Q 3: Quantum Technologies – Enabling Technologies

Time: Monday 11:45–13:00 Location: P 5

Q 3.1 Mon 11:45 P 5

Compact and fully-integrated ZERODUR vacuum system for quantum sensing applications — •David Latorre Bastidas[1], Sören Boles-Herresthal[1], Nora Bidzinski[2], Bojan Hansen[2], André Wenzlawski[1], Ortwin Hellmig[2], Klaus Sengstock[2], and Patrick Windpassinger[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz — [2]Institute for Quantum Physics, University of Hamburg

In the context of advancing quantum sensing technologies for real-life applications, we propose a compact, fully integrated, passively pumped ultra-high vacuum chamber based on ZERODUR. This glass-ceramic has a negligible coefficient of thermal expansion (CTE) and ultra-low helium permeability, making it an ideal candidate for vacuum chambers.

This contribution presents the demonstration of a Rubidium-87 magneto-optical trap inside a compact home-built ZERODUR vacuum chamber, using a nanostructured diffraction grating chip (gMOT) and a PCB for the generation of the quadrupole magnetic field. The chamber integrates UV-activated alkali metal dispensers and non-evaporable getters, eliminating the need for electrical feedthroughs. Results are presented on the characterization of the vacuum chamber, where the MOT is used as a pressure sensor, as well as on the MOT performance. This system approach sets the foundation for future compact quantum sensors, offering significant potential for practical, real-world applications.

Q 3.2 Mon 12:00 P 5

Topology-Optimized Two-Port Beam Splitters for Quantum Photonic Integrated Circuits — Shiang-Yu Huang[1], •Alessandro Ciorra[1], Jonas Höpker[1], Jeldrik Huster[1], Yannick Augenstein[2,3], Carsten Rockstuhl[2,3], and Stefanie Barz[1,4] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [3]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [4]Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, 70569 Stuttgart, Germany

In quantum information processing, two-port beam splitters serve as the essential elements where multiphoton interference occurs, which enables the generation of photonic quantum states. Meanwhile, topology optimization has recently advanced integrated photonics by enabling ultracompact, high-performance devices through efficient exploration of large design spaces and the discovery of non-intuitive geometries. In this work, we explore how different constraints in the topology optimization, such as device footprint, minimum feature size, etc., affect the performance of the beam splitter designs. We characterize the beam splitters using single-photon and two-photon measurements. We also reconstruct each devices transfer matrix and analyze the linear transformations they implement. Our results provide insight into how the inverse-designed beam splitters operate and highlight their potential for scalable and densely integrated quantum photonic systems.

Q 3.3 Mon 12:15 P 5

Microwave Generation for the Manipulation of Rubidium Ensembles — •Valeria Camacho Molina, Maike Diana Lachmann, and Tobias Bartusch — Airbus Defence and Space GmbH , Willy-Messerschmitt-Strasse 1, 82024 ,Taufkirchen , Germany

Ultra-cold atomic ensembles, with their microscopic coherence times, narrow momentum distributions, and highly controllable quantum states, are essential for high-precision measurements and advanced quantum technologies. Precise control of both the internal and motional states of the atoms is critical for reproducible and accurate performance.

In this work, a microwave subsystem is implemented to drive evaporative cooling of a Rubidium-87 atomic ensemble in a magnetic trap to achieve Bose*Einstein condensation. Additionally, after condensation, the system is used for state preparation, transferring the atoms in well-defined internal states to ensure reproducible and controlled experimental conditions. The subsystem integrates low-phase-noise frequency generation, agile frequency control, and thermally stable electronics to achieve consistent and reproducible performance. Its compact, robust, and low-power design makes it well suited for space-deployable quantum sensors, where reliability and environmental robustness are critical.

Q 3.4 Mon 12:30 P 5

Entropy-Based Complexity Characterization of Integrated Photonic Physical Unclonable Functions — •Himadri Sahoo, Rick Bevers, Daan J. de Ruiter, Lars van der Hoeven, Daan P. Stellinga, Matthias C. Velsink, and Pepijn W. H. Pinkse — MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, the Netherlands

Integrated photonic Physical Unclonable Functions (PUFs) offer high intrinsic complexity due to fabrication-induced disorder and multimode interference. We present an entropy-based framework to quantify their information content using repeated time-domain optical responses. From current amplitude-only spectra, we extract lower bounds on effective entropy and identify correlations limiting independent degrees of freedom. Numerical simulations based on these experimental spectra are employed to visualize response variations and support the evaluation of different entropy estimators. To achieve a more complete complexity assessment, we propose complementary vector network analyzer measurements providing phase-resolved transfer functions with higher spectral resolution. This combined experimental-numerical approach advances complexity determination in photonic hardware security primitives.

Q 3.5 Mon 12:45 P 5

Verification of Electron-Photon Entanglement — •Phila Rembold[1], Alexander Preimesberger[1,2], Sergei Bogdanov[1,2], Santiago Beltrán-Romero[1,2], Dennis Rätzel[1,2,3], Isobel C Bicket[1,2], Elizabeth Agudelo[1], Nicolai Friis[1], and Philipp Haslinger[1,2] — [1]Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria — [2]University Service Centre for Transmission Electron Microscopy, TU Wien, Wiedner Hauptstraße 8-10/E057-02, 1040 Vienna, Austria — [3]ZARM, University of Bremen, 28359 Bremen, Germany

Entanglement, a central concept in quantum physics, describes correlations between particles that cannot be explained classically. While routinely verified in photonic and atomic systems, direct experimental evidence in transmission electron microscopy (TEM) has been missing. We report the detection of position*momentum entanglement between single free electrons and photons generated via coherent cathodoluminescence in a TEM. The method relies on a general separability bound: for classically correlated particles, the product of the conditional variances in relative position and total momentum cannot fall below a fixed limit. Using coincidence-based ghost imaging, adapted from quantum optics, we measure both spatial and momentum correlations of electron-photon pairs. The observed variance product is significantly below the classical limit, confirming entanglement. This result links the well-developed tools of photonic quantum optics with the capabilities of electron microscopy, offering a route toward quantum-enhanced imaging at the atomic scale.