Q 32: Precision Measurements and Metrology (Optical Clocks)

Time: Wednesday 14:00–16:00 Location: a310

Q 32.1 Wed 14:00 a310

Prospects of frequency distribution networks to validate and reference satellite gravity prove Earth observation satellite missions — Stefan Schröder[1], •Simon Stellmer[2], and Jürgen Kusche[1] — [1]Institut für Geodäsie und Geoinformation, Universität Bonn, Nussallee 17, 53115 Bonn — [2]Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

Optical clocks have shown fractional instabilities in the range of 10^{-18} and continue to be improved in terms of precision and accurary, uptime, and transportability. Their "ticking rate" depends on the gravitational redshift, which opens the possibility to deploy such clocks for a measurement of the local gravitational potential. An ensemble of optical clocks could provide a geopotential reference system.

Here, we investigate the prospects of an optical time and frequency distribution network to provide a reference for satellite missions such as GRACE, GRACE-FO and Next-Generation Satellite Missions. The importance of such missions in the observation of mass transport related to climate change cannot be underestimated. New concepts to provide ground validation and referencing for these missions are highly desired.

Q 32.2 Wed 14:15 a310

Quintupling of a laser at telecom wavelength — •Maya Büki, David Röser, and Simon Stellmer — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

The demand for highly accurate frequency standards has lead to the development and improvement of optical clocks. For a broad spectrum of applications, also outside of the laboratory, an improvement of already existing optical clocks is required. The $^1S_0 - {}^3P_0$ transition in zinc could form the basis of such a novel optical clock.

The advantage of zinc is that the clock transition at 309.5 nm and the intercombination line $^1S_0 - {}^3P_1$ at 307.6 nm can be derived as the fifth harmonic of a laser at telecom C-Band wavelength, which allows transfer of the clock signal via optical fibres.

We report on the development of a frequency quintupled diode laser at 1538 nm using three frequency conversion stages in nonlinear crystals.

Q 32.3 Wed 14:30 a310

Rubidium vapor-cell frequency references based on 5S to 6P transitions — •Julien Kluge[1], Klaus Döhringshoff[1,2], Conny Glaser[3], Florian Karlewski[4], Jens Grimmel[3], Manuel Kaiser[3], Andreas Günther[3], Helge Hattermann[3], József Fortágh[3], and Markus Krutzik[1,2] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [3]Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen — [4]HighFinesse GmbH

Optical frequency standards based on spectroscopy of Rubidium vapor benefit from high component technology readiness level, allow for vapor-cell micro-integration and therefore physics package miniaturization. In this presentation, we discuss the optical properties of Rubidium beyond the D1/D2 line and show recent results of high precision absolute frequency measurements of the 6P manifold in conjunction with hyperfine structure constants evaluation. Additionally, we give an overview of two concepts we currently study for future compact frequency references onboard small satellites. One is based on direct modulation transfer spectroscopy of the $5S \to 6P$ transition using GaN based diode laser operating at 420 nm and the other on spectroscopy of the two-photon transition from $5S \to 5D$ at 778 nm.

This work is supported by the DLR with funds from the BMWi under grant number 50WM1857, 50RK1971 as well as by the DFG (SSP 1929 GiRyd and CIT) and BMBF (FKZ: 13N14903). C. Glaser would like to thank the Evangelische Studienstiftung Villigst e.V.

Q 32.4 Wed 14:45 a310

Progress towards a frequency measurement campaign for magnesium lattice clock — •Nandan Jha, Dominika Fim, Steffen Sauer, Waldemar Friesen-Piepenbrink, Klaus Zipfel, Wolfgang Ertmer, and Ernst Maria Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

The $^1S_0$ - $^3P_0$ clock transition of Mg with much lower sensitivity to black body radiation compared to Sr and Yb could be interesting for future room temperature optical clocks. In Hannover, we therefore are working on the development of a bosonic magnesium optical lattice clock. We have previously reported on using a two stage MOT to load 10^3 atoms into an optical lattice operating at the magic wavelength of 468 nm where the optical lattice potential generated inside an enhancement cavity allows us to perform spectroscopy in the Lamb Dicke regime. In 2017, we performed the first frequency measurement for the $^1S_0$ - $^3P_0$ clock transition in the 10^{-15} regime. In this contribution, we will discuss our recent spectroscopy measurements with a resolved clock transition linewidth of 7(3) Hz, which allows us to perform self-comparison measurements with a precision in the 10^{-17} regime. We have therefore been able to determine some of the systematic frequency shift contributions with an uncertainty in the 10^{-17} regime as well. We will give details on these preliminary measurements for the uncertainty budget as we progress towards our next frequency measurement campaign.

Q 32.5 Wed 15:00 a310

Exploring zinc as a possible candidate for optical clocks — •David Röser, Maya Büki, and Simon Stellmer — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

Recent advances in the development of optical clocks including the exploration of various atomic platforms lead to impressive fractional precision of frequency measurements.

Although many alkaline-earth like elements (group IIa & IIb) are investigated with regard to possible clock performance, zinc has never been investigated experimentally.

We report on the advantages of using zinc and present the status of our experiment probing suitable concepts of constructing a zinc clock.

Q 32.6 Wed 15:15 a310

Towards a strontium beam optical frequency reference based on the $^1S_0 \to {}^3P_1$ intercombination line on a sounding rocket — •Martin Jutisz[1], Oliver Fartmann[1], Conrad L. Zimmermann[1], Franz B. Gutsch[1], Vladimir Schkolnik[1], Frederik Böhle[2], Matthias Lezius[2], Ahmad Bawamia[3], Christoph Pyrlik[3], Achim Peters[1,3], Ronald Holzwarth[2], Andreas Wicht[3], and Markus Krutzik[1,3] — [1]Humboldt Universität zu Berlin — [2]Menlo Systems GmbH, Martinsried — [3]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin

Compact and rugged optical clocks and frequency references receive increased attention with respect to spaceborne operation as interspacecraft ranging often relies on frequency stabilized lasers and optical clocks are candidates for next-generation GNSS core equipment. In the OPUS project, we are working towards a compact sounding rocket payload consisting of a strontium beam optical frequency reference and a frequency comb. We utilize the 7.5 kHz broad $^1S_0 \to {}^3P_1$ intercombination line in ^{88}Sr for Ramsey-Bordé interferometry with a pre-stabilized 689 nm ECDL. Furthermore, we employ electron shelving detection on the 32 MHz broad $^1S_0 \to {}^1P_1$ line at 461 nm for reading out the interference fringes. We will give an overview on the system architecture, present first results of the ground testbed activities and discuss an expected error budget. 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 DLR50WM1851-53.

Q 32.7 Wed 15:30 a310

Control of mixed Coulomb crystals in a multi-ion clock — •Hartmut Nimrod Hausser, Tabea Nordmann, Jan Kiethe, Leon Schomburg, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

The relative uncertainty of a few 10^{-18} of state-of-the-art single-ion optical clocks paves the way for new applications such as relativistic geodesy, resolving height differences with cm-precision [1] and for the search of physics beyond the standard model, e.g. for dark matter [2]. In order to resolve the atomic frequencies in shorter time the concept of the multi-ion clock was proposed [3]. Here we present the progress towards an $^{115}In^+$-multi-ion clock. In our approach, we trap $^{115}In^+$

and $^{172}Yb^+$ ions in a chip-based linear Paul trap forming a mixed Coulomb crystal. The In^+/Yb^+-configuration is optimized in terms of cooling time and reproducibility. We present the deterministic loading of a controlled number of In^+ and Yb^+ ions and reordering after collisions with background gas. Finally, we will discuss the estimated uncertainty of the indium multi-ion clock for our experimental setup.

This project has received funding from the European Metrology Programme for Innovation and Research (EMPIR) co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme (Project No. 17FUN07 CC4C).

[1] T.E. Mehlstäubler et al., *Rep. Prog. Phys.* **81**, 6 (2018).
[2] A. Derevianko, *Phys. Rev. A* **97**, 042506 (2015)
[3] C. Champenois et al., *Phys. Rev. A* **81**, 043410 (2010).

Q 32.8 Wed 15:45 a310

Charactarization of a segmented multi-ion trap for transportable optical clocks with low micro motion — •Hendrik Siebeneich[1], Florian Köppen[1], Pedram Yaghoubi[1], Michael Johanning[1], Christof Wunderlich[1], Malte Brinkmann[2], Alexandre Didier[2], Tanja Mehlstäubler[2], Stefan Brakhane[3], and Dieter Meschede[4] — [1]Universität Siegen — [2]Physikalisch Technische Bundesanstalt — [3]Toptica — [4]Universität Bonn

Single ion clocks can serve as one of today's best frequency standards with an accuracy of order 10^{-18} [1]. Developing a transportable optical ion clock using the $2S_{1/2}$ - $2D_{3/2}$ resonance with wavelength near 436 nm in a single $^{171}Yb^+$ ion is the goal of the *opticlock* [2] consortium. As part of this project we develop a next-generation set-up employing a linear multi-ion trap in order to reduce the measurement time necessary to reach a desired uncertainty. For a beneficial operation of a multi-ion clock, the rate of collisions with background gas has to be kept small. Also, sufficiently low micromotion has to be ensured for all ions in a linear ion crystal. With focus on these aspects, we present the status of the experimental setup, and characterize its operation.

[1] N. Huntemann et al., Phys. Rev. Lett. 116, 063001
[2] https://www.opticlock.de; *opticlock* is supported by the bmbf under grant no. 13N14385.