling via coherent scattering but this regime has been out of reach to experimental systems. We report the first levitated optomechanical system to operate in the ultrastrong coupling regime, reaching a maximum coupling of $gx/\Omega x = 0.5$ operating in the resolved sideband regime. We demonstrate future extensions to this system which can dramatically improve the optomechanical cooperativity and further boost the coupling rates, which opens up quantum experiments in the ultrastrong coupling or even deep strong coupling regime to simple table-top systems.

Q 59.56 Thu 16:30 Empore Lichthof

Studying exceptional points in an optical fiber — •Quentin Levoy[1], Flore K. Kunst[1], and Birgit Stiller[1,2] — [1]Max-Planck-Institut für die Physik des Lichts, Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander-Universität, Erlangen, Germany

Exceptional points (EPs) are physical features appearing in non-Hermitian systems, which are typically systems subjected to loss and gains. At these EPs, the eigenvectors of the system coalesce and unique physical phenomena are displayed, such as an unusual dispersion and higher sensitivity to perturbations. EPs are the object of both theoretical and experimental studies. Even though they are associated to ubiquitious properties such as gain and loss and open system behaviour, it is not always straightforward to identify a physical platform that provides the right parameters to reach these EPs and to experimentally study them. Recently, it was proposed to use nonlinear optics and more specifically optoacoustics to finely tune gain and loss in an experimental setup, for instance an optical fiber. Here, we explore in detail how the interaction of optical and acoustic waves can provide an interesting framework to explore the properties of EPs and non-Hermitian physics. Observing this interaction in an optical fiber is one possible way to experimentally observe and study EPs of different orders, using only an optical fiber and a few laser beams.

Q 59.57 Thu 16:30 Empore Lichthof

A nanofabricated solid immersion lens for bright and high-purity single-photon emission from a germanium-vacancy center in diamond — •Justus Christinck[1,2], Franziska Hirt[1,2], Helmuth Hofer[1], Markus Etzkorn[2,3], Zhe Liu[2,3], Toni Dunatov[4], Milko Jakšić[4], Jacopo Forneris[5,6,7], and Stefan Kück[1,2] — [1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology (LENA), Braunschweig, Germany — [3]Technische Universität Braunschweig, Braunschweig, Germany — [4]Ruder Bošković Institute, Zagreb, Croatia — [5]University of Torino, Torino, Italy — [6]Istituto Nazionale di Fisica Nucleare (INFN), Torino, Italy — [7]Istituto Nazionale di Ricerca Metrologica (INRiM)

The group IV-vacancy color centers in diamond, such as the germanium-vacancy (GeV) center, are potential candidates for quantum metrology applications at room temperature. We report on the fabrication of a GeV center doped diamond sample by implantation of Ge-ions and subsequent high-temperature vacuum annealing. To enhance the photon-extraction from the diamond, solid immersion lenses were fabricated into the diamond surface in a focused ion beam scanning electron microscope (FIB-SEM) setup. A bright GeV center in a solid-immersion lens was examined in terms of its saturation behavior and its single-photon purity through the measurement of the $g^{(2)}(\tau)$ function. A saturation count rate at the detector of (833 ± 9) kcps was reached. A simultaneous count rate of 580 kcps and $g^{(2)}(0) = (0.12 \pm 0.06)$ were measured in the experiment.

Q 59.58 Thu 16:30 Empore Lichthof

Mechanically Isolated Quantum Emitters in Hexagonal Boron Nitride — •Andreas Tangemann[1], Patrick Maier[1], Michael Hoese[1], Prithvi Reddy[2], Andreas Dietrich[1], Michael K. Koch[1], Konstantin G. Fehler[1], Marcus W. Doherty[2], and Alexander Kubanek[1] — [1]Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany. — [2]Laser Physics Centre, Research School of Physics and Engineering, Australian National University, Australian Capital Territory 2601, Australia.

Single Photon emitters are a crucial resource for novel photonic quantum technologies. Quantum emitters hosted in two-dimensional hexagonal Boron Nitride (hBN) are a promising candidate for the integration into hybrid quantum systems. One type of emitters hosted in hBN has shown the remarkable property of Fourier limited linewidths from cryogenic up to room temperatures. This property can be attributed to mechanically isolated orbitals of the defect centers, which do not couple to in-plane phonon modes. Here, we present our recent results towards identifying the origin of this mechanical decoupling, which could be caused by out-of-plane emitters. We also present quantum random number generation using the symmetric dipole emission profile of these emitters.

Q 59.59 Thu 16:30 Empore Lichthof

Insights into the photophysics of the SnV center in diamond — •Philipp Fuchs[1], Johannes Görlitz[1], Michael Kieschnick[2], Jan Meijer[2], and Christoph Becher[1] — [1]Universität des Saarlandes, Fachrichtung Physik, Campus E2.6, 66123 Saarbrücken, Germany — [2]Universität Leipzig, Angewandte Quantensysteme, Linnéstraße 5, 04103 Leipzig, Germany

The negatively charged tin vacancy center (SnV^-) in diamond has been shown to be a versatile system that can be used as a quantum sensor, long-lived qubit, and single photon source. However, exploiting these properties requires active stabilization of the charge state, as the SnV^- can be easily ionized to its double negative charge state (SnV^{2-}) upon laser illumination, which is optically inactive [1].

In this work, we propose a simple rate equation model that includes this ionization process. We apply the model to an extensive set of measurements on different SnV centers, along with a thorough characterization of the efficiency of our measurement setup. We conclude that a charge-stabilized SnV^- center is a nearly ideal single photon source in terms of quantum efficiency, since we can describe any reduced photon rate by ionization to the optically inactive SnV^{2-} charge state without assuming other non-radiative decay channels.

[1] J. Görlitz et al., npj Quantum Inf 8, 45 (2022)

Q 59.60 Thu 16:30 Empore Lichthof

Optical investigations of evaporated dibenzoterrylene layers in a C60-fullerene matrix — •Franziska Hirt[1,2], Justus Christinck[1,2], Helmuth Hofer[2], Gunilla Harm[2,3], Andreas Reutter[2,3], Mike Stummvoll[2,3], Neda Noei[3], Uta Schlickum[2,3], and Stefan Kück[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Laboratory for Emerging Nanometrology, Langer Kamp 6a/b, 38106 Braunschweig — [3]Technische Universität Braunschweig, Universitätsplatz 2, 38106 Braunschweig

Polycyclic aromatic hydrocarbons are suitable to be used in a single-photon source at cryogenic and room temperatures, respectively. One prerequisite is their embedment in a stabilizing solid matrix protecting them from oxygen and thermal induced bleaching effects. We report a method based on a high temperature and high vacuum deposition procedure allowing for a controllable growth of single layers of dibenzoterrylene (DBT) molecules. They are placed between several monolayers of C60-fullerenes, which are forming the protection against the environmental conditions. An absorption spectrum of this composite was measured, revealing a linear superposition. Raman spectroscopy measurements proved that the DBT molecules were still intact after being deposited. First experiments in a self-built confocal laser scanning microscope did not show any emission at all, indicating a quenching behavior of the molecule after being evaporated. Thermal annealing could cancel out these quenching and an emission of DBT layers was detected. Further investigations will be presented at the conference.

Q 59.61 Thu 16:30 Empore Lichthof

Optimizing silicon vacancies in silicon carbide through nanophotonic integration — •Di Liu[1], Öney Soykal[2], Jawad Ul-Hassan[3], Florian Kaiser[4], Petr Siyushev[1], and Jörg Wrachtrup[1] — [1]University of Stuttgart and IQST, Germany — [2]Booz Allen Hamilton, USA — [3]Linköping University, Sweden — [4]LIST, Luxembourg

The silicon vacancy (V_{Si}) in silicon carbide (SiC) is an emerging spin qubit for quantum computing and quantum network applications, due to its excellent spin-optical properties and progressive nanophotonic integration. A fully scalable application requires a complete understanding of the system's internal spin dynamics in order to further engineer cavity-emitter coupling. In this work, we unravel relevant radiative and non-radiative transition rates of V_{Si} in 4H-SiC. They allow evaluation of several crucial parameters such as the quantum efficiency for estimation of the desired Purcell enhancement factor or the radiative transition cyclicity defining the maximally achievable emission rate.

We also show our latest results on integrating V_{Si} centers in nanophotonic waveguides, including direct waveguide-to-fiber coupling in cryogenic environment. This technique allows us to boost the platform efficiency towards relevant applications in quantum communication and computation.

Q 59.62 Thu 16:30 Empore Lichthof

3D Printed Optical Waveguide Structures with Microdiamonds containing NV Centers — •Marina Peters[1,2], Adrian Abazi[2], Daniel Wendland[2], Tim Buskasper[2], Lara Lindloge[1], Markus Gregor[1], and Carsten Schuck[2] — [1]Department of Engineering Physics, FH Münster, Germany — [2]Department for Quantum Technology, University of Münster, Germany

Quantum technology holds great potential for novel communication, computation and sensing concepts, however, current approaches do not easily scale to large system size. Integrated photonics offers possibilities to address such scaling challenges by leveraging modern nanofabrication processes for implementing complex nanophotonic circuitry. Here we show how nitrogen vacancy centers in diamond, as a prototypical quantum system, can be embedded into optical waveguides that allow for optical excitation and fluorescence collection. We achieve this by employing a lithographic positioning technique for microdiamonds on a silicon chip, which are subsequently integrated into polymer waveguides, produced in 3D direct laser writing. Our method allows for producing hundreds of devices with waveguide-integrated quantum systems on a chip, which can be addressed and read out via optical fiber arrays.

Q 59.63 Thu 16:30 Empore Lichthof

Integration and coupling of quantum emitters in 2D materials to laserwritten waveguides — •Josefine Krause[1], Simone Piacentini[2], Mostafa Abasifard[1], Roberto Osellame[2], Giacomo Corrielli[2], and Tobias Vogl[1,3] — [1]Institute of Applied Physics, Albert-Einstein-Str. 15, 07745 Jena, Germany — [2]Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche (IFN-CNR), Piazza Leonardo da Vinci 32, 20133 Milano, Italy — [3]Fraunhofer-Institute for Applied Optics and Precision Engineering IOF, Albert-Einstein-Str. 7, 07745 Jena, Germany

The practical application of quantum optics, for example in satellite-based quantum communication, requires the miniaturization of optical components into small devices. A hybrid solution is to integrate quantum emitters hosted in layered two-dimensional (2D) materials onto a photonic chip containing femtosecond laser-written waveguides. Emitters in 2D materials, such as hexagonal boron nitride, are suitable photon sources because of their high photon extraction efficiency due to the material's thinness. We demonstrate a deterministic transfer of an exfoliated tungsten disulfide emitter, employed as a test material for its bright fluorescence at room temperature, onto the front face of a waveguide through a viscoelastic stamping technique. The spectral emission properties of the integrated flake were maintained after the integration and coupling through the waveguide. Furthermore, with the goal of space-based applications, we successfully qualified different miniaturized photonic chips in their mechanical robustness during vibration and shock exposure imitating a rocket launch.

Q 59.64 Thu 16:30 Empore Lichthof

Green's function calculations for two-dimensional arrays of molecular emitters — •Davide Torriglia, Daniel M. Reich, and Christiane P. Koch — Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany

Collective excitations of atomic or molecular arrays have recently attracted a lot of interest in quantum optics as a tool to control the propagation, scattering and storage of light fields.

In this project, we aim to describe the coupling of a two-dimensional molecular array with a quantized light mode and investigate the effect of a graphene substrate on the collective state of the molecules.

As a first step towards this, we calculate the dyadic Green's function for various geometries to describe the propagation of the electromagnetic field classically according to Maxwell's equations.

Employing the resulting Green's functions in quantum mechanical simulations, we aim to directly account for the field-propagation effects on molecular arrays in complex geometries, such as those used in the generation of polaritons in modern experiments.

Q 59.65 Thu 16:30 Empore Lichthof

Influence of nonlocal and dispersive material response on fields of metallic plasmons — •Gino Wegner[1,2], Dan-Nha Huynh[1], Bill Antonio Bernhardt[1], Francesco Intravaia[1], and Kurt Busch[1,3] — [1]Institut für Physik, Humboldt-Universität zu Berlin, AG Theoretische Optik & Photonik, 12489 Berlin, Germany — [2]Institute of Condensed Matter Theory and Optics, Friedrich-Schiller-University Jena, Max- Wien-Platz 1, 07743 Jena, Germany — [3]Max-Born-Institut, 12489 Berlin, Germany

Based on the insight that using (noble) metallic nanostructures or -

features as subtrates for molecules, can significantly boost the Raman signal of nearby molecules due to plasmonic resonances, we investigate the fields of the latter in the vicinity of the metal surface. Based on established material models for the conduction-electronic response to light, we perform analytical Mie calculations as well as numerical simulations employing the Discontinuous Galerkin Time Domain method. The role of nonlocal and dispersive response is critically examined always keeping in mind the intertwining with geometrical features of the subtrates. For a selection of geometries, this study sheds light on pecularities, that have to be kept in mind, when designing metallic substrates for Surface Enhanced Raman Scattering/Spectroscopy.

Q 59.66 Thu 16:30 Empore Lichthof

Design of metasurface for carbon dioxide reduction photocatalysis — •Ning Lyu[1,2], Zelio Fusco[2], Fiona Beck[2], and Christin David[1] — [1]Institute of Condensed Matter Theory and Optics, Abbe Center of Photonics, Friedrich Schiller University of Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]School of Engineering, Australian National University, Acton ACT 2601, Australia

As artificial photosynthesis, the photocatalytic reduction of CO_2 addresses the emission of greenhouse gases by converting them back to organic fuels with solar energy. These redox reactions include multiple electron transfer processes and various products were generated vas separated reaction pathways simultaneously, such as formic acid, formaldehyde, methanol, methane, and some higher hydrocarbons products. Therefore, it is challenging to have a highly efficient, stable conversion of a selected single product. Metasurface with a large surface-to-volume ratio promote the concentration of hot electrons in the active site on surface and have a great potential in photocatalysis and co-catalysis applications.

We investigate how TiO_2 metasurfaces with nanopillars (NPs) and hollow nanotubes (NTs) affect selected pathways of CO_2 reductions in their optical properties with the Finite Element Method (FEM). Polarization- and angle-sensitive resonances were designed to overlap with selected reaction pathways using asymmetric pitches. By changing the polarization, the absorption efficiency for selected pathways remained at approximately 90% under the solar spectrum, while other pathways varied from about 96% to only 48%.

Q 59.67 Thu 16:30 Empore Lichthof

An Automated Setup for Single-Photon Fluorescence Microscopy Measurements — •Raphael V. Wichary, Matthias Nuss, and Tobias Brixner — Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We present a setup with automated beampath selection to perform ultrafast nonlinear fluorescence microscopy at the single-photon level in a diffraction-limited focus. Pneumatically movable mirrors built into an optical cage system enable quick and reliable changes in the beam path with accurate position reproducibility. The setup includes motorized waveplates for full excitation polarization control with a laser spectrum ranging from 675 nm to 810 nm. Incorporation of a TWINS interferometer [1] enables spectrally resolved measurements of single quantum emitters. Detection is handled either by avalanche photodiodes or by a superconducting nanowire single-photon detector (SNSPD). A Hanbury-Brown–Twiss Interferometer enables verification of anti-bunched photon statistics.

[1] D. Brida et al., Opt. Lett., 37, 3027-3029 (2012)

Q 59.68 Thu 16:30 Empore Lichthof

Quantum coherent interactions between electron vortices and chiral optical near-fields — •Neli Streshkova and Martin Kozák — Department of Chemical Physics and Optics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, CZ-121 16 Prague, Czech Republic

In the recent years new possibilities of shaping free electron beams into the so-called vortex beams have emerged. They hold the promise for many applications in electron microscopy. Specifically, electron vortex beams could be used as a sensitive probe for monitoring the optical near-fields, which emerge around chiral nanostructures under laser light illumination, with near nanometer precision.

Here we present numerical simulations of the inelastic interaction between electron vortex beams and chiral optical near-fields. Initially, the electron wavefunction is modulated via inelastic ponderomotive scattering induced by the interference of two optical waves, one of which is an optical vortex wave carrying orbital angular momentum (OAM). The OAM is transferred to the electron beam, which then interacts with a chiral optical near-field of a golden nanosphere excited by circularly polarized optical field. This interaction leads to changes in the electron spectrum in dependence on the amplitude of the near-field, phase relation between the near-field and the modulating fields and the interplay between the helicity of the beam and the near-field itself. Such interaction scheme will in future allow full reconstruction of the optical and plasmonic near-field distribution of various nanostructures including both the amplitude and the phase.

Q 59.69 Thu 16:30 Empore Lichthof

Scattering of free electrons by optical fields and all-optical method for electron pulse characterization — •Kamila Moriová and Martin Kozák — Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 12116 Prague 2, Czech Republic

Free electrons can scatter of a standing light wave formed by two counter-propagating optical beams of identical frequency in vacuum. The coherent reflection of electron wave at periodic ponderomotive potential of the optical standing wave was first proposed by Kapitza and Dirac in 1933 [1] and it was experimentally demonstrated in 2001 [2]. The Kapitza-Dirac-like diffraction was also theoretically described for more general case with two counterpropagating light waves at different frequencies [3]. In this contribution we discuss different regimes of the interaction between electrons and light fields. Further we study the application of the classical regime of electron scattering at an optical standing wave formed by pulsed laser fields for full characterization of femtosecond electron pulses in an electron microscope [4], which is crucial for ultrafast pump-probe experiments with electron probes. [1] Kapitza, P. L. and Dirac, P. A. M. Proc. Camb. Phil. Soc. 29, 297-300 (1933). [2] Freimund, D. L. et al. Nature 413, 142 (2001) [3] Smirnova, O. et al. Phys. Rev. Lett. 92, 223601 (2004) [4] Hebeisen, C. T. et al. Opt. Express 16, 3334-3341 (2008)

Q 59.70 Thu 16:30 Empore Lichthof

Rapid Dilution Mass Photometry — •Carla M. Brunner[1], Emanuel Pfitzner[2], and Philipp Kukura[2] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg — [2]Department of Chemistry, University of Oxford

Mass Photometry (MP) is an optical method based on interferometric scattering microscopy that enables label-free detection of single proteins in solution based on their scattering contrast. Multiple species in a heterogeneous solution can be differentiated by their molecular mass and consequently, binding affinities can be determined. The study of weak interactions calls for high sample concentrations on the order of μM whereas MP requires low concentrations in the nM range.

Developing a rapid dilution method, we explored how the application of MP can be extended beyond these current constraints. Using microcapillaries, we show that we can inject high concentration solutions of transferrin and the IgG antibody 17b into a buffer medium whereupon the sample is diluted by several orders of magnitude within seconds, maintaining the possibility of single-particle detection and the capability to reliably distinguish different species. Nevertheless, carrying out further experiments with a wider range of protein species revealed that some improvements to the setup are required in order to be able to use our methodology more broadly. Measurements performed with HspB1 showed that aggregation of proteins in the capillary tip inhibits the precise determination of mass distributions. A careful investigation of our findings allowed us to pin down current limitations and suggest necessary modifications.

Q 59.71 Thu 16:30 Empore Lichthof

The squeeze laser — •Axel Schönbeck, Jan Südbeck, Jascha Zander, Dieter Berz-Vöge, Pascal Gewecke, Malte Hagemann und Roman Schnabel — Institut für Laserphysik der Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

An increasing number of laser-based measurements in metrology are performed at the quantum-noise limit. Squeezed light helps to overcome this limit. For example, as of 2019, all gravitational-wave observatories (GWOs) worldwide use squeezed vacuum states of light.

"Squeeze laser" is a well-motivated name for what is often referred to as a "squeezed light source". Squeezed light is generated in a laser resonator by parametric down-conversion. The laser's output modes have a large coherence time and are in a near-perfect TEM00 mode. We are launching a spin-off from UHH that will offer these squeeze lasers. Which applications benefit from them?

The squeeze laser is a valuable tool for research laboratories. It is required for one-sided device-independent quantum key distribution (QKD) [Nature Commun. 6, 8795 (2015)] and enables a new technique for absolute calibration of photo sensors [Phys. Rev. Lett. 117, 110801 (2016)]. Measurement-based optical quantum computing requires squeezed states [Science 366, 369-372 (2019)]. The squeeze laser can improve industrial laser Doppler vibrometers in environments with low optical losses [Review of Scientific Instruments 87, 102503 (2016)] [Quantum Sci. Technol. 8, 01LT01 (2022)]. It is also beneficial in the detection and imaging of biological cells and macromolecules [Nature Photon. 7, 229-233 (2013)].

Q 59.72 Thu 16:30 Empore Lichthof

Simulations with IfoCAD for tilt-to-length coupling characterization in LISA — •Rodrigo García Álvarez, Megha Dave, Gerhard Heinzel, and Gudrun Wanner — Albert Einstein Institüt, Hannover, Germany

A major contributor of noise in LISA is the so-called tilt-to-length coupling (TTL). This is the path length signal noise induced by angular and lateral jitters in an interferometric setup. Various TTL noise simulations conducted using IfoCAD, an in-house interferometry analysis tool are presented. These simulations include TTL noise in the test mass interferometers and the inter-satellite interferometers, caused by the jitter of the transmitting and receiving spacecraft. The status of IfoCAD simulations using LISA's latest optical design is included.

Q 59.73 Thu 16:30 Empore Lichthof

Characterization of laser noise with an optical fiber interferometer composed of a 3x3 fiber coupler — •Robin Klöpfer[1,2], Francesca Celine Catalan[1], Ralf Albrecht[1], Annika Belz[2], Harald Kübler[2], Robert Löw[2], Gareth Lees[1], and Tilman Pfau[2] — [1]AP Sensing GmbH, Herrenberger Straße 130, 71034 Böblingen, Germany — [2]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Over the past few decades, fiber-based sensors have been widely deployed in different areas. Distributed acoustic sensing (DAS) in particular has been an important tool for infrastructure monitoring and seismic activity detection. A DAS device sends coherent light into an optical fiber and evaluates the Rayleigh backscattering to monitor strain and acoustic signals over long distances in real time. Because of the high sensitivity of DAS, it is important to ensure a stable optical architecture, starting with a low-noise light source.

Here we characterize the phase and frequency noise of narrow-linewidth lasers using a 120° phase difference unbalanced Michelson interferometer composed of a 3x3 optical fiber coupler. This Michelson interferometer is capable of direct as well as wavelength- and polarization-independent extraction of the differential phase of the incoming laser light, without the need for noise models.

In addition, laser noise measurements are complemented by DAS performance evaluation to identify the most suitable laser for future sensor performance improvements.

Q 59.74 Thu 16:30 Empore Lichthof

Bright Squeezed Light Generation and Quantum Correlation Measurements — •Jasper Venneberg, Henning Vahlbruch, and Benno Willke — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) und Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstraße 38, 30167 Hannover, Germany

State-of-the-art, high-precision metrology experiments like gravitational wave detectors require carefully stabilized laser sources with exceptionally low relative power noise (RPN). The RPN is fundamentally quantum noise limited by the relative shot noise (RSN) for classical states of light. As the RSN scales inversely with the square root of the optical power, it can be reduced by increasing the power, i.e., making the laser "brighter". However, this poses various technical challenges and cannot be scaled indefinitely. Thus, additionally "squeezed" states of light can be applied to reduce the RPN below the classical quantum noise limit. This project investigates methods to generate high-power, sub-relative-shot-noise (or "bright squeezed") light. Also, the quantum correlation measurement technique is investigated as an alternative to traditional power noise sensing by correlating two photodetector signals. As presented, this method is capable of sub-shot noise measurements and could serve as a bright squeezing sensor.

Q 59.75 Thu 16:30 Empore Lichthof

Development and characterization of a 2D THz-imaging system based on a 3D printed telecentric f-theta-lens — •Viola-Antonella Zeilberger[1], Konstantin Wenzel[1], Sarah Klein[2], Martin Traub[2], Robert B. Kohlhaas[1], and Lars Liebermeister[1] — [1]Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Einsteinufer 37, 10587 Berlin, Germany — [2]Fraunhofer Institute for Laser Technology ILT, Steinbachstraße 15, 52074 Aachen, Germany

In recent years, terahertz (THz) time-domain spectroscopy (TDS) has become an established tool for various applications, of which non-destructive layer thickness measurements and defect localization are of particular interest. These applications require rapid 2D imaging. Currently, 2D THz imaging is realized by translating either the single point sensor or the sample, which limits the measurement speed. In this work, we present a THz scanning system based on mechanical beam steering by a motorized gimbal mirror and a telecentric f-theta lens. This system contains a commercial THz-TDS system with a photoconductive THz transceiver as the sensor head. The lens fabricated by a 3D printer using a cyclic olefin copolymer (TOPAS) is designed to scan an area of 1.5 cm x 1.5 cm. We characterize this lens by investigating its focusing properties, the f-theta distortion, and scattering losses caused by the 3D printing process. We find that our scanning system offers diffraction-limited imaging up to 2 THz and satisfies the f-theta condition very well. Hence, this approach offers simple, cost-effective THz-imaging with the potential for high scanning rates.

Q 59.76 Thu 16:30 Empore Lichthof

Laser Power Stabilization via Radiation Pressure — •Graziano Pascale, Marina Trad Nery, and Benno Willke — Max Planck Institute for Gravitational Physics (AEI), Hannover

This work reports a new scheme for laser power stabilization in which the power fluctuations of a laser beam are detected via the radiation pressure they produce in a suspended mirror. The ultimate goal of this experiment is to demonstrate an improved technique for power stabilization that can be implemented in the future generations of Gravitational Wave Detectors (GWDs). Most of the current stabilization techniques rely on sensing a small fraction of the laser power by a photodetector. These techniques are fundamentally limited by the high relative shot noise in the photodetector, which couples as sensing noise in the feedback loop.

To overcome this limit, the technique presented on this poster consists on sensing the full beam power of the laser via radiation pressure in a highly reflective micro-oscillator mirror. A proof of principle experiment has been successfully demonstrated in the past years and now an upgraded version is being setup. A key component of the current experiment is a novel micro-oscillator mirror with a spring constant smaller than 10-5 N/m and that might withstand 4 W of power. With the experiment presented in this poster, we want to demonstrate a relative power noise below 10^(-9) Hz^(-(1/2)) at frequencies around 10 Hz, which might be required in future GWDs.

Q 59.77 Thu 16:30 Empore Lichthof

Influence of Temperature and Salinity on the Spectral Characteristics of Brillouin-Scattering in Water — •Daniel Koestel and Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, 64289 Darmstadt, Germany

In our group we are developing a LiDAR-system for remote sensing the temperature and salinity in the ocean upper-mixed layer (~100m depth). We successfully demonstrated the functionality of this setup with a temperature resolution of up to 0.07°C and a depth resolution of up to 1m [1]. Both, spectral Brillouin shift and Brillouin linewidth (FWHM), depend on temperature and salinity. The spectral shift dependency of said parameters has already been studied extensively in the past [2,3]. This contribution aims to bring light to the less researched linewidth dependency on temperature and salinity [4]. For this purpose, we generated spontaneous Brillouin-scattering at 530nm in water in a laboratory environment at different temperatures and salinities. We will present our latest results and discuss further steps in the development. [1] A. Rudolf, Th. Walther, "Laboratory demonstration of a Brillouin lidar to remotely measure temperature profiles of the ocean", Opt. Eng. 53(5) (2014). [2] K. Schorstein, E. S. Fry, and Th. Walther, "Depth-resolved temperature measurements of water using the Brillouin lidar technique", Appl. Phys. B 97(4), 931-934 (2009). [3] E. S. Fry et al., "Remote sensing of the ocean: measurement of sound speed and temperature", Proc. SPIE (1998). [4] E. S. Fry et al., "Temperature dependence of the Brillouin linewidth in water", J. Modern Opt. 49(3-4), 411-418 (2002).

Q 59.78 Thu 16:30 Empore Lichthof

Novel tunable cw UV laser system for laser cooling of bunched relativistic ion beams — •Jens Gumm, Jonas Moos,

and Thomas Walher — TU Darmstadt

Experiments with highly charged ions at relativistic energies are of great interest for many atomic and nuclear physics experiments at accelerator facilities. In order to decrease the longitudinal momentum spread and emittance, laser cooling has proven to be a powerful tool. In this work, we present a cw UV laser system operating at 257.25 nm for ion beam cooling at the ESR at GSI. The laser system will be used to minimize the final ion beam momentum spread and, therefore, the ion bunch length.
The laser can be scanned mode-hop free, via two SHG stages, over 20 GHz with a 50 Hz scan rate. In our latest measurements, we achieve a power of 1.7 W in the UV regime employing a novel elliptical focussing cavity to reduce the degradation effect in BBO.

Q 59.79 Thu 16:30 Empore Lichthof

A pre-stabilized 1550 nm laser source for the ETpathfinder — •Nicole Knust, Fabian Meylahn, and Benno Willke — Leibniz Universität Hannover / Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Callinstr. 38, 30167 Hannover, Germany

The ETpathfinder is a new facility for testing technologies for the future third-generation gravitational wave observatory called Einstein Telescope. Three of the six interferometers of the Einstein Telescope are proposed to use silicon mirrors at a cryogenic temperature of about 10 K to reduce thermal noise. For compatibility with the new mirror material silicon, a shift to longer wavelengths than the currently used 1064 nm is required. The ETpathfinder will support the investigation of the potential of longer wavelengths in combination with silicon mirrors and the cryogenic cooling of an interferometer. Here we present the frequency and power stabilized laser source for the ETpathfinder with a wavelength of 1550 nm. In our design, the beam of a low-noise, low-power external cavity diode laser is amplified to 10 W output power in two stages. To reduce the beam pointing and higher order mode content, the beam is filtered by an optical cavity. Active, multiple path, and high-bandwidth laser power and frequency stabilizations are implemented to achieve the laser stability needed for use in gravitational wave detectors.

Q 59.80 Thu 16:30 Empore Lichthof

Laser noise in interferometric gravitational wave detectors — •Robert Fabian Maciy — Callinstraße 38, 30167 Hannover — Prinz-Albrecht-Ring 40, 30657 Hannover

This poster presents simulations of laser noise requirements for the laser source of future interferometric gravitational wave detectors, especially for the Einstein Telescope. The Einstein Telescope is a third generation gravitational wave detector that is currently in the design phase and is anticipated to achieve higher sensitivity over a wider frequency range compared to second generation gravitational wave detectors like Advanced LIGO by using longer interferometer arms and advanced experimental techniques. An understanding of how laser frequency and power noise couples to the detector output is crucial to calculate the stringent requirements for the laser system and the optics as well as to possible optimize the interferometer and laser design.

On this poster we will show the results from analytical and numerical calculations of the transfer functions of laser noise propagating through individual optical subsystems and the complete interferometer. As the detector is a complex instrument we will present an intuitive description of noise coupling at different complexity levels. Finally a initial requirement for the stability of the laser source for the Einstein Telescope is shown and discussed.