A 18: Precision Measurements and Metrology V (joint session Q/A)

Time: Wednesday 14:00–15:30 Location: Q-H11

A 18.1 Wed 14:00 Q-H11

A two-way free-space link for optical frequency comparisons — •Jingxian Ji[1,2], Alexander Kuhl[1], Atif Shehzad[1], and Sebastian Koke[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]DLR-Institute for Satellite Geodesy and Inertial Sensing, Hannover, Germany

Optical clock networks connected by phase-coherent links have enormous potential in basic and applied sciences such as geodesy, astronomy and global navigation satellite systems. Free-space links extend fiber-based connection capabilities and offer to connect a larger community of users. In future, free-space links may even link earthbound stations, satellites or the international space station.

Here we investigate a two-way free-space frequency comparison link using a continuous wave laser signal. Through this two-way approach, the influence of the path length fluctuations is supressed by processing the beat signals at the two end points. This system enables us to characterize the non-reciprocity of free-space connections, i.e., the fundamental uncertainty limit. Different from earlier publications, we elimate the interferometric noise contributions completely. By this we achieve fractional frequency comparison uncertainties below 10^{-21} for the averaging time of only 1000 s showing a significant improvement in resolution. This result opens the way to the high-resolution frequency comparison with simple electronics over free-space links.

A 18.2 Wed 14:15 Q-H11

Highly stable transportable UV laser system for an optical clock — •Benjamin Kraus[1,2], Stephan Hannig[1,2], Sofia Herbers[1,2], Fabian Dawel[1], Johannes Kramer[1], Constantin Nauk[1,2], Christian Lisdat[1], 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 provide the most precise frequency standards. They enable high accuracy tests of fundamental physics, relativistic geodesy, and a possible future redefinition of the SI second. For side-by-side clock comparisons, accurate transportable optical clocks are necessary. We present a rack-integrated highly stable clock laser system at 267.4 nm for a transportable Al^+ clock. The system consists of a fibre laser at 1069,6 nm locked to a cavity designed to reach fractional frequency instabilities as low as 10^{-16}. Two sequential single-pass second harmonic generation stages are hermetically sealed inside an aluminium box to form a robust, compact, and stable fibre-coupled frequency quadrupling module. The setup is interferometrically phase-stabilized, enabling second long probe times.

A 18.3 Wed 14:30 Q-H11

Rubidium vapor-cell frequency reference based on 5S to 5D two-photon transition for space applications — •Julien Kluge[1,2], Klaus Döringshoff[1,2], Daniel Emanuel Kohl[1], Aaron Strangfeld[1,2], and Markus Krutzik[1,2] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Höchstfrequenztechnik

Optical frequency standards based on two-photon spectroscopy using rubidium vapor are a promising candidate for realization of simple and compact optical clocks for space applications.

In this presentation, we show the development of an optical clock working at the rubidium 5S to 5D two-photon transition at 778 nm. For short timescales, a fractional frequency in-stability in the order of 10^{-13} is achieved in a setup with a small size, weight and power (SWaP) budget. Details of the corresponding vapor cell assembly, the supporting simulations and its parameters are shown as well. Recent progress towards miniaturization and automated operation of the physics package enables the future development of a compact and reliable setup to meet the stringent requirements of a prospective space mission.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers 50RK1971, 50WM2164.

A 18.4 Wed 14:45 Q-H11

Towards a strontium optical frequency reference based on Ramsey-Bordé interferometry — •Ingmari C Tietje[1], Oliver Fartmann[1], Martin Jutisz[1], Conrad L Zimmermann[2], Vladimir Schkolnik[1,2], and Markus Krutzik[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik — [2]Ferdinand-Braun-Institut GmbH, Leibniz-Institut für Höchstfrequenztechnik, Berlin

We present the status of our optical frequency reference based on Ramsey-Bordé interferometry using the $^1S_0 \rightarrow {}^3P_1$ intercombination line in strontium. Next to the current state of the atom interferometer based on a thermal atomic beam, we will present details of our compact and high-flux atomic oven as well as the cavity-stabilised laser system at 689 nm.

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 DLR50WM1852 and by the German Federal Ministry of Education and Research within the program quantum technologies - from basic research to market under grant number 13N15725.

A 18.5 Wed 15:00 Q-H11

Dynamical decoupling for a robust Lorentz Symmetry test with $^{172}Yb^+$ ions — •Chih-Han Yeh[1], Kai C. Grensemann[1], Laura S. Dreissen[1], Henning A. Fürst[1,2], Dimitri Kalincev[1], André P. Kulosa[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 report on our progress of a novel test of local Lorentz invariance (LLI) in the electron-photon sector using the meta-stable electronic F-state of trapped $^{172}Yb^+$ ions [1]. The Zeeman structure of the F-state contains highly relativistic, orthogonally oriented electron orbitals which provide access for testing LLI violation. A potential violation would lead to an anomalous fluctuation of the energy splitting between the substates. We measure this fluctuation via detection of the population imbalance after a dynamical decoupling (DD) [2] sequence. This sequence uses rf pulses to suppress magnetic field noise for enabling long coherence times.

Starting with a single ion, we have demonstrated coherent excitation to the F-state via an electric octupole transition [3]. A coherence time of several seconds has been achieved with the DD sequence in the F-state. With these preparations, we have recently demonstrated a 24 h-run of the LLI test sequence and are now evaluating the systematics.

[1] V.A. Dzuba et al., *Nature Physics* **12**, 465-468 (2016). [2] R. Shaniv et al., *Phys. Rev. Lett.* **120**, 103202 (2018). [3] H. A. Fürst et al., *Phys. Rev. Lett.* **125**, 163001 (2020)

A 18.6 Wed 15:15 Q-H11

A dual-species multi-ion clock — •Hartmut Nimrod Hausser[1], Tabea Nordmann[1], Jan Kiethe[1], Jonas Keller[1], Nishant Bhatt[1], Moritz von Boehn[1], and Tanja E. Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Leibniz Universität Hannover, Hannover, Germany

The best optical ion clocks achieve systematic uncertainties around 1×10^{-18} enabling new applications such as relativistic geodesy with cm-level height resolution [1] and advancing the search for physics beyond the standard model. The major drawback of single-ion clocks is the low signal-to-noise ratio due to quantum projection noise which requires averaging times of several weeks to achieve a matching systematic uncertainty. Increasing the number of ions for example by a factor N ideally leads to N-times shorter averaging time for a given frequency resolution. Due to its intrinsically low sensitivities, $^{115}In^+$ is an ideal candidate for a multi-ion clock with low systematic shifts [2]. We characterize clock operation with an $^{115}In^+$ ion sympathetically cooled by an $^{172}Yb^+$ ion in a segmented linear Paul trap and discuss its systematic uncertainty budget at the 10^{-17}-level. We present our solution for scaling up the number of clock and cooling ions including the control of their order within the crystal and show multi-ion spectroscopy results that are optimized for contrast. The observed excitation agrees with our simple model, which accounts for the Debye-Waller effect due to the crystal dynamics after sympathetic cooling.

[1] T.E. Mehlstäubler et al., *Rep. Prog. Phys.* **81**, 6 (2018)
[2] N. Herschbach et al., *Appl. Phys. B* **107**, 891-906 (2012)