A 46: Precision Measurements and Metrology (Optical Clocks) (joint session Q/A)

Time: Friday 10:30–12:15 Location: K 2.013

A 46.1 Fri 10:30 K 2.013

Precision Paul trap for frequency metrology with Coulomb crystals — •André P. Kulosa, Dimitri Kalincev, Jan Kiethe, Tabea Nordmann, Nimrod Hausser, Chih-Han Yeh, Alexandre Didier, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Deutschland

We report on our new scalable precision ion trap capable of trapping Coulomb crystals with 100 ions and more in each of the trap segments. We demonstrate that the excellent control of 3D excess micromotion over a single ion [1] also holds for a linear chain of 14 ions via spatial imaging with atomic resolution. We find that in a trap segment of our ion trap the time dilation shift due to axial micromotion is as low as 10^{-19} over a range of 400μm and below 10^{-18} within 2mm. After quench-assisted cooling of a single $^{172}Yb^+$ ion to its motional ground state, we observe a heating rate of less than 1 phonon/s and in total a $1/f$ dependence on electric field noise induced by fluctuating charges on the trap electrodes. Based on further experimental investigations of the trap environment, we derive an uncertainty budget close to 1×10^{-19} for a multi-ion clock operated with mixed In^+/Yb^+ crystals.

[1] J. Keller et al., *J. Appl. Phys.* **118**, 104501 (2015)

A 46.2 Fri 10:45 K 2.013

^{24}Mg optical lattice clock — •Nandan Jha, Dominika Fim, Klaus Zipfel, Steffen Rühmann, Steffen Sauer, Waldemar Friesen-Piepenbrink, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Magnesium is a promising candidate for an optical lattice clock due to its low black body radiation sensitivity. In our previous measurements, the tunneling induced broadening for the bosonic ^{24}Mg in shallow lattices had limited the linewidth of the clock transition to kHz scale [1]. We have improved upon these measurements by increasing the intra-cavity optical lattice power to perform spectroscopy in a $50\,E_r$ deep lattice. Reduced tunneling along with improved detection efficiency further allowed us to operate at lower excitation fields to achieve a linewidth below 50 Hz. With the reduced linewidth, we have performed our first systematic shift measurements with an overall error budget in the 10^{-15} regime. The fiber link setup by the group of G. Grosche between IQ, Hannover and PTB, Braunschweig [2] allowed us to compare the Mg lattice clock against the frequency references at PTB. In this contribution, we discuss our systematic shift measurements, as well as our efforts towards further improving the line-Q factor of the clock transition.

[1] A. Kulosa et al., Phys. Rev. Lett. **115**, 240801 (2015).
[2] G. Grosche, Opt. Lett. **39**, 2545 (2014).

A 46.3 Fri 11:00 K 2.013

An iodine frequency reference based on an ECDL at 1064 nm for a sounding rocket mission. — •Franz Balthasar Gutsch[1], Klaus Döringshoff[1], Vladimir Schkolnik[1,2], Markus Krutzik[1,2], Achim Peters[1,2], and Team JOKARUS[1,2,3,4,5] — [1]Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut, Berlin — [3]ZARM, Uni Bremen — [4]Johannes Gutenberg-Universität Mainz — [5]Menlo Systems GmbH, Martinsried

Within the JOKARUS collaboration, we built a autonomously operating, active optical absolute frequency reference at 1064 nm based on molecular iodine that is scheduled for launch on a sounding rocket (TEXUS 54) in April 2018. Laser-based frequency references with high accuracy and stability are needed for space missions dedicated to precision tests of fundamental physics, Earth observation, navigation or gravitational wave astronomy. Frequency stabilization to the narrow, sub-MHz hyperfine transitions of the iodine R(56)32-0 line provides the means to fulfill the requirements of planned missions like LISA or NGGM. Our system relies on modulation transfer spectroscopy of iodine gas at 532 nm, using a frequency-doubled, micro-integrated, narrow-linewidth ECDL MOPA. In order to verify the lock stability, there will be an in-flight comparison to an RF-clock-referenced frequency comb. In this talk, we report on the system design, performance and results of environmental testing. Further, we present the auto-lock as well as our approach to experiment control. This work is supported by the DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant number DLR 50WM 1646.

A 46.4 Fri 11:15 K 2.013

Characterisation of a Reference Cavity for a Transportable Sr Optical Clock. — •Sofia Herbers, Sebastian Häfner, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Ultra-stable high-finesse cavities are used, inter alia, in interrogation lasers of optical clocks, that are employed for relativistic geodesy or test of fundamental physics.

One limiting factor of ultra-stable high-finesse cavities is the Brownian noise of the mirror coatings. This noise is reduced for state-of-the-art cavities by using single-crystalline mirror coatings. Furthermore, the cavity needs to be isolated from environmental conditions like seismic noise or temperature fluctuations that result in a length change of the cavity. Therefore, special mounts have to be employed to decouple the cavity from seismic noise. However, for a transportable cavity, most of these approaches like a soft and loose mounting are not suitable. Thus, other solutions must be found that do not degrade the cavity performance.

Here, we present the characteristics of a transportable 20 cm long reference resonator for a transportable Sr lattice clock heading for a fractional frequency instability of $1\cdot10^{-16}$ using single-crystalline mirrors with a finesse up to 300 000 as well as a rigid cavity mounting.

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A 46.5 Fri 11:30 K 2.013

Possibility of laser stabilization with trapped cavity-coupled ions — •Georgy Kazakov[1,2] and Thorsten Schumm[1] — [1]Technische Universität Wien — [2]Wolfgang Pauli Institut

The concept of an active optical frequency standards was proposed about 10 years ago [1,2]. The idea is to use optically trapped alkaline-earth atoms as a gain medium to built an extremely narrow-line laser, whose frequency will be robust to fluctuations of the cavity length. The main challenge towards the realization of this concept is the short trap lifetime of the atoms. Recently we showed [3], that in such a laser, neutral atoms may be replaced by charged ions in a radio-frequency Paul trap with much longer lifetime. Our idea is based on the effect of syncronization of radiating dipoles and on the possibility to compensate (in leading orders) micromotion-induced shifts for some ion species in specially designed traps. We discuss in detail the perspectives of creating of the bad cavity laser based on a Coulomb crystal in the linear Paul trap. We consider compensation of the micromotion-induced shifts, coupling of the quadrupole transition with the cavity mode in different geometries, various ion species and clock transitions as well as pumping schemes, and estimate attainable characteristics of different trapped-ion bad-cavity lasers.

[1] J. Chen, X. Chen, Proceedings of the 2005 IEEE Int. Freq. Cont. Symp. Exp. 608 (2005) [2] D. Meiser et al, Phys. Rev. Lett. 102, 163601 (2009) [3] G. Kazakov et al, Phys. Rev. A 96, 023412 (2017)

A 46.6 Fri 11:45 K 2.013

QUEEN: Design Study for Optical Frequency References on Small Satellites — •Aline N. Dinkelaker[1], Heike Christopher[2], Doreen Brandt[2], Philipp Werner[3], Julian Bartholomäus[3], Merlin F. Barschke[3], and Markus Krutzik[1] — [1]Humboldt-Universität zu Berlin — [2]FBH Berlin — [3]TU Berlin

Optical frequency references are key to fundamental physics experiments involving cold atoms or optical atomic clocks. For future experiments in space, the frequency references have to be compact and robust in order to meet the size, weight and power (SWaP) requirements while providing the experiments with frequency stabilized light of sufficient optical output power. In the Phase 0/A study QUEEN, a mission for the demonstration of optical frequency references is investigated. Small satellites are ideally suited for in-orbit demonstration as they allow rapid, iterative mission development. For QUEEN, the modular, flight-proven TUBiX20 platform by TU Berlin will be adjusted to match the payload's requirements. We examine the use of a micro-integrated, frequency-stabilized semiconductor diode laser system by HU Berlin and FBH for in-orbit demonstration of an optical frequency reference and present possible mission scenarios. Long-term tests in orbit –specifically with respect to thermal variation and exposure to radiation– thus complement existing experiments in drop towers and on sounding rockets.

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A 46.7 Fri 12:00 K 2.013

Laser-induced electronic bridge for characterization of the ^{229m}Th isomer transition with a tunable optical laser — •Pavlo Bilous[1], Ekkehard Peik[2], and Adriana Pálffy[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

The isotope ^{229}Th is unique among the other nuclei due to its long-lived first excited state ^{229m}Th at the energy of 7.8 eV lying in the optical range. Its decay to the ground state has very narrow width and high stability to external fields, rendering ^{229}Th a candidate for a first nuclear clock at unprecedentedly high relative accuracy of 10^{-19}. Precise knowledge of the transition parameters such as energy and γ-decay rate is however needed for its implementation.

Due to the low energy of the state ^{229m}Th the nuclear transition can be strongly coupled to the atomic shell processes with considerable enhancement of the nuclear decay rate. An example of such processes is laser-induced electronic bridge (LIEB) [1]. The excited nuclear state decays by transfering its energy to the outer electrons. The electronic shell is then promoted to a high-lying bound state by absorption of a laser photon and a virtual photon coming from the nucleus. Here we investigate theoretically LIEB as a means for precise determination of the ^{229m}Th energy and γ-decay rate. Depending on the actual value of the nuclear transition energy, the enhancement factor compared to the radiative nuclear decay can achieve up to 10^8 [1].

[1] P. V, Bilous, E. Peik and A. Pálffy, New J. Phys. in press (2017)