MON 20: Quantum Sensing and Decoherence: Contributed Session to Symposium II

Time: Monday 16:30–18:30 Location: ZHG009

MON 20.1 Mon 16:30 ZHG009

Ultrastable multicolor laser system with 10^-20-level frequency stability for quantum computing, sensing and timing applications — •Thomas Quenzel[1], Michele Giunta[1,2], Martin Wolferstetter[1], Maurice Lessing[1], Wolfgang Hänsel[1], Michael Mei[1], Marc Fischer[1], and Ronald Holzwarth[1,2] — [1]Menlo Systems GmbH, Bunsenstraße 5, D-82152 Martinsried, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München, Germany

Photonics-based quantum technologies often require ultrastable and ultralow phase noise lasers that are turn-key operated. Here we present such an ultrastable laser system with multiple wavelengths based on a continuous-wave (CW) laser referenced to an optical reference system (ORS), an optical frequency comb (OFC), and application-dependent CW lasers, supporting 20 digits of fractional stability measurements.

The ORS guarantees sub-Hz linewidth performance and fractional frequency stability of <7x10^-16 in 1 second. The OFC is based on a femtosecond fiber laser operating ~1560 nm, which is modelocked using the figure 9 technique. The stabilized CW laser serves as optical input to the OFC, and by a direct high-bandwidth phase lock the stability and narrow linewidth of this laser can be copied to every single comb line of the OFC. Finally, multiple CW lasers are locked to the corresponding comb lines extending from the UV to the Mid-IR, depending on the application. The outcome is a multicolor, ultrastable laser system, with fractional stability on the 10^-18 level in one second, and 10^-20 in 1,000 seconds.

MON 20.2 Mon 16:45 ZHG009

Top-Hat Laser Beams for Accurate Quantum Gravity Sensing — •Niranjan Myneni[1], Joël Gomes Baptista[1], Sébastien Merlet[1], Leonid Sidorenkov[1], Camille Janvier[2], and Franck Pereira Dos Santos[1] — [1]LTE, Observatoire de Paris, Université PSL, Sorbonne Université, Université Lille, LNE, CNRS, Paris, France. — [2]Exail, Quantum Sensors, Gradignan, France.

Within the FIQUgS (Field Quantum Gravity Sensors) project, we investigate the use of top-hat laser beams to improve the performance of atom interferometers in precision inertial sensing. This work extends earlier efforts [1] demonstrating the benefits of flat-top beams towards evaluating systematic errors. We analyze both measured (Shack-Hartmann wavefront sensing) and simulated intensity and wavefront profiles, studying their propagation stability and aberration sensitivity over relevant distances. Atomic simulations quantify their impact on interferometric contrast, phase stability and accuracy. We explore beam-reducing/expanding optics to adapt top-hat beams to the required beam size for various sensor architectures. Simulations are conducted for both the FIQUgS instruments and other experimental platforms [2] available at LTE (formerly SYRTE). The results of these simulations will be benchmarked against the performance of the FIQUgS instruments evaluated during an extensive metrological campaign. This work contributes to advance compact, high-precision quantum gravimeters [3] and enhance their robustness for field deployment.

1. Appl. Phys. Lett., 113 (16), 161108(2018). 2. Phys. Rev. A 106, 013303 (2022). 3. Phys. Rev. A 105, 022801 (2022).

MON 20.3 Mon 17:00 ZHG009

Coherent feedback for quantum expander in gravitational wave observatories — •Niels Böttner, Joe Bentley, Roman Schnabel, and Mikhail Korobko — Institut für Quantenphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg

The observation of gravitational waves from binary neutron star mergers offers insights into properties of extreme nuclear matter. However, their high-frequency signals in the kHz range are often masked by quantum noise of the laser light used. We propose the "quantum expander with coherent feedback", a new detector design that features an additional optical cavity in the detector output and an internal squeeze operation. This approach allows to boost the sensitivity at high frequencies, at the same time providing a compact and tunable design for signal extraction. It allows to tailor the sensitivity of the detector to the specific signal frequency range. We demonstrate that our design allows to improve the sensitivity of the high-frequency detector concept NEMO (neutron star extreme matter observatory), increasing the detection rates by around 14%. Our approach promises new level of flexibility in designing the detectors aiming at high-frequency signals.

MON 20.4 Mon 17:15 ZHG009

Geometry of variational qubit dynamics with its applications on quantum control and sensing — •Xiu-Hao Deng — Shenzhen International Quantum Academy — Hefel National Lab

Quantum systems are fragile to perturbations from their environment. The variation of parameters brings deviation to the qubit dynamics. These variations may originate from noises, parameter uncertainty and weak signals to detect. We discover that the variational part of the qubit dynamics has beautiful geometric properties on its manifold, which includes space curves and areas. By applying the geometric theory to suppress the errors generated by noise, we find that the space curves on the manifold of the variational quantum dynamics should be close and encircle vanishing areas. Using this theory, we have obtained very robust quantum gates and quantum circuits. On the other hand, to obtain enhanced sensing, the curves should be far from the origin. We have also demonstrated enhanced signal precision and sensitivity. I will also present some experimental results in this talk.

MON 20.5 Mon 17:30 ZHG009

Phonon Dynamics and Quasi-Particle Interactions in Proximitized 2D Systems — •Zamin Mamiyev, Narmina O.Balayeva, Dietrich R.T. Zahn, and Christoph Tegenkamp — Institut für Physik, Technische Universität Chemnitz

Understanding and controlling phonon behavior in two-dimensional (2D) materials is crucial for tailoring their electronic, optical, thermal, and mechanical properties. In this context, confinement epitaxy serves as a versatile approach to create chemically protected, atomically thin 2D materials while enabling the study of proximity interactions in stacked structures [1]. In this work, we investigate phonon dynamics in epitaxial graphene (EG) intercalated with H, Sn, and In, using a combination of variable-wavelength and temperature-dependent Raman spectroscopy, complemented by electron energy loss spectroscopy. Our results demonstrate that intercalation is not merely a doping mechanism but an effective route to tune vibrational properties in EG via proximity effects [2]. Detailed analysis reveals that the primary mechanism influencing phonon behavior is the modification of electron-phonon coupling (EPC), governed by charge transfer or the strength and nature of interfacial interactions. While band filling and strain induce rigid phonon shifts, altered EPC impacts phonon group velocity. Furthermore, we show that beyond atomic-scale effects, interface engineering also significantly influences the thermal conductivity of EG.

[1] Z. Mamiyev et al., 2D Materials. 11 (2024) 025013
[2] Z. Mamiyev et al, Carbon 234 (2025) 120002

MON 20.6 Mon 17:45 ZHG009

Optomechanical cooling using a nonlinearly-driven cavity — Surangana Sengupta[1], Björn Kubala[1,2], Joachim Ankerhold[1], and •Ciprian Padurariu[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University — [2]German Aerospace Center (DLR), Institute for Quantum Technologies, Ulm

Conventional optomechanics combines a harmonic cavity mode with a mechanical element that modulates the cavity frequency [1]. The limitation of the method arises due to back-action of the cavity on the mechanical mode. This results in a residual heating effect that sets a limit to the lowest phonon occupation that can be reached via optomechanical cooling.

In this talk, I will show how driving the cavity in a nonlinear fashion can alleviate the residual heating effect, increasing the overall cooling. This method allows cooling down to orders of magnitude lower phonon occupation. As an example, the talk will focus on the case when the nonlinear drive is implemented in a superconducting circuit setup, using a Josephson junction as the nonlinear element.

In the semiclassical regime, our cooling method shows a significant advantage both in the regime where the nonlinearly-driven cavity shows multi-stable states, as well as below the threshold for multi-stability. In the future, a nonlinear cavity drive could be combined with other methods to improve the performance of optomechanical cooling, such as using intrinsically nonlinear cavity modes [2].

[1] F. Marquardt *et al.*, Phys. Rev. Lett. **99**, 093902 (2007).

[2] D. Zoepfl *et al.*, Phys. Rev. Lett. **130**, 033601 (2023).

MON 20.7 Mon 18:00 ZHG009

Amplification and Detection of Single Itinerant Microwave Photons — Lukas Danner[1,2], Ciprian Padurariu[2], Max Hofheinz[3], Joachim Ankerhold[2], and •Björn Kubala[1,2] — [1]German Aerospace Center (DLR), Institute of Quantum Technologies, Ulm (Germany) — [2]Institute for Complex Quantum Systems and IQST, University of Ulm, Ulm (Germany) — [3]Institut Quantique, Université de Sherbrooke, Sherbrooke, Québec (Canada)

The detection of single microwave photons plays a crucial role in a wide range of technological applications using quantum microwaves. Standard readout techniques relying on linear amplification [1] add noise, limiting the chance of identifying single photons. Here, we propose schemes to amplify single itinerant mircowave photons using highly-nonlinear Josephson photonics devices [2]. These devices consist of a dc-voltage biased Josephson junction, connected in series with two microwave cavities. By tuning the dc voltage, various resonances can easily be accessed, such that, e.g., a Cooper pair tunneling through the junction enables a coherent transfer between one excitation in the first cavity and n excitations in the second cavity. Using a recently developed formalism [3], we describe how a single photon pulse is absorbed by the device to trigger the leakage of multiple photons from the second cavity that can subsequently be detected, and calculate performance parameters, such as detection probabilities and dark count rates.

[1] C. M. Caves, Phys. Rev. D 26, 1817 (1982)
[2] J. Leppäkangas et al., Phys. Rev. A 97, 013855 (2018)
[3] AH. Kiilerich and K. Mølmer, Phys. Rev. Lett. 123, 123604 (2019)

MON 20.8 Mon 18:15 ZHG009

Quantum imaging with undetected photons enabled by position correlation — •Balakrishnan Viswanathan[1], Gabriela Lemos[2], and Mayukh Lahiri[3] — [1]Optics and Quantum Information Group, The Institute of Mathematical Sciences, Chennai 600113, India — [2]Instituto de Fisica, Universidade Federal do Rio de Janeiro, Av. Athos da Silveira Ramos 149, Rio de Janeiro, CP 68528, Brazil — [3]Department of Physics, 145 Physical Sciences Bldg., Oklahoma State University, Stillwater, OK 74078, USA

Quantum imaging with undetected photons (QIUP) is a novel interferometric technique in which the light that illuminates the object is not detected. The image is constructed from the single-photon interference pattern of the photon that never interacted with the object. The basic ingredients of QIUP are two identical pairs of correlated photons and the Zou-Wang-Mandel interferometer. This imaging technique exploits the absence of path information to induce interference. We develop a theory of QIUP in which both the object and the camera are placed in the near-field with respect to the sources. It turns out that in this configuration, the imaging is enabled by the position correlation between the twin photons. Furthermore, we also investigate the resolution limit in the near-field configuration of QIUP.