A 53: Precision measurements and metrology III (with Q)

Time: Friday 10:30–12:30 Location: DO24 1.101

Group Report A 53.1 Fri 10:30 DO24 1.101

Towards the Quantum Limit: Update from the AEI 10-meter Prototype — •Conor Mow-Lowry and the 10m prototype team — Max-Planck Institute for Gravitational Physics, Hannover, Germany

At the Albert Einstein Institute in Hannover we are building a prototype facility capable of housing experiments that will probe the boundaries of interferometric sensitivity. Our core experiment is a Fabry-Perot Michelson interferometer designed to reach the Standard Quantum Limit (SQL), the point where quantum radiation pressure noise and photon shot noise are equal. From there we can investigate techniques to surpass this limit.

Many of the infrastructure components of our facility are themselves research projects, borrowing from developments in space-based metrology and from the most sensitive devices in the world, interferometric gravitational-wave detectors. I will describe the status of the 10-meter project with a focus on the many interesting challenges between us and meeting our design goals.

A 53.2 Fri 11:00 DO24 1.101

Growing and characterisation of (thorium-doped) calcium fluoride crystals for a solid-state nuclear clock — •Matthias Schreitl[1], Georg Winkler[1], Christoph Tscherne[1], Simon Stellmer[1], Philipp Dessovic[2], Peter Mohn[2], Robert Jackson[3], and Thorsten Schumm[1] — [1]Vienna Center for Quantum Science and Technology (VCQ), Atominstitut, Technische Universität Wien — [2]Center for Computational Materials Science, Technische Universität Wien — [3]School of Physical and Geographical Sciences, Keele University

The isotope ^{229}Th is predicted to provide a unique low-energy excited nuclear state situated only 7.8 ± 0.5 eV [1] above the ground state, opening the possibility to access nuclear physics with lasers. An estimated lifetime of hours [1] makes this narrow transition an excellent candidate for a new time standard.

The transition energy still remains to be determined with higher precision. Our experimental approach is based on embedding ^{229}Th ($> 10^{14}$ nuclei) in the UV-transparent crystal structure of Calcium fluoride (CaF_2).

We present progress in CaF_2 growth in order to produce single crystals which are transparent in the relevant wavelength region. As the relevant isotope ^{229}Th is radioactive and only available in very small quantities, preliminary measurements are carried out with the stable isotope ^{232}Th. Here, we investigate the implantation of thorium ions into the crystal lattice and how this affects the transparency.

[1] B. R. Beck et al., Phys. Rev. Lett. 98, 142501 (2007)

A 53.3 Fri 11:15 DO24 1.101

Characterization of a Transportable Strontium Lattice Clock — •Stefan Vogt, Sebastian Häfner, Stephan Falke, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt (PTB); Bundesallee 100; 38116 Braunschweig

The excellent performance of optical frequency standards offers new prospects for applications as well as for fundamental research. Applications include the operation as optical clock and relativistic methods for geodesy. In fundamental research, new bounds for variations of e.g. the fine structure constant can be set and hence experimental input to the search for physics beyond the standard model can be provided.

Here we present the progress on a new apparatus for a lattice clock with strontium atoms, which is designed to be transportable. Laser cooling of strontium atoms into an optical lattice has been achieved and spectroscopy on the clock transition has been carried out. First characterizations of the apparatus indicate that a low inaccuracy of about 10^{-17} will be feasible with the transportable setup.

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A 53.4 Fri 11:30 DO24 1.101

Spectroscopy of the $^1S_0 \rightarrow {}^3P_0$ clock transition in magnesium — •André Kulosa, Steffen Rühmann, Dominika Fim, Klaus Zipfel, Steffen Sauer, Birte Lampmann, Leonie Theis, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

We report on the latest status of the magnesium optical lattice clock experiment at IQ in Hannover. 10^4 magnesium atoms are optically trapped in a lattice at the predicted magic wavelength of 469 nm. In order to fulfill the power requirements for sufficient trapping, the lattice is generated within a build-up cavity with a power enhancement factor of 30. The maximum circulating power is 2 W which can be computer-controlled for removing the hottest atoms during a ramping sequence.

As the bosonic isotope ^{24}Mg does not possess a nuclear spin and thus no hyperfine structure, the linewidth of the spin-forbidden clock transition naturally equals zero as there is no coupling to other states. However, laser excitation is possible under presence of a strong magnetic field coupling the $^3P_0$ state to the $^3P_1$ state.

Performing spectroscopy on the clock transition, we observe a clear asymmetry between the red and the blue sideband of the carrier signal where we calculate the temperature of the atoms to be 1.3 μK. Varying lattice power and wavelength, we are able to give a first estimate on the magic wavelength between 467.66 and 468.95 nm.

A 53.5 Fri 11:45 DO24 1.101

Detection of a single charge using the NV center in diamond — Florian Dolde[1], Marcus Doherty[2], Julia Michl[1], •Ingmar Jakobi[1], Philipp Neumann[1], Neil Manson[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut und SCoPE Research Center, Universität Stuttgart, Germany — [2]Laser Physics Centre, Australian National University, Canberra, Australia

Advancement towards the characterization of nanoscale systems is a matter of particular interest in metrology. A fundamental step in this progress is the sensing of single particles.

Using electric field sensing techniques with nitrogen-vacancy (NV) centers in diamond we are able to detect a single charge under ambient conditions [1].

We use a pair of NV centers for our studies. One NV center can be employed as a sensitive electrometer to detect changes in the electric field. The second NV is used as a source, where a single electron can be displaced by optically switching between its neutral and negative charge states. For this purpose the NV centers need to have a close distance which we show using super-resolution techniques. In consequence, our measurements provide direct insight into the charge dynamics inside the material on a nanoscopic scale.

[1] F.Dolde, et al., arXiv:1310.4240 (2013)

A 53.6 Fri 12:00 DO24 1.101

Long spin coherence of nitrogen-vacancy centres in high purity nanodiamonds — •Dhiren Kara, Helena Knowles, and Mete Atature — Cavendish Laboratory, University of Cambridge, Cambridge, UK

The nitrogen-vacancy centre (NV) in diamond provides a highly localised spin-state that can be initialised and probed optically, and coherently manipulated with microwave fields. In addition to quantum information applications, the centre can be used for magnetic field and temperature sensing in a wide range of environments. NVs embedded in nanodiamond crystals are of particular interest for sensing purposes because they can be placed in close proximity to the target and, being bio-compatible, inserted into cells. However, their use has been limited by low sensitivity due to poor spin coherence times.

This talk focuses on measurements performed in ambient conditions on nanocrystals milled from low nitrogen content (50 ppm) bulk diamond, where we are able to extend the free precession time from 0.4 to 1.27 μs by driving dark paramagnetic spin impurities in the lattice into the motionally averaged regime [1]. Further, using dynamical decoupling schemes we achieve a coherence time of 60 μs, an order of magnitude improvement on previous reports. Our results show that these nanodiamonds offer a d.c. and a.c. magnetic field sensitivity of 600 and 140 nT $Hz^{-1/2}$ respectively.

[1] H. S. Knowles, D. M. Kara and M. Atature, Nat. Mater. DOI:10.1038/NMAT3805 (2013)

A 53.7 Fri 12:15 DO24 1.101

Angle Resolved Electric Field Sensing with Single Spin Defects in Solids — •Julia Michl[1], Marcus Doherty[2], Ingmar Jakobi[1], Florian Dolde[1], Philipp Neumann[1], Tokuyuki Teraji[3], Junichi Isoya[4], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Germany — [2]Australian National University, Canberra, Australia — [3]National Institute for Materials Science, Tsukuba, Japan — [4]Research Center for Knowledge Communities, University of Tsukuba, Japan

In recent years, the nitrogen-vacancy (NV) center in diamond has emerged as a promising candidate not only for quantum computing, but also for sensing applications. Electric field sensing via NV, contrary to magnetic field sensing, is a rather unexplored topic of research. Here, we conduct new measurements using transverse magnetic and electric fields, which allows further verification and refinement of the Stark-shift Hamiltonian.

With such measurements, the strength of electric fields in transverse direction can be measured. Additionally, conclusions about its angular direction can be drawn, as the C_{3v} symmetry of the NV center affects the Stark-shift under certain angles. Hence, these measurements allow to assert the orientation along the symmetry axis of the NV.