A 49: Precision measurements and metrology II (with Q)

Time: Thursday 16:30–18:30 Location: DO24 1.101

Group Report A 49.1 Thu 16:30 DO24 1.101

Phase-predictable tuning of single-frequency optical synthesizers — •Felix Rohde[1], Erik Benkler[1], Thomas Puppe[2], Reinhard Unterreitmayer[2], Armin Zach[2], Christoph Raab[2], and Harald R. Telle[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, Braunschweig D-38116 — [2]TOPTICA Photonics AG, Lochhamer Schlag 19, D-82155 Graefelfing

Single-frequency optical synthesizers (SFOS) provide an optical field with arbitrarily adjustable frequency and phase which is phase-coherently linked to a reference signal. Ideally, they combine the spectral resolution of narrow linewidth frequency stabilized lasers with the broad spectral coverage of frequency combs in a tunable fashion. In current state-of-the-art SFOSs, a dedicated comb line order switching was used to enable tunability over carrier frequency intervals wider than the repetition frequency of the employed mode-locked laser. This imposes technical overhead, leads to forbidden frequency gaps and limits the tuning agility of the SFOS. Here, we present the first characterization of a novel type of SFOS which relies on serrodyne-shifting the carrier frequency of the employed frequency comb. We investigate the tuning behavior of two identical SFOSs, sharing a common reference, by comparing the phases of their output signals. We achieve phase-stable and cycle slip free frequency tuning over 500 comb lines (28.1 GHz) with a maximum differential phase error of 62 mrad. The tuning range in this approach can be extended to the full bandwidth of the frequency comb.

Group Report A 49.2 Thu 17:00 DO24 1.101

Optimally designed magnetic field sensing with nitrogen-vacancy centers — Tobias Nöbauer[1], •Björn Bartels[2], Andreas Angerer[1], Florian Mintert[2,3], and Johannes Majer[1] — [1]Atominstitut, TU Wien & Vienna Center for Quantum Science and Technology, Stadionallee 2, 1020 Wien, Austria — [2]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Albertstr. 19, 79104 Freiburg, Germany — [3]Department of Physics, South Kensington Campus, Imperial College, London, SW7 2AZ, UK

Sensing of small magnetic fields on the nano-scale can be achieved with the help of nitrogen-vacancy (NV) centers. We experimentally demonstrate an enhancement of sensitivity in a spin-echo-based sensing scheme by using shaped microwave pulses. The pulses are the result of optimization in frequency space, which permits us to find narrow-band pulses that achieve robustness against imperfections, such as ensemble broadening. We verify this robustness experimentally with quantum gates on individual NV centers and use these gates for sensing with macroscopic ensembles of NV centers. The potential of the present framework for applications beyond sensing is demonstrated theoretically with the control of entanglement dynamics and the realization of time-optimal gates.

A 49.3 Thu 17:30 DO24 1.101

X-ray frequency combs via optical quantum control — •S. M. Cavaletto, Z. Harman, Z. Liu, C. Ott, C. Buth, T. Pfeifer, and C. H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Optical frequency combs had a revolutionary impact on precision spectroscopy and metrology. The spectrum of a frequency comb, consisting of evenly spaced lines, is the result of an infinite train of femtosecond pulses produced in a mode-locked ultrafast laser. Recently, frequency-comb technology was extended to the extreme-ultraviolet spectral regime via high-harmonic generation (HHG) in a femtosecond-enhancement cavity [1]. We propose optical schemes to transfer the coherence of a driving, optical frequency comb to the radiation emitted by transitions of higher frequencies [2,3,4]. The comb structure we predict in the x-ray emission or absorption spectra might eventually represent an alternative scheme for x-ray frequency-comb generation, able to overcome the frequency limitations of present HHG-based methods. – [1] A. Cingöz *et al.*, Nature **482**, 68 (2012). [2] S. M. Cavaletto *et al.*, Phys. Rev. A **88**, 063402 (2013). [3] Z. Liu *et al.*, submitted (2013); arXiv:1309.6335. [4] S. M. Cavaletto *et al.*, submitted (2013).

A 49.4 Thu 17:45 DO24 1.101

Optical Frequency Transfer over a 1840-km Fiber Link with superior Stability — •Stefan Droste[1], Thomas Udem[1], Theodor Hänsch[1], Ronald Holzwarth[1], Filip Ozimek[2], Harald Schnatz[2], and Gesine Grosche[2] — [1]Max-Planck-Institut für Quantenoptik — [2]Physikalisch-Technische Bundesanstalt

The comparison of the latest generation of atomic frequency standards calls for new methods of transferring highly stable optical frequencies. Well established satellite-based frequency dissemination techniques do not reach the required stability set by state-of-the-art frequency standards. Recently, a lot of work has been put into investigating fiber links as a possible medium for transferring optical frequencies.

We established a fiber connection between the two institutes Max Planck Institute of Quantum Optics (MPQ) in Garching and the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig. In a loop configuration we transferred an optical carrier frequency at 194 THz over a 1840 km long fiber link. By investigating the underlying noise structure we found an, until now, unconsidered noise type that leads to a τ^{-2} dependency in the modified Allan deviation. The instability of the transferred frequency drops below 10^{-18} after only 70 s and we found no systematic offset between the sent and transferred frequency within an uncertainty of about 3×10^{-19}.

A 49.5 Thu 18:00 DO24 1.101

Optical feedback frequency stabilized cavity ring-down spectroscopy — •Johannes Burkart and Samir Kassi — Université Joseph Fourier (Grenoble 1) / CNRS, LIPhy UMR 5588, F-38041 Grenoble, France

Metrological applications of molecular spectroscopy such as a determination of the Boltzmann constant necessitate highly linear absorption and frequency axes. These issues are addressed by our novel optical feedback frequency stabilized cavity ring-down spectrometer (OFFS-CRDS) which combines arbitrary resolution down to the kilohertz level with a shot-noise limited absorption detectivity of a few $10^{-13}\,cm^{-1}$ over one second averaging time. Its unprecedented performance is based on a single-sideband-tuned distributed-feedback diode laser that is optical-feedback locked to a highly stable V-shaped reference cavity [1]. The frequency stability of this source is transferred to a linear ring-down cavity by means of an all-fibered Pound-Drever-Hall locking scheme, which maximizes cavity transmission and yields several hundred ring-down events per second. We characterize the performance of the OFFS-CRDS spectrometer experimentally and present results from first applications to absorption line shape studies and Doppler thermometry.

[1] J. Burkart, D. Romanini, and S. Kassi, Opt. Lett. **38**, 2062-2064 (2013).

A 49.6 Thu 18:15 DO24 1.101

Towards VUV frequency comb based high-precision spectroscopy of an optical nuclear transition of Thorium-229 — •Georg Winkler[1], Enikoe Seres[1,2], Josef Seres[1], and Thorsten Schumm[1,2] — [1]Insitute of Atomic and Subatomic Physics, Vienna University of Technology, Stadionallee 2, 1020 Vienna, Austria — [2]Wolfgang Pauli Institute, CNRS UMI 2842, Nordbergstrasse 15, 1090 Vienna, Austria

The radio isotope Thorium-229 is predicted to possess a unique extremely low-energy excited state of the nucleus in the range of $7.6 \pm 0.5\,eV$ [1], promising the chance to coherently manipulate a nucleus by UV laser light for the first time. Apart from exciting fundamental research questions this well-shielded narrow-linewidth transition opens up the possibility to realize a compact solid-state optical time standard surpassing the precision of existing systems by orders of magnitude.

Here we report about the ongoing project to build a UV frequency comb suited to interrogate and characterize the nuclear transition in its solid-state environment when embedded into a host crystal. In particular, precise comparison to established radio-frequency clock transitions should be made possible with this modern research tool.

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