Q 7: Precision Measurements and Metrology I

Time: Monday 14:00–15:45 Location: M 11

Q 7.1 Mo 14:00 M 11

How to determine the blackbody shift in Sr optical lattice clocks — •Thomas Middelmann, Christian Lisdat, Stephan Falke, Joseph Sundar Raaj Vellore Winfred, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Optical clocks have surpassed ^{133}Cs microwave clocks in stability and systematic uncertainty. The $^1S_0 - {}^3P_0$ clock transition of ^{88}Sr and ^{87}Sr is investigated as atomic reference in an optical lattice clock. Currently the largest contribution to the uncertainty of $1 \cdot 10^{-16}$ is due to the ac Stark effect from ambient blackbody radiation. In good approximation the blackbody shift is proportional to the differential static polarizability of the two clock states and to the fourth power of the environmental temperature.

To reduce the uncertainty of the blackbody shift we prepare to measure the differential static polarizability in a dc electric field. Moreover, we want to reduce the blackbody shift itself by a low temperature environment. Trapped in a horizontal 1-D optical lattice the strontium atoms will be transported into a dc electric field or a liquid nitrogen cooled environment respectively. It is necessary to move the interference pattern together with the focus position to ensure invariant trap depth. This is achieved by moving the lattice optics, which are on opposite sides of the vacuum system, with two air bearing stages. The current status of the experiment will be presented in the talk.

The work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and the ERA-NET Plus Programme.

Q 7.2 Mo 14:15 M 11

A compact source of ultracold Yb for an optical lattice clock — •Charbel Abou-Jaoudeh, Cristian Bruni, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, 40225 Düsseldorf

Neutral ytterbium (Yb) is an interesting candidate for the realization of an optical clock at a wavelength of 578 nm. In the fermionic isotopes, the corresponding transition $^1S_0 - {}^3P_0$ has a natural linewidth of a few tens of mHz. The use of bosonic istopes (e. g. ^{174}Yb) in an optical lattice clock is also possible if well-controlled magnetic fields are used to enable the otherwise forbidden direct optical excitation of the clock transition.

Here we report on the development of a transportable source of ultracold Yb atoms for an optical lattice clock. All laser systems in the compact apparatus are diode-based. We have already implemented the first cooling stage using blue laser diodes at 399 nm and realized a magnetooptical trap with more than 10^7 atoms. Successful transfer of bosonic ^{174}Yb and fermionic ^{171}Yb into the second stage magnetooptical trap operating on the narrow $6^1S_0 \rightarrow 6^3P_1$ at 556 nm and further cooling of the atoms to temperatures of a few 100 μK has also been achieved. The next step will be to load the atoms into a 3D optical lattice at the magic wavelength of 759 nm which is formed in a folded linear resonator inside the vacuum chamber. The special design of the lattice setup allows for a large-volume optical lattice with a diameter of 150 μm and a potential depth of 100 μK if 200 mW of radiation from a tapered diode laser are coupled into the resonator.

Q 7.3 Mo 14:30 M 11

Development of a sub-Hz laser system for optical clocks — •Christian Hagemann[1], Thomas Kessler[1], Uwe Sterr[1], Fritz Riehle[1], Michael J. Martin[2], and Jun Ye[2] — [1]Physikalisch-Technische Bundesanstalt and Centre for Quantum Engineering and Space-Time Research QUEST, Bundesallee 100, 38116 Braunschweig, Germany — [2]JILA, NIST and University of Colorado, 440 UCB, Boulder, CO 80309-0440, USA

Today's best optical clocks are outperforming the best primary Cs frequency standards. The short-term performance of such clocks is limited by the frequency stability of the lasers that are used to interrogate the atomic or ionic quantum transition used as the pendulum of the atomic clock. In such setups a interrogation laser is locked to a high performance cavity for frequency stabilization.

In the QUEST framework we are developing a novel single-crystal silicon cavity operated at a temperature of 120 K aiming at achieving a stabilized laser linewidth well below 1 Hz. In this talk we present the design of the silicon cavity and current setup, comprising the cryostat as well as the laser system. Possible noise sources limiting the frequency stability such as mechanical vibrations, temperature drifts and thermal noise will be discussed.

Q 7.4 Mo 14:45 M 11

Octave-Spanning Frequency Comb Generation in a Microresonator — Pascal Del'Haye[1], •Tobias Herr[1], Emanuel Gavartin[2], Ronald Holzwarth[1], and Tobias Kippenberg[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]École Polytechnique Fédérale de Lausanne, CH 1015, Lausanne, Switzerland

We demonstrate for the first time the generation of an octave-spanning optical frequency comb via four-wave mixing in a fused silica microresonator. The microresonator is resonantly pumped via a tapered optical fiber with an amplified tunable diode laser (continuous-wave) at a pump power of 2.5 Watt. The generated frequency combs extend from 990 nm to 2170 nm, covering more than a full octave and are continuously tunable over more than 1 THz by changing the pump laser frequency. Octave spanning frequency combs directly generated in a monolithic microresonator are an important step towards fully self-referenced optical frequency combs on a chip.

Q 7.5 Mo 15:00 M 11

Optical single-ion clock using quantum logic — •Olaf Mandel, Ivan V. Sherstov, and Piet O. Schmidt — QUEST Inst. for Exp. Quantum Metrology, PTB Braunschweig and Leibniz Univ. of Hannover, Germany

We present the status of a recently started project to build a transportable optical clock based on a single aluminum ion. $^{27}Al^+$ has been chosen as the clock ion since it has a narrow (8 mHz) clock transition at 267 nm which exhibits no electric quadrupole shift and a low sensitivity to black-body radiation. The design goals for the frequency standard are an inaccuracy of 10^{-17} or better and relative stability of 10^{-15} in one second.

The $^{27}Al^+$ "clock ion" will be trapped together with a $^{40}Ca^+$ ion which will act as a "logic ion" and is used for sympathetic cooling and internal state detection of the clock ion. After interrogating the $^{27}Al^+$ ion with the clock laser, its internal quantum state will be transferred to the logic ion with techniques developed for quantum information processing. The result of the clock interrogation can then be read out via the $^{40}Ca^+$ ion (see also [1]).

Clock comparison beyond a fractional uncertainty of 10^{-16} is only possible via dedicated optical fibers or by direct comparison of two physically close standards. As a consequence, we plan to build a portable system that allows us to travel to other sites and perform frequency measurements at the 10^{-17} level or below.

[1] C.-W. Chou *et al.*, arXiv:0911.4527v1 [quant-ph] (2009)

Q 7.6 Mo 15:15 M 11

Entanglement and precision measurements with states of a fluctuating number of particles — •Philipp Hyllus[1], Augusto Smerzi[1], and Luca Pezze[2] — [1]BEC-CNR-INFM and Dipartimento di Fisica, Università di Trento, I-38050 Povo, Italy — [2]Laboratoire Charles Fabry, Institut d'Optique, 2 Avenue Fresnel, 91127 Palaiseau - France

For linear interferometers operating with states with a fluctuating number of particles, we define the shot-noise limit and the ultimate limit allowed by quantum mechanics, the so-called Heisenberg limit, taking into account properly the number m of single measurement runs that a phase-estimation experiment consists of. We discuss the relation between sub shot-noise sensitivity and entanglement of the particles and generalize the spin-squeezing parameter of [D.J. Wineland, *et al.*, *Phys. Rev. A* **50**, 67 (1994)] to the case of non-fixed N.

Q 7.7 Mo 15:30 M 11

High precision cold atom gyroscope — •Christian Schubert, Sven Abend, Peter Berg, Timo Denker, Michael Gilowski, Gunnar Tackmann, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Due to its high potential, matter wave interferometry has been investigated as a tool for high precision inertial measurements for years. The research topic of the CASI project (Cold Atom Sagnac Interferometer) is a gyroscope using laser cooled Rubidium atoms and aiming for a sensitivity of a few 10^{-9} rad/s/Hz$^{1/2}$ for 10^8 atoms per shot. The atomic ensemble is launched in a pulsed mode onto a flat parabola with a forward drift velocity of 2,79 m/s leading to an interrogation time of over 50 ms. Via coherent beamsplitting using Raman transitions, the atomic trajectories forming the interferometer paths can enclose an area of several mm^2. In this talk we discuss the influence of the main noise sources which limit the sensitivity of our quantum sensor. Particularly, contributions affecting the beam splitting process as well as the detection will be considered. Furthermore, the lastest interferometry measurements will be presented. This work is supported by the DFG, QUEST, and IQS.