Q 41: Quantum Technologies (Color Centers and Ion Traps) I (joint session Q/QI)

Time: Wednesday 14:30–16:30 Location: HS Botanik

Invited Talk Q 41.1 Wed 14:30 HS Botanik

Integration of fiber Fabry-Perot cavities for sensing applications and cavity optomechanics — •Hannes Pfeifer[1], Lukas Tenbrake[2], Carlos Saavedra[3], Florian Giefer[2], Jana Blechmann[2], Johanna Stein[2], Daniel Stachanow[2], Dieter Meschede[2], Karol Krzempek[4], Randall Goldsmith[3], Witlef Wieczorek[1], Stefan Linden[2], and Sebastian Hofferberth[2] — [1]Chalmers University of Technology, Gothenburg, Sweden — [2]University of Bonn, Germany — [3]University of Wisconsin-Madison, USA — [4]Wroclaw University of Science and Technology, Poland

Since their first realization during the 2000s, fiber-based Fabry-Perot cavities (FFPCs) have found their way into an increasing manifold of optical experiments. Driven by the accessibility of their optical mode volume, quantum systems down to single atoms and up to macroscopic mechanical oscillators have been interfaced through FFPCs. Besides their unique features: the strong miniaturization, direct fiber coupling, and large optical access; key challenges such as their experiment integration, coupling efficiency, susceptibility to mechanical vibration, and thermal load remain. In my talk, I will report on the developments from the Bonn Fiber Lab addressing these issues, with a focus on the integration of sensing applications and cavity optomechanics experiments within FFPCs. I will touch upon the realization of highly sensitive readout schemes for gas spectroscopy and single molecule detection, and discuss the structural integration of mechanical resonators using direct laser writing. Finally, I will discuss the prospects of using FFPCs to interface and manipulate mechanical multimode systems.

Q 41.2 Wed 15:00 HS Botanik

Ion trap chips for two-dimensional coupling experiments — •Michael Pfeifer[1,2], Simon Schey[1,3], Fabian Anmasser[1,2], Jakob Wahl[1,2], Matthias Dietl[1,2], Marco Valentini[2], Marco Schmauser[2], Michael Pasquini[2], Eric Kopp[2], Philip Holz[4], Martin van Mourik[4], Thomas Monz[2,4], Christian Roos[2], Clemens Rössler[1], Yves Colombe[1], and Philipp Schindler[2] — [1]Infineon Technologies Austria AG, Villach, Austria — [2]University of Innsbruck, Innsbruck, Austria — [3]Stockholm University, Stockholm, Sweden — [4]Alpine Quantum Technologies GmbH, Innsbruck, Austria

Ion trap quantum processors need two-dimensional connectivity between ions to harness their full potential **[1]**. We report on industrially fabricated ion trap chips designed to investigate radial and axial double-well potentials as building blocks of two-dimensional scalable architectures. The coupling between ions in the double-wells on the chips can be tuned by variation of the radial and/or axial separations.

The ion trap chips are fabricated on dielectric substrates - Fused Silica and Sapphire - at Infineon Technologies **[2,3]**. We discuss the design and fabrication of the ion traps as well as recent developments.

[1] M. Valentini *et al.*, arXiv:2406.02406 (2024)
[2] S. Auchter *et al.*, Quantum Sci. Technol. **7**, 035015 (2022)
[3] P. Holz *et al.*, Adv. Quantum Technol. **3**, 2000031 (2020)

Q 41.3 Wed 15:15 HS Botanik

Integrated Cryo-Electronics for Scalable 2D Surface Ion Traps — •Fabian Anmasser[1,2], Mohammad Abu Zahra[3,4], Matthias Brandl[3], Klemens Schueppert[2], Jens Repp[3], Matthias Dietl[1,2], Yves Colombe[2], Clemens Roessler[2], Philipp Schindler[1], and Rainer Blatt[1,5] — [1]Institute for Experimental Physics, Innsbruck, Austria — [2]Infineon Technologies Austria AG, Villach, Austria — [3]Infineon Technologies AG, Neubiberg, Germany — [4]Technical University of Munich, Germany — [5]Institute for Quantum Optics and Quantum Information, Innsbruck, Austria

2D surface ion traps provide a promising foundation for building scalable quantum computers. However, as the number of ions increases, so does the number of independently controllable electrodes, leading to a ”wiring challenge”. Current surface traps require individual routing of electrodes out of the cryogenic system, which becomes impractical for traps with over 1000 qubits.

We present a solution to the wiring challenge by integrating cryogenic electronics underneath a surface ion trap. Our approach involves a control chip that multiplexes 37 inputs to 199 DC electrodes, enabling control of a large number of electrodes with reduced connections. The surface trap is glued on top of the control chip, with electrical connections made using gold wire bonds. Initial Ca+ ion trapping trials have been conducted, and future steps include measuring heating rates and exploring advanced DC shuttling techniques. This work paves the way for scalable surface ion trap devices, bringing us closer to a practical quantum computer.

Q 41.4 Wed 15:30 HS Botanik

Micro fabricated ion trap with integrated optics — •Jakob Wahl[1,2], Alexander Zesar[1,3], Marco Schmauser[2], Martin van Mourik[2], Marco Valentini[2], Klemens Schüppert[1], Clemens Rössler[1], Philipp Schindler[2], and Christian Roos[2] — [1]Infineon Technologies Austria — [2]Universität Innsbruck — [3]Technische Universität Graz

Trapped ions have shown great promise as a platform for quantum computing, with long coherence time, high fidelity quantum logic gates, and the successful implementation of quantum algorithms. However, to take trapped-ion quantum computers from laboratory setups to practical devices for solving real-world problems, the number of controllable qubits must be increased while improving error rates. One of the major challenges for scaling trapped-ion quantum computers is the need to switch from free-space to integrated optics, to achieve lower drift and vibrations of light relative to the ion, and therefore more stable and scalable ion-addressing.

In this talk, we show an ion trap produced at Infineon's industrial semiconductor facilities that has integrated femtosecond laser-written waveguides. We show details of the fabrication and present recent measurements and results on the performance of the trap. We compare the trapping behavior with and without the integrated features that expose dielectric to the ion, and potentially increase stray fields and heating rates. This work paves the way towards ion traps with robust and integrated ion addressing.

Q 41.5 Wed 15:45 HS Botanik

Advancements in Ultra-High Vacuum Technology for Trapped Ion Quantum Computing — •Helin Özel, Tabea Stroinski, Julian Harald Wiener, Felix Stopp, Björn Lekitsch, and Ferdinand Schmidt-Kaler — Johannes Gutenberg University, Mainz, Germany

We present experimental results on advancements in ultra-high vacuum (UHV) technology to support the development of next-generation quantum processor systems for continuous and stable operation at room-temperature. Our research focuses on improving UHV technology by applying innovative coating techniques. We optimize the pumping speed and achieve improved pressure levels alongside with reduced degassing rates, which are essential for maintaining the stability of quantum systems. Additional improvements address optical alignment and in-vacuum designs to support long-term operation. For preservation of qubit coherence we use three layers of Mu-metal shielding against magnetic noise, while a Halbach magnet configuration is employed to generate a stable magnetic quantization field. These advancements will enhance the reliability and operation quality of the trapped ion processor.

Q 41.6 Wed 16:00 HS Botanik

Implementing the SUPER Scheme for Tin-Vacancy Spin Qubit Manipulation and Entanglement — •Cem Güney Torun[1], Mustafa Gökçe[1], Thomas K. Bracht[2], Mariano Isaza Monsalve[1], Sarah Benbouabdellah[1], Özgün Ozan Nacitarhan[1], Marco E. Stucki[1,3], Domenica Bermeo Alvaro[1,3], Matthew L. Markham[4], Tommaso Pregnolato[1,3], Joseph H. D. Munns[1], Gregor Pieplow[1], Doris E. Reiter[2], and Tim Schröder[1,3] — [1]Department of Physics, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Condensed Matter Theory, Department of Physics, TU Dortmund, 44221 Dortmund, Germany — [3]Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Höchstfrequenztechnik, 12489 Berlin, Germany — [4]Element Six, Harwell, OX110 QR, United Kingdom

We investigate the SUPER scheme, a detuned coherent excitation method enabling spectral separation of excitation and emission fields, for spin qubit inversion in tin-vacancy center in diamond. Simulations show high-fidelity inversion of spin superposition is achievable with optimized parameters, while spin T_1 measurements confirm that the broadband pulses do not induce significant spin mixing. Additionally, we propose a spin-spin entanglement protocol leveraging broadband excitation to encode photons in the frequency domain, enabling remote entanglement generation.

Q 41.7 Wed 16:15 HS Botanik

Coupling of alkali vapors and rare gases for quantum memories — •Denis Uhland[1], Norman Vincenz Ewald[2,3], Alexander Erl[2,3], Andrés Medina Herrera[3], Wolfgang Kilian[3], Jens Voigt[3], Janik Wolters[2,4], and Ilja Gerhardt[1] — [1]Leibniz University Hannover, Institute of Solid State Physics, Light and Matter Group, Hannover — [2]Deutsches Zentrum für Luft- und Raumfahrt, Institute of Optical Sensor Systems, Berlin — [3]Physikalisch-Technische Bundesanstalt, 8.2 Biosignals, Berlin — [4]Technische Universität Berlin, Institute of Optics and Atomic Physics, Berlin

Optical quantum memories allow for the storage and retrieval of quantum information encoded in photons. Despite using an optical interface for photons stored in collective spin excitation via EIT with milliseconds storage time [1], hot mixtures of alkali and rare gas atoms can achieve coherence times up to several hours [2], resulting from spin-exchange collisions, where the optically addressable alkali metals couple to the nuclear spin of the rare gas. R. Shaham et al. [3] discussed how to achieve strong coupling between the electron spin of potassium and the nuclear spin of helium, allowing for efficient spin transfer. We follow the proposed scheme to achieve strong coupling between a hot ensemble of rubidium and xenon, which paves the way towards an efficient quantum memory device and fundamental studies of spin dynamics. [1] L. Esguerra *et al.*, Phys. Rev. A (2023) 107, 042607, [2] C. Gemmel *et al.*, Eur. Phys. J. D (2010) 57, 303, [3] R. Shaham *et al.*, Nat. Phys. L (2022), Vol. 18, No. 5