Early Career Conference in Trapped Ions

6^{th} to 11^{th} September 2026

Oxford

Book of Abstracts

Sponsors

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9:30 - 10:00 **Welcome and registration**
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Stefanos Pelonis (KU Leuven)

10:25 - 10:45 Towards ultra-high precision optical and radiofrequency spectroscopy of stable and radioactive Sr+
Robbe Van Duyse (KU Leuven)

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Quantum Simulation
Chair:

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Louis Gallagher (University of Amsterdam)

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Irini Lindmar and Raffaele Lanini (ETH Zürich)

12:05 - 12:25 Single-Setting Measurements for Characterizing Many-Body Quantum States
Leo Walz (Universität Innsbruck)

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Quantum Simulation
Chair:

13:30 - 13:50 Interaction-Induced Dynamics in Ultracold Atom–Ion Mixtures
Alexander Döring (Universität Freiburg)

Quantum Technologies
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13:50 - 14:15 Fundamental building blocks for a trapped-ion quantum repeater link
Max Bergerhoff (Saarland University)

14:15 - 14:40 Scalable components for microwave-driven cryogenic trapped-ion quantum computing experiments
Sophie Najwa Al-Zaki (Leibniz Universität Hannover)

14:40 - 15:00 Ion trap surface investigation using Kelvin probe force microscopy
Christian Flasch (Infineon Technologies)

15:00 - 15:20 Coffee break

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15:20 - 15:45 Computational Capabilities and Compilation Strategies for Trapped-Ion Quantum Computers
Jurek Eisinger (Johannes Gutenberg University Mainz)

15:45 - 16:05 Superconducting Ion Trap System for 87Sr+ Hyperfine Qubit
Qifeng Lao (Komaba Institute for Science (KIS), The University of Tokyo)

16:05 - 16:30 Distributed quantum error detection across a trapped-ion network
Ellis Ainley (University of Oxford)

16:30 - 16:50 Scaling up trapped ion processors using high-speed and high-connectivity two-qubit gates
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18:00 - 21:00 **Pub Trip**
The Up In Arms, 241 Marston Rd, Headington, Oxford OX3 0EN

Tuesday 8th September

9:00 - 10:00 **Lab tours**
Meeting outside the Martin Wood Lecture Theatre

10:00 - 12:30 **Poster session 1**
Foyer

12:30 - 13:30 **Lunch**

Molecular Spectroscopy
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13:30 - 13:55 Precision spectroscopy and coherent control of single molecular nitrogen ions
Nicolas Adrian Nuñez Barreto (University of Basel)

13:55 - 14:15 Quantum Logic Spectroscopy - What happens if the Raman lasers can access the dissociation continuum?
Srishti Sharma (Vrije Universiteit Amsterdam)

14:15 - 14:40 Infrared absorption spectroscopy of a single trapped polyatomic molecular ion
Tim Duka (Universität Innsbruck)

14:40 - 15:00 Novel Background-Free, Agent-Driven, Ion-Trap Action Spectrometer for Radioactive Molecular Ions
Nicholas Schnoor (Texas A&M University)

15:00 - 15:20 **Coffee break**

Quantum Technologies
Chair:

15:20 - 15:45 Conformal mapping for computationally efficient ion trap designs
Peter Drmota (University of Oxford)

15:45 - 16:10 A Cryogenic Surface Trap with Rydberg Ions
Vinay Shankar (Stockholm University)

16:10 - 16:30 Quantum characterization and control of single molecules
Max Koppelstätter (Universität Innsbruck)

16:30 - 16:55 Towards Cavity QED with Trapped Barium Ions
Savelii Dudoladov (Okinawa Institute of Science and Technology)

16:55 - 17:55 **Lab tours**
Meeting outside the Martin Wood Lecture Theatre

Wednesday 9th September

9:00 - 10:00 **Lab tours**
Meeting outside the Martin Wood Lecture Theatre

10:00 - 12:30 **Poster session 2**
Foyer

12:30 - 13:30 **Lunch**

Clocks and Precision Spectroscopy
Chair:

13:30 - 13:55 Towards a network of 43Ca+ optical clocks for entanglement-enhanced metrology
Ayush Agrawal (University of Oxford)

13:55 - 14:20 Sensing thermal motion of single ions with structured light
Muriel Bonetto (Universidad de Buenos Aires)

14:20 - 14:40 Three Body Quantum Scattering in a Hybrid Atom-Ion System
Patrick Mullan (Albert-Ludwigs-Universität Freiburg)

14:40 - 15:00 Measurements of the bound-electron g factor in highly charged ions: testing fundamental physics
Max Anton Gramberg (Max Planck Institute for Nuclear Physics)

15:00 - 15:20 **Coffee break**

Quantum Computing
Chair:

15:20 - 15:40 Implementing and Characterising Error Mitigation by Virtual Distillation under Structured Noise
Iver Romvig Øvergaard (University of Oxford)

15:40 - 16:05	Generation of Two-Photon Entanglement Using a Single Ion–Cavity System Adrien Amour (University of Sussex)
16:05 - 16:30	Observation of Cooperative Scattering Light in Trapped-Ion Crystals Kratveer Singh (Palacky University Olomouc)
16:30 - 16:50	Practical quantum error correction on maximally modular networked architectures Tenzan Araki (University of Oxford)

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Quantum Computing
Chair:

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9:50 - 10:10	Non-destructive parity measurement of a motional cat state Ingrid H. Zimmermann (University of Colorado Boulder)
10:10 - 10:30	Four- and six-photon stimulated Raman transitions for coherent qubit and qudit operations Gabriel Gregory (University of Oregon)
10:30 - 10:50	Entanglement of trapped-ion qubits over a 50 km-long fiber link Armin Winkler (Universität Innsbruck)

10:50 - 11:15 Coffee break

Quantum Technologies
Chair:

11:15 - 11:40	Remote Entanglement of Trapped Ions Using Integrated Photonics for Collection and Interference Sam Bishop (MIT)
11:40 - 12:05	Fabrication and Automated Characterisation of Optical Cavity Mirrors for Quantum Networking Catherine Challoner (University of Oxford)
12:05 - 12:30	A Linear Ion Trap with Integrated Fiber Fabry–Perot Cavity for Distributed Quantum Computing Shuma Oya (Okinawa Institute of Science and Technology)

12:30 - 13:30 Lunch

Antimatter
Chair:

13:30 - 13:50 Improved Precision for Hyperfine Spectroscopy of Magnetically Trapped Antihydrogen at ALPHA
Jay Suh (University of Calgary)

13:50 - 14:10 Be+-Assisted Synthesis of Antihydrogen
Tom Robertson-Brown (Swansea University)

14:10 - 14:30 Developments of BASE Hannover towards quantum logic spectroscopy of the (anti-)proton g-factor
Nikita Poljakov (Leibniz Universität Hannover)

Quantum Computing
Chair:

14:30 - 14:50 Quantum information processing using 176Lu+ Qudits
Prachi Nagpal (University of Sydney)

14:50 - 15:10 Native polyqubit gate mediated by multi-tone drive
Sophie Decoppet (University of Oxford)

15:10 - 15:30 Coffee break

Quantum Technologies
Chair:

15:30 - 15:55 Trapped ions as a platform for quantum communication over an urban fiber link
Christian Haen (Universität des Saarlandes)

15:55 - 16:20 Experimental Characterization of Normal Modes in Planar Ion Traps by Selective Mode Excitation
Ryosuke Nishimoto (University of Osaka)

16:20 - 16:40 Quantum computing with X- junction for 2D navigation of trapped ion qubits
Salvi Mohandas (Johannes Gutenberg-Universität Mainz)

16:40 - 17:00	Switchable low-noise permanent magnet gradients for long-wavelength trapped-ion quantum information Caleb Burhan (University of Sussex)

19:30 - 21:30	**Conference dinner** Christ Church College, St Aldate's, Oxford OX1 1DP Dress code: Smart

Friday 11th September

Clocks and Precision Spectroscopy
Chair:

9:30 - 9:50 A transportable Al+ quantum logic optical clock
Joost Hinrichs (Leibniz University Hannover, Physikalisch-Technische Bundesanstalt)

9:50 - 10:10 Development of a Second $^{171}Yb^{+}$ Ion Optical Clock at NPL Towards the Redefinition of the SI Second
Thilina Senaviratne (National Physical Laboratory)

10:10 - 10:30 A Penning trap single-photon counter for axion detection
Marko Wojtkowiak (Imperial College London)

10:30 - 10:50 Implementation of a Josephson Voltage Standard for the First Direct Measurement of the Nuclear Magnetic Moment of $^{3}He^{2+}$
Felix Grüner (MPI Nuclear Physics, Heidelberg)

10:50 - 11:15 Coffee break

Quantum Computing
Chair:

11:15 - 11:35 Progress on room-temperature microwave-driven two qubit quantum processor
Alexander Onkes (Leibniz Universität Hannover, Physikalisch-Technische Bundesanstalt)

11:35 - 11:55 Enabling mid-circuit measurement and readout with trapped barium ions
Phoebe Grosser (Universität Innsbruck)

11:55 - 12:15 Toward Mixed-Species Quantum Logic Using Microwave and RF Magnetic Fields in Trapped Ions
Deviprasath Palani (NIST, Boulder)

12:15 - 12:35 Trapped-Ion Quantum Computing Setup Joining Shuttling- and Addressing-Based Architecture
James Rumbold (Johannes Gutenberg University)

12:35 - 13:00 Closing Remarks

13:00 - 14:00 Lunch

14:00 - 17:00 **Social Activities**
Meeting outside the Martin Wood Lecture Theatre

2 List of Posters

Track key:

N	Nuclear Physics
QS	Quantum Simulation
QT	Quantum Technologies
QC	Quantum Computing
MS	Molecular Spectroscopy
AC	Atomic Clocks
PS	Precision Spectroscopy
A	Antimatter

2.1 Session 1: Tuesday 8th September

Presenters	Track	Poster Title
Gauthier Guignard	N	Offline commissioning of the double Penning trap PIPERADE
Larisa Thorne	QS	OPEN-2QS: Rydberg interactions in planar ion crystals
Alan Kahan	QS	Real-time collisions of fractional charges in a trapped-ion Jackiw-Rebbi field theory
Phillip Cloud	QT	Integrated Photonics and metasurfaces for scaling trapped-ion quantum computing and miniaturizing atomic clocks
Nora Daria Stahr	QT	Microfabrication and Integration Strategies for Scalable Surface-Electrode Ion Traps
Isaline Emilie Duperon	QT	Phase-stable injection-locked laser at 674 nm for manipulating trapped strontium ions
Benjamin Zenz	QT	Versatile trapped-ion crystal platform for efficient measurement of photon correlations and emergent quantum structures induced by optical forces

Giorgio Canalella	QT	Coherent Control of Trapped-Ion Spin-Boson Systems
Tomomi Higashi	QT	Development of Local Magnetic Field Diagnostics Using Dark Resonance of Trapped Ions
Matthew Aylett & Mohamed Saleh & Sameer yadav	QT	Fabrication of advanced ion traps with inner-segmented electrodes and integrated microwave antennas
James Urquhart	QT	Benchmarking Microfabricated QCCD Junctions for Fast Transport
Erin Malinowski	QT	Improving the Capabilities of a Quantum Network
Victoria Schwab	QT	Fabrication of Surface Ion Traps with Integrated 3D Glass Microstructures
Molly Smith	QC	Single-qubit gates with errors at the 10^{-7} level
Tim Wohlers-Reichel	QC	Rapid all-optical loading of trapped ions using a miniaturised atom source
Emily Hirsch	QC	Fast, High-Fidelity Entanglement in Multi-Ion Chains
David Christoph Stuhrmann	QC	Towards mode coupling and cooling of a mixed species ion crystal
Toby Maddock	QC	Towards Entanglement distribution between Two Separated Ion-Trap Modules
Alika Ho & Jakob Helms	QC	Limits to rate and fidelity in cavity-assisted remote entanglement
Nadezhda Markova	QC	Analysis of Entanglement, Stability, Coupling, and Robustness in a MAGIC-Coupled 171Yb Ion System
Felix W. Knollmann	QC	How to make modular quantum computing with ions work
Mathew Dave Chan	QC	Developing Control Electronics for Trapped-Ion Quantum Processors Using MAGIC Technology
Parsa Rahimi	QC	High-Fidelity Electronic $\sigma_z\sigma_z$ Gate on an Axial Mode via Near-Motional Oscillating Magnetic Field Gradients
Siddhartha Sankar Payra	MS	Ion-molecule reactions of N-bearing PAH in a 22-pole radio-frequency ion trap
Julie Hernandez	MS	Towards Quantum Simulation with Trapped Molecular Ions
Max Glantschnig	AC	Towards an industrially microfabricated 3D ion trap for clock applications

Valentin Martimort	PS	Towards the sympathetic cooling of a light ion species using laser-cooled heavy ions : an experimental simulation of one step of the GBAR experiment
Julius Franke	PS	High-precision Q value determination of the ^7Be decay through Penning-trap mass measurements
Kamal Abdellatif	PS	An Improved Superconducting Radio-Frequency Trap for Precision Spectroscopy of Highly Charged Ions
Rico Holz	A	Non-neutral plasma manipulation for controlled antiproton annihilations at PUMA
Tomoka Imamura	A	Improving magnetic field homogeneity of the BASE experiment at CERN

2.2 Session 2: Wednesday 9th September

Presenters	Track	Poster Title
Finn Köhler	N	Development and Commissioning of an RFQ Cooler-Buncher for Laser Spectroscopy
Simon Euchner	QS	Rydberg ion crystal as a quantum simulator for coupled exciton-phonon dynamics
Joshua Weißenfels	QS	Fractal ground state of mesoscopic ion chains in periodic potentials
Lilay Gros-Desormeaux	QT	Trapped and cooled 88Sr+ ions in a cylindrical potential provided by a micro-fabricated ring trap
He Zhang	QT	Detecting axion dark matter with an electron Penning trap
Sacha Guesne	QT	Characterization of stray electric fields induced by UV laser exposure in a microfabricated surface ion trap
Rares Barcan	QT	IonLab: A framework for noise-aware simulation of trapped-ion quantum operations
Kilian Teck	QT	Integrated 313nm Waveguide Characterisation for $^{9}Be^{+}$ Penning Micro-Traps
Mohammad Masum Billah	QT	Scalable Surface Electrode Ion Trap with Near-Field Microwave Gates and Chip-Integrated Nano-Photonics: Progress and Challenges
Janina Bätge	QT	Surface-Electrode Ion Trap Design with Chip-Integrated Microwave Conductors for Near-Field Microwave Quantum Control
Daisy Smith	QT	IonVision and ARTIQEase: Open-Source Tools to aid Ion-Trappers
Kevin Rempel	QT	Electrical upgrades for a cryogenic X-junction ion trap for quantum computation and simulation
Arjun Rao	QT	Cavity-Enhanced Modular Ion Traps for Optically-Interconnected Networks
Abdul-Rahman Rasul	QC	Microwave driven single-qubit gates on trapped ions in a magnetic field gradient
Benjamin Revie	QC	Control of ion strings in a linear segmented microtrap: splitting, combining and entangling

Thomas Clarke	QC	Robust Phase Estimation: Characterising Coherent Transport Operations in a Trapped Ion Quantum Processor
Hon-Kwan Chan	QC	Laser-Driven Universal Control of Zeeman Qudits for Quantum Information Processing
William Cutler	QC	A multi-level trapped ion system for probing quantum thermodynamics
Gareth Hopkins	QC	Towards a Scalable Logical Qubit: Sympathetic Cooling with Barium in a Ytterbium Qubit system
David Verran	QC	Construction of Global Controlled-Phase Gates on Trapped-Ions with Resilience Against Motional Heating
Matthew Casey	QC	CaQTUS - Calcium Quick Turnaround System
Finnlay ODwyer	QC	Characterising Single Qubit Operations with Interleaved Transport and State Mapping in a Switchable Magnetic Gradient
Laura Blackburn	MS	Towards a nitrogen molecular ion clock for fundamental physics tests
Mikhail Popov	MS	Towards quantum-nondemolition state detection of single trapped water ions
Constantijin Karels	MS	Precision & Molecular Spectroscopy
Klaus Kiendlhofer	AC	3D glass chip ion trap for clock applications
Magdalena Winkelvoß	PS	Search for New Physics with Highly Charged Californium
Ruben Henninger	PS	Ground-State Cooling of Mixed-Species Ion Crystals in the Intermediate Lamb-Dicke Regime
Joanna Peszka	PS	Fundamental physics tests with Highly Charged Ions at GSI
Philipp Luca Hoffmann	A	Fabrication process for a micro structured Penning trap for (anti-)proton-beryllium coupling

3 Abstracts: Talks

3.1 Nuclear Physics

Monday 7th September, 10:05
Trapping and laser cooling of fast Sr+ beams: A stepping stone towards in-trap laser spectroscopy of short-lived isotopes

Presenter: Stefanos Pelonis
KU Leuven

To better understand key nuclear properties, tremendous effort has been put into various theoretical models (eg. [1,2]), capable of reproducing experimental data with increasing accuracy. Benchmarking these models requires precise measurements of key nuclear observables, among which electromagnetic moments and charge radii play complementary roles. Laser Spectroscopy (LS) techniques allow one to measure all these quantities within a single experiment in an efficient and precise manner [3].

As an alternative to the well-established in-source and collinear LS methods, an offline beamline has been commissioned at KU Leuven to develop new spectroscopic methods to be implemented on trapped ions at Radioactive Ion Beam (RIB) facilities [4], complementing a pre-existing high-precision trap optimized for stable isotopes. This will substantially increase the laser-ion interaction time from a few microseconds to multiple seconds, ultimately limited only by the half-life of the radioactive ions. Via the excitation of weak transitions, such as radiofrequency transitions within a hyperfine manifold [5], electromagnetic moments beyond the electric quadrupole moment, like the magnetic octupole one, can be obtained. Therefore, another nuclear observable will be added as a benchmark for nuclear theory and provide information on the proton distribution inside the nucleus.

This contribution will give an overview of the project and present the latest results from our linear Paul trap, which includes the deceleration, trapping and laser cooling of Sr+ ions from 10 keV beam energy to below 10 mK temperature and the formation of Coulomb crystals. As an initial spectroscopic benchmark, the dipole-forbidden S1/2 $\rightarrow$ D5/2 transition was driven to quantify broadening mechanisms. Finally, the status of the ongoing installation of this setup at the IGISOL RIB facility [6] will be presented. The latter will enable both in-trap LS measurement of radioactive species and the preparation of ultra-cold ion bunches for Penning trap mass measurements [7].

References: [1] A. Ekstrom et al., Frontiers in Physics 11, 29094 (2023) [2] D. Bonatsos et al., Atoms 11(9), 117 (2023) [3] X. F. Yang et al., Progress in Particle and Nuclear Physics 129, 104005 (2023) [4] P. Imgram et al., Review of Scientific Instruments 96, 093302 (2025) [5] X. F. Yang et al., PRA 90, 052516 (2014) [6] I.D. Moore et al., Nuclear Instruments and Methods in Physics Research Section B 317, 208-213 (2013) [7] S. Sels et al., Physical Review Research 4, 033229 (2022)

Monday 7th September, 10:25

Towards ultra-high precision optical and radiofrequency spectroscopy of stable and radioactive Sr+

Presenter: Robbe Van Duyse

KU Leuven

The nucleus is generally described using a number of observables, each providing a characteristic insight into nuclear properties. Two particularly interesting properties are the nuclear charge density distribution and nuclear multipole expansion. The charge density distribution is described by an expansion ($\delta\langle r^2\rangle$, $\delta\langle r^4\rangle$, $\delta\langle r^2\rangle^2$...) and the nuclear multipole expansion is described similarly (magnetic dipole μ, electric quadrupole Q, magnetic octupole Ω...) [1]. Both distributions are successfully probed using Collinear Laser Spectroscopy (CLS) across the nuclear chart. However, the technique is limited in precision and can therefore only access the lowest order multipoles, $\delta\langle r^2\rangle$, μ and Q.

Using ion traps, by operating in the Lamb-Dicke regime and exploiting long interaction times, allows us to improve the precision of the measurements by many orders of magnitude as compared to conventional methods used at Radioactive Ion Beam (RIB) facilities, gaining access to Ω, $\delta\langle r^4\rangle$ and $\delta\langle r^2\rangle^2$. Despite extensive developments in ion trapping, an ion trap for high precision optical spectroscopy of short-lived radioactive isotopes has not yet been installed at an ISOL (Isotope Separator On-Line) facility [2]. This motivated the building of two ion trapping setups at KU Leuven, one aimed at high precision optical spectroscopy, the BICEPS (Bespoke Ion Cooling Experiment for Precision Spectroscopy) trap, and another focused on deceleration and trapping of radioactive ions [3]. Both traps are fully operational and actively performing measurements.

Using BICEPS, we will perform high precision Isotope Shift (IS) spectroscopy of stable bosonic Sr^+ isotopes, as well as radiofrequency spectroscopy, probing the hyperfine structure of $^{87}Sr^+$ to measure Ω [4]. Eventually, the IS will allow us to probe the higher order charge density moments and to put meaningful bounds on Beyond Standard Model (BSM) physics [5]. We have already performed first low-precision IS measurements on single $^{84}Sr^+$, $^{86}Sr^+$ and $^{88}Sr^+$ and currently performing Rabi oscillations between the two Zeeman levels of the ground state of $^{88}Sr^+$. This demonstrates our capacity to coherently manipulate state populations on single ions. Furthermore, in this contribution the ongoing developments of BICEPS regarding trap control and precision laser spectroscopy as well as prospects to measure nuclear observables with high precision on radioactive isotopes at an ISOL facility will be discussed.

References: [1] Reinhard, P. G., Nazarewicz, W., Garcia Ruiz, R. F., Phys. Rev. C, 101 (2020). [2] Takamine, A. et al., Phys. Rev. Lett., 112, 162502 (2024). [3] P. Imgram et al., Review of Scientific Instruments 96, 093302 (2025) [4] Lewty, N., et al., Opt. Express, 20, 21379 (2012). [5] Door, M., et al., Phys. Rev. Lett., 134, 063002 (2025).

3.2 Quantum Simulation

Monday 7th September, 11:15
Non-paraxial effects on laser-qubit interactions

Presenter: Louis Gallagher
University of Amsterdam

Optical tweezers offer new opportunities to control and manipulate trapped ions with applications in quantum information processing. We consider the light potentials induced on trapped ions by an optical tweezer beyond the paraxial approximation. Longitudinal field components in the beam center cause spatially-dependent Rabi frequencies and AC Stark shifts, leading to unexpected qubit-motion coupling [1]. We characterize single- and two-qubit gate infidelities due to this, and provide strategies to minimize adverse effects [2]. We further detail a novel method for driving a quantum logic gate which uses non-paraxial effects to excite the ion chain's vibrational modes [3]. The proposed gate may offer key benefits such as infrastructural simplification – the light only has to be supplied from one direction - and enhanced long-ranged interactions between the ion qubits. Finally, we detail a novel scheme to implement quadratic spin-phonon coupling using optical tweezers on trapped ions. With the addition of Mølmer-Sørenson-type interactions, we show the resulting system can be used to simulate a class of Bose-Hubbard models [4].

References: [1] R.J.C. Spreeuw. Physical Review Letters 125, 233201 (2020). [2] Gallagher, L. P. H., et al. Physical Review Research 8, 013077 (2026). [3] M. Mazzanti et al. Physical Review Research 5 (3), 033036 (2023). [4] Gallagher, L. P. H., et al. Physical Review A 112, L020401 (2025).

Monday 7th September, 11:40
Using Qudits for Quantum Simulation

Presenter: Irini Lindmar and Raffaele Lanini
ETH Zürich

Simulating non-adiabatic quantum dynamics, such as those governing photochemical processes in human vision or DNA resistance to UV, remains a major challenge [1]. Specifically, because these phenomena lie beyond the Born-Oppenheimer approximation, requiring both electrons and nuclei to be treated as an entangled quantum system, they are inherently hard to simulate classically. To describe these dynamics, we use the linear vibronic coupling model (LVCM), where N electronic configurations couple to M vibrational modes via vibronic couplings κ_{mij}:

$$H_{\mathrm{mol}} = \sum_{i,j}^{N} \Delta_{ij}\psi_i^\dagger \psi_j + \sum_{m}^{M} \nu_m a_m^\dagger a_m + \sum_{m}^{M}\sum_{i,j}^{N} \kappa_{mij}\psi_i^\dagger \psi_j (a_m^\dagger + a_m). \tag{3.1}$$

Previous simulations restricted this model to two electronic states ($N = 2$) via single-qubit encodings. We overcome this bottleneck by employing qudits, directly expanding the simulation to $N = d$ configurations. Trapped ions provide an ideal mapping for this scaled architecture. The d-dimensional electronic space is encoded into discrete internal ion states, while the vibrational modes map naturally onto the continuous motion of a calcium-ion chain.

A key objective of this work is to assess how various algorithmic and physical error sources impact the simulation. First, since LVCM interaction terms are not natively available, we theoretically derive the necessary gate sequences for a qutrit ($d = 3$) to implement short-time evolution operators, which are then combined using Trotterization. Second, we study how experimentally relevant noise sources, such as motional heating, amplitude damping, and dephasing, impact these simulated dynamics. Finally, we analyze the validity of the Lamb–Dicke approximation, quantifying the systematic errors that arise when approaching its breakdown regime. For our qutrit encoding, we aim to identify an optimal operating regime that balances these competing errors within the hardware's coherence limits.

Our work will provide concrete parameters for feasible simulations on the MILC trapped-ion platform and establish a pathway toward scaling to higher-dimensional qudits ($d > 3$). Over the next five months leading up to the conference, I will extend these pulse constructions to larger qudit spaces, refine the error models, and explore noise mitigation strategies. By establishing these theoretical bounds, this work will dictate exactly which complex non-adiabatic chemical dynamics can be feasibly simulated on current trapped-ion hardware.

References: [1] M. Kang et al., Seeking a quantum advantage with trapped-ion quantum simulations of condensed-phase chemical dynamics, Nat. Rev. Chem. 8 (2024), pp. 340–358. [2] J. Whitlow et al., Quantum simulation of conical intersections using trapped ions, Nat. Chem. 15 (2023), pp. 1509–1514. [3] C. H. Valahu et al., Direct observation of geometric-phase interference in dynamics around a con-

ical intersection, Nat. Chem. 15 (2023), pp. 1503–1508. [4] T. Navickas et al., Experimental quantum simulation of chemical dynamics, arXiv:2409.04044 (2024)

Monday 7th September, 12:05

Single-Setting Measurements for Characterizing Many-Body Quantum States

Presenter: Leo Walz
Universität Innsbruck

In quantum computations and simulations, it is important to have methods for measuring properties of interest of the quantum system. For small systems containing only a few qubits, the gold standard is to reconstruct these properties via quantum state tomography (QST). However, the number of distinct measurement settings required to obtain a tomographically complete dataset scales exponentially with the number of qubits. For intermediate-scale quantum simulators beyond only a few qubits, QST already becomes unfeasible. We therefore forsake the goal of reconstructing the entire quantum state and turn to methods that allow arbitrary properties of a quantum state's density matrix to be estimated directly. One such method is the implementation of a symmetric informationally complete positive operator-valued measure (SIC-POVM), in which a single experimental setting provides access to an informationally complete measurement record. I will present our latest experimental advances in implementing such a SIC-POVM-based measurement on our trapped-ion quantum simulator with 91 highly connected ion qubits arranged in a 2D crystal. Following Ref. [1], we implement the SIC-POVM by locally mapping the prepared qubit state onto multiple energy eigenstates of the $^{40}Ca^{+}$ ion and detecting the POVM outcomes in a sequence of repeated exposures recorded in a single camera image, differentiating between four different brightness levels. In contrast to more commonly used measurement schemes based on projection-valued measures, which require an additional layer of single-qubit addressing to apply random unitaries or rotate each qubit into the desired measurement basis, thereby adding experimental complexity and potentially errors, the method we use can be implemented entirely within a single experimental setting. It is independent of system size due to the use of global laser pulses acting on all ions in parallel. Because each shot of the SIC-POVM samples from an informationally complete distribution of the full quantum state, the method naturally combines with recent advances in randomized measurements and enables realtime estimation of arbitrary polynomial functions of the density matrix, with precision improving as more repetitions are accumulated.

References: [1] Stricker et al., PRX Quantum 3, 040310 (2022)

Monday 7$^{\text{th}}$ September, 13:30
Interaction-Induced Dynamics in Ultracold Atom-Ion Mixtures

Presenter: Alexander Döring
Universität Freiburg

We investigate quantum atom-ion scattering in the s-wave regime using a hybrid apparatus comprising a single $^{138}Ba^+$ ion in a linear Paul trap and a ^6Li Fermi gas. The atomic sample is prepared via sequential cooling in a magneto-optical trap (MOT) and a compressed MOT (cMOT) before confinement in a crossed optical dipole trap (xODT). Inelastic collision rates are manipulated via magnetically tunable Feshbach resonances. To overcome micromotion-induced energy limits in RF traps, we use radial displacement fields E_{dc} to control the ion's excess kinetic energy ΔE_{ion}. This technique, calibrated via molecular dynamics (MD) simulations, allows for the systematic tuning of collision energies over four orders of magnitude—from the classical $E^{-3/4}$ scaling regime to below the s-wave limit $E_s = 8.8\ \mu\text{K} \cdot k_B$. We present a characterization of the Feshbach spectrum between 240 G and 340 G with an average resonance density of 0.58(1) G^{-1}, utilizing fluorescence-based detection of ion survival probability P_{surv}. Technical emphasis is placed on the manipulation of the substructure of individual three-body resonances. We demonstrate that the resonance position, width, and amplitude are modulated by the external fields and the ion's driven motion. These techniques enable high-speed interaction control, a prerequisite for future many-body quantum simulations.

3.3 Quantum Technologies

Monday 7$^{\text{th}}$ September, 13:50
Fundamental building blocks for a trapped-ion quantum repeater link

Presenter: Max Bergerhoff
Saarland University

The quantum repeater (QR) [1] is a fundamental building block for the realization of large, long-distance quantum networks. By dividing a transmission link into segments of entangled quantum memories and cells generating asynchronously entangled photons [2], it is possible to overcome the exponential loss of direct transmission. We report on the implementation of a quantum repeater cell with free-space-coupled photons from two $^{40}Ca^{+}$ ions in the same Paul trap acting as memories. Ion-photon entanglement is generated asynchronously by controlled emission of single photons from the individually addressed ions into separate single-mode fibers. Photon-photon entanglement with 77.8(6)% average fidelity is then generated by applying a Mølmer–Sørensen gate and state projection of the ions. The advantage of this protocol is highlighted by a 100-fold improvement of the photon pair probability compared to a synchronously operated QR cell, resulting in a single-attempt probability of $9.76(2) \cdot 10^{-5}$ and a photon-pair detection rate of $11.34(2)\mathrm{s}^{-1}$ [3]. A QR segment connects individual QR cells to form a quantum repeater link. We demonstrate the implementation of such a segment in the same setup with two $^{40}Ca^{+}$ quantum memories that are entangled by entanglement swapping of free-space-coupled single photons after generating ion-photon entanglement [4]. Entanglement of the two memories is verified by a parity measurement using two $\pi/2$ rotation pulses on the ions after photonic coincidence detection. To demonstrate the possible use for heterogeneous systems in which the second memory emits at a different wavelength, and to reduce attenuation for long-distance communication, the photons are converted to the telecom C band using polarization-preserving quantum frequency conversion [5] before their detection. The parity oscillation shows a peak-to-peak value of 1.36(15), with a value larger than one being sufficient to prove entanglement [6]. This corresponds to a fidelity of better than 68(8)%. We produce entangled memories at a rate of 4.7 per day, which will be enhanced in the future by the use of an optical resonator.

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Monday 7th September, 14:15

Scalable components for microwave-driven cryogenic trapped-ion quantum computing experiments

Presenter: Sophie Najwa Al-Zaki
Leibniz Universität Hannover

Surface electrode ion traps are a promising platform for building quantum computers. In our cryogenic experiments, we encode qubit states in a first-order magnetic field insensitive hyperfine transition. The qubit control is implemented with microwave conductors that are integrated into the chip, following the microwave near-field approach, which reduces the number of lasers required. To scale up the number of qubits, we need to commission more advanced chips, develop methods to significantly increase the number of electrical signals required for dense ion storage and transport zones on future chips, and need to develop more integrated laser access. In one experiment, we are commissioning an 8-qubit chip with a qubit interaction zone in between two storage registers. All-to-all connectivity will be implemented through swapping operations combined with linear transport between the storage zones. An upcoming junction chip for several more ions is also going to be installed in a second experiment later this year. In a third experiment, we are exploring hybrid-integrated cryogenic control electronics, such as integrated microwave sources and DACs for multiplexed ion shuttling. Reducing the number of cables entering the cryostat will reduce the conductive heat load and enable more advanced chip architectures. A scalable system will inevitably require a larger chip size with dedicated zones for cooling and detecting ions. To enhance the laser access for larger chip sizes, we are preparing to upgrade a fourth experiment to use integrated waveguides in trap chips and report on the progress made towards this.

Monday 7th September, 14:40

Ion trap surface investigation using Kelvin probe force microscopy

Presenter: Christian Flasch
Infineon Technologies

For applications of ion traps in quantum computing and metrology, understanding the origins of anomalous heating and dc stray fields is highly relevant. Anomalous heating and stray fields can both be linked to effects occurring on the ion trap surface e.g., adsorbate movement, fluctuating dipoles, two level fluctuators for anomalous heating and laser-induced charging, surface contaminations for stray fields[1], [2]. Despite numerous studies on different materials no definitive conclusion on root causes could be reached, yet. Some of the most recent studies focus on analyzing the elemental composition of ion trap surfaces using techniques such as Auger electron microscopy and X-ray photoelectron spectroscopy (XPS), aiming to improve the understanding of ion trap surfaces[3], [4]. In our research, we use a Kelvin probe force microscope (KPFM) to study ion trap surfaces. Unlike XPS, KPFM does not analyze the elemental composition of the surface, but rather the electrical potential. The KPFM technique is based on atomic force microscopy; therefore, a very fine tip is used to scan the sample surface. During this scan, the topography and surface potential are mapped simultaneously. The ion trap potential can be derived from the electrical potential the tip is measuring. However, due to the tip's small diameter of approximately 10 nm, a much higher lateral resolution can be achieved than with the ion itself. Using this technique in ambient conditions, we demonstrate that the common assumption in ion trapping, that metals have an equipotential surface, is a drastic oversimplification. For both noble and non-noble metals, we found that surface potential divergences of 50-100 mV are common for chip trap surfaces. In certain cases, potential changes up to 0.5V were found. The main reasons for these changes in potential are grain boundaries and changes in grain structure. In addition to these changes in untreated surfaces, we demonstrated that exposing aluminum to blue laser wavelengths alters the surface potential by up to 0.45 V (Illumination settings: Wavelength:405nm; Laser Power: 100µW; Laser diameter: 10µm; Illumination time: 5s) . We demonstrated that the change in potential is locally confined and stable over several days. Experiments are currently being conducted to show the correlation between these KPFM measurements and in-situ ion trap measurements

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Tuesday 8th September, 15:20
Conformal mapping for computationally efficient ion trap designs

Presenter: Peter Drmota
University of Oxford

Solving the electrostatic problems governing the potentials in ion traps is typically performed using numerical finite element methods. However, these simulations are slow due to the large number of mesh points needed to accurately approximate the potential. It has been recognised that translationally invariant [1] and axisymmetric [2] geometries can be solved analytically using the conformal mapping approach. The solutions to Laplace's equation expressed in the complex plane are harmonic functions. Conformal maps are holomorphic functions which conserve this property. They can therefore be used to transform a solution from a simple geometry, such as a circle, to a more complicated geometry, such as an open polygon. Historically, conformal maps have been used to calculate laminar airflow around a Joukowsky foil by transforming the solution obtained for a cylinder. Here, we employ the Schwarz-Christoffel transformation to calculate the electric potential and pseudopotential produced by arbitrary electrode configurations, to find optimal ion trap geometries with different boundary constraints.

References: [1] J. H. Wesenberg, PRA, 78, 063410 (2008). [2] A. Valette and P. Indelicato, PRST, 13, 114001 (2010).

Tuesday 8th September, 15:45

A Cryogenic Surface Trap with Rydberg Ions

Presenter: Vinay Shankar
Stockholm University

Trapped Rydberg ions are a unique platform for quantum information processing, metrology and simulations [1,2] as they combine the exceptional control over trapped ions with the tunable, long-range interactions of Rydberg states. Rydberg ions have been used to demonstrate sub-microsecond entangling gates [3] but one of the biggest challenges while working with Rydberg ions is double ionisation due to blackbody radiation since Rydberg states are close to the ionisation threshold. The operation of the system in a cryogenic environment would reduce this effect significantly and here we present such an experimental system. The setup hosts a surface ion trap, with separate trapping and experimental zones. The first measurements with the surface trap are presented with the goal of showcasing Rydberg excitations on such a system. The large polarisability of Rydberg ions makes them highly sensitive to surrounding electric fields and can be utilised as a precise probe for sensing microwave fields around the chip.

References: [1] M. Müller, et al., NJP, 10, 093009 (2008). [2] F. Schmidt-Kaler, et al., NJP, 13, 075014 (2011). [3] C. Zhang, et. al., Nature 580, 345 (2020)

Tuesday 8th September, 16:10
Quantum characterization and control of single molecules

Presenter: Max Koppelstätter
Universität Innsbruck

The QCosmo team studies quantum states and dynamics in trapped polyatomic molecular ions with quantum logic spectroscopy (QLS). This method maps molecular transitions to a co-trapped atomic logic ion via a shared motional mode, enabling robust and efficient state readout. We focus on novel spectroscopy techniques, rovibronic state preparation and control, and the possibilities and limitations of applying quantum information processing techniques such as quantum error correction to molecular ions [B. Furey et al. Quantum 8, 1578 (2024)]. We have measured the photodissociation spectra of $CaOH^+$ [Z. Wu et al. J. Chem. Phys. 161, 044304 (2024), and more recently the infrared vibrational transition frequency in the OH stretch mode of a single trapped $CaOH^+$ molecular ion using cat state recoil spectroscopy [Z. Wu et al., arXiv:2511.19687[quant-ph] (2025)]. This method uses non-classical spin-motion-entangled cat states to amplify the detection of the recoil of a single absorbed photon via an accumulated geometric phase. We are also developing Raman QLS to enable molecular hyperfine and rotational spectroscopy and control. Ongoing work includes planning and development of a cryogenic experiment with a segmented ion trap. The segmented design enables potential splitting, allowing the realization of specific Coulomb-crystal configurations of logic and spectroscopy ions. Additionally, it facilitates shuttling operations, such that selected ions are positioned in tightly focused laser beams to perform logic operations. The cryogenic environment suppresses quantum jumps from thermal radiation and background gas collisions, thus extending ion storage and coherence times. Also under development is an ion-injection system, which introduces molecular ions into the ion trap from an external source. It comprises a quadrupole mass filter and a quadrupole deflector, enabling a highly species-selective injection as well as flexible adaptation to different molecular species. The trap dynamics can be synchronized with the molecular injection by monitoring the ion yield using a time-of-flight mass spectrometer.

Tuesday 8th September, 16:30
Towards Cavity QED with Trapped Barium Ions

Presenter: Savelii Dudoladov
Okinawa Institute of Science and Technology

Scalability remains one of the central challenges to achieve fault-tolerant quantum computation in trapped-ion systems. A modular approach, where multiple ion trap modules are interconnected using optical photons [1] is a promising route to tackle this endeavor. In this context, efficient coupling of ions to well-defined optical modes is essential for achieving the remote-entanglement rates required between modules. Cavity QED in the strong coupling regime [2,3], with applications such as efficient single photon sources [4], nodes for quantum communication [5], and non-linear optics at the quantum level [6], enables fast ion-photon entanglement generation with applications in quantum computing and networks. We report our plans and progress towards implementing such a system with barium ions.

Small mode volumes that are required for strong coupling between the ion and cavity can be obtained using fiber-based microcavities [7,8]. We discuss progress and challenges towards integrating microcavities in an ion trap for coupling to barium ion's strong S-P transition at 493 nm, with the long-term goal of using ion-cavity modules as nodes of a quantum network or qubits of a quantum computer that can be entangled by using photonic flying qubits. Cavities operating at short wavelengths have been hampered by degradation in vacuum [9]. We present results showing stable cavity operation at 493 nm in vacuum at low circulating powers [10].

Further, we discuss a number of planned experiments, including fast generation of atom-photon entanglement, fast cavity-assisted state readout, and state readout in the dispersive regime. Additionally, we present our monolithic ion trap platform fabricated via selective laser-induced etching (SLE) with integrated fiber-based Fabry-Perot cavity (FFPC). Together, these represent the crucial step toward a cavity QED system with barium ions, contributing to the broader effort of building modular trapped-ion quantum computers.

Acknowledgements: This work was supported by JST Moonshot R&D Grant Number JPMJMS2063 and MEXT Quantum Lead Flagship Program (MEXT Q-LEAP) Grant Number 20181503.

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Thursday 10th September, 11:15

Remote Entanglement of Trapped Ions Using Integrated Photonics for Collection and Interference

Presenter: Sam Bishop
MIT

Large-scale quantum processors will likely require modular architectures, and photon-mediated entanglement is a promising route to achieving high-fidelity interconnection using trapped ions. Current implementations rely on bulk photon-collection and interference optics, where mode-matching constraints and system-to-system variability impede scalability and limit the rates at which entangled pairs can be generated. To address these limitations, we demonstrate remote entanglement using an integrated photonics platform that enables passive phase stability, straightforward photonic manipulation, and intrinsic reproducibility. Specifically, we engineer waveguide-integrated gratings to couple photons emitted from trapped ions into single optical modes that are interfered on a multi-mode interferometer beam splitter within a microfabricated ion-trap chip, with detection of a single photon heralding entanglement between ions in separate trapping zones. The integrated collection gratings support straightforward multiplexing of remote entanglement in future devices. This demonstration could thus lay the foundation for scalable, high-rate, high-fidelity interconnects between modules of a distributed trapped-ion quantum computer.

Thursday 10$^{\text{th}}$ September, 11:40

Fabrication and Automated Characterisation of Optical Cavity Mirrors for Quantum Networking

Presenter: Catherine Challoner
University of Oxford

To achieve high rates of entanglement generation in trapped ion quantum networks [1], the Purcell enhancement offered by optical cavities can be used to reach near-unit photon collection efficiency [2]. In this work, we address the challenges of fabricating and characterizing microcavity mirrors with ultralow, Å-level roughness, necessary to achieve high cooperativity in ion-cavity systems. We use focused ion beam (FIB) milling to produce features with state-of-the-art surface roughness for this size and scale [3,4]. To rapidly characterize these mirrors and to drive iterative improvements of the fabrication methods used, we design and build an automated cavity mode-matching experiment. An algorithm controls the degrees of freedom of a multi-axis stage (hexapod), on which the cavity is mounted. Using this method, we can achieve dominant coupling to the fundamental within the span of minutes, for a wide range of initial misalignments, and obtain the cavity finesse through automated measurements. These fabrication and characterisation developments offer a repeatable and scalable route to realising high finesse microcavities suitable for integration into ion trap network nodes.

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Thursday 10th September, 12:05

A Linear Ion Trap with Integrated Fiber Fabry–Perot Cavity for Distributed Quantum Computing

Presenter: Shuma Oya

Okinawa Institute of Science and Technology

Distributed quantum computing with trapped ions is expected to rely on modular architectures in which many small ion registers are connected by photonic links [1]. In such a network, efficient ion–cavity coupling is crucial because it increases photon collection into a well-defined cavity mode and fiber channel, thereby boosting the remote-entanglement rate between modules. Short fiber Fabry–Perot cavities (FFPCs) are a promising route to this regime, but bringing dielectric mirrors close to the ion can introduce stray charging, trap distortion, and excess heating [2]. We present a combined hardware and fabrication approach toward compact, shielded ion–cavity interfaces for a linear ion trap. First, we developed a miniaturized, monolithic linear Paul trap for transverse FFPC integration, fabricated from gold-coated fused silica via selective laser etching [3]. The monolithic geometry removes post-fabrication electrode alignment, preserves trap symmetry, and provides large optical access while allowing conductive shielding of nearby cavity holders. Single 40Ca+ ions were successfully trapped, and the measured secular frequencies agree with finite-element simulations, yielding fitted imperfection factors of 0.96, 0.95, and 0.92 for the two radial and axial modes, respectively. Second, we developed an adaptive CO2-laser machining method for fiber mirrors with in situ interferometric imaging [4]. The method updates multi-shot ablation patterns from the measured surface after each step. A key control parameter is the pause between shots, which tunes heat accumulation and therefore the lateral extent of each ablation event, enabling a controlled transition between global shaping and local correction. Using this approach, we fabricate Gaussian or near-spherical concave mirrors with radii of curvature of 250-700 µm, effective diameters of about 60 µm, and low ellipticity ($r_e < 0.2$) with close-to-unity yield. After high-reflectivity coating, the resulting FFPCs reach a finesse of 1.510^5 at 854 nm and maintain $> 10^5$ for cavity lengths up to 430 µm. These results provide key components for scalable, low-loss ion–photon interfaces in distributed trapped-ion quantum computing.

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Thursday 10th September, 15:30

Trapped ions as a platform for quantum communication over an urban fiber link

Presenter: Christian Haen
Universität des Saarlandes

Large-scale quantum networks provide the basis for many potential quantum communication applications, such as quantum key distribution (QKD) and distributed quantum computing. Due to the widespread availability of telecom fibers used in classical communication, these could serve to implement such networks over potentially several hundred kilometers by encoding and sending quantum information via photons. Using long fiber-based networks also provides challenges such as environmentally induced polarization drifts, high losses due to splices, and the ability to interface different types of quantum memories. We report on the realization and characterization of a 14 km-long quantum communication fiber testbed as well as the implementation of several quantum network protocols based on a single $^{40}Ca^{+}$ ion as a quantum memory. Due to an exposed above-ground section, a fast and automated polarization drift compensation is implemented that allows us to maintain 99% process fidelity . Using the $^{40}Ca^{+}$ ion and an ion-resonant photon-pair source, we demonstrate entanglement distribution with up to 99 % fidelity and atom-to-photon quantum state teleportation [1] with an average fidelity of 84 % over the fiber link [2]. To reduce transmission loss, we utilize quantum frequency conversion from the ionic wavelength of 854 nm to 1550 nm [3]. We also demonstrate the conversion of atom-photon entanglement from polarization to time-bin encoding in order to enable interfacing dissimilar quantum memories, such as ions and color centers. We use a fiber-based telecom encoding and analyzer setup with active phase and temperature stabilization with a conversion fidelity of 97.8 %. The resulting converted atom-photon entanglement fidelity is 70.4 % compared to 93 % without conversion to time-bin. The reduction is mainly due to a low signal-to-background ratio and long-term drifts in the setup. We also demonstrate a device-independent quantum key distribution protocol [4] based on atom-photon entanglement over an emulated fiber link of 20 km length. We also include quantum frequency conversion to telecom and back to the ion wavelength, as well as automated polarization compensation and classical communication to show the viability of the protocol for the actual fiber testbed.

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Thursday 10$^{\text{th}}$ September, 15:55

Experimental Characterization of Normal Modes in Planar Ion Traps by Selective Mode Excitation

Presenter: Ryosuke Nishimoto

University of Osaka

Our group has demonstrated the trapping of parallel chains of $^{40}Ca^{+}$ ions using a planar-electrode ion trap. By applying two radio-frequency (RF) voltages, a double-well potential is generated, and the distance between ion chains can be controlled by adjusting the ratio of these RF voltages. Ideally, the trapping potential is perfectly harmonic for a one-dimensional ion chain. In practice, however, distortions arise from stray electric fields and electrode asymmetries. These effects become more pronounced in double-well configuration, where more complex electrode structures are required. In this study, we characterize the trapping potential from ion imaging data by extracting higher-order motional eigenmodes. To this end, we develop and demonstrate techniques to optically excite motional modes and perform time-resolved imaging. These methods provide access to higher-order modes and their phase information, enabling detailed characterization of stray fields and nonlinear components of the trapping potential. These techniques are expected to enable accurate estimation of trapping potentials via the mode-structure measurements, extending beyond harmonic confinement to anharmonic potentials and two-dimensional ion configurations.

We define the direction along which ions align in a single chain as the z-axis. For a system of N ions confined in a harmonic potential, the total potential consists of the harmonic confinement and the Coulomb interaction between ions. This system exhibits N normal modes of vibration along the z-axis. The curvature of the harmonic potential corresponds to the eigenvalue of the fundamental motional mode, known as the center-of-mass (COM) mode, in which all ions oscillate in phase with equal amplitude.

There are two primary methods for measuring motional frequencies. One method is based on sideband spectroscopy, which identifies modes from carrier and sideband transitions, but requires highly stable lasers and precise spectroscopic techniques. The other method is electrical “tickling,” in which forced oscillations are induced by applying an AC signal to a DC electrode. By detecting resonance, the eigenfrequency of a mode can be determined. This method is widely used due to its simplicity; however, because it generates a global excitation field acting on the entire ion chain, it becomes increasingly difficult to excite higher-order modes due to the asymmetry of their eigenvectors. To overcome this limitation, we investigate an alternative approach termed optical tickling, in which motional modes are excited via amplitude modulation of the cooling laser. By individually addressing ions, a localized excitation field is generated, enabling efficient excitation of all normal modes, including higher-order modes that are difficult to access electrically. In parallel, we are developing a time-resolved imaging technique capable of measuring eigenvectors of the excited modes with phase resolution. We have demonstrated this method for

COM and stretch modes by using an acousto-optic modulator as a fast optical shutter. In this presentation, we report recent progress in the excitation of higher-order motional modes using optical tickling and their characterization via time-resolved imaging.

Thursday 10$^{\text{th}}$ September, 16:20
Quantum computing with X- junction for 2D navigation of trapped ion qubits

Presenter: Salvi Mohandas
Johannes Gutenberg-Universität Mainz

Trapped-ion quantum processors are currently transitioning from proof-of-concept laboratory experiments to robust, scalable, and user-ready devices. A critical requirement for large-scale computation, particularly within a Quantum Charge-Coupled Device (QCCD) architecture, is the ability to dynamically shuttle ions through multi-zone, micro-structured trap arrays. Leveraging advanced trapped ion control electronics, our team at Johannes Gutenberg University Mainz (JGU) is refining the reliable transport of ion crystals across complex trap junctions. We utilize a segmented X-trap which is fabricated in our own clean room via Selective Laser Etching (SLE). Fully sculptured trap geometry has been meticulously engineered and scaled down to optimize radiofrequency (RF) requirements, mitigate anomalous heating, and minimize stray capacitance. The design features a central X-junction equipped with a split bridge to facilitate highly controlled transport. The voltage protocols driving this transport are generated using a recently developed numerical toolchain tailored for fast, low-excitation ion shuttling in segmented trap [1]. Based on a precise electrostatic model of our trap electrode geometry, this framework combines an electrostatic field solver with efficient unconstrained optimization and dynamical simulations of ion motion. It computes time-dependent voltage waveforms that realize prescribed transport trajectories across the junction while strictly adhering to real-world experimental constraints. Here, I describe the experimental setup in detail. Moreover, I sketch the sequence comprising initial ground-state preparation via sideband cooling, followed by the transport of an ion crystal across the X-junction to benchmark the performance of both the SLE trap and the computed waveforms. Important characterizations include the measurement of the motional excitation per round trip. The X-trap will eventually serve to distribute qubit entanglement in a scalable 2D quantum computing architecture.

References: [1] Conta, Andreas, Santiago Bogino, Frodo Köhncke, Ferdinand Schmidt-Kaler, and Ulrich Poschinger. "Toolchain for shuttling trapped-ion qubits in segmented traps." arXiv preprint arXiv:2601.08495 (2026).

Thursday 10th September, 16:40
Switchable low-noise permanent magnet gradients for long-wavelength trapped-ion quantum information

Presenter: Caleb Burhan
University of Sussex

Static magnetic field gradients can be used to couple the spin and motional states of trapped-ions, allowing for two-qubit gates using long-wavelength radiation. The use of permanent magnets to create such gradients give rise to much better noise specifications than the use of current carrying wires (CCWs), enabling much higher entanglement fidelities while reducing the required power consumption. The desire for scalability, as well as the need to switch fields off between gate and shuttling operations, has led to the development of trap-integrated current carrying wire methods of gradient generation. Gradients produced by CCWs inevitably introduce current-dependant noise which must be mitigated with bulky low-noise current supplies. We present a method of generating magnetic field gradients with a novel magnetic field switching system. This “Saturable Electronic Reluctance Switch” (SERS) allows the field of a permanent magnet to be switched on and off by application of a current, but without any current dependence at the output field. This allows for fully stable output field akin to a permanent magnet allowing for high-fidelity two-qubit gates, but with the ability to switch the field on and off for shuttling operations within a QCCD architecture. This method is the first bi-stable magnetic field switch, and can find applications in other areas of atomic and molecular physics such as micro-NMR imaging and neutral atom traps.

3.4 Quantum Computing

Monday 7th September, 15:20
Computational Capabilities and Compilation Strategies for Trapped-Ion Quantum Computers

Presenter: Jurek Eisinger
Johannes Gutenberg University Mainz

Trapped-ion quantum computers mature to larger qubit numbers, but their computational capability is limited by architectural and control constraints. We present a framework for quantifying and optimizing the computational capabilities of trapped-ion processors. Using compiler techniques from classical computer science, we show how arbitrary quantum circuits can be mapped to hardware-efficient sequences of operations, optimized for metrics such as shuttling distance and gate overhead. The approach builds on and extends existing work on circuit compilation for trapped-ion quantum computers [1], and relates to analogous compiler frameworks developed for neutral atom systems [2]. It is demonstrated for both 1D and 2D [3] shuttling architectures, and extended toward logical qubit encodings to support fault-tolerant operations in future large-scale systems. In this context, we introduce a universal routing and scheduling algorithm for a shuttling-based trapped-ion quantum computer that efficiently orchestrates qubit register reconfiguration and gate execution, tailored to varying levels of ion-qubit connectivity.

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This work is carried out in collaboration with the group of Prof. Robert Wille (Technical University of Munich) and neQxt GmbH.

Monday 7$^{\text{th}}$ September, 15:45
Superconducting Ion Trap System for 87Sr+ Hyperfine Qubit

Presenter: Qifeng Lao
Komaba Institute for Science (KIS), The University of Tokyo

Large-scale trapped-ion quantum processors require highly integrated control architectures capable of supporting high-fidelity gate operations. An all-electronic control platform offers significant advantages in on-chip integration, scalability, and operational fidelity. Recently, a near-field gradient-based entangling method has demonstrated the highest two-qubit gate fidelity among all quantum computing platforms [1]. To date, the near-field gradient required for entangling operations is typically generated by alternating currents flowing through normal-metal trap electrodes. The maximum current that can be applied is constrained by Joule heating in the narrow trap electrodes and the associated power limits required to prevent chip damage. This limitation not only restricts the achievable gate speed but also presents a significant challenge for scaling to large systems, where tens to hundreds of traps may be integrated on a single chip, as the total power dissipation becomes substantial. To address this challenge, we have demonstrated a full-superconducting surface ion-trap design incorporating a high-Q microwave resonator that generates sub-ampere oscillating currents with sub-milliwatt input power [2]. Furthermore, hyperfine splitting in trapped ions enables qubit encoding in the microwave regime, allowing compact on-chip resonator designs while maintaining long coherence times. Based on these considerations, the 87Sr+ ion is selected as the qubit platform. In this work, we present the current progress in developing a cryogenic system for a superconducting ion trap based on 87Sr+ ions. This includes the design of a superconducting helical resonator, fabrication of the superconducting ion trap, and the implementation scheme for 87Sr+ ion operation.

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Monday 7th September, 16:05
Distributed quantum error detection across a trapped-ion network

Presenter: Ellis Ainley
University of Oxford

One approach towards a utility scale quantum computer uses smaller processors that are linked via a quantum network. In such systems, both computation and error correction must be performed across these nodes. Here, we demonstrate quantum error detection across a distributed trapped-ion network. Logical qubits are encoded in physical qubits that are spatially separated across two ion traps, ~ 2 m apart. Shared entanglement is used as a non-local resource to measure stabilisers between them.

Our platform consists of two mixed-species ion trap modules that are linked photonically, each containing $^{88}Sr^{+}$ network qubits and $^{43}Ca^{+}$ circuit qubits. Remote entanglement between network qubits is created by generating one photon from each ion and interfering them, with coincident detection heralding entanglement, achieving fidelities exceeding 96% at a rate of ~ 10 s^{-1} [1]. Combined with mixed-species entangling gates, and classical feedforward, we have performed teleported gates between remote circuit qubits [2].

Building on this, we implement non-local stabiliser measurements using our shared Bell pair as an ancilla. Specifically, we encode logical information in the X-basis subspace of two remote circuit qubits and measure the XX stabiliser with local entangling operations and measurements on the network qubits. We characterise the performance of a single round of this stabiliser measurement across a range of dephasing error rates. By conditioning on successful detection outcomes, we observe clear error suppression and an improved stabiliser value. Repeating this over multiple rounds progressively enhances the stabiliser expectation value, a key requirement for quantum error correction. Finally, we will extend the protocol to entangled logical states by preparing the remote circuit qubits in a Bell state, and then detecting and correcting both phase- and bit-flip errors on this state.

Our demonstration of non-local stabiliser measurements across a quantum network establishes a key building block for scalable, fault-tolerant quantum computing in modular architectures.

References: [1] D. Main et al., arXiv:2506.14334. [2] D. Main et al., Nature 638, 383-388 (2025).

Monday 7$^{\text{th}}$ September, 16:30

Scaling up trapped ion processors using high-speed and high-connectivity two-qubit gates

Presenter: Isabelle Savill-Brown
The Australian National University

Conventional two-qubit gate mechanisms feature high connectivity between spatially-separated qubits, mediated by collective vibrations of ions within a single trap. However, controlling off-resonant excitation of spectator modes becomes increasingly challenging as the length of the chain increases, reducing gate speeds and fidelities. Modern architectures circumvent this challenge by separating ions into small chains connected via ion shuttling or photonic interconnects. However, these approaches introduce significant resource overheads, making them the primary bottlenecks when scaling trapped-ion processors.

An alternative pathway to increasing quantum logic rates in trapped-ion systems is to employ 'fast gate' protocols, where the ions are subject to sequences of spin-dependent kicks (SDKs) driven by broadband laser pulses. Previous studies suggest fast gates can enable MHz quantum logic rates in current trapped-ion processors without reduction of gate speed in scaled ion crystals, while also supporting more flexible trap geometries. However, while fast gates have been widely studied in the context of nearest-neighbour operations, their potential for enabling scalable, high-connectivity architectures remains an open question.

We present a theoretical study of fast all-to-all entangling gates in trapped-ion processors [1]. We explore how fast gate protocols operating in different regimes of the ion dynamics can be exploited to achieve high-fidelity, non-local entangling operations in scalable trapped-ion crystals. In particular, we identify a regime of phonon-mediated entanglement in which gates between arbitrary ion pairs can be performed in approximately 1.3-2 center-of-mass oscillation periods. We further assess the experimental feasibility of the proposed gate schemes, showing that the required SDK resources are independent of both chain length and qubit separation [2].

These results suggest that entangling gates based on impulsive spin-dependent excitation can overcome key scaling bottlenecks in trapped-ion platforms, and outline pathways toward combining fast operation, high connectivity, and modular scalability in future quantum processors.

References: [1] I. Savill-Brown, J. J. Hope, A. K. Ratcliffe, V. D. Vaidya, H. Liu, et al. High-Speed and High-Connectivity Two-Qubit Gates in Long Chains of Trapped Ions. 2025. arXiv: 2506.11385 [quant-ph]. [2] I. Savill-Brown, Z. Mehdi, A. K. Ratcliffe, V. D. Vaidya, H. Liu, et al. Error-Resilient Fast Entangling Gates for Scalable Ion-Trap Quantum Processors. 2025. arXiv: 2508.07593 [quant-ph].

Wednesday 9th September, 15:20
Implementing and Characterising Error Mitigation by Virtual Distillation under Structured Noise

Presenter: Iver Romvig Øvergaard
University of Oxford

Error mitigation is a key tool for improving the performance of near-term quantum devices, but its efficacy depends strongly on the structure of the underlying noise [1]. In realistic systems, errors can exhibit temporal and spatial correlations, which determine which suppression strategies are effective. Virtual distillation (VD) is a promising approach, where exponential error suppression in the estimation of observable expectation values is achieved by increasing the number of state copies [2,3,4]. Like many mitigation techniques, however, it relies on the assumption that noise acts independently across copies.

Here, we combine error mitigation with a direct probe of this assumption. We demonstrate VD for the first time on a trapped-ion platform and introduce a scheme based on randomised benchmarking using parallel ("k-copy") sequences that isolates correlated error components with minimal experimental overhead. Applying this method before and after VD allows us to study the effect of correlated errors on its performance. Together, these results provide a scalable route to implementing, diagnosing, and validating error mitigation in the presence of structured noise.

References: [1] Z. Cai, et al., Rev. Mod. Phys. 95, 045005 (2023). [2] B. Koczor, Phys. Rev. X 11, 031057 (2021). [3] W. J. Huggins, et al., Phys. Rev. X 11, 041036 (2021). [4] T. Araki, J. F. Goodwin, and B. Koczor, Phys. Rev. A 112, 042619 (2025).

Wednesday 9th September, 15:40
Generation of Two-Photon Entanglement Using a Single Ion–Cavity System

Presenter: Adrien Amour
University of Sussex

Control over the internal states of trapped ions makes them the ideal system to generate single and two-photon states. Coupling a single ion to an optical cavity enables efficient emission of single photons into a single spatial mode and grants control over their temporal shape, phase and frequency. Using the long coherence time of the ion's internal states and employing a scheme to protect the coherence of the ion-cavity interaction, we demonstrate the generation of a two-photon entangled state with full control over the phase. Initially, ion-photon entanglement is generated. A second photon is subsequently generated, mapping the ion's state onto the second photon. By adjusting the drive field the phase of the entangled state can be fully controlled. We implement this scheme in the most resource efficient way by utilizing a single $40Ca^+$ ion coupled to an optical cavity and demonstrate the generation of a two-photon entangled stated with full phase control with a fidelity of up to 82%.

Wednesday 9th September, 16:05
Observation of Cooperative Scattering Light in Trapped-Ion Crystals

Presenter: Kratveer Singh
Palacky University Olomouc

Understanding the collective interaction of light with quantum emitters is of paramount importance in quantum optics and a wide range of applications. Trapped-ion systems provide an ideal platform for studying light–matter interaction at the level of a few atomic scatterers, offering precise control over both electronic and motional degrees of freedom, and enabling access to a regime where emitters can be individually controlled yet collectively probed.

We experimentally demonstrate control over the photon statistics of light emitted by several mutually independent quantum scatterers - trapper ions using interference. In particular, we observe a transition from sub-Poissonian to super-Poissonian statistics for constructive and destructive interference of the elastically scattered component of resonance fluorescence, respectively. We show that this effect can be exploited in the mesoscopic regime to achieve deviations from the thermodynamic limit of photon statistics, highlighting the persistent role of coherent scattering. The interference between coherent scattering and spontaneous emission leads to spatial variations in both intensity and two-photon correlations, $g^{(2)}(\tau = 0)$, demonstrated for ion chains with up to 18 ions.

To further enhance control over trapped ion–light interactions and to enable the observation of subtle cooperative phenomena, we implement several crucial methods to increase the coherent fraction of scattered light. This is achieved by implementing electromagnetically induced transparency cooling of linear strings of $^{40}Ca^{+}$ ions, combined with a fast pulsed excitation sequence that optimizes coherent scattering on a selected dipolar transition within the S–P level transition manifolds. With these improvements, we reach unprecedentedly high coherent fractions in the scattered light. For example, the interference visibility for a four-ion string reaches 97.4 ± 0.9, approaching the limit set by ground-state position uncertainty.

This enhanced control enables the observation of the onset of cooperative effects in a well-controlled and addressable system of laser-cooled ion strings. In particular, we resolve significant peak-to-peak modulations of the scattering rate arising from dipole–dipole interactions between two ions in a steady-state, with amplitude of up to $\sim$2 and investigate its scaling with the number of ions in the crystal.

Our results mark a new milestone in optical scattering from ion crystals, bridging the regime from interference-dominated photon statistics to one where cooperative emission effects become observable. This establishes trapped-ion crystals as a platform for exploring cooperative quantum optical phenomena in fully controlled and addressable systems, and for engineering novel quantum light sources based on mesoscopic many-body light–matter interactions in free space.

Wednesday 9th September, 16:30

Practical quantum error correction on maximally modular networked architectures

Presenter: Tenzan Araki
University of Oxford

Scaling quantum devices while preserving coherence remains a central challenge for practical quantum computation. Quantum error correction (QEC) addresses this, but its implementation depends critically on hardware constraints. By the threshold theorem, errors can be suppressed arbitrarily by increasing the number of physical qubits if physical error rates fall below a code-dependent threshold, motivating architectures that combine scalability with high-fidelity qubits.

Trapped ions are a promising platform for QEC due to their high fidelities and connectivity, both advantageous for codes encoding a high number of logical qubits per physical qubits [1, 2]. Decoding speeds are also unlikely to be limiting due to the relatively slow gate speeds. The challenge is then to scale the architecture without degrading its appealing properties.

Traditional approaches scale trapped-ion systems either by extending ion chains or by shuttling ions between zones. Both define a single quantum processing unit (QPU) and face limitations at large scales: long chains suffer from overly crowded motional mode frequencies, while shuttling introduces overhead from transport and cooling. More broadly, scaling a single QPU appears challenging across qubit platforms.

Modular architectures offer a complementary approach, where multiple moderate-sized QPUs connected via entanglement enable universal quantum computation. This shifts the challenge from scaling individual QPUs to reliably generating inter-module entanglement, which has been demonstrated in trapped ions using photonic links [3, 4].

In this work, we study a “maximally modular” architecture where each QPU contains a minimal number of (around 2–5) ions [5, 6]. This keeps local operations fast and reliable, but makes probabilistic, noisy entanglement generation the main bottleneck. Its stochastic nature complicates QEC scheduling, as asynchronously generated entanglement must be coordinated to minimise redundancy and errors.

We develop scheduling strategies across multiple layers, including parallelised parity checks, cutoff policies for aborting delayed operations, and synchronised entanglement attempts. We numerically simulate the performance of our implementation using a realistic error model based on modular trapped-ion devices. Our analysis provides a practical framework for implementing distributed QEC in trapped-ions and beyond.

References: [1] N. P. Breuckmann et al., Quantum low-density parity-check codes, PRX Quantum 2, 040101 (2021). [2] S. Bravyi et al., High-threshold and low-overhead fault-tolerant quantum memory, Nature 627, 778 (2024). [3] L. J. Stephenson et al., High-rate, high-fidelity entanglement of qubits across an elementary quantum network, Phys. Rev. Lett. 124, 110501 (2020). [4] D. Main et al., Distributed quantum computing across an optical network link, Nature 638, 383 (2025). [5] N. H. Nickerson et al., Topological quantum computing with a very noisy network and local error rates approaching one percent, Nature Communications 4, 1756 (2013). [6] N. H. Nickerson et al., Freely scalable quantum technologies using cells of 5-to-50 qubits with very lossy and noisy photonic links, Phys. Rev. X 4, 041041 (2014).

Thursday 10$^{\text{th}}$ September, 9:30
Microwave-driven same-species sympathetic cooling

Presenter: Emma Vandrey
University of Oxford

Trapped ions are a promising hardware platform for quantum computing as they unite properties such as long coherence times, high gate fidelities, low state preparation and measurement errors, and networking capabilities. While running algorithms composed of long gate sequences on trapped-ion quantum computers, it is essential to cool the ions' motional modes in order to minimise errors caused by motional heating. This can be achieved by sympathetically cooling the logic ion with an ion of a different species, such that the laser beams required for cooling one ion do not affect the information stored in the other. However, this approach significantly increases the hardware complexity, and the difference in mass between the ion species leads to a suboptimal cooling efficiency.

Using microwave-driven sideband cooling in combination with a narrow-linewidth quadrupole laser at 729 nm, we demonstrate sympathetic cooling with two ions of the same species to an average phonon number of $\overline{n} = 0.09(3)$. Due to the large hyperfine splitting of the $^{43}Ca^+$ ground-state manifold at 28.8 T, the information stored in the logic ion is well-isolated from the cooling process and the introduced error of $9(1) \times 10^{-4}$ per cooling cycle does not limit algorithm performance.

In addition to reducing hardware complexity and increasing cooling efficiency, same-species sympathetic cooling offers the benefit that, between cooling cycles, the coolant ions could be repurposed as ancilla qubits for error correction schemes.

Thursday 10th September, 9:50
Non-destructive parity measurement of a motional cat state

Presenter: Ingrid H. Zimmermann
University of Colorado Boulder

Quantized motional states of trapped ions are a quantum degree of freedom that is emerging as a platform for applications such as quantum computing and quantum simulation that involve bosonic degrees of freedom. One important tool, useful for example in quantum error correction, is parity measurement. Non-destructive measurements of the parity of a motional state enable mid-circuit projections into eigenstates of parity and can be used for example in bosonic stabilizer error correction schemes. However, ion internal state measurements typically rely on conditional fluorescence of an ion, "bright" or "dark". The state of a motional mode will generally not be preserved after "bright" detection due to motional heating when the ion experiences thousands of photon recoils.

To preserve motional information upon measurement, we engineer the motional modes of a multi-species ion chain and entangle the internal state of an ion with a motional state of a mode in which this ion does not participate. This enables protection of the motional state from decoherence due to photon recoils when the ion fluoresces. We aim to demonstrate non-destructive parity measurements and apply them to create and characterize motional "Schrödinger's cat" states in a mixed-species ion crystal of 9Be+-25Mg+-9Be+. We entangle motional states with two internal states of the Mg+ ion using a parity operation. This parity operation is implemented with a simple ion trapping tool, a Raman carrier pulse, making use of its motional dependence due to a finite Lamb-Dicke parameter. The motional states are then swapped from the motional mode on which the entanglement was performed to a "protected" motional mode, in which the Mg+ ion does not participate, by applying oscillating fields to the trap electrodes that coherently couple the two modes. Fluorescence detection on the Mg+ ion projects it to a particular internal and motional state and avoids the effects of photon recoil on the protected mode. A coherent state of motion whose parity is measured in this way will be projected into either an even or odd motional cat state, with the cat-state parity heralded non-destructively by the measurement. The parity can subsequently be verified by a second, destructive or non-destructive, measurement.

I will show results of critical steps needed to realize this protocol, including the entanglement of states on a single ion and on a multi-ion chain, Wigner function tomography of non-classical motional states on a single ion, and protection of the motional parity from detection by using motional mode-mode coupling on a multi-ion chain.

Thursday 10th September, 10:10

Four- and six-photon stimulated Raman transitions for coherent qubit and qudit operations

Presenter: Gabriel Gregory
University of Oregon

We experimentally demonstrate transitions between electronic angular momentum states with a difference in magnetic quantum numbers $\Delta m_J = 3$, 4, and 5 via resonant four- and six-photon stimulated Raman transitions in a single trapped atom. Derivation of the corresponding Rabi frequencies, which are verified experimentally, follows the standard treatment of two-photon transitions including the adiabatic elimination of intermediate states. We demonstrate a four-photon transfer fidelity of 96(1)% and discuss pathways to increase the observed multi-photon transition fidelities to ¿99.99%, providing a tool for efficient, high-fidelity control of qudits and single-atom logical qubits. Additionally, we measure ac Stark shifts up to eighth order in perturbation theory and speculate on potential applications to driving a two-qubit "light-shift" entangling gate on clock qubits and reducing crosstalk in individually-addressed qubit arrays.

Thursday 10th September, 10:30
Entanglement of trapped-ion qubits over a 50 km-long fiber link

Presenter: Armin Winkler
Universität Innsbruck

Quantum networks of registers of atoms have promising applications in cryptography, distributed computing, sensing, and clock synchronization. The realization of such networks requires the establishment of entanglement between atoms tens of kilometers apart. We recently performed an experiment to entangle two trapped atomic ions separated by 50 km of spooled optical fiber. Preliminary analysis of the data shows clear entanglement between the two ions. The entanglement is heralded by the detection of two photons – each collected from an ion using an optical cavity. In my presentation I will detail the experimental setup, give a quantitative analysis of our results in terms of the achieved Bell state fidelity and rates, and present our understanding of the main limiting factors. A key feature of our approach is the use of the two-photon click scheme, which does not require interferometric stabilization of the 50 km fiber path. Our results therefore open the door to robust metropolitan-scale networks of trapped-ion quantum processors, sensor arrays and clocks.

Thursday 10th September, 14:30
Quantum information processing using 176Lu+ Qudits

Presenter: Prachi Nagpal
University of Sydney

Extending the computational Hilbert space, we encode qudits in the magnetically insensitive hyperfine states in the 3D1 manifold of Lutetium ions. Equipped with error-suppressing pulses through optimized dynamical modulation of optically driven couplings, this is designed to implement universal control for qudit quantum information processing. Additionally, the system can co-trap ytterbium ions, enabling exploration of practical applications such as quantum non-demolition measurements [1], quantum-logic-assisted syndrome readout protocols, and quantum simulations for chemistry [2].

References: [1] D. Hume et al., Phys. Rev. Lett. 99, 120502 (2007). [2] R. J. MacDonell et al., Chem. Sci., 2021,12, 9794-9805 (2021).

Thursday 10$^{\mathrm{th}}$ September, 14:50
Native polyqubit gate mediated by multi-tone drive

Presenter: Sophie Decoppet
University of Oxford

The leading approach to increase the computational capabilities of an ion-trap quantum computer is to increase the number of ions in the device. Employing multi-level systems, however, also significantly increases the Hilbert space dimension but with less hardware overhead. In trapped ions, multi-level systems can be made, for example, by using more atomic states or by harnessing the harmonic modes of motion of the chain. The multiple levels can be treated either as one large base-d register (known as qudits) or as multiple base-2 qubits (known as polyqubits or virtual qubits).[1] While the two interpretations are equivalent, the theoretical and experimental study of qubits is much more mature than that of qudits. Interpreting each ion as multiple qubits might provide more insight and intuition.

Manipulating a multi-level system is technically challenging. Driving gates within a single multi-level system requires control of multiple tones: at least $d-1$ tones are needed to address a d-level system. Generating these tones is experimentally complex, especially in certain use cases where they must be phase-locked to each other. The tones are usually driven sequentially, and switching between them exposes the system to errors that don't appear in qubit devices.[2] Each pair of states within the polyqubit must remain phase coherent with its driving tone, so any phase that is accrued while that transition is not addressed must be tracked and corrected.

We present a novel approach to driving individual qubits in a polyqubit that addresses the sources of error inherent to single-tone gate schemes. We also provide an implementation of this gate in a polyqbuit with two qubits stored in a single $^{137}\mathrm{Ba}^{+}$ ion across the ground $S_{1/2}$ and metastable $D_{5/2}$ levels. Our multi-tone technique directly drives single-qubit gates with one pulse, compared to single-tone schemes which use multiple two-qubit gates to construct single-qubit gates. In our polyqubit gate, all tones are driven at the same time, creating a closed-contour interaction[3,4]. The tones interfere with each other to create the desired dynamics that drive a single-qubit gate. Choosing whether to drive one qubit versus the other can be done in software by simply updating the relative phases of the tones. This technique leverages the unique features of multi-level systems instead of using techniques originally developed for two-level systems to create a more native polyqubit gate.

References: [1] Shivam et al., arXiv:2406.19332 (2024). [2] A. Vazquez-Brennan, PhD thesis. Manuscript in preparation (2026). [3] Buckle et al., Optica Acta: International Journal of Optics, 33(9), 1129–1140 (1986). [4] Barfuss et al., Nat. Phys. Volume 14, 1087–109 (2018).

Friday 11th September, 11:15
Progress on room-temperature microwave-driven two qubit quantum processor

Presenter: Alexander Onkes
Leibniz Universität Hannover, Physikalisch-Technische Bundesanstalt

Our group develops scalable ion-trap quantum computers based on the Charge-Coupled Quantum Device (QCCD) architecture. To realize elementary quantum gate operations on the trapped-ion qubits, we employ the microwave near-field approach [1] which uses microwave conductors embedded in the trap structure and the resulting amplitude gradients of the microwave magnetic field. This poster reports on results from a room-temperature surface-electrode ion trap apparatus, which we employ to develop new gate schemes and qubit control techniques. The setup employs $^{9}Be^{+}$ ions in a surface-electrode ion trap. We have recently demonstrated a universal computation register based on amplitude-modulated two-qubit microwave gates and micromotion-sideband single-ion addressing [2]. We report on important experimental upgrades to this setup, including a new control system and an individual-ion real-time capable readout, which significantly enhances our gate analysis capability, as well as novel multi-qubit gate schemes. This work has been supported by the QVLS-Q1 project, the BMFTR ATIQ project and the EU Millenion-SGA1 project.

References: [1] C. Ospelkaus et al., Nature 476 7359 (2011) [2] N. Pulido-Mateo et al.,Phys. Rev. Research 6, 2 (2024)

Friday 11$^{\text{th}}$ September, 11:35
Enabling mid-circuit measurement and readout with trapped barium ions

Presenter: Phoebe Grosser
Universität Innsbruck

Mid-circuit measurement and readout (MCMR) are essential requirements for fault-tolerant trapped-ion quantum computers, as they enable syndrome measurement and feedback in quantum error correction protocols. Implementing these operations on auxiliary qubits in single-species trapped ion crystals remains challenging, as photon absorption due to resonance-fluorescence detection can introduce significant decoherence in nearby data qubits. In this work, we investigate a simplified MCMR architecture with trapped barium ions that utilises tightly focused, far off-resonant lasers combined with a global beam that couples to the $6S_{1/2} \to 5D_{3/2}$ transition at 2051 nm in Ba^{+}. We propose to mitigate decoherence in data qubits by implementing background-free detection of the auxiliary qubits with the 2051 nm laser, after which the auxiliary qubits can be cooled via mid-sequence sideband cooling with the same laser. To support stable operation, we perform frequency stabilisation of the 2051 nm laser via locking to an optical frequency comb. Ultimately, this work supports the implementation of MCMR and mid-sequence cooling in single-species quantum processors.

Friday 11$^{\text{th}}$ September, 11:55
Toward Mixed-Species Quantum Logic Using Microwave and RF Magnetic Fields in Trapped Ions

Presenter: Deviprasath Palani
NIST, Boulder

We report progress on quantum logic implemented using microwave and radiofrequency magnetic fields together with magnetic field gradients in a mixed-species trapped-ion system. This approach avoids direct optical interactions on the data ion, thereby mitigating spontaneous-emission-induced errors and surface charging associated with short-wavelength laser light, and offers a path toward scalable laser-free quantum information processing. Our platform consists of a co-trapped $^{25}\text{Mg}^{+}$ data ion and $^{40}\text{Ca}^{+}$ helper ion confined in a surface-electrode trap. The charge-to-mass ratio mismatch between species leads to imbalanced participation in the shared motional modes, particularly the radial modes relevant for magnetic-field-gradient-based spin–motion coupling. We implement mode–mode coupling between Mg-dominant and Ca-dominant motional modes to achieve controlled hybridization and redistribution of mode participation, enabling sympathetic cooling of data-ion-dominant modes via the Ca^{+} helper ion and providing a means of tuning the effective spin–motion coupling in the mixed-species crystal. Building on this, we pursue quantum logic state preparation of $^{25}\text{Mg}^{+}$ via microwave sideband pumping within its hyperfine manifold, with dissipation provided indirectly through repeated Ca^{+}-based ground-state cooling of the shared motional modes. Together, mode–mode coupling, microwave-driven spin–motion interactions, and helper-ion-mediated state preparation and readout establish the essential ingredients for mixed-species quantum logic and provide a pathway toward entangling gate operations between data and helper ions mediated by magnetic field gradients.

Friday 11$^{\text{th}}$ September, 12:15

Trapped-Ion Quantum Computing Setup Joining Shuttling- and Addressing-Based Architecture

Presenter: James Rumbold
Johannes Gutenberg University

To enhance the capabilities of trapped-ion quantum computers, systems possessing hundreds of qubits are required. In pursuit of this objective, our system combines single-ion addressing with the transport of ion chains in a micro-segmented Paul trap [1]. Our setup will feature two independent laser addressing zones, each capable of performing quantum gates, while shuttling facilitates connectivity between the ions in the two zones [2]. Each zone is designed to address a ten-ion chain, and the segmented electrode architecture allows additional chains to be stored between the addressing regions. This design therefore has the potential to perform quantum algorithms involving multiple chains of ten qubits. Addressing is implemented using a crossed-AOD system, enabling fast beam steering without shifting the beam frequency [3]. The addressing design was simulated to provide a tightly focused beam with minimal aberrations along the entire ion chain, resulting in low nearest-neighbour intensity crosstalk. To improve coherence times, the system will be housed in three layers of mu-metal shielding to suppress magnetic field fluctuations, and the quantisation axis is generated by a temperature-stabilised Halbach coil configuration. This poster presents the current progress on the system, including characterisation measurements of the trap frequencies, qubit and motional coherence times, as well as the motional heating rates. We further compare the simulated and measured addressing crosstalk, as well as the beam profiles for all ten ions.

References: [1] Ruster, T., et al. Experimental realization of fast ion separation in segmented Paul traps. Physical Review A, 90(3), p.033410, 2014. [2] Kreppel, F., et al. Quantum circuit compiler for a shuttling-based trapped-ion quantum computer. Quantum, 7, p.1176, 2023. [3] Chen, Y.L., et al. Low-crosstalk optical addressing system for atomic qubits based on multiple objectives and acousto-optic deflectors. Physical Review Applied, 22(5), p.054003, 2024.

3.5 Molecular Spectroscopy

Tuesday 8th September, 13:30

Precision spectroscopy and coherent control of single molecular nitrogen ions

Presenter: Nicolas Adrian Nuñez Barreto
University of Basel

In this work, we demonstrate the quantum control and precision spectroscopy of a clock transition in a single molecular nitrogen ion. We report the first observation of Rabi oscillations and spectra on a mid-infrared electric-quadrupole rovibrational transition in a molecular ion, thus establishing a robust platform for the coherent manipulation of high-fidelity molecular qubits and clock transitions. Our experimental architecture utilizes a single calcium atomic ion co-trapped with the molecule in a linear Paul trap. State detection is achieved via a quantum-logic-inspired scheme based on optical lattice-induced coherent motional excitation, enabling high-fidelity, non-destructive identification of the molecular state [1]. Due to the extremely narrow linewidth of the transitions, we employ wide-range rapid adiabatic passage (RAP) scans for initial signal identification, followed by iterative RAP-based frequency narrowing to enable high-resolution Rabi spectroscopy [2]. The spectroscopic measurements are referenced to the Swiss primary frequency standard at the Swiss National Institute of Metrology (METAS) via a stabilized optical-fiber link enabling SI-traceability of measured frequencies [3]. Our results demonstrate a clear pathway toward the realization of molecular clocks, the study of state-resolved reaction dynamics, tests of fundamental physics, and the development of molecular qubits for quantum information processing.

References: [1] Sinhal, M., Meir, Z., Najafian, K., Hegi, G., and Willitsch, S. (2020). Quantum-nondemolition state detection and spectroscopy of single trapped molecules. Science, 367(6483), 1213-1218. [2] Shlykov, A., Diouf, M. L., Karl, R., Roguski, M., Joshi, U. C., and Willitsch, S. (2026). Quantum-logic spectroscopy of forbidden vibrational transitions in single nitrogen molecular ions. arXiv preprint arXiv:2603.10553. [3] Husmann, D., Bernier, L. G., Bertrand, M., Calonico, D., Chaloulos, K., Clausen, G., ... and Morel, J. (2021). SI-traceable frequency dissemination at 1572.06 nm in a stabilized fiber network with ring topology. Optics express, 29(16), 24592-24605.

Tuesday 8th September, 13:55

Quantum Logic Spectroscopy - What happens if the Raman lasers can access the dissociation continuum?

Presenter: Srishti Sharma

Vrije Universiteit Amsterdam

H_2^+ is the simplest molecular system, and its energy-level structure can now be calculated at the parts-per-trillion level[1]. Comparing experimental and theoretical transition frequencies enables the improvement of the value of fundamental constants, such as the proton-to-electron mass ratio $\frac{m_p}{m_e}$[2].

An increased sensitivity to $\frac{m_p}{m_e}$ can be obtained when measuring microwave transitions between weakly-bound levels located just below the H(1s) + H^+ dissociation threshold. These levels are comprised of spin-rotational states from the highest vibrational level of the electronic ground state $X^+ \ {}^2\Sigma_g^+$ and the lowest vibrational level of the first excited electronic state $A^+ \ {}^2\Sigma_u^+$[3]. Using fast ion beams, microwave transitions between these levels have been observed[4].

In an ongoing experiment, H_2^+ ions are selectively prepared in weakly-bound levels using a resonant multi-photon excitation of H_2 Rydberg states, followed by field ionization. The resulting ions will then be injected into an RF ion trap for precision measurements[5].

To avoid destructive detection and ion loss, Quantum-Logic Spectroscopy can be employed[6], as already demonstrated in the determination of the hyperfine structure interval of the H_2^+ X^+ vibrational ground state[7]. In such measurements, a stimulated Raman transition in the infrared is used, which overcomes the small Lamb-Dicke parameter, typical of long-wavelength microwave transitions.

We discuss whether stimulated Raman transitions remain feasible for the weakly-bound states, where the lasers can access the vibrational continuum, potentially resulting in loss of the molecules because of photodissociation.

AC polarizabilities of the molecular levels and Rabi frequencies for the stimulated Raman transitions are calculated using a Green's function technique. This eliminates the necessity for an explicit sum-over-states approach and naturally includes the effect of the continuum. Implemented using both the Numerov method and Discrete Variable Representation, the effects of all other rotational, vibrational (bound and continuum), and electronic levels are taken into account systematically. In addition to a specific calculation for H_2^+, we also provide a widely applicable model involving Morse potentials, which can be easily adapted to other molecules.

References: [1] V. I. Korobov et al., Phys. Rev. Lett. 118, 233001 (2017). [2] S. Alighanbari et al., Nature 644, 69-75 (2025). [3] R. Moss, Molecular Physics 80, 1541-1554 (1993). [4] A. Carrington et al., Faraday Trans. 89, 603 (1993). [5] D. Y. Knapp et al., 10.48550/arXiv.2602.15668 (2026). [6] P. O. Schmidt, edited by D. Bruß et al., 799-826 (2016). [7] D. Holzapfel et al., Phys. Rev. X 15, 031009 (2025).

Tuesday 8th September, 14:15
Infrared absorption spectroscopy of a single trapped polyatomic molecular ion

Presenter: Tim Duka
Universität Innsbruck

Quantum logic spectroscopy (QLS) has been established as a versatile technique for high-precision spectroscopic studies of diatomic molecular ions co-trapped with atomic ions in an ion trap, contributing to fundamental physics research and quantum information applications [1-6]. However, extending this protocol to larger polyatomic molecular species is challenging due to their more complex internal structure and has not yet been demonstrated experimentally. Furthermore, QLS is not directly applicable to studies that use broadband ultra-short laser pulses to investigate fast molecular processes such as intramolecular vibrational redistribution, which plays an important role in chemical and biological processes. Using an adapted version of quantum logic methods, we investigate polyatomic molecular ions by probing their photon-absorption signal. This is achieved by preparing the shared motional mode of the trapped molecular and atomic ions in a non-classical state that is sensitive to the momentum recoil associated with the absorption of a single photon [7]. We demonstrate this scheme by measuring the infrared absorption spectrum corresponding to the O-H stretch mode of a $CaOH^+$ ion co-trapped with a Ca^+ ion using broadband femtosecond laser pulses [8]. The measured spectrum shows good agreement with ab initio theoretical predictions for the transition frequency and oscillator strength. This suggests that the recoil detection method has potential applications in studying more complex polyatomic molecular ions at the single-particle level, such as in the initial identification of transitions, as well as in pump-probe experiments using femtosecond laser pulses that facilitate the investigation of ultrafast intramolecular dynamics [9]. Furthermore, improvements in the signal-to-noise ratio could enable single-shot readout using this technique, combined with spectral shaping this would allow for measurement-based rotational state preparation in polyatomic molecules.

References: [1] P. O. Schmidt et al., Science 309(5735),749-752 (2005). [2] F. Wolf et al., Nature 530(7591), 457-460 (2016). [3] C. W. Chou et al., Nature 545(7653), 203-207 (2017). [4] M. Sinhal et al., Science 367(6483), 1213-1218 (2020). [5] D. Holzapfel et al., arXiv:2409.06495 (2024). [6] L. Qi et al., arXiv:2411.07137 (2024). [7] C. Hempel et al., Nature Photonics 7, 630-633 (2013) [8] Z. Wu et al., arXiv:2511.19687 (2025) [9] P. Schindler, New J. Phys. 21(8), 083025 (2019).

Tuesday 8th September, 14:40

Novel Background-Free, Agent-Driven, Ion-Trap Action Spectrometer for Radioactive Molecular Ions

Presenter: Nicholas Schnoor
Texas A&M University

Radioactive molecules provide an incredible 10^{12}-fold boost in precision for measuring parity violation in the nuclear weak force [1]. Realizing this potential requires accurate rotational spectroscopy to locate, assign, and control the relevant quantum states. Moreover, the rotational transitions of heavy, short-lived molecules lie in the microwave-to-radio domain, providing a powerful, largely untapped tool for radio astronomy to nucleosynthesis production pathways in space [2]. However, spectroscopic data on such radioactive molecules remain scarce due to low production rates, short lifetimes, and spectral complexity.

To explore these exotic species, we developed a novel ion-trap-based action spectrometer with single-ion sensitivity. The method integrates three techniques: Multi-Reflection Time-of-Flight (MRTOF) ion trap filtering, multi-step photon dissociation for resonance identification, and MRTOF enhancement of spatial resolution of constituent ions with single-ion detection - all within milliseconds. Our first spectroscopic results on SiO+ will be presented, along with our ongoing efforts to automate the setup using an agent-based digital twin.

References: [1] Karthein et al. Phys. Rev. Lett. 133, 033003 (2024) [2] T. Kaminski et al., A&A 644, A59 (2020)

3.6 Clocks and Precision Spectroscopy

Wednesday 9th September, 13:30
Towards a network of 43Ca+ optical clocks for entanglement-enhanced metrology

Presenter: Ayush Agrawal
University of Oxford

Over the past few decades, advancements in optical atomic clocks have enabled measurements of time and frequency with unprecedented stability and systematic uncertainty [1,2]. Precision frequency comparisons between macroscopically separated clocks have applications in geodesy [3], probing variations in fundamental constants, and in dark matter searches [4]. Frequency comparisons between independent clock systems are limited by the standard quantum limit (SQL). In contrast, a set of N entangled atomic clocks can achieve a $\sqrt{N}$ stability improvement to surpass the SQL and approach the Heisenberg limit - the ultimate precision possible in quantum theory.

We previously demonstrated this enhancement in a network of two ion Sr^{88} clocks [5] on the 674 nm $5S_{1/2} \leftrightarrow 4D_{5/2}$ quadrupole transition using Ramsey spectroscopy, whose stability was mainly limited by the short probe duration of 20 ms due to magnetic field fluctuations. We are now setting up the next generation of the experiment wherein we map the remote Sr-Sr entanglement onto two $^{43}Ca^{+}$ ions. The 729 nm $^{43}Ca^{+}$ $|4S_{1/2}, F = 4, m_F = 4\rangle \leftrightarrow |3D_{5/2}, F = 4, m_F = 3\rangle$ optical clock transition is field-insensitive at 4.96 G, enabling probe durations at the excited state lifetime limit of ~ 1 s (comparable to the start-of-the-art clocks [1]) and thus improve our stability.

We will present progress towards these clock experiments, including the setup of a 729 nm laser system locked to a high finesse cavity, as well as fibre noise cancellation on a 20 m fibre. We will further present some theoretical work on quantum metrology with Dicke states in the presence of spontaneous decay in larger networks of clocks.

References: [1] M. C. Marshall et al., Phys. Rev. Lett. 135, 033201 (2025). [2] E. Oelker et al., Nature Photonics 13, 714–719 (2019). [3] T. E. Mehlstaubler et al., Reports on Progress in Physics 81, 064401 (2018). [4] M. S. Safronova et al., Rev. Mod. Phys. 90, 025008 (2018). [5] B. C. Nichol et al., Nature 609, 689–694 (2022)

Wednesday 9th September, 13:55
Sensing thermal motion of single ions with structured light

Presenter: Muriel Bonetto
Universidad de Buenos Aires

We present results showing that using LG beams allows sensing temperature in the direction perpendicular to the propagation of the beam and with increased sensitivity with respect to plane waves. We use two counterrotating and copropagating vortex laser beams, which isolates the azimuthal gradients of the fields, eliminating longitudinal and curvature effects. By performing Coherent Population Trapping spectroscopy with this configuration we are able to measure the thermal motion of the ion in the direction transversal to the propagation of the beam. Furthermore, by having tightly focused beams we can perform this experiments near the center of the vortex, achieving sensitivity beyond the plane wave Doppler Shift.

Wednesday 9th September, 14:20
Three Body Quantum Scattering in a Hybrid Atom-Ion System

Presenter: Patrick Mullan
Albert-Ludwigs-Universität Freiburg

We investigate quantum atom-ion scattering in the s-wave regime using a hybrid system comprising a single $^{138}Ba^+$ ion trapped in a linear Paul trap and a near-degenerate ^6Li Fermi gas confined in a crossed optical dipole trap. The ion is positioned within the Fermi gas and will undergo collisions. Inelastic collisions are directly related to formation of molecular states. The rates of inelastic collision can be tuned via magnetic Feshbach resonances using external fields, allowing for the enhancement or suppression of molecular formation channels. The existence of those channels depend on electronic states. To date, we have characterised both two-body (atom-ion) and three-body (atom-atom-ion) processes. While Feshbach resonances are well-established in neutral atom experiments, achieving the ultracold regime in RF traps remains challenging due to micromotion, which limits the minimum achievable collision energy. Building on our previous characterisation of resonances' position, width, and asymmetry across parameter space (collisional energy, magnetic field, and atomic spin polarization), we present an ongoing study focused on manipulating the substructure of single three-body Feshbach resonances. We demonstrate that this substructure is modulated by the external fields and the ion motion. These investigations aim to refine the theoretical understanding of few-body dynamics in atom-ion systems and establish the precise control necessary for future many-body quantum simulations.

Wednesday 9th September, 14:40

Measurements of the bound-electron g factor in highly charged ions: testing fundamental physics

Presenter: Max Anton Gramberg
Max Planck Institute for Nuclear Physics

The g factor of the bound electron in few-electron highly charged ions is a highly sensitive probe for new physics and its measurement allows to test the predictions of quantum electrodynamics (QED) in the extremely strong electric field of the nucleus. Studying these simple atomic systems allows to examine bound-state (BS-) QED and even nuclear effects to high accuracy. ALPHATRAP [1] is a cryogenic Penning-trap apparatus for high-precision g-factor measurements. By confining single ions in ultra-stable electromagnetic fields, the g-factor can be determined at the sub-ppb level [2]. Here, I will present the results of our recent g-factor measurements at ALPHATRAP as well as the future plans on an even more precise measurement on $^{12}C^{5+}$ and $^{14}C^{5+}$.

References: [1] S. Sturm, *et al. Eur. Phys. J. Spec. Top.* **227**, 1425-1491 (2019). [2] J. Morgner, *et al. Nature* **622**, 53–57 (2023).

Friday 11th September, 9:30
A transportable Al+ quantum logic optical clock

Presenter: Joost Hinrichs
Leibniz University Hannover, Physikalisch-Technische Bundesanstalt

Optical atomic clocks are the most precise measurement tools, achieving fractional frequency uncertainties below 10^{-18}. Transportable systems can extend this accuracy to a broader range of applications. High-precision frequency ratio measurements are essential to validate clock accuracy and ensure consistency across platforms - a key requirement towards the redefinition of the SI second. Transportable systems allow these comparisons on-site at various metrology institutes when a connecting fiber link is missing. Furthermore, transportable optical clocks can be used for relativistic geodesy as they allow height difference measurements on the cm level over large distances. Our fully rack-integrated clock setup is based on the ${}^1S_0 \rightarrow {}^3P_0$ transition in ${}^{27}\mathrm{Al}^+$. A co-trapped ${}^{40}\mathrm{Ca}^+$ ion allows for sympathetic cooling and state detection through quantum logic spectroscopy. We present the results of our investigation of various frequency shifts in our optical clock. Furthermore, we present ground state cooling, quantum logic spectroscopy, and our progress towards clock operation.

Friday 11th September, 9:50
Development of a Second $^{171}Yb^+$ Ion Optical Clock at NPL Towards the Redefinition of the SI Second

Presenter: Thilina Senaviratne
National Physical Laboratory

Optical frequency standards now surpass caesium frequency standards in accuracy and stability, forming the motivation for the future redefinition of the SI second [1]. Key requirements for the redefinition are the validation of uncertainty budgets at the level of $\lesssim 2^{-18}$ and agreement between independent optical frequency ratios at uncertainty $\lesssim 5^{-18}$. The $^{171}Yb^+$ optical clock at the National Physical Laboratory (NPL), based on the electric octupole (E3) transition (NPL-E3Yb+3), has demonstrated the first of these requirements through systematic evaluations reported in [2], achieving a total fractional systematic uncertainty of 2.2^{-18}. Recent improvements in NPL-E3Yb+3, including reduced systematic uncertainties, longer coherence times of the atom–laser interaction, and increased operational uptime have reduced the overall measurement uncertainties still further. Local comparisons with the strontium optical frequency standard at NPL (NPL-Sr1) and remote comparisons with European optical frequency standards have now demonstrated measurement uncertainties at the required level of 5^{-18}. These results represent significant progress towards fulfilling the criteria for redefining the second.

To extend capability, a second $^{171}Yb^+$ optical clock is under construction at NPL, and we report progress on its development. The new system is based on an updated end-cap ion trap [3] with a redesigned RF feed-through that reduces capacitance to the vacuum chamber, suppressing RF dielectric heating and the associated temperature rise. This will improve control of black-body radiation shifts and support trap-related fractional uncertainties below 10−18. The setup also incorporates a multi-layer magnetic shield with a shielding factor of 1000 to suppress the ambient field fluctuations. This enhanced stability enables the operation of the E3 clock on Zeeman-sensitive transitions, cancelling the electric quadrupole shift and reducing the associated uncertainty in the second-order Zeeman shift. In addition, automated beam alignment will be implemented using piezo-actuated translation stages to increase operational robustness and unmanned operation. The second Yb+ system will enable a direct comparison with the first, providing a rigorous test of calculated systematic uncertainty budgets and supporting frequency ratio measurements at the low 10^{-18} level of uncertainty. References

References: [1] N. Dimarcq et al., "Roadmap towards the redefinition of the second", Metrologia, vol. 61, p. 012001, 2024. [2] A. Tofful et al., "171Yb+ optical clock with 2.2 × 10-18 systematic uncertainty and absolute frequency measurements", Metrologia, vol. 61, p. 045001, 2024. [3] P. B. R. Nisbet-Jones et al., "A single-ion trap with minimized ion–environment interactions", Appl. Phys. B vol. 122, 57, 2016.

Friday 11th September, 10:10
A Penning trap single-photon counter for axion detection

Presenter: Marko Wojtkowiak
Imperial College London

The Quantum enhanced particle astrophysics (QuEPA) project attempts to use an electron Penning trap as one part of a detector for axion dark matter [1]. Axions emerged as a dark matter candidate after initially being proposed to resolve the observed lack of charge parity (CP) violation in the strong interaction. Axions can convert into microwave photons in the presence of a strong magnetic field due to their coupling to the electromagnetic field [2]. A microwave single photon counter dramatically improves the scanning rate of an axion detector [3]. As no technology currently exists to efficiently detect photons in the frequency band of 30-60 GHz, we propose the use of a single electron in a Penning trap as a microwave photon counter. Incoming photons are absorbed by the electron's cyclotron motion, which, through the continuous Stern-Gerlach effect, produces a detectable phase shift in the axial oscillation.

In this session, we present an update on the progress towards realising this detector. We have designed and built a novel cryogenic Penning trap system housed within a dilution refrigerator capable of reaching temperatures below 50 millikelvin. We have developed a custom impedance-matched image-current detection system featuring GaAs semiconductor switches, allowing electronic switching between detection and cooling modes, laying the groundwork for cooling the electron below its ambient temperature. We have successfully trapped clouds of around 500 electrons on demand and are currently performing initial trap characterisation measurements, with preliminary dark matter searches and phase-sensitive detection of the axial motion as the next steps.

References: [1] J. A. Devlin, M. L. Wojtkowiak, S. R. Banhatti, H. Zhang, J. Shi, T. S. Dofher, J. M. H. Gosling, M. R. Tarbutt, and R. C. Thompson, A Penning trap single-photon counter for axion detection, arXiv:2601.05472 (2026). [2] I. G. Irastorza and J. Redondo, New experimental approaches in the search for axion-like particles, Prog. Part. Nucl. Phys. 102, 89 (2018). [3] S. K. Lamoreaux, et al., Phys. Rev. D 88, 035020 (2013).

Friday 11th September, 10:30

Implementation of a Josephson Voltage Standard for the First Direct Measurement of the Nuclear Magnetic Moment of $^3He^{2+}$

Presenter: Felix Grüner
MPI Nuclear Physics, Heidelberg

The first direct high-precision measurement of the magnetic moment of the bare $^3He^{2+}$ nucleus requires resolving minuscule spin-flip-induced axial frequency shifts of the order of 50 mHz, a factor of 400 smaller than observed for $^3He^+$ ions [1]. This challenging measurement will be performed on a single ion confined in a Penning trap at MPIK. Current axial frequency stability is limited, amongst others, by the stability of the state-of-the-art commercial voltage source, the UM1-14, which enables relative frequency stabilization at a level $2 \cdot 10^{-8}$ [2], corresponding to several tens of mHz. To overcome this limitation, we replace the UM1-14 with a 1 V programmable Josephson Voltage Standard (PJVS), built at PTB Braunschweig. Based on the inverse AC Josephson effect, the PJVS generates a voltage that depends solely on the irradiation frequency of the Josephson junctions and fundamental constants which are fixed to exact values in the SI system. This eliminates dependencies on junction geometry, temperature, and other experimental conditions. This near-ideal frequency-to-voltage conversion is expected to improve axial frequency resolution by at least a factor of two. We present progress in the integration and characterization of the PJVS, report stability measurements and outline the timeline toward achieving the first direct determination of the $^3He^{2+}$ magnetic moment.

References: [1] Schneider et al., Nature 606, 878–883 (2022). [2] Kaiser et al., Appl. Phys. Lett. 124, 224002 (2024).

3.7 Antimatter

Thursday 10th September, 13:30

Improved Precision for Hyperfine Spectroscopy of Magnetically Trapped Antihydrogen at ALPHA

Presenter: Jay Suh

University of Calgary

Antihydrogen, the antimatter counterpart of hydrogen, provides a unique platform for testing fundamental symmetries in nature. One of its key properties, the ground-state hyperfine splitting (GSHFS), serves as a sensitive probe for Charge-Parity-Time (CPT) symmetry. In hydrogen, this splitting is known to a precision of 1.4 parts in 10^{12} [1], offering a precise benchmark for comparison. As the GSHFS is also sensitive to nuclear structure, precise measurements in antihydrogen enable stringent tests of CPT symmetry through direct comparisons with hydrogen.

The ALPHA Collaboration, an international research team at CERN, leads efforts to investigate the fundamental properties of antihydrogen by producing and trapping antihydrogen atoms within a magnetic minimum trap for precision spectroscopy. One of ALPHA's primary experimental efforts focuses on the GSHFS of antihydrogen, with the aim of performing precise comparisons with the well-known value in hydrogen. Previous measurements have yielded a value of $1{,}420.4 \pm 0.5$ MHz [3], limited primarily by statistics and magnetic field uncertainties. The introduction of Be^+-assisted antihydrogen production, which vastly increases the production rate [4], combined with improved magnet control and characterization [5], has enabled significantly improved measurements of the GSHFS in antihydrogen.

This presentation will report on the most recent antihydrogen GSHFS measurements from the ALPHA experiment, highlighting the experimental method, achieved precision, and the outlook for future improvements in GSHFS spectroscopy at ALPHA.

References: [1] H. Hellwig, R. F. C. Vessot, M. W. Levine, P. W. Zitzewitz, D. W. Allan, and D. J. Glaze, "Measurement of the Unperturbed Hydrogen Hyperfine Transition Frequency," IEEE Trans. Instrum. Meas., vol. 19, no. 4, pp. 200–209, Nov. 1970, doi: 10.1109/TIM.1970.4313902. [2] V. A. Kostelecký and A. J. Vargas, "Lorentz and C P T tests with hydrogen, antihydrogen, and related systems," Phys. Rev. D, vol. 92, no. 5, p. 056002, Sep. 2015, doi: 10.1103/PhysRevD.92.056002. [3] M. Ahmadi et al., "Observation of the hyperfine spectrum of antihydrogen," Nature, vol. 548, no. 7665, pp. 66–69, Aug. 2017, doi: 10.1038/nature23446. [4] R. Akbari et al., "Be+ assisted, simultaneous confinement of more than 15000 antihydrogen atoms," Nat. Commun., vol. 16, no. 1, p. 10106, Nov. 2025, doi: 10.1038/s41467-025-65085-4. [5] R. Akbari et al., "The ALPHA-2 apparatus - facilitating experimentation with trapped antihydrogen," Nucl. Instrum. Methods Phys. Res. Sect. Accel. Spectrometers Detect. Assoc. Equip., vol. 1072, p. 170194, Mar. 2025, doi: 10.1016/j.nima.2024.170194.

Thursday 10$^{\text{th}}$ September, 13:50
Be+-Assisted Synthesis of Antihydrogen

Presenter: Tom Robertson-Brown
Swansea University

The antihydrogen atom (the antimatter counterpart of a standard hydrogen atom) provides a unique testbed for probes of CPT invariance and the Weak Equivalence Principle (WEP) due to its mathematical simplicity and neutral charge respectively. However, prior to performing any such tests the antiatoms must first be synthesised from their constituent particles. Presented here are the recent developments in antihydrogen synthesis and trapping made by the ALPHA collaboration in both the ALPHA-2 and ALPHA-g experiments. Novel techniques first reported in [1], (and implemented in ALPHA-2) use laser cooled Be^+ ions to sympathetically cool e^+ plasmas to around 7 K, compared to 18 K without Be^+ ions. The resulting synthesis produces antihydrogen at lower temperatures thereby confining a larger fraction of the produced population within ALPHA's magnetic minimum trap. Despite only trapping around 0.05% of the produced antihydrogen, ALPHA can repeat the synthesis cycle an arbitrary number of times and is now regularly able to accumulate samples over 10^4 atoms. Near-linear increases in the antihydrogen trapping with the number of antiprotons used in synthesis have further revealed that the sympathetic cooling provided by the Be^+ ions not only reduces the e^+ plasma temperature but also help to maintain it throughout synthesis. This additional cooling power counteracts the inherent heating rates associated with the merge of the antiproton and positron plasmas as well as heating due to patch potentials on the electrode surfaces and the radial octupole magnetic field (which provides radial confinement of the antihydrogen atoms in the magnetic trap). [2] The effects of other parameters that contribute to the 3-body recombination reaction underlying antihydrogen formation at ALPHA [3] such as e^+ density, e^+ temperature and the shape of the magnetic minimum trap fields have also been studied in efforts to maximise the antiatom yield. In 2024, the Be^+ system was fully integrated into the ALPHA-g experiment where, as expected, it immediately outperformed the traditional synthesis reported in [4]. At present, the collaboration is able to obtain antihydrogen populations comparable to those in ALPHA-2 in the ALPHA-g machine. The significant increase in antiatom availability for experiments is a paradigm shift in ALPHA's capabilities which in the future may permit ALPHA to perform stronger tests of CPT invariance via precision spectroscopy of antihydrogen[5] (in the ALPHA-2 apparatus), as well as further probes of the Weak Equivalence Principle through future gravity release protocols (in the ALPHA-g machine).

References: [1] Akbari, R., de Araujo Azevedo, L.O., Baker, C.J. et al. Be+ assisted, simultaneous confinement of more than 15000 antihydrogen atoms. Nat Commun 16, 10106 (2025) [2] Goncalves, Maria. Be+-Assisted Antihydrogen Synthesis and Trapping. Swansea, 2026. [3] Zammit, M. et al. Antihydrogen Chemistry, Phys. Rev. A 111, 050101 (2025) [4] Anderson, E.K., Baker, C.J., Bertsche, W. et al. Observation of the effect of gravity on the motion of antimatter. Nature 621, 716–722 (2023) [5] Baker, C.J., Bertsche, W., Capra, A. et al. Precision spectroscopy of the hyperfine components of the 1S–2S transition in antihydrogen. Nat. Phys. 21, 201–207 (2025)

Thursday 10th September, 14:10
Developments of BASE Hannover towards quantum logic spectroscopy of the (anti-)proton g-factor

Presenter: Nikita Poljakov
Leibniz Universität Hannover

In our cryogenic multi-Penning trap experiment, we aim to contribute to high-precision (anti-)proton g-factor[1,2] measurements pursued by the BASE collaboration, providing stringent tests of CPT symmetry[3]. To reach precision at the parts-per-trillion level and to gain access to SME coefficients currently unreachable with existing techniques, we are implementing techniques based on quantum logic spectroscopy (QLS)[4,5], where both sympathetic cooling and spin-state detection of the (anti-)proton are mediated with a single $^9Be^+$ ion. This will be achieved by coupling the particle motions via Coulomb interaction in a double-well potential.

In a previous experimental phase, we demonstrated several key QLS prerequisites in Penning traps, including optical sideband spectroscopy[6], ground-state cooling[7] of a single $^9Be^+$, and fast adiabatic transport[8]. In this contribution, we report on our current status, including the implementation of a new Penning trap stack. Within this setup, we aim to load protons, and achieve motional coupling between two $^9Be^+$ ions in a symmetric double-well potential. This configuration serves as a proof-of-principle demonstration in which both particles are laser-accessible, before extending the scheme to the coupling of a $^9Be^+$ ion to the (anti-)proton in an asymmetric double-well potential due to the 9:1 mass ratio of the particles.

Finally, we highlight recent developments for the future experimental phase, where we aim to sympathetically cool the (anti-)proton. We show simulations[9] describing the proposed cooling scheme, along with progress in the development of a microfabricated coupling trap where this cooling will be implemented. We also show that this cooling scheme could be applied to the vibrational spectroscopy molecular (anti-)hydrogen ions[10].

References [1] G. Schneider et al., Science 358 (2017). [2] C. Smorra et al., Nature 550 (2017). [3] R. Lehnert, Symmetry 8 (2016). [4] D. J. Heinzen and D. J. Wineland, Phys. Rev. A 42 (1990). [5] P. O. Schmidt et al., Science 309 (2005). [6] J. M. Cornejo et al., Phys. Rev. Res. 5 (2023). [7] J. M. Cornejo et al., Phys. Rev. Res. 6 (2024). [8] M. v. Boehn et al., Comms. Phys. 8 (2025). [9] N. Poljakov et al., arXiv:2602.22826 (2026). [10] S. Schiller et al., in review (2026).

4 Abstracts: Posters

4.1 Nuclear Physics

Tuesday 8th September, Poster Session 1
Offline commissioning of the double Penning trap PIPERADE

Presenter: Gauthier Guignard
LP2iB

Of the approximately 7,000 nuclei predicted by nuclear models, fewer than half have had their mass measured experimentally. Many of the remaining nuclei are highly unstable and difficult to produce. Precise mass measurements play a crucial role in nuclear structure studies and nucleosynthesis modelling, and require advanced instrumentation to reach the most exotic isotopes.

At the DESIR facility at GANIL, radioactive nuclei will be provided both by the S3 low-energy branch, delivering heavy, neutron-deficient nuclei via fusion-evaporation reactions, and by SPIRAL1, producing light, neutron-rich isotopes through fragmentation. The Exotic Nuclei group at LP2iB is developing PIPERADE, a double Penning trap dedicated to high-resolution purification and precise mass measurements of exotic nuclei.

I will present the current status of PIPERADE, which is currently undergoing offline commissioning at LP2iB in Bordeaux. While the Time-of-Flight Ion-Cyclotron Resonance (ToF-ICR) technique is already well established and has yielded promising results, current efforts are focused on the implementation and optimization of the Phase-Imaging Ion-Cyclotron Resonance (PI-ICR) method. The current level of precision achieved will be presented. Although PI-ICR is a well-established technique, its deployment at PIPERADE requires careful tuning of the trap configuration and beamline parameters to meet performance expectations. Some of the encountered and resolved issues will also be discussed during the presentation.

The setup is scheduled to be relocated to the DESIR facility in 2027, with first on-line experiments planned for 2028. These developments will pave the way for precise mass measurements at DESIR, extending the accessible range of exotic nuclei and contributing to the facility's scientific programme.

Wednesday 9th September, Poster Session 2
Development and Commissioning of an RFQ Cooler-Buncher for Laser Spectroscopy

Presenter: Finn Köhler
Institut für Kernphysik TU Darmstadt

For collinear laser spectroscopy experiments, radio-frequency-based beam cooler-bunchers (RFQCB) are particularly used to prepare ion beams with kinetic energies of several 10 kV. They can accumulate rare beams for up to several seconds, cool them through collisions with a buffer gas, and emit ion bunches with a short time and energy width. This contribution will report on the development of a new, compact RFQCB that produces ion bunches well suited for laser spectroscopy measurements at the Collinear Apparatus for Laser Spectroscopy and Applied Physics (COALA) in Darmstadt. A two level differential pumping scheme allows for a high-pressure region at the entrance of the RFQCB to efficiently capture incoming ions despite its short length. A laser ablation ion source is included at the injection side of the device to give access to a wide variety of ion species. We will report on the first commissioning results at COALA. As a next step, the device will serve as an injector, paving the way for laser-spectroscopy studies of ion bunches separated and extracted directly from a multi-reflection time-of-flight (MR-ToF) mass spectrometer. This project was supported by DFG (Project-ID 279384907- SFB 1245) and BMFTR (05P24RD8).

4.2 Quantum Simulation

Tuesday 8th September, Poster Session 1
OPEN-2QS: Rydberg interactions in planar ion crystals

Presenter: Larisa Thorne
Johannes Gutenberg University Mainz

Current state-of-the-art quantum simulators are limited by their short observation times. The OPEN-2QS platform leverages the advantages of Rydberg ions [1] with those of Penning trap configurations [2] to allow significantly longer observation times, up to 7 orders of magnitude longer than microscopic timescales [3]. The Rydberg interaction boosts the effective interaction strength between ions to about 1MHz, which is approximately 3 orders of magnitude larger than what is currently achievable in laser-driven gate operations [4]. This combination of features allows us to pursue fundamental research directions previously inaccessible, such as study of long-time evolution in quantum systems, characterization of collective dynamics beyond decoherence timescales, and non-equilibrium phenomena in open many-body quantum systems. In order to realize such a quantum simulator, we present the first stages of an ambitious R&D program in Mainz. This includes the design of a Penning trap constructed from a Halbach array of permanent magnets, suited to 2D-confinement of $^{40}Ca^{+}$ Rydberg ion crystals at cryogenic (5K) temperatures.

References: [1] A. Mokhberi et al, Adv. Atom. Mol. Opt. Phys. 69, 233–306 (2020) [2] A. Polloreno et al, arXiv:2203.05196 (2022) [3] C. Chen et al, Nature 616, 691 (2023) [4] W. Martins et al, arXiv:2601.01626 (2026)

Tuesday 8th September, Poster Session 1
Real-time collisions of fractional charges in a trapped-ion Jackiw-Rebbi field theory

Presenter: Alan Kahan
Instituto de Física Teórica UAM-CSIC

We propose and analyze a trapped-ion quantum simulator of the Jackiw–Rebbi model, a paradigmatic quantum field theory in (1+1) dimensions where solitonic excitations of a scalar field can bind fermionic zero modes leading to fractionally-charged excitations. In our approach, the scalar field is a coarse-grained description of the planar zigzag ion displacements in the vicinity of a structural phase transition. The internal electronic states of the ions encode spins with interactions mediated by the transverse phonons and in-plane spin-phonon couplings with a zigzag pattern, which together correspond to a Yukawa-coupled Dirac field. Instead of assuming a fixed soliton background, we study the effect of back-reaction and quantum fluctuations on the coupled dynamics of the full fermion–boson system. We start by applying a Born–Oppenheimer approximation to obtain an effective Peierls–Nabarro potential for the topological kink, unveiling how the fermionic back-reaction can lead to localization of the kink. Beyond this limit, a truncated Wigner approximation combined with fermionic Gaussian states captures the quantum spreading and localization of a kink and kink-antikink scattering. Our results reveal how back-reaction and quantum fluctuations modify the stability and real-time evolution of fractionalized fermions, predicting experimentally accessible signatures in current trapped-ion architectures.

Wednesday 9th September, Poster Session 2

Rydberg ion crystal as a quantum simulator for coupled exciton-phonon dynamics

Presenter: Simon Euchner
University of Tübingen

Trapped ions excited to high-lying electronic states, so-called Rydberg ions, combine strongly coupled collective vibrational and electronic degrees of freedom with long-range interparticle interactions. These ingredients enable the quantum simulation of biochemical processes associated with the dynamics of excitons in non-perturbative parameter regimes. The key features of this quantum simulator are electronic state-dependent molecular potential surfaces, which can be strongly coupled. This allows to create and study vibrationally assisted exciton transfer and excitonic relaxation dynamics induced by molecular conformational changes. We illustrate this in a system of three trapped ions, which is amenable to an *ab initio* treatment. However, given that ion traps can be routinely prepared with hundreds of ions, they can immediately realise scenarios which are inaccessible by current numerical methods.

Wednesday 9th September, Poster Session 2
Fractal ground state of mesoscopic ion chains in periodic potentials

Presenter: Joshua Weißenfels
Universität des Saarlandes

Trapped ions in a periodic potential are a paradigm of a frustrated Wigner crystal. The dynamics are captured by a long-range Frenkel-Kontorova model. We show that the classical ground state can be mapped to the one of a long-range Ising spin chain in a magnetic field, whose strength is determined by the mismatch between the chain's and substrate lattice's periodicity. The mapping is exact when the substrate potential is a piecewise harmonic potential and holds for any two-body interaction decaying as $1/r^{\alpha}$ with the distance r. We show that the ground state is a devil's staircase of regular, periodic structures as a function of the mismatch and of the interaction exponent α. The predictions of the piecewise parabolic potentials are compared with the case when the substrate is a sinusoidal potential.

4.3 Quantum Technologies

Tuesday 8th September, Poster Session 1

Integrated Photonics and metasurfaces for scaling trapped-ion quantum computing and miniaturizing atomic clocks

Presenter: Phillip Cloud
University of Cambridge

Optical control of quantum matter – from trapped atoms and ions to quantum dots and defects, is foundational for quantum information science and technology. Development of integrated photonics opens the possibility for realization of scalable circuits with complex functionalities, advancing both science and technology frontiers and enabling real-world applications in quantum sensing and precision measurements. Here, we present our work on scalable, robust and multifunctional nanophotonic interfaces to trap neutral atoms or address trapped ions. Our nanophotonic platform, combining metasurfaces with integrated photonics, replaces bulk optical elements and promises increased complexity and functionality in a batch-fabricated optical microsystem ultimately fully replacing the laboratory optical table to enable cold atom clocks and quantum computers. Metasurfaces – ultrathin, planar arrays of subwavelength resonators – engineer the local electromagnetic response to provide precise, spatially-varying control over phase and amplitude within a single lithographic layer. By tailoring resonator geometry across the aperture, complex wavefront transformations such as Gaussian-to-top-hat beam shaping, tight focusing, and arbitrary polarization conversion can be realized in components fully compatible with CMOS fabrication processes. Metasurface optics can additionally be multi-functional within a single layer. Trapped-ion quantum computing faces a scaling bottleneck: delivering tightly focused, individually addressed beams to ions in extended linear or 2D arrays via free-space optics becomes increasingly untenable as qubit counts grow toward fault-tolerant thresholds. Photonic integrated circuits (PICs) offer a natural solution, routing light to individual sites via on-chip waveguides, with metasurface elements providing final-stage beam shaping, polarization control, and NA-matched focusing directly above the trap electrodes. Metasurface optics can also provide complex beam-conditioning in a compact, robust form factor before final beam delivery to the ion trap. This approach opens the possibility of integrating multi-wavelength functionality – simultaneously handling Doppler cooling, qubit manipulation, and state detection wavelengths – within a single compact layer. We also use metasurfaces when designing fluorescence collection optics to remove the need for large, high-NA objectives. An important area of research is ensuring that metasurface optics and integrated photonics are compatible with ion trap material platforms and electrode trap fabrication techniques. In atomic clock architectures, metasurface optics offer a direct route to replacing bulk telescopes, waveplates, and beam-shaping elements required for laser cooling and state preparation. Integrated with on-chip photonic waveguides at clock-relevant wavelengths, metasurface outcouplers and beam-forming elements can deliver structured, polarization-controlled fields needed for Zeeman state preparation and narrow-line cooling transitions, collapsing multiple optical functions into a single planar element and dramatically reducing system volume and alignment sensitivity. Designing metasurfaces that simultaneously satisfy multi-objective constraints – intensity uniformity, low wavefront aberration, polarization purity, and multi-wavelength operation – is a non-trivial inverse design problem. We apply reinforcement learning (RL) to navigate this high-dimensional nanostructure parameter space, demonstrated in designing a metasurface for beam shaping within a miniaturized magneto-optical trap (MOT). The RL framework naturally accommodates discrete, non-differentiable design choices inherent to fabrication-constrained geometries while allowing simultaneous optimization across competing performance metrics relevant to efficient atomic capture and cooling.

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Tuesday 8th September, Poster Session 1

Microfabrication and Integration Strategies for Scalable Surface-Electrode Ion Traps

Presenter: Nora Daria Stahr
Leibniz Universität Hannover

Scalable surface-electrode ion traps require advanced microfabrication techniques capable of integrating different trap architectures as well as integrated electric and photonic circuits with high reliability. Microfabricated surface-electrode ion traps provide a promising platform for quantum information processing, but their fabrication remains challenging in terms of integration density and scalability [1,2]. Quantum operations rely on laser beams, microwaves, and DC and RF electric fields [3], making the integration of optical and electrical pathways essential for scalable architectures [4]. Through-substrate vias (TSVs) enable dense electrical routing with reduced parasitic effects, while integrated waveguides allow on-chip laser delivery [5,6]. Here, TSVs are produced using selective laser-induced etching (SLE), which enables structures with high aspect ratios and modifications of the refractive index in materials such as fused silica and sapphire, while integrated waveguides are realized in several ways using SLE and e-beam lithography. The goal is to combine the various microfabrication technologies to enable a scalable multilayer trap architecture.

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Tuesday 8th September, Poster Session 1
Phase-stable injection-locked laser at 674 nm for manipulating trapped strontium ions

Presenter: Isaline Emilie Duperon
Stockholm University

For optical qubit encoding, laser phase noise limits the coherence time for qubit manipulations. In this thesis, we address this challenge by replicating a low-phase-noise laser system for qubit manipulation of trapped ions in a cryogenic environment. Using injection locking technology, we inject a laser diode with another laser, ensuring the replicated light retains the same spectral properties. We describe the implementation of this technique, analyse its impact on the laser spectrum, and validate it by comparing its coherence time on a trapped-ion qubit with the previously used laser. Our results demonstrate that the new laser system preserves the coherence time achieved with the seed laser, with a qubit coherence time of $T_{coh} = 2.52 \pm 0.15$ms, paving the way for scalable and robust quantum computing and simulation in the cryogenic setup. In the future, the laser phase noise may be further reduced by spectral filtering techniques with a narrowband optical cavity. This work contributes to overtake one of the key obstacles in trapped-ion quantum computation: having long qubit coherence time.

Tuesday 8^{th} September, Poster Session 1

Versatile trapped-ion crystal platform for efficient measurement of photon correlations and emergent quantum structures induced by optical forces

Presenter: Benjamin Zenz

Johannes Gutenberg University Mainz

Trapped ions constitute an exceptionally well-controlled quantum system, featuring truly identical particles confined in deep potentials and manipulated with high precision. Each ion acts as a deterministic single-photon emitter, enabling the investigation of collective light–matter interactions at a fundamental level. In previous work, we observed interference effects in both first- and second-order photon correlation functions. These measurements revealed the emergence of spin textures [1], spatially dependent photon bunching and antibunching [2], as well as signatures of superradiance, subradiance, and measurement-induced entanglement [3]. Here, I present a novel experimental platform that combines a multisegmented ion trap for highly flexible control over emitter positions with high-numerical-aperture photon detection from opposing directions, enabling efficient and scalable measurements of spatiotemporal photon correlations in ion crystals comprising 50 or more ions. In addition, the system provides large optical access, allowing the implementation of a wide range of tailored optical potentials [4,5]. Utilizing these optical potentials as well as the flexible control over ion positions, this platform opens the door to exploring the emergence of hierarchical structures in ion crystals in a bottom-up approach, including the formation of solitons and soliton superstructures.

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Tuesday 8$^{\text{th}}$ September, Poster Session 1
Coherent Control of Trapped-Ion Spin-Boson Systems

Presenter: Giorgio Canalella
University of Oxford

Trapped ions have proven to be a formidable platform for quantum computation, with record-high fidelities in state preparation and measurement, single- and two-qubit gates. However, scaling the number of qubits remains a key challenge, requiring either larger traps or distributed architectures. An alternative paradigm is to exploit the inherently hybrid nature of trapped-ion systems, leveraging the coupling between the ions' quantised motion and their internal electronic states. This approach provides access to the large Hilbert space of bosonic modes while alleviating some experimental challenges of continuous-variable approaches. Nonetheless, control schemes for trapped-ion hybrid systems remain limited and relatively unexplored.

In previous work, we have shown how the application of simultaneous, non-commuting spin-dependent forces in hybrid spin-boson systems allows for the generation of a wide range of effective nonlinear bosonic interactions [1], including squeezing, trisqueezing, and quadsqueezing [2]. Combined with single-qubit rotations and mid-circuit measurements, these interactions enable the generation of arbitrary superpositions of exotic bosonic states [3]. These states exhibit strong non-classical features, such as Wigner negativity and non-Gaussianity.

Building on these tools, we show how such resources can be used to generate squeezing-mediated many-body interactions in multi-qubit chains [4]. These versatile interactions pave the way for enhanced control of discrete, continuous-variable, and hybrid quantum systems, with potential applications in quantum computing, simulation, and sensing.

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Tuesday 8$^{\text{th}}$ September, Poster Session 1

Development of Local Magnetic Field Diagnostics Using Dark Resonance of Trapped Ions

Presenter: Tomomi Higashi

Osaka University

Ion-trap-based quantum computers have attracted significant attention as a promising platform because ions used as qubits exhibit long coherence times and low error rates. For scaling up these systems, it is important to maintain a uniform qubit environment. Considering the dependence of energy levels on external magnetic fields, both the uniformity and stability of the magnetic field are key factors. In fact, magnetic field gradients have been reported to reduce the coherence time of qubits [1]. Therefore, it is necessary to locally measure and evaluate the magnetic field at each ion position. In this study, we develop a method to evaluate the magnetic field at individual ion positions by analyzing the dark resonance spectra of trapped ions. Furthermore, to investigate the effect of magnetic materials in the packaged trap used in our system, we constructed an experimental setup that allows easy exchange of traps, aiming to visualize the magnetic field distribution. We use a planar trap to confine $^{40}Ca^+$ ions and perform Doppler cooling using 397 nm and 866 nm lasers, addressing the $^2S_{1/2} - ^2P_{1/2}$ and $^2D_{3/2} - ^2P_{1/2}$ transitions, respectively. First, using simulations with QuTiP (Quantum Toolbox in Python) [2], we examined the dark resonance spectra under applied magnetic fields. The results showed that the spacing of dark resonances increases with the magnetic field strength. We also confirmed that the measurement resolution depends on the laser linewidth, frequency stability, and intensity. These results indicate that it is possible to quantitatively evaluate the magnetic field through the observation of dark resonance spectra. The expected magnetic field resolution is on the order of 1 mG, estimated from the laser linewidth (100–200 kHz) and the frequency scanning step (10 kHz). In the experiment, by scanning the wavelength of the 866 nm laser under an applied magnetic field, we observed dips corresponding to dark resonances. However, we found that the current laser linewidth limits the spectral contrast, making quantitative evaluation of the magnetic field challenging, and we plan to improve the laser system to achieve higher-resolution measurements. Furthermore, this study focuses on the influence of trap materials on the magnetic field at the ion positions. The land grid array (LGA), which supports the trap chip, contains magnetic materials that may affect the local magnetic field. To investigate this effect, we constructed an experimental setup in which the trap can be easily exchanged and performed ion trapping experiments using this setup. In addition, to reduce external magnetic noise, we incorporated a single-layer magnetic shield and magnetic-field compensation coils. Based on electromagnetic simulations of our setup, a magnetic field gradient of approximately 13 mG/mm is expected. Assuming a magnetic field resolution of 1 mG, the spatial resolution is estimated to be about 77 μm. Therefore, the magnetic field distribution at this scale can be evaluated using an ion string.

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Tuesday 8th September, Poster Session 1

Fabrication of advanced ion traps with inner-segmented electrodes and integrated microwave antenna

Presenter: Matthew Aylett & Mohamed Saleh & Sameer Yadav
University of Sussex

A key requirement for scalable trapped-ion quantum computing architectures, such as that proposed by Lekitsch et al. [1], is the development of ion traps incorporating inner DC electrodes. These electrodes enable higher secular frequencies, reduced motional heating during ion transport, and support faster and more complex transport operations. Additionally, large magnetic field gradients are necessary for implementations based on global radiation fields, allowing for individual ion addressing. The integration of on-chip microwave delivery further enhances performance by enabling significantly higher microwave power at the ion compared to external delivery methods, resulting in increased Rabi frequencies and faster gate operations.

The incorporation of inner DC electrodes introduces substantial fabrication challenges. In particular, vertical interconnects and dedicated routing layers are required to deliver DC signals from bonding pads at the chip periphery through thick dielectric layers to the inner electrodes. While complex, this approach distinguishes the devices presented here from the majority of conventional surface ion traps. This next-generation trap design represents a significant increase in structural complexity compared to the current generation used at IQT, but offers considerable improvements in predicted performance.

References: [1] Bjoern Lekitsch et al. "Blueprint for a microwave trapped ion quantum computer". In: Science Advances 3.2 (Feb. 2017). issn: 2375-2548. doi: 10.1126/sciadv.1601540. url: http://dx.doi.org/10.1126/sciadv.1601540.

Tuesday 8th September, Poster Session 1
Benchmarking Microfabricated QCCD Junctions for Fast Transport

Presenter: James Urquhart
University of Sussex

One approach for developing a quantum computer is a controllable array of electrodes (QCCD) on a microchip, capable of transporting trapped ions between different zones. To make the array 2-dimensional, junctions between linear zones need to be integrated, additionally allowing all-to-all connectivity. It is important for transport operations to be diabatic (fast and with low motional excitation) to increase the clock speed and improve coherent quantum operations.

Since the performance of diabatic transport depends on both the electrode design [1] and the sequence of electric potentials [2] realised by a voltage waveform, we have explored finding an optimal junction design by numerically simulating ion trajectories for a large number of candidate designs. In our work, the designs span a Pareto front [3], and the waveform is obtaining by applying machine learning techniques to implement multidimensional optimal control [4].

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Tuesday 8th September, Poster Session 1
Improving the Capabilities of a Quantum Network

Presenter: Erin Malinowski
University of Oxford

Trapped atomic ions present an ideal platform for quantum computing due to their long coherence times, precise control, and inherent qubit connectivity.These systems have already demonstrated the functionality of small, fully controllable universal quantum computers. However, scaling remains a significant challenge. As the number of qubits increases, control becomes more difficult due to factors like single-qubit addressing and spectral crowding. Solving this challenge is critical, as most practical applications require a larger number of qubits to achieve "quantum advantage" — where quantum computers out perform classical ones in specific tasks. This scaling challenge is not unique to ion-based systems but affects all quantum computing platforms.

One potential solution is to interconnect discrete, fully controllable quantum processor modules via photonic entanglement networks, rather than concentrating all qubits in a single processor. In this approach, single photonsemitted by ions create quantum connections between different processors allowing for flexible, long-distance connections with minimal decoherence. Additionally, photons can be routed to connect any two processors in a network,not just adjacent ones, allowing for highly adaptable quantum networks.

Our team at the University of Oxford has developed a pioneering ion trap network, comprising two separate ion trap processors. The system has suc cessfully demonstrated proof-of-principle protocols for distributed quantum computing [1], blind quantum computing [2], quantum communications [3], and remote quantum sensing [4]. While a two-node network is sufficient for these initial experiments, it is far from enough to prove the scalability required for practical quantum computing. Therefore, we aim to advance the network's capabilities by developing the techniques and technologies that will allow for distributing entanglement across multiple nodes; i.e. to demonstrate a quantum repeater as shown in Fig. 1.

There are 3 key milestones to be reached before performing this experiment. An improved BSA is being built to increase the rate and fidelity of remote entanglement. A high-quality, high-NA collection lens will then be designed and fabricated to optimally match the mode of the collected photons to that of the fibre being coupled into. This should also increase the rate of remote entanglement. This should allow us to beat our already world record winning results demonstrated in [1-4]. A multi-fibre array system is being developed to act as a switch and allow selective routing of photons from the trapped ions. This would show proof-of-principle for adaptable networking between multiple quantum processors.

![FIG. 1. Ion-ion entanglement is created between Alice and Bob through photonic entanglement swapping at the Bell state analyser (BSA). Additional ion-photon Bell pairs are created between Alice and Node1, and Bob and Node2. Local operations map the Alice-Bob entanglement onto the Alice-Node1 and Bob-

Node2 entanglement, creating end-to-end entanglement between photons at Node1 and Node2.][A] FIG. 1. Ion-ion entanglement is created between Alice and Bob through photonic entanglement swapping at the Bell state analyser (BSA). Additional ion-photon Bell pairs are created between Alice and Node1, and Bob and Node2. Local operations map the Alice-Bob entanglement onto the Alice-Node1 and Bob-Node2 entanglement, creating end-to-end entanglement between photons at Node1 and Node2.

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[A]: https://gcdnb.pbrd.co/images/ac1AWThfEpOu.png?o=1

Tuesday 8th September, Poster Session 1

Fabrication of Surface Ion Traps with Integrated 3D Glass Microstructures

Presenter: Victoria Schwab
Infineon Technologies / University of Innsbruck

Trapped ions are a leading hardware platform for quantum computing, but scaling to a large number of qubits remains a significant challenge [1]. To overcome this, it is essential to mitigate heating effects and integrate photonic elements directly into the trap for reliable light delivery. While semiconductor substrates, such as silicon, are commonly used for surface ion trap fabrication due to established processing expertise, they pose challenges due to laser-induced charging and RF losses [2]. These issues can be addressed by using dielectric substrates like fused silica, which offer a wider bandgap, lower RF losses, and inherent optical transparency. This enables the integration of optical elements directly into the substrate, eliminating the need for additional shielding and facilitating the development of scalable ion trap architectures.

My PhD project focuses on the design and fabrication of a surface ion trap on a fused silica substrate that integrates 3D microstructures directly into the substrate. The microstructures are fabricated using a Laser Selective Etching (SLE) technique, allowing to etch out complex structures from the substrate up to micrometer precision [3]. This method enables the monolithic integration of 3D structures, such as holes for high optical access, into the ion trap chip, facilitating laser access and ion loading. In contrast to other monolithically fabricated ion traps with SLE techniques [4, 5], the method is incorporated into a scalable fabrication process provided by the means of a large-scale semiconductor foundry. This requires the development of a suitable protection layer during the etch process that shields the structured metal electrodes on the wafer front side from the etchant. Once the fabrication of the integrated ion trap is complete, the chip will be integrated into a cryogenic setup and evaluated in terms of trapping performance and heating rates. The built-in high optical access slot will enable more flexible single-ion addressing using a qubit laser directed from the vertical axis of the chip. Additionally, this slot can be used for integrated detection of ion fluorescence by incorporating Single Photon Avalanche Diodes (SPADs) beneath the ion trap chip, allowing for the detection of light transmitted through the slot. Ultimately, this project aims to demonstrate a scalable surface ion trap architecture that can be used as a building block for the development of practical quantum computing technologies.

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Wednesday 9th September, Poster Session 2
Trapped and cooled $^{88}Sr^{+}$ ions in a cylindrical potential provided by a micro-fabricated ring trap

Presenter: Lilay Gros-Desormeaux
MPQ Université Paris Cité

Laser-cooled trapped ions platform is one of the best candidates for the development of future quantum computing. This has generated a major worldwide research effort aimed at scaling and integrating trapping devices. As part of this effort, we are developing miniature atomic ion traps in the laboratory: Paul linear surface traps manufactured in collaboration with Nanyang Technology University and the Microelectronics Institute of Singapore. An original feature of the manufacturing process is that all the electrical contacts of the trap electrodes are made through the Silicon substrate (TSV: through silicon vias). In this way, the wire-bondings usually soldered directly to the electrodes can be offset or completely eliminated [1]. This opens the way to complex architectures, in particular cylindrically symmetrical ring traps, which cannot be made with surface connections that would break the desired symmetry. The trapping and laser cooling of ions in cylindrically symmetrical linear Paul traps (called "ion storage rings" in their macroscopic version, diameters of around 100 mm) was demonstrated in pioneering work at Garching [2] and subsequently extended to microfabricated traps (multilayer technology) at Sandia National Labs (diameter 2.5 mm) [3] and Berkeley (diameter 95 μm) [4]. These devices are of interest because, in the absence of defects, they enable rotational symmetry for the trapped ions and thus periodic boundary conditions for the confined cold ion system (Coulomb crystal). They are also candidates for observing and manipulating the rotational quantum state of trapped ion ensembles [4]. We will present our latest results concerning the performance of TSV surface ring traps manufactured in Singapore. In particular, we loaded these traps with Doppler-cooled 88Sr+ ions (from a single ion to several hundreds). Laser cooling and image acquisition enable us to estimate the defects of the trapping potential with respect to perfect rotational symmetry. The application of DC voltages to a set of segmented electrodes then makes it possible to compensate for most of these defects, which nevertheless remain the major problem to be solved in order to achieve sub milikelvin free motion.

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Wednesday 9th September, Poster Session 2
Detecting axion dark matter with an electron Penning trap

Presenter: He Zhang
Imperial College London

The QCD axion is a compelling dark matter candidate [1][2]. The Quantum Enhanced Particle Astrophysics (QuEPA) experiment at Imperial searches for axions with masses between 124 μeV and 248 μeV [3]. The experiment consists of two parts: a Fabry–Pérot cavity, which converts axions into microwave photons, and a cryogenic Penning trap single-photon counter for detecting axion-induced microwave photons in the 30–60 GHz range. This poster focuses on the photon-counting component of the experiment. It presents the motivation for and advantages of using an electron Penning trap for dark matter axion detection, as well as the latest experimental results from the characterisation of the trap.

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Wednesday 9th September, Poster Session 2

Characterization of stray electric fields induced by UV laser exposure in a microfabricated surface ion trap

Presenter: Sacha Guesne

Laboratoire Matériaux et Phénomènes Quantiques - Université Paris Cité, Crystal Quantum Computing SAS

Trapped atomic ions are among the most advanced technologies for realizing quantum computation and quantum simulation, based on a combination of high-fidelity quantum gates and long coherence times[1]. Most two-qubit quantum gates for trapped ions are based on collective vibrational modes (phonons), such as the Mølmer-Sørensen gate [2]. While these gates have demonstrated high two-qubit gate fidelities with error rates as low as 10^{-4} as well as reduced sensitivity to ion temperature[3], these systems remain inherently one-dimensional, limiting their scalability. A different entanglement process in trapped-ion systems relies on dipole–dipole Rydberg interactions and has demonstrated sub-microsecond gate times[4], making it one of the fastest gate implementations realized in such systems. The dipole-dipole Rydberg interaction enables two-dimensionnal qubit connectivity beyond linear architectures. To excite ions into Rydberg states, we plan to use a STIRAP sequence with 243 nm and 305 nm lasers[4]. However, these UV lasers can generate stray charges in the vicinity of the trap, producing stray electric fields that increase the motional heating rate and lead to decoherence.

In this work, we will investigate stray electric fields arising from surface charging induced by UV laser exposure on ion trap surfaces. This effect of photo-electrically generated charges is strengthened by the presence of dielectric material near the trap electrode, such as the silicon dioxide substrate located in the inter-electrode gaps where charge accumulation may occur. The static component of the stray electric field is measured using phase-resolved fluorescence measurements[5], by correlating photon arrival times with the RF trapping drive phase. Oscillating stray fields lead to ion heating and will be characterized using a thermometry technique based on dark resonances[6]. This method has the advantage of addressing all vibrational modes simultaneously, without the need for multiplexing. We implement this method to characterize the motional heating rate of our surface Paul trap and investigate its evolution upon UV laser exposure in the vicinity of the trap.

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Wednesday 9th September, Poster Session 2

IonLab: A framework for noise-aware simulation of trapped-ion quantum operations

Presenter: Rares Barcan
University of Sussex

The performance of trapped-ion quantum processors is fundamentally limited by noise arising from both control electronics and the trapping environment. While experimental techniques such as Ramsey and Hahn-echo sequences provide important information about noise spectra, translating these measurements into quantitative predictions of errors in trapped-ion quantum operations for a specific ion species, transition, and control scheme remains challenging. Here, we present IonLab, a modular simulation framework designed to bridge this gap by enabling noise-aware modelling of trapped-ion dynamics at the Hamiltonian level. Unlike general-purpose libraries such as QuTiP, IonLab is specifically designed for trapped-ion systems, enabling realistic simulation of a Yb-171 io qubit under experimentally relevant conditions. The framework incorporates configurable noise channels, experimental parameters, and decoherence mechanisms within a unified architecture. IonLab supports both spin-only and spin-motion Hamiltonians, enabling the simulation of single- and multi-ion systems. Its flexible and extensible design also allows integration with external trap-modelling tools, providing a pathway to incorporate trap-specific parameters such as mode frequencies, coupling strengths, and field gradients. This facilitates predictive simulations that connect measured noise spectra to observable dynamics, using QuTiP-based master-equation solvers for both spin-only Hamiltonians and spin-motion models in a truncated Fock basis. We present representative simulations of coherence dynamics and phase accumulation in the presence of frequency-dependent noise, highlighting how low-frequency noise can dominate control infidelity in typical experimental regimes. Future developments will extend the framework toward experimentally relevant control sequences, including benchmarking protocols in trapped-ion systems, providing a route to connect measured gate performance with underlying noise processes in future experiments, while also exploring more efficient numerical approaches to enable simulations of larger Hilbert spaces and longer timescales. In addition, its transparent structure makes it a useful platform for teaching and onboarding new researchers in trapped-ion quantum control and simulation.

Wednesday 9th September, Poster Session 2
Integrated 313 nm Waveguide Characterisation for $^9Be^+$ Penning Micro-Traps

Presenter: Kilian Teck
ETH Zurich

Penning micro-traps offer a promising scalable architecture for trapped-ion quantum computation. Individually confined low-mass $^9Be^+$ ions in a homogeneous magnetic field enable strong spin-motion coupling and potentially faster entangling gates compared to heavier species such as Ca^+, while reducing laser overhead due to a simpler level structure. Integrated waveguide beam delivery presents an attractive approach for coupling light into cryogenic vacuum environments, alleviating the complexity of free-space alignment and improving long-term stability in the presence of static trap potentials. However, operation at 313nm, required for the $S_{1/2} \leftrightarrow P_{3/2}$ transitions, poses significant material and fabrication challenges. Recent advances in Al_2O_3-based photonic integrated circuits have demonstrated suitability for deep-UV applications. Here, we present the development of a dedicated photonic integrated circuit (PIC) characterisation platform for 313nm operation. We investigate propagation losses, transmission stability under continuous UV exposure, and the spatial profiles of beams outcoupled via resonant waveguide gratings.

Wednesday 9th September, Poster Session 2

Scalable Surface Electrode Ion Trap with Near-Field Microwave Gates and Chip-Integrated Nano-Photonics: Progress and Challenges

Presenter: Mohammad Masum Billah
Leibniz Universität Hannover

In order to perform meaningful computations using the trapped-ion quantum processor, one of the most promising approaches is to utilize a micro-fabricated scalable Quantum Charged Coupled Device (QCCD) architecture [1]. However, reliance on free-space lasers hinders efficient scaling. In our research group, the implementation of microwave near-field gate operations have been demonstrated to be a viable approach for mitigating the free-space laser overhead [2–5]. Furthermore, comprehensive scalability can be facilitated by the integration of photonics, which would ensure the delivery of focused laser beams to the desired location for the purpose of ionization, cooling, state preparation, read-out and other relevant processes [6]. The present study focuses on the design of a surface electrode ion trap quantum processor with integrated photonics for $^{40}Ca^{+}$, taking into consideration light polarization and phase, opto-electric effects, the overall impact on the trap's electromagnetic behavior, and the optimization of the micro-fabrication process of a multilayer ion trap with integrated optical waveguides and grating couplers on a dielectric substrate, such as fused silica, and sapphire [7–10].

Keywords: QCCD, near-field microwave, trapped-ion quantum processor, nanophotonics, microfabrication

References: [1] D. Kielpinski, C. Monroe, and D. J. Wineland. In: Nature (June 13, 2002). [2] C. Ospelkaus et al. In: Physical Review Letters (Aug. 29, 2008). [3] C. Ospelkaus et al. In: Nature (Aug. 2011). [4] U. Warring et al. In: Physical Review Letters (Apr. 22, 2013). [5] U. Warring et al. In: Physical Review A (Jan. 31, 2013). [6] Carmelo Mordini et al. In: Physical Review X (Feb. 24, 2025). [7] Guochun Du, Elena Jordan, and Tanja E. Mehlst¨aubler. arXiv.org. Mar. 26, 2025. url: https://arxiv.org/abs/2503.20387v2. [8] Henning Hahn et al. arXiv.org. Dec. 6, 2018. url: https://arxiv.org/abs/1812.02445v2. [9] A Bautista-Salvador et al. In: New Journal of Physics (Apr. 2019). [10] Tobias Kippenberg, Martin Hubert Peter Pfeiffer, and Arne Kordts. U.S. pat. Ecole Polytechnique Federale de Lausanne EPFL. Nov. 10, 2016.

Wednesday 9th September, Poster Session 2
Surface-Electrode Ion Trap Design with Chip-Integrated Microwave Conductors for Near-Field Microwave Quantum Control

Presenter: Janina Bätge
Leibniz Universität Hannover

Surface-electrode ion traps are a promising platform for scalable quantum computers. In the Quantum CCD architecture, transport of ions between registers allows to limit the number of ions that has to be kept in a single potential well at any given time and to im- plement specialized registers for storage, cooling, detection and gate operations. Here we present the design of a demonstrator chip based on an X-junction and quantum gate operations with chip-integrated microwave conductors. This design has been developed with the goal of increasing the storage capacity, optimizing laser access and improving gate operations. Furthermore, we show results of high-frequency simulations to optimize the microwave gate zone of this design, which essential for high fideltity gate operations.

Wednesday 9$^{\text{th}}$ September, Poster Session 2

IonVision and ARTIQEase: Open-Source Tools to aid Ion-Trappers

Presenter: Daisy Smith

National Quantum Computing Center

We present two software tools developed at the NQCC to streamline common tasks in trapped-ion research and reduce duplicated effort across the community. The first, IonVision, is an open-source framework for generating both energy-level diagrams and pulse-sequence diagrams from concise and easily configurable JSON specifications. IonVision is designed as a structured alternative to general-purpose drawing software such as Inkscape or PowerPoint, providing a reproducible and scriptable workflow for producing clear, publication-ready visualisations.

The second tool, ARTIQEase, aims to simplify the development and reuse of ARTIQ-based experiments. It provides a collection of wrapper classes that abstract recurring patterns in ARTIQ code, reducing the recreation of boilerplate code and lowering the barrier for both new and experienced users to make progress with ARTIQ.

Although IonVision and ARTIQEase address different aspects of experimental work, both tools reflect a shared goal: to provide robust, reusable resources that support efficient development, clearer communication, and greater collaboration within the trapped-ion community.

Wednesday 9th September, Poster Session 2
Electrical upgrades for a cryogenic X-junction ion trap for quantum computation and simulation

Presenter: Kevin Rempel
Leibniz Universität Hannover

In the context of a universal quantum processor, trapped ions are a promising physical platform, uniting desirable properties like all-to-all interconnectivity of qubits, long coherence times, and high gate fidelities. We will report on the electrical design work for a microfabricated X-junction surface trap which allows the control of up to 16 $^9Be^+$ hyperfine qubits. It features independent storage, detection, and interaction zones. The internal and motional states are manipulated by a 1 GHz oscillating magnetic field gradient which is generated by a trap-integrated microwave electrode. We are preparing to implement sympathetic cooling based on the coupling of specific motional modes in a symmetric dual-species ion crystal by superimposing an oscillating electrical field on the trap DC potential. Therefore, the new chip requires an increased number of DC and high frequency signals. In order to build a scalable system, we use flexible PCBs as DC cables. To decrease the heat load on the trap, we explore the possibility of using a commercial ceramic PCB as an interposer, and design thermalisation structures for all signals.

Wednesday 9th September, Poster Session 2

Cavity-Enhanced Modular Ion Traps for Optically-Interconnected Networks

Presenter: Arjun Rao
University of Oxford

Ion trap quantum processors have achieved the highest single and two-qubit gates [1,2], but due to constraints on optical access, electrode routing and motional mode crowding, scaling to larger qubit registers within a single device remains limited [3]. A modular architecture, in which multiple traps operate as independent nodes connected via photonic interconnects, offers a path to scalar quantum computation through remote entanglement generation. In such networked systems, the relevant metrics become the remote entanglement fidelity, photon collection efficiency η_p and remote entanglement generation rate R_e. High fidelity operation requires reproducible node fabrication and efficient light matter entanglement. Optical cavities integrated within the trap structure can enhance spontaneous emission into a well defined optical mode via the Purcell factor F_P, thereby increasing both η_p and R_e.

An architecture for optically interconnected ion trap networks is defined here through the production of a fused silica selective laser etched (SLE) ion trap node alongside an integrated atomic source, also fabricated in SiO_2 [4]. The matched material platform and three dimensional geometry provide mechanical stability and thermal compatibility, making this architecture well suited to compact and potentially cryogenic implementations. This fused SiO_2 ion trap platform offers a scalable pathway toward cavity compatible modular nodes for networked trapped ion quantum computing systems.

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4.4 Quantum Computing

Tuesday 8$^{\text{th}}$ September, Poster Session 1
Single-qubit gates with errors at the 10^{-7} level

Presenter: Molly Smith
University of Oxford

In trapped-ion quantum computing, quantum logic gates are most commonly performed using lasers. Alternatively, gates can be performed electronically, for which the technology offers attractive features for scalability: robustness, cost and size, straightforward amplitude and phase control, and simple integration of waveguides onto surface traps. Additionally, electronically-controlled trapped-ions have been used to perform the highest fidelity single- (this work) [1] and two- [2,3] qubit gates of any platform. In this work, we report the achievement of single-qubit gates with sub-part-per-million error rates in a trapped-ion $^{43}Ca^{+}$ hyperfine clock qubit [1]. We explore the speed/fidelity trade-off for gate times $4.4 \leq t_g \leq 35$ μs, and benchmark a minimum error per Clifford gate of $1.5(4) \times 10^{-7}$. Calibration errors are suppressed to $< 10^{-8}$, leaving qubit decoherence ($T_2 \approx 70$ s), leakage, and measurement as the dominant error contributions. Through further analysis, we identify the source of these errors to be noise in the microwave-drive chain, charting a path towards even higher fidelity operations.

References: [1] M.C. Smith, A. D. Leu, et al., Phys. Rev. Lett., 134, 230601 (2025) [2] A. C. Hughes et. al., arXiv:2510.17286 (2025) [3] R. Srinivas et. al., Nature, 597, 209-213 (2021)

Tuesday 8th September, Poster Session 1
Rapid all-optical loading of trapped ions using a miniaturised atom source

Presenter: Tim Wohlers-Reichel
University of Oxford

We characterise an efficient optically-heated neutral atom source for ion trapping. We observe loading rates of up to 24(3) ions per second with heating powers below 85 mW, and demonstrate loading of a single ion in under 30 s with 41.4(4) mW of optical power in a room-temperature ion trap system with an ionisation probability of $1.50(5)\times10^{-5}$. We calibrate a thermal model for the source's internal temperature by imaging the fluorescence of a collimated flux of neutral calcium that effuses from the source at various optical heating powers. We show that the thermal performance of this source is mainly limited by radiative losses. We explore the effect of second-stage photo-ionisation laser power on the loading rate, and identify a path beyond the loading rates reported in this study. We predict that this source is also well-suited to a wide range of metals used in ion trapping.

Tuesday 8th September, Poster Session 1
Fast, High-Fidelity Entanglement in Multi-Ion Chains

Presenter: Emily Hirsch
University of Oxford

The trapped ion platform has demonstrated among the highest reported two-qubit gate fidelities and coherence times, and constitutes a promising platform for quantum computing. A longstanding limitation of the trapped-ion platform, however, is the duration of two-qubit gates. Previous work has demonstrated two-qubit gate durations below the motional period ($\lesssim$1 μs) for Raman-mediated gates [2]. Mølmer-Sørensen gates mediated instead by motional sidebands of an infrared quadrupole carrier transition are limited by off-resonant carrier coupling, which we have mitigated geometrically via structured light addressing in previous work [1].

Here, we present a new apparatus with custom crossed acousto-optical deflectors for individual addressing of $^{40}Ca^{+}$ ions in chains of 5-10 along the 729 nm quadrupole transition. With dual high-numerical aperture objectives, we prepare individually addressed beams with 1.50(1) um waist radius and crosstalk error of $4.16(2) \times 10^{-4}$. We present work toward an array of individually addressed standing waves for fast, reconfigurable, carrier-free two-qubit gates, for which we have designed a robust interferometric stabilization scheme for optical phase control near the ion position.

Increasing ion number leads necessarily to an increase in the number of nearby motional modes, which are often excited as we drive faster two-qubit gates. We plan to mitigate residual spin-motion entanglement from these spectator modes via amplitude pulse shaping [2]. With these tools, we aim to demonstrate two-qubit Mølmer-Sørensen gates that are non-adiabatic with respect to the motional mode frequency, for application in high-speed, high-fidelity, intermediate-scale quantum computing.

References: [1] S. Saner, O. Băzăvan, et. al, Phys. Rev. Lett. 131, 220601 (2023). [2] V. M. Schäfer, et. al, Nature (London) 555, 75 (2018).

Tuesday 8th September, Poster Session 1

Towards mode coupling and cooling of a mixed species ion crystal

Presenter: David Christoph Stuhrmann

Leibniz Universität Hannover

Surface electrode ion traps are one of the most promising platforms in the context of scalable quantum computing hardware. With high-fidelity qubits, long coherence times and all-to-all connectivity the elementary requirements are fulfilled. The ongoing challenge lies in scaling up the systems in terms of the number of trapped ions and controlled qubits, a process which necessitates improvements in hardware, as well as in experimental techniques. I present the current status of the laser system and progress towards the implementations of motional state measurements. These are steps towards sympathetic cooling which is a technique that enables the motional cooling of logical ions without destroying the stored quantum information. While this has been demonstrated in a variety of experiments, our microwave driven two-qubit gates require a more complex three ion mixed species crystal: 43Ca+—88Sr+— 43Ca+. To be able to characterize the motional modes and their couplings we use multiple lasers especially such ones driving narrow-line width electric-quadrupole transitions (729nm and 674nm). The goal is to couple the mode used for the two-qubit gate with an easily sympathetically cooled mode. This is beneficial for cooling ions right before performing gates, since the ion transport will inevitably lead to some amount of heating. The development of sympathetic cooling in a simple chip is expected to be directly transferable to an upcoming X-junction chip, where ions will need to be sympathetically cooled during longer algorithms.

Tuesday 8th September, Poster Session 1

Towards Entanglement distribution between Two Separated Ion-Trap Modules

Presenter: Toby Maddock
University of Sussex

Towards entanglement distribution between two surface ion trap quantum computing chips T. Maddock, M. S. Brown, S. Weidt, W. K. Hensinger The ability to generate and distribute entanglement in engineered quantum systems is a prerequisite for a fully-fledged quantum computer [1]. Our group has demonstrated rapid distribution of quantum information using a transport-baed approach between two surface ion trap quantum computing chips. This demonstration was limited to single-ion state encoding, meaning the next logical step is to entangle two ions and verify the preservation of entanglement following rapid two-ion separation, shuttling to the second module, and recombining. In preparation for this work, the system has been retrofitted with working Current Carrying Wires (CCWs), enabling entangling operations using magnetic field gradients [2]. In preparation for work involving entanglement distribution, a small defect was found to obstruct linear shuttling between the modules; we found that we were able to ablate the chip as a cleaning technique, which restored shuttling success rates past where the link was formerly obstructed to near unity, with no damage to the chip itself. Additionally, the use of globally applied microwave radiation has proven to enable useful quantum control interleaved with transport techniques. For instance, following qubit initialisation in the ground state, single-qubit rotations can be arbitrarily applied if dead times are used between shuttle (transport) legs, or indeed during ion transportation, with the ion at any point of the trap, not just allocated gate zones. This allows for mid-transport pulsed dynamical decoupling, which can reduce the effective clock cycle of quantum circuits. Additionally, by applying microwave pulses with variable delays from the start of shuttle playback, the ion frequency can be used analogously to a light gate, precisely indicating the ion's position in time with extremely high precision. With initial two-qubit gate data taken, in addition to ongoing ion separation work, we hope to demonstrate rapid distribution of Doppler-cooled trapped ion pairs between two surface ion traps, ultimately enabling distributed entanglement between modules [3]. References:

References: [1] B. Lekitsch et al., "Blueprint for a microwave trapped ion quantum computer", Science Advances 3 (2017). [2] M. S. Brown et al., "Fabrication of surface ion traps with integrated current carrying wires enabling high magnetic field gradients", Quantum Science and Technology 7, 034003 (2022). [3] M. Akhtar et al., "High-fidelity quantum links between trapped-ion modules", Nature

Tuesday 8th September, Poster Session 1

Limits to rate and fidelity in cavity-assisted remote entanglement

Presenter: Alika Ho & Jakob Helms

University of Oxford

Cavity-assisted photon-mediated protocols are a promising approach for generating remote entanglement between trapped-ion nodes, a key requirement for scalable quantum networks. Time-bin encoding offers robustness against polarisation drift and fibre-induced decoherence [1], while optical cavities enhance photon extraction via the Purcell effect, addressing a major bottleneck in heralded entanglement generation schemes [2]. A recently proposed [3] protocol for 88Sr+ combines these advantages using cavity-assisted vacuum-stimulated Raman adiabatic passage (vSTIRAP) to generate time-bin encoded ion–photon entanglement.

In this work, we perform a detailed theoretical and numerical analysis of the proposed cavity-assisted, time-bin encoded heralded ion-ion entanglement protocol. We focus on quantifying both the entanglement generation rate and fidelity and identifying the dominant physical error mechanisms arising from realistic atom-laser-cavity dynamics. The protocol is analysed at the level of single attempt cycles, including optical pumping, quadrupole pulses, and photon generation via vSTIRAP, followed by two-photon interference and heralding. We also investigate motion-induced errors originating from recoil during photon emission which introduce spin-motion-photon entanglement. Using recent kick-operator-based descriptions of recoil processes as developed in Refs. [4,5], we evaluate their impact on entanglement fidelity in our architecture.

The system dynamics are modelled using a Lindblad master equation formalism, incorporating all relevant atomic sublevels and spontaneous emission channels. Off-resonant couplings and multi-level effects are explicitly included to capture leakage into non-target states. To evaluate the emitted photon wave-packets, we combine input-output theory in the Markov approximation with a non-Hermitian (no-jump) evolution approach, allowing extraction of the complex temporal mode amplitudes required to assess indistinguishability.

Closely following Ref. [6], we derive expressions for the herald-conditioned ion-ion density matrix in the time-bin encoding basis and show that the resulting entanglement fidelity is directly determined by the overlap of the emitted photon wave packets. We identify residual population in the D3/2 manifold after optical pumping, off-resonant excitation during coherent operations and differential mode cavity lengths between nodes as key sources of fidelity degradation. We calculate that static cavity length differences of 1pm between the nodes correspond to a 20% bell-state error, while off-resonant interactions correspond to a <1% bell-state error. We obtain an estimated attempt cycle duration of 5 us. These results provide the first systematic quantitative analysis of a cavity-assisted, time-bin encoded ion–ion entanglement scheme, offering practical guidance for experimental optimisation and parameter selection.

References: [1] S. Saha et al., “High-fidelity remote entanglement of trapped

atoms mediated by time-bin photons", Nature Communications, 2025. [2] S. Gao, "Optimization of Scalable Ion-Cavity Interfaces for Quantum Photonic Networks", DPhil Thesis, University Of Oxford, 2023. [3] W. J. Hughes, "Towards scalable ion trap nodes for cavity-enhanced quantum networking", DPhil Thesis, University Of Oxford, 2022. [4] D. P. Nadlinger and J. Apolín, "Recoil-induced errors and their correction in photon-mediated entanglement between atom qubits," 2025. [5] S. Kikura et al., "Taming the Recoil Effect in Cavity-Assisted Quantum Interconnects," 2025. [6] D. P. Nadlinger, "Device-Independent Key Distribution between Trapped-Ion Quantum Network Nodes", DPhil Thesis, University Of Oxford, 2022.

Tuesday 8th September, Poster Session 1

Analysis of Entanglement, Stability, Coupling, and Robustness in a MAGIC-Coupled ^{171}Yb Ion System

Presenter: Nadezhda Markova
Sofia University

This work investigates a two-ion system based on $^{171}Yb^+$ ions confined in a microwave (MW) Paul trap at the University of Siegen. The system employs MW-driven control in combination with magnetic gradient-induced coupling (MAGIC). Two continuous microwave fields are applied to the ions, with discrete phase jumps implemented according to a URDD-modulation sequence [1], forming the basis of a dynamically controlled entangling protocol. Our work's primary objective is to develop a comprehensive understanding of the mechanisms underlying entanglement generation in this setting. This is achieved through a combination of analytical derivations and numerical simulations, focusing on the emergence of effective interactions between the two qubits. A central aspect of the analysis is the characterization of stability and robustness of the entangling protocol. The impact of environmental effects, including control imperfections, is investigated to assess the degree of protection provided by the URDD phase jump sequence and different orders are compared to one another. This allows for a detailed comparison between the effectiveness of the Dynamical Decoupling (DD) schemes. We also compare results with prior work employing a different DD scheme in the same setting [2]. In addition, we investigate how MAGIC gives rise to an effective coupling between the ions, and how this coupling is modified by the presence of MW driving fields. Analytical expressions for the coupling strength are derived and benchmarked against experimental data.

References: [1] Genov, G. et al. (2016). Arbitrarily Accurate Pulse Sequences for Robust Dynamical Decoupling. 10.48550/arXiv.1609.09416. [2] Nunnerich, M. et al. (2025). Fast, Robust, and Laser-Free Universal Entangling Gates for Trapped-Ion Quantum Computing. Phys. Rev. X, 15, 021079.

Tuesday 8th September, Poster Session 1
How to make modular quantum computing with ions work

Presenter: Felix W. Knollmann
MIT

There are three key metrics for a remote entanglement link: rate, fidelity, and scalability. All current demonstrations of remote entanglement fail to meet the requirements of large-scale fault-tolerant computing on all three metrics. In contrast, demonstrations of local operations do hit operational requirements. If we assume that at some size a trapped ion quantum computer will outgrow the practical limits of a single module such as shuttling distance or heat load, then remote entanglement links become the limiting factor. I will lay out a plan to overcome this limitation by bringing the rate and fidelity of remote entanglement in line with local operations. In this scheme, integrated optics could parallelize the simultaneous creation of many Bell pairs across various modules. I will touch on initial experimental results on remote entanglement generation using such integrated optics.

Tuesday 8^{th} September, Poster Session 1
Developing Control Electronics for Trapped-Ion Quantum Processors Using MAGIC Technology

Presenter: Mathew Dave Chan
University of Siegen, eleQtron

In recent years, trapped ions have emerged as a prime candidate for the establishment of noisy intermediate-scale quantum (NISQ) computers. We utilize 171Yb+ ions interacting via MAGIC (MAgnetic Gradient Induced Coupling), where MAGIC [1] refers to the deployment of a static magnetic field gradient along the ion chain. This gradient results in a differentiation between the qubit transition energy at each ion position, facilitating the use of microwave frequencies to achieve coherent control of individual ions whilst minimizing undesirable crosstalk. This also induces a coupling between ions which can be exploited for the implementation of multi-qubit gates. Additionally, mature microwave technology in the commercial space is leveraged to overcome the scalability challenge. For the next generation of MAGIC-based quantum computers, we are focused on scaling up our ion trap platform. To this end, we are developing a control system partially housed within ultra-high vacuum and cryogenic conditions, which enables low-noise DC control for multi-zone shuttling. To meet the technical demands of such a system, we draw on the emerging field of cryo-electronics to develop the necessary hardware. Here, we present a summary of the technical building blocks of such devices and a future path to scalability for digital quantum computing with trapped ions in the NISQ era.

References: [1] F. Mintert and C. Wunderlich, Ion-trap quantum logic using long-wavelength radiation, Phys. Rev. Lett. 87, 257904 (2001)

Tuesday 8th September, Poster Session 1
High-Fidelity Electronic $\sigma_z\sigma_z$ Gate on an Axial Mode via Near-Motional Oscillating Magnetic Field Gradients

Presenter: Parsa Rahimi
University of Sussex

Laser-free entangling gates using magnetic field gradients offer a promising pathway toward scalable trapped-ion quantum information processing. Here, we report the first experimental demonstration of a $\sigma_z\sigma_z$ gate implemented on an axial motional mode using a near-motional oscillating magnetic field gradient. We entangle two 171Yb+ ions in roughly 650 μs using the axial breathing mode at 470 kHz. The operations are performed in a microfabricated surface trap with an ion height of 120 μm. A known challenge with near-motional gradients is the "tickling" effect, where the finite impedance of current-carrying electrodes creates an oscillating electric potential that drives the ion's motion. To mitigate this, our trap design buries the current-carrying wires beneath the trapping electrodes with an intermediate ground layer. This configuration shields electric fields much more strongly than magnetic fields. While a nonzero presence of tickling remains on the common axial mode, the breathing mode exhibits no signs of tickling, making it an ideal bus for the entangling operation. Despite relying exclusively on Doppler cooling, our initial implementation consistently achieves gate fidelities in excess of 95%, currently limited by a number of factors including residual motional frequency errors. We present an analysis of leading causes of infidelity for the scheme, explain steps to take to raise the entanglement fidelity above the fault-tolerant threshold, and discuss potential strategies to further enhance robustness, significantly suppressing sensitivity to motional frequency drifts.

Wednesday 9th September, Poster Session 2

Microwave driven single-qubit gates on trapped ions in a magnetic field gradient

Presenter: Abdul-Rahman Rasul
eleQtron GmbH

For scalable quantum computing based on surface ion-traps high fidelity shuttling is vital for cross register entanglement. A prerequisite for this is qubits with coherence times greater than the shuttling protocol time.

In our architecture we use as computational qubits a microwave driven hyperfine ground state magnetic field sensitive transition of Yb171+, in a linear Paul trap, placed within a magnetic field gradient. This architecture allows low cross talk single qubit gate operation and magnetic gradient induces coupling (MAGIC) for two qubit gates but have comparably low bare coherence times due to its sensitivity to magnetic field fluctuations which may result in insufficient shuttling fidelities. To overcome this challenge recoding the qubit state from the computational qubit to the hyperfine ground state clock transition (storage qubit) with high fidelity single qubit pulses is more promising for coherent shuttling.

In this work we benchmark our single qubit gate performance on the clock and magnetic sensitive transition inside a magnetic field gradient. Prior to that we assess the contribution of the microwave chain to the infidelity at magnetic-field-insensitive conditions.

Wednesday 9th September, Poster Session 2
Control of ion strings in a linear segmented microtrap: splitting, combining and entangling

Presenter: Benjamin Revie
National Physical Laboratory / University of Strathclyde

Trapped ions can provide a platform for high fidelity quantum computing, as well as for other areas such as optical clocks and quantum metrology. Recent progress made at the National Physical Laboratory on two ion entanglement in a microfabricated linear segmented trap will be presented. In addition, work on the dynamic control of axial potentials for shuttling, splitting and combining 88Sr+ ions will be shown. This will lay the foundations for single ion addressing and will also provide the framework for an isotopically pure loading scheme. In this scheme, ions are loaded individually in a loading zone then transported to a storage zone where they are combined with the existing string of ions. Ordinarily, loading longer strings of ions without loading the incorrect isotope is probabilistic, but this scheme will be able to achieve this with unit efficiency.

Wednesday 9th September, Poster Session 2

Robust Phase Estimation: Characterising Coherent Transport Operations in a Trapped Ion Quantum Processor

Presenter: Thomas Clarke

Sussex Centre for Quantum Technologies

Roadmaps for next-generation trapped ion quantum computers are built on distributed architectures, where qubits are shuttled between different zones for loading, gates and readout. When the ion is shuttled, changes in the magnetic field environment can lead to the spin on the ion accumulating a phase dependent on the transport path and duration. As the number of qubits on commercially available quantum processors increases, the total duration of circuit time occupied by shuttling increases. If the shuttling phase is not corrected, ion transport can become a significant source of error as transport becomes a larger overhead on wider quantum circuits. A method to characterise this transport phase is demonstrated that offers some robustness to calibration errors, whilst achieving phase resolution beyond the standard quantum limit. To mitigate the error, phase-compensation can be utilised in which applying a virtual Z-gate cancels the phase accumulated during transport without requiring pulsed dynamical decoupling. Quantum state tomography can be used to validate the error model. Finally, randomised benchmarking of the Clifford-1 group can characterise the error attributed to shuttling, where the phase is left uncorrected compared with phase compensation (if needed).

Wednesday 9th September, Poster Session 2

Laser-Driven Universal Control of Zeeman Qudits for Quantum Information Processing

Presenter: Hon-Kwan Chan
University of Sydney

Controlling magnetic (Zeeman) sublevels in large-spin atomic hyperfine manifolds enables their use as high-dimensional qudits for quantum information processing. SU(d) control of Zeeman qudits have been demonstrated using radiofrequency (RF)-driven optimal SU(2) rotations. However, RF-based controls are difficult to implement on systems with small Zeeman splittings, and individual addressing remains challenging. Laser-driven qudit operations are a clear way around these challenges. Existing laser-driven qudit schemes are limited by the weak effective couplings in multiphoton interaction and complications from spectrally unresolved Zeeman energy structures. In our work, we theoretically and numerically investigate SU(d) universal control of Zeeman qudits in an efficient single continuous pulse using the two-photon stimulated Raman transitions without spectrally resolved individual qudit states. We demonstrate universal control capabilities under two sets of experimentally feasible laser parameters. As a concrete example, we apply this control scheme to a $d = 15$ Hilbert space spanned by the Zeeman sublevels of an $F = 7$ hyperfine manifold, and illustrate arbitrary qudit state preparations with fidelities as high as 0.99. This scheme is broadly applicable to other systems with different quantum numbers.

Wednesday 9th September, Poster Session 2
A multi-level trapped ion system for probing quantum thermodynamics

Presenter: William Cutler
University of Oxford

Quantum thermodynamics has recently emerged as a rich field of both fundamental interest and practical utility [1]. Exactly how classical thermodynamics and irreversibility emerge at large scales from unitary quantum mechanics is the subject of current research. At the microscopic level, coherent interactions can be harnessed to build devices such as quantum heat engines or refrigerators that outperform their classical counterparts.

Trapped ion systems are an excellent platform for quantum thermodynamics; they enjoy long coherence times and demonstrate state preparation, measurement, single- and two-qubit gates at high fidelity [2]. Laser pulses can implement Hamiltonian quenches that manipulate the ions' energy landscape, thereby performing microscopic work instantaneously relative to the thermalization time [3]. Furthermore, ground state laser cooling enables coherent control of the ions' harmonic vibrational modes, which provide an additional degree of freedom and all-to-all connectivity between ions in a chain [1].

We present an individually-addressed chain of $^{137}Ba^{+}$ ions as an especially effective system for thermodynamic tasks. Its hyperfine structure ($I = \frac{3}{2}$) and long-lived metastable $D_{5/2}$ manifold permit numerous encoding options for clock qubits across 32 ground and metastable levels. This readily enables mid-circuit measurement, which is crucial for re-thermalizing specific parts of the system and implementing two-point measurement protocols [3]. In addition, we have demonstrated coherent manipulation of higher-dimensional qudit encodings within a single ion [4]. As a result, this platform can realize multi-level thermal machines and measure work and heat statistics in regimes inaccessible to classical systems.

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Wednesday 9th September, Poster Session 2
Towards a Scalable Logical Qubit: Sympathetic Cooling with Barium in a Ytterbium Qubit system

Presenter: Gareth Hopkins
University of Sussex

Multi-species trapped-ion quantum computing provides a promising route to overcoming challenges associated with motional heating and competing operational requirements in quantum devices. We present progress towards the implementation of sympathetic cooling within a mixed-species platform using ytterbium and barium ions in a microwave-driven trapped-ion architecture. Our group uses ytterbium ions as data qubits [1], encoded in hyperfine ground states, while barium ions act as auxiliary cooling ions. As direct laser cooling of the ytterbium qubits during computation would destroy stored quantum information, cooling is achieved via coupling to shared motional modes of co-trapped barium ions. We demonstrate the integration of barium ions into an existing ytterbium system and investigate their performance as a sympathetic cooling resource. Cooling of the barium ions will be investigated via doppler cooling on the 493nm S $\frac{1}{2} <-> $ P $\frac{1}{2}$ transition alongside an EIT cooling protocol [2] and the resulting reduction in motional excitation of the coupled ytterbium ions is to be characterised using coherence time measurements and resolved sideband thermometry of the Yb ions. The system is implemented in a X-junction surface trap enabling flexible reconfiguration of ion chains for cooling and future gate operations. Barium ions are loaded via pulsed laser ablation and we assess the compatibility of this approach with existing ytterbium loading techniques.

References: [1] Weidt, S., et al. "Trapped-ion quantum logic with global radiation fields." Physical Review Letters 117.22 (2016): 220501. [2] Lechner, Regina, et al. 'Electromagnetically-Induced-Transparency Ground-State Cooling of Long Ion Strings'. Physical Review A, vol. 93, no. 5, May 2016, p. 053401.

Construction of Global Controlled-Phase Gates on Trapped-Ions with Resilience Against Motional Heating

Presenter: David Verran
University of Oxford

Entangling operations on trapped-ion processors are typically mediated by the motional states of a linear string of ions. This is achieved by coupling the electronic qubit subspace of ions with the bosonic phonon subspace of quantised normal mode oscillations of the entire ion string. Typically, the common mode, defined by all ions participating equally and oscillating in phase, is used. This is motivated by the structure of the resulting unitary having favourable scaling properties when used as part of a universal gate set for quantum computing. However, the common mode famously heats the most under electric field noise, which causes deleterious decoherence effects and significantly reduces the resulting gate fidelity. Furthermore, for large ion strings, individual mode addressing without incurring parasitic phase contributions from the other modes is typically infeasible without various compensation methods to mitigate these errors. Here, we present an alternative method that uses mode-engineering and multitone driving to resolve both of these problems, in order to achieve an equivalent unitary whilst minimising the use of the common mode. We demonstrate the viability of this method by presenting an example solution for the case of N = 10 ions.

Wednesday 9th September, Poster Session 2
CaQTUS – Calcium Quick Turnaround System

Presenter: Matthew Casey
University of Oxford

Progress in trapped-ion quantum computers depends on developing scalable, high-fidelity control of trapped-ion qubits. Laser-based systems have demonstrated high-fidelity, all-to-all connectivity at small scales [1]. However, the practicality of scaling complex, high-precision laser systems remains uncertain. An alternative approach for manipulating hyperfine qubits is to drive transitions directly using microwaves. Microwave technology is mature, offers a high degree of control, and can be directly integrated into chip-based ion traps. Additionally, microwave-driven trapped-ion qubits have achieved the highest-fidelity single-qubit [2] and two-qubit gates of any platform [3, 4].

Here, we report on the development of a closed-cycle cryostat system for manipulating trapped $^{43}Ca^{+}$ ions. The goal of this system is to enable rapid turnaround for testing novel trap architectures. We have set up a multi-stage cryogenic system that can be fully cycled in 48–72 hours. The system supports all lasers required for state preparation and measurement of $^{43}Ca^{+}$. We have also installed and tested a thermal oven for ion loading. In parallel, building on [1], we have designed, developed, and characterised a new high-fidelity microwave drive, with the aim of pushing gate operations to even higher fidelities.

References: [1] Ransford, A. et al. (2025) Helios: A 98-qubit trapped-ion quantum computer. [2] M.C. Smith, A. D. Leu, et al., Phys. Rev. Lett., 134, 230601 (2025) [3] A. C. Hughes et. al., arXiv:2510.17286 (2025) [4] R. Srinivas et. al., Nature, 597, 209-213 (2021)

Wednesday 9th September, Poster Session 2

Characterising Single Qubit Operations with Interleaved Transport and State Mapping in a Switchable Magnetic Gradient

Presenter: Finnlay O'Dwyer
University of Sussex

Scalable quantum computing architectures require the ability to individually address qubits, maintain long coherence times relative to gate times, and support arbitrary qubit connectivity. We are developing a quantum processor architecture based on modular ion traps and physical ion shuttling, this allows for maximum connectivity, as well as zones dedicated for loading, coherent operations and measurements (Lekitsch, B. et. al. 2017). Coherent operations are performed in a magnetic field gradient, to allow for spin-motion coupling and the use of global microwave fields. Before transporting ions, magnetic gradients are ramped down to preserve qubit coherence. In this work, we demonstrate the feasibility of this architecture by implementing randomised benchmarking of dressed state qubits in Yb171+, interleaved with gradient ramping, dressed state mapping and ion transport. Randomised single qubit gates are performed on a multi-level dressed state basis in the presence of a magnetic field gradient. The qubit is mapped into a clock state, using protocols described in (Randall J. et. al. 2018). We calibrate the transition frequencies of our bare states and implement power matching techniques to achieve dressed state mapping with errors below 1×10^{-4}. We characterise the ramping of the magnetic field gradient using the ion as a magnetic field sensor. The gradient is ramped within a few microseconds using an external current source, incurring average errors below 1×10^{-2}. We also characterise the error from interleaved ion transport for a total distance of 240 μm in 140 μs and demonstrate average errors below 1×10^{-4}. Finally, we measure a total process error, demonstrating that with appropriate calibration we maintain the individual quantum state of single qubits to high fidelity throughout the interleaved ion reconfiguration. The results validate an important core element of the proposed operational protocol and confirm the practicality of this modular architecture.

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4.5 Molecular Spectroscopy

Tuesday 8th September, Poster Session 1
Ion-molecule reactions of N-bearing PAH in a 22-pole radio-frequency ion trap

Presenter: Siddhartha Sankar Payra
Indian Institute of Technology Madras

Nitrogen-bearing polycyclic aromatic hydrocarbons (N-PAHs) are key precursors to complex organic molecules in both the interstellar medium and nitrogen-rich planetary atmospheres. Despite the recent detections of nitrogen functionalized astromolecules [1], their formation pathways remain an open question. The discrepancies between their predicted and observed abundances point to unknown mechanisms such as ion-molecule reaction that govern their evolution in the astrophysical environments. Here we employed a newly built 22-pole radio-frequency ion trap [2] to probe cosmically relevant ion-molecule reaction. Since, the nitrogen atom in the aromatic ring gives rise to exotic interactions that enable their molecular growth [3], we choose pyrimidine ($C_4H_4N_2$), an aromatic heterocycle containing two N-atoms. Our kinetic study augmented by quantum chemistry calculations reveal a spontaneous formation of hitherto unreported endocyclic N-PAHs, revealing pathways which could be active in space.

References: [1]. G. Wenzel, et al., Discovery of the Seven-ring Polycyclic Aromatic Hydrocarbon Cyanocoronene (C24H11CN) in GOTHAM Observations of TMC-1. The Astrophysical Journal Letters 984 (1), L36 (2025). [2]. N. R. Behera, S. Dutta, R. Chacko, S. Barik, G. Aravind, A 22-pole radiofrequency ion trap setup for laboratory astrophysical studies. Review of Scientific Instruments 95 (1) (2024). [3]. D. B. Rap, J. G. Schrauwen, A. N. Marimuthu, B. Redlich, S. Brunken, Low-temperature nitrogen-bearing polycyclic aromatic hydrocarbon formation routes validated by infrared spectroscopy. Nature Astronomy 6 (9), 1059–1067 (2022).

Tuesday 8th September, Poster Session 1
Towards Quantum Simulation with Trapped Molecular Ions

Presenter: Julie Hernandez
University of Oxford

Trapped atomic ions offer long lifetimes and high-fidelity operations [1]. However, their relatively simple internal structure can pose a limitation for scalability. In contrast, diatomic molecules possess a rich internal structure of rotations, vibrations and hyperfine levels, allowing each molecule to store more information than a single atomic ion [2]. Furthermore, the permanent electric dipole moments of polar molecules produce tuneable long-range dipole-dipole interactions.

These properties make trapped molecular ions an attractive platform for quantum computing, simulation and fundamental science. Microwave fields allow coherent manipulation of rotational states, providing a means to encode quantum information and implement gate operations [3,4,5]. Additionally, the dipolar nature of molecules enables entangling operations mediated by electric dipole-dipole interactions [6]. By addressing rotational states with microwave fields, it is possible to induce state-dependent interactions between molecules and realize entangling gates, such as iSWAP, without relying on shared motional modes [3]. This approach offers a potential route towards a scalable architecture that circumvents some limitations associate motional mode-based gates in atomic ion systems.

Beyond quantum simulations, molecules' high sensitivity to fundamental constants facilitates probing fundamental physics in the laboratory. [7]. A trapped molecular ion system shows potential to combine the strengths of both atomic ion traps and neutral molecules. In this work, we present path towards producing a hybrid atomic-molecular ion trap for Sr+ and SrF+.

A key component for this work is the development of a reliable and controllable source of SrF radicals, which can be selectively photoionized. For this purpose, we are designing a compact supersonic beam source of SrF radicals. Using the X-¿A transition at 663nm, we aim to selectively excite a single quantum state of the molecule and drive it to the continuum, creating a high-flux source of molecular ions.

We cover the development of a custom laser system for laser-induced-fluorescence detection of SrF. This system will characterize the performance of our supersonic source by measuring the velocity distribution via time-of-flight imaging. Additionally, we will use the laser for the first stage in a two-photon ionization process which will enable future measurements of the photoionization threshold of SrF. These developments establish a foundation for controlled production and trapping of molecular ions, enabling future studies of dipole-modulated quantum gates, and quantum simulations with hybrid ion systems.

References: [1] Smith, Molly et al. 'Single-Qubit Gates with Errors at the 10 - 7 Level'. Physical Review Letters (2025) [2] Rahul Sawant et al 'Ultracold polar molecules as qudits' New J. Phys. (2020) [3] Ni, Kang-Kuen, et al. 'Dipolar Exchange Quantum Logic Gate with Polar Molecules'. Chemical Science (2018) [4] Hepworth, Tom, et al. 'Long-Lived Multilevel Coherences and Spin-1 Dynamics

Encoded in the Rotational States of Ultracold Molecules'. Nature Communications (2025) [5] Jacob Blackmore et al 'Ultracold molecules for quantum simulation: rotational coherences in CaF and RbCs' Quantum Sci. Technol. (2019) [6] Ruttley, Daniel, et al. 'Long-Lived Entanglement of Molecules in Magic-Wavelength Optical Tweezers'. Nature (2025) [7] Roussy, Tanya , et al. 'An Improved Bound on the Electron's Electric Dipole Moment'. Science (2023)

Wednesday 9th September, Poster Session 2
Towards a nitrogen molecular ion clock for fundamental physics tests

Presenter: Laura Blackburn
University of Sussex

Many beyond-the-Standard Model theories predict that the fundamental constants may change in time and space. Potential changes in one of those constants, the proton-to-electron mass ratio μ, can be detected by comparing vibrational or rotational transitions in molecules to optical transitions in atoms. In our experiment, a vibrational transition in N_2^+ will be compared to atomic clocks within the QSNET network of quantum sensors [1]. The nitrogen ion will be co-trapped in a linear Paul trap with an auxiliary $^{40}Ca^+$ ion which will be used for ground state cooling and state detection via a quantum logic scheme. I will report on our recent progress on the experiment.

References: [1] G. Barontini et al., EPJ Quantum Technology 9, 12 (2022).

Wednesday 9th September, Poster Session 2

Towards quantum-nondemolition state detection of single trapped water ions

Presenter: Mikhail Popov
University of Basel

Molecular ions can be utilized to probe fundamental theories [1] as well as for cold chemical reactions and collision studies. Unlike their atomic counterparts, molecules lack cycling optical transitions, which, along with the overall complexity of their internal energy level structure, significantly complicate cooling and internal state control. These challenges were successfully solved for a range of diatomic molecular ions using quantum logic spectroscopy (QLS) [2-4]. Polyatomic molecules exhibit a new set of properties, such as isomerism and chirality, which may be utilized in tests of fundamental physical theories [5].

Building on these advances, we aim to extend QLS methods to H_2O^+ molecular ions. Molecules are ionized using a 2+1 resonant-enhanced multiphoton photoionization technique [6] and sympathetically cooled by a crystal of laser-cooled Ca^+ ions. The internal state of the molecule is prepared by thermalization with a cryogenic environment. Then the rovibrational state of the H_2O^+ is detected non-destructively using a single co-trapped Ca^+ ion by exerting a state-dependent off-resonant optical dipole force on the molecule and reading out the resulting motional excitation of the ion pair.

Here we discuss the characterization of a cryogenic ion trapping apparatus, which is used for trapping and sympathetic cooling of single water molecular ions, as well as the current progress towards the state detection of water ions in our setup.

References: [1] T. Roussy et al., Science 381, 6653 (2023) [2] M. Sinhal et al., Science 367, 1213 (2020). [3] F. Wolf et al., Nature 530, 457 (2016). [4] C.-W. Chou et al., Nature 545, 203 (2017). [5] M. Quack et al., Annu. Rev. Phys. Chem. 59, 741 (2008). [6] X. Tong et al., Phys. Rev. Lett. 105, 143001 (2010).

Wednesday 9th September, Poster Session 2
Precision & Molecular Spectroscopy

Presenter: Constantijin Karels
University of Strasbourg

Molecules have rich energy level structures with transitions ranging from the kHz to PHz range, some of which exhibiting excellent coherence properties. Molecules are therefore promising for quantum information processing, as well as precision measurements, e.g. realizing quantum sensors and novel clocks, in particular for testing fundamental physics. However, the lack of cycling transitions is a challenge for both laser cooling and state detection and thus for high-precision spectroscopic measurements. In this context, molecular ions co-trapped with atomic ions are very promising. The atomic ions contain cycling transitions and laser cooling is achieved by a combination of Doppler and sideband cooling. Due to the Coulomb interaction between the atomic and molecular ions, the latter can be indirectly or 'sympathetically' cooled to the motional ground state. The interaction can also be used for state detection of the molecular ions through quantum logic spectroscopy schemes. The goal of this project is to achieve motional ground-state cooling of a two-ion system of SrH+ and Sr+. This will allow the implementation of quantum logic protocols to coherently manipulate the molecular (ro)vibrational energy levels. To span the wide range of energy levels, several laser technologies will be used. Purely rotational transitions in the THz range,are covered by driving stimulated Raman transitions with a frequency comb. Vibrational transitions in the near-infrared, will be reached with a stabilized quantum cascade laser. In particular, this project will pave the way towards realizing a molecular clock and to search for time variations of the electron to proton mass ratio. As of now, we have trapped Sr+ ions and performed mass measurements of co-trapped molecular ions. We are preparing the first spectroscopic measurements of SrH+ and SrOH+.

4.6 Clocks and Precision Spectroscopy

Tuesday 8th September, Poster Session 1

Towards an industrially microfabricated 3D ion trap for clock applications

Presenter: Max Glantschnig
Infineon Technologies Austria AG

Optical atomic clocks with 10^{-18} fractional frequency uncertainty enable a broad range of applications, including precise tests of fundamental physics and relativistic geodesy. In the past years, several studies have reached this level of uncertainty [1-3]. In the cited experiments, a single ion in an RF Paul trap was used for frequency stabilization. Owing to the low signal-to-noise ratio of a single atom, averaging times of several weeks are typically required to resolve 10^{-18} inaccuracies. Interrogating N ions simultaneously reduces the required averaging time by $1/\sqrt{N}$, as proposed in 2012 [4], and nevertheless allows high accuracy clocks with systematic uncertainties below 10^{-19} [5].

To store more ions on a smaller footprint, traps must be miniaturized, which can be achieved using conventional semiconductor manufacturing, yielding so-called "chip traps". A prominent implementation is the surface trap [6,7], in which all RF and DC electrodes lie in a single plane and the ion is trapped ~ 100 μm above the chip surface. For clock applications, however, this 2D geometry has drawbacks: The lack of point symmetry around the RF null leads to non-vanishing RF magnetic fields at the ion, and confinement is typically weaker [8] and less harmonic than in 3D geometries. It is therefore of particular interest to combine industrially mature processes with 3D electrode designs. An initial step was taken by Auchter et al. [8], who realized a 3D chip-trap structure on silicon via wafer bonding in the highly automated manufacturing environment of Infineon Technologies.

In my doctoral research, a collaboration between Infineon and the Physikalisch-Technische Bundesanstalt (PTB), this approach will be advanced by replacing silicon with glass and implementing a point-symmetric RF electrode design. Unlike silicon, glass does not generate photocharges from stray light at wavelengths typically needed for ion trap experiments, allowing to omit a continuous shielding layer, reducing RF capacitance and thus on-chip power dissipation [9]. The substrate change, however, introduces challenges because Infineon's processes are optimized for silicon wafers, and new processes are required to integrate through-glass vias (TGVs) and through-holes for optical access. To this end, we showed the compatibility of LIDE® (Laser induced deep etching) with our trap fabrication.

A 3D trap prototype is currently in fabrication. We will characterize key performance metrics such as heating rate, stray fields and micromotion in a cryogenic setup at Infineon in Villach and in a room temperature setup at PTB's Quantum Technology Competence Center (QTZ).

References: [1] C.W. Chou et al., Phys. Rev. Lett. 104, 070802 (2010). [2] N. Huntemann et al., Phys. Rev. Lett. 116, 063001 (2016). [3] H. N. Hausser et al., Phys. Rev. Lett. 134, 023201 (2025). [4] N. Herschbach et al., Appl. Phys. B

107, 891–906 (2012). [5] J. Keller et al., Phys. Rev. A 99, 013405 (2019). [6] M. Valentini et al., Phys. Rev. X 15, 041023 (2025). [7] Z.D. Romaszko et al., Nat Rev Phys 2, 285–299 (2020). [8] S. Auchter et al., Quantum Sci. Technol. 7, 035015 (2022). [9] M. Dietl et al., Adv Quantum Technol. 8, no. 11 (2025).

Tuesday 8th September, Poster Session 1

Towards the sympathetic cooling of a light ion species using laser-cooled heavy ions: an experimental simulation of one step of the GBAR experiment

Presenter: Valentin Martimort

Laboratoire Matériaux et Phénomènes Quantiques - Université Paris Cité

The GBAR collaboration (Gravitational Behaviour of Antihydrogen at Rest) at CERN [1] aims to test the equivalence principle with antimatter by measuring the gravitational acceleration experienced by antihydrogen $\overline{\mathrm{H}}$ prepared at rest. This experiment involves the use of laser-cooled $^9\mathrm{Be}^+$ ions and a sympathetically cooled $\overline{\mathrm{H}}^+$ ion.

The experiment relies in part on the efficient cooling of the $\overline{\mathrm{H}}^+$ antimatter ion composed of an antiproton and two positrons. The principle of this cooling step, proposed by Jochen Walz and Theodor W. Hänsch in 2004 [2] consists in capturing an antihydrogen ion launched with an energy of about 1 eV. Then, starting a sympathetic cooling process using a crystal of about a thousand $^9\mathrm{Be}^+$ ions confined in an ion trap. After this step, the $\overline{\mathrm{H}}^+$ ion temperature is expected to reach a few mK. This first cooling stage is preliminary to Raman sideband cooling (this topic will not be covered in the presentation). Ultimately, the goal is to measure the gravitational acceleration experienced by antimatter with an uncertainty of approximately 1

Our experiment aims to simulate the sympathetic cooling stage of the GBAR project. It consists in launching, with a controlled energy, a single $^9\mathrm{Be}^+$ ion into a cloud of laser-cooled $^{88}\mathrm{Sr}^+$ ions and studying the sympathetic cooling process. These two species are particularly well suited for this experimental simulation, as their mass ratio is very close to that of the ($\overline{\mathrm{H}}^+$, $^9\mathrm{Be}^+$) pair, making the sympathetic cooling dynamics in both systems nearly identical. In particular, we aim to characterize the cooling times as a function of the initial energy.

This presentation will focus on our ability to launch a single ion with a controlled energy from an initial to a final potential well in a linear surface Paul trap. I will detail the Doppler recooling technique [3] used to characterize the ion's initial energy. This characterization relies on analyzing the fluorescence rate dynamics as the ion evolves from an initial hot state to a final cold state. Since this technique strongly depends on the scattering rate of the ion, I will also present a recent study [4] providing a quantitative understanding of the scattering rate for atomic ions with metastable states, such as $^{88}\mathrm{Sr}^+$.

References: [1] P. Perez and Y. Sacquin. The gbar experiment: gravitational behaviour of antihydrogen at rest, *Classical and Quantum Gravity 29(18) 184008, 2012. [2] Jochen Walz and Theodor W. Hänsch. A Proposal to Measure Antimatter Gravity Using Ultracold Antihydrogen Atoms, General Relativity and Gravitation 36(3) 561–570, 2004. [3] J. H. Wesenberg, R. J. Epstein, D. Leibfried, R. B. Blakestad, J. Britton, J. P. Home, W. M. Itano, J. D. Jost, E. Knill, C. Langer, R. Ozeri, S. Seidelin, and D. J. Wineland. Fluorescence during doppler cooling of a single trapped atom, Phys. Rev. A 76 053416, 2007. [4] V. Martimort, S. Guesne,

D. Drapier, V. Tugayé, L. Gros-Desormeaux, V. Cambier, A. Douillet, L. Guidoni and J-P. Likforman. Incoherent repumping scheme in the $^{88}Sr^{+}$ five-level manifold, arXiv preprint arXiv :2512.08710, Dec 2025.

Tuesday 8th September, Poster Session 1

High-precision Q value determination of the ^{7}Be decay through Penning-trap mass measurements

Presenter: Julius Franke

PENTATRAP experiment - Max Planck Institute for Nuclear Physics, Heidelberg

The cryogenic Penning-trap mass spectrometer PENTATRAP, located at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, achieves mass-ratio determinations with relative uncertainties in the low 10^{-12} range [1]. This is made possible by measuring the free-space cyclotron frequency of highly charged ions (HCI) confined in a stack of five cylindrical Penning traps within a homogeneous 7 T magnetic field, utilizing a non-destructive image current detection system. PENTATRAP has contributed with high-precision mass-ratio measurements in several fields of fundamental physics with applications in atomic, nuclear and neutrino physics. Notably, the setup features access to two Electron Beam Ion Traps serving as external sources for HCI. They both employ in-trap laser-induced desorption, a system specifically suited for the injection of very rare nuclides. This contribution will focus on the planned Q value determination of the electron capture decay process of ^{7}Be. At PENTATRAP, the Q value is determined from a measurement of the free-space cyclotron frequency ratio of HCI of ^{7}Be and its daughter nuclide ^{7}Li. The binding energy difference of the missing electrons in both HCI is taken into account using precisely measured atomic binding energies, which for these few-electron systems are experimentally accessible with sufficient precision. The Q value is crucial for the BeEST [2] experiment, which performs a model-independent kinematic study of the decay in the search for sterile neutrinos in the keV mass range. To prevent the Q value uncertainty from limiting the experimental sensitivity, we aim to achieve sub-eV precision, corresponding to atomic mass-ratio measurements with relative uncertainties at the few times 10^{-12} level. Efficient preparation and handling of samples containing extremely small quantities, in the tens of nano grams range, of the synthetic radioisotope ^{7}Be are essential due to its limited availability. We will explore ion implantation at a radioactive ion beam facility as a potential method for producing such a target.

References [1] Schweiger, Ch., et al., Nat. Phys. 20, 921, (2024) [2] Leach, K.G. et al., J. Low. Temp. Phys. 209, 796 (2022)

Tuesday 8$^{\text{th}}$ September, Poster Session 1

An Improved Superconducting Radio-Frequency Trap for Precision Spectroscopy of Highly Charged Ions

Presenter: Kamal Abdellatif
Max-Planck-Institute for Nuclear Physics

Radio-frequency ion traps have enabled unprecedented advancements in high-precision spectroscopy. In recent years, this progress was extended to highly charged ions (HCIs). HCIs feature an increased sensitivity to QED and relativistic effects while also being less susceptible to external fluctuations, which makes them excellent candidates for testing fundamental physics.

To perform high-precision spectroscopy on HCIs, we have built a novel linear Paul trap design using a superconducting resonator. The trap chamber strongly suppresses magnetic field fluctuations while also providing long lifetimes and low heating rates due to the cryogenic environment. Together with an excitation laser stabilized to an ultra-stable optical cavity via a frequency comb, we plan to perform quantum logic spectroscopy (QLS) on HCIs through sympathetic cooling and quantum logic readout of co-trapped Be^+ ions. These techniques have allowed us to perform ground-state cooling on a single Be^+ ion. However, high heating rates and an insufficient quality factor of the cavity form significant challenges for our current experimental system.

We present our progress to implement an improved design to reach higher trapping frequencies at lower temperatures. An resulting increase in trapping potential allows us achieve lower Lamb-Dicke factors, which represents a crucial step on the way towards quantum logic spectroscopy on HCIs.

Wednesday 9th September, Poster Session 2
3D glass chip ion trap for clock applications

Presenter: Klaus Kiendlhofer
Infineon Technologies Austria AG

Optical ion clocks have previously achieved relative accuracies below 10-18 [1]. Such clocks have applications in satellite navigation [2], communication protocols [3], geodesy [4], and precision probing of fundamental physics such as the predictions of general relativity [5].

High-accuracy single ion clocks require long interrogation times, which limits their feasibility for a commercial product. In this project, a multi-ion trap will be fabricated. Every ion in a multi-ion trap has a different frequency shift depending on its local environment. If this challenge is overcome, multiple ions enable more elaborate interrogation schemes as well as significantly shorter interrogation times [6]. Industrial microfabrication can enable inexpensive and repeatable fabrication of large numbers of scalable ion traps.

One of the leading contributions to the clock's uncertainty budget is thermal radiation from the trap's surfaces. It induces an AC Stark shift that changes the clock transition frequency significantly, even when choosing the ion species accordingly. In order to achieve competitive accuracy, the trap's temperature must be known up to tenths of a Kelvin [7]. Due to the scaling of thermal radiation intensity with temperature, the inaccuracy grows with trap temperature at constant temperature variation. This is why the trap should present low resistance and low capacitance to the RF supply, and why the material choice should minimise RF dissipation [7]. In this project, the RF resistance is reduced by developing new types of conducting wafer bonds for ion traps and by developing a process to fabricate through-substrate-vias to contact the top wafer electrodes.

Silicon substrate exhibits higher RF dissipation than glass, making glass substrate the first choice [8]. However, silicon substrate enables more sophisticated fabrication techniques, which could enable more complicated multilayer metal stacks [9] as well as integrated photonic layers in the future. The trade-off between silicon and glass substrate will be evaluated through electromagnetic and thermal simulation in this project.

References: [1] M. C. Marshall et al. 2025, Physical Review Letters 135, 033201. [2] G. Michalak et al. 2021, Advances in Space Research, Volume 68, Issue 12, Pages 4753-4782. [3] V. Martin et al. 2021, EPJ Quantum Technology. 8. 10.1140/epjqt/s40507-021-00108-9. [4] T. Mehlstäubler et al. 2018, Rep. Prog. Phys. 81 064401. [5] Andrei Derevianko et al. 2022, Quantum Sci. Technol. 7 044002. [6] J. Keller et al. 2019, PHYSICAL REVIEW A 99, 013405. [7] Nordmann et al. 2020, Rev. Sci. Instrum. 91, 111301. [8] M. Dietl et al. 2025, Adv Quantum Technol.8, no. 11. [9] S. Auchter et al. 2022 Quantum Sci. Technol. 7 035015

Wednesday 9th September, Poster Session 2
Search for New Physics with Highly Charged Californium

Presenter: Magdalena Winkelvoß
Max-Planck-Institute for Nuclear Physics

Several theories beyond the standard model predict variation of physical constants, for example the fine-structure constant α. Highly charged ions (HCIs) are ideal candidates to search for these variations because their electronic transitions show low sensitivity to external perturbations while simultaneously showing strong relativistic effects making them highly sensitive to α. The TwinTraps project aims at measuring optical transition frequencies of highly charged californium (Cf15+ and Cf17+). Both ions will be trapped simultaneously in two cryogenic Paul traps and measured by high-precision quantum logic spectroscopy using beryllium. This poster presents an overview of the planned experiment, focusing on the production and transportation of the HCIs. The HCIs are produced in an electron-beam ion trap (EBIT). Atoms are inserted close to the electron beam and subsequently ionized into higher charge states by the electron beam itself. They are then extracted and transported through an electrostatic beam line to two different Paul traps. A y-shaped electrostatic bender can be used to load any charge state into any trap. To improve the vacuum conditions in the Paul trap thus increasing the life time of the HCIs, the traps are placed in a cryogenic environment cooled down to 4K. I will present tests of the laser ablation used to inject californium into the EBIT, as well as first extraction and transport measurements of the HCIs, to characterize the efficiency and stability of the loading process.

Wednesday 9th September, Poster Session 2
Ground-State Cooling of Mixed-Species Ion Crystals in the Intermediate Lamb-Dicke Regime

Presenter: Ruben Henninger
Max-Planck-Institute for Nuclear Physics

Precise control over the motional states is a cornerstone of modern trapped-ion experiments, where reaching the motional ground state is essential for high-fidelity quantum gates or the suppression of systematic shifts in precision metrology. In particular, the preparation of ions in the motional ground state of mixed-species ion crystals is a prerequisite for quantum logic spectroscopy (QLS). QLS allows for the interrogation of atomic systems that lack the cycling transitions necessary for direct laser cooling and state detection. An example of such systems are highly charged ions (HCIs), which are sensitive probes for testing fundamental physics and searching for physics beyond the Standard Model. However, these ions typically feature level structures that are inaccessible to current laser technology, as their primary transitions lie deep in the ultraviolet regime." To shield the ions from magnetic field noise we use a superconducting resonator Paul trap. A significant challenge in our setup is that the trap operates in an intermediate Lamb-Dicke regime, with the Lamb-Dicke parameter η reaching up to 0.7 for a single $^{9}Be^{+}$ ion. Building upon our previous success in demonstrating ground-state cooling of a single $^{9}Be^{+}$ ion in this regime , we have extended these protocols to a two $^{9}Be^{+}$ ion crystal. We performed a systematic evaluation of optimal pulse durations, pulse ordering, and a comparison between pulsed and continuous sideband cooling to maximize the ground-state population. We report on our current progress towards achieving ground-state cooling of the axial motional modes of a $^{9}Be^{+}$-$^{40}Ar^{13+}$ mixed-species crystal. This includes a detailed characterization of the crystal's mode structure and the optimization of cooling sequences. These advancements represent an essential step towards QLS on HCIs, paving the way for spectroscopic tests of fundamental physics.

Wednesday 9th September, Poster Session 2
Fundamental physics tests with Highly Charged Ions at GSI

Presenter: Joanna Peszka
GSI Helmholtz Centre for Heavy Ion Research

Highly Charged Ions (HCI), ionised atoms with one or few deeply-bounded electrons, are interesting systems for testing of fundamental physics due to the extreme electromagnetic field experienced by electrons in the proximity of nucleus. Strong-field QED effects of the quantum vacuum on the atomic structure, nuclear size effects, binding energies and fine structure, all scale up with increasing atomic number Z. Therefore heavy HCI are of particular interest as sensitive probe to search for a new physics. HCIs are also promising atomic clock candidates for precision frequency standards. Typically, HCI ions are produced via electron impact ionisation process in Electron Beam Ion Traps (EBIT), which requires high voltage instrumentation, and increase in technical difficulty with increasing charge state of HCIs. The accelerator facility at GSI Helmholtz Centre for Heavy Ion Research is capable of producing HCIs up to bare uranium U^{92+} at energies of hundreds of MeV/u. HCIs injected to Experimental Storage Ring (ESR) can be used for measurements or decelerated to 4 MeV/u using electron cooling. With further deceleration at the HITRAP facility, HCIs will reach sufficiently low energy to be captured in ion traps. HITRAP decelerator itself includes one Penning trap dedicated to electron-cooling of HCIs and it host two experimental Penning traps: ARTEMIS for bound electron g-factor measurements and SPECTRAP for laser spectroscopy of HCI. Additionally, an installation of an RF trap for quantum logic spectroscopy of HCIs is underway. I will provide a update on our work at the HITRAP facility at GSI: progress on the HCI sources and low energy experiments: specifically precision mass determination of HCIs for QED tests, studies of thorium for nuclear clock applications, and progress towards improved beam diagnostics with passthrough image charge detectors.

4.7 Antimatter

Tuesday 8th September, Poster Session 1
Non-neutral plasma manipulation for controlled antiproton annihilations at PUMA

Presenter: Rico Holz
TU Darmstadt

The antiProton Unstable Matter Annihilation (PUMA) experiment at CERN studies the distribution of protons and neutrons in the nuclear density tail using low-energy antiprotons. By studying stable and short-lived nuclei, PUMA investigates surface phenomena such as nuclear halos and neutron skins. The experiment leverages the sensitivity of antiprotons to both neutrons and protons, with the neutron-to-proton annihilation ratio serving as the key observable. [1]

The controlled annihilation of antiprotons and the ions of interest takes place in a Penning-Malmberg trap. The antiproton plasma is cooled by an overlapping electron plasma and compressed by applying the rotating wall technique. This enables storage of the antiproton plasma for a sufficiently long time to transport it to ISOLDE. There, the antiproton plasma is mixed with the plasma of the ions of interest.

The Charged particle Analysis Trap (CAT) was built to develop a procedure suitable for these steps. It is a replica of the PUMA Penning trap, easier accessible and offers more diagnostic tools. In this contribution, the current status of the PUMA experiment will be discussed, as well as recent advances in the CAT-trap. The main goals of the CAT-trap are to provide a detailed characterization of an electron plasma by non-destructive diagnostics using a vector analyzer. Furthermore, the mixing of ions and electrons, as well as the cooling of negative ions with electrons, are studied in order to mimic the processes in the PUMA Penning trap.

References: [1] T. Aumann et al., Eur. Phys. J. A (2022) 58:88

Tuesday 8th September, Poster Session 1

Improving magnetic field homogeneity of the BASE experiment at CERN

Presenter: Tomoka Imamura

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The BASE experiment at CERN investigates the fundamental properties of protons and antiprotons to perform tests of the fundamental charge (C), parity (P), and time (T) reversal invariance in the baryon sector. With its cryogenic multi-Penning-trap system, the magnetic moment of the antiproton has been measured with a fractional precision of 1.5 ppb [1]. Our current statistical measurement precision, 20 times better than in [1], is limited by systematic uncertainties, particularly due to magnetic field fluctuations and inhomogeneities. Accordingly, two technical improvements have been implemented in the experiment: the superconducting joints of our persistent magnetic shielding system [2] and the introduction of a ferro-magnetic compensation ring, to locally tune the most important trap (PT) for precision frequency measurements to high magnetic homogeneity. Our trap stack is placed inside a superconducting magnet that provides a field of 1.945 T. To conduct our g-factor measurements via the continuous Stern Gerlach Effect [3], a magnetic bottle is created by using ferro magnetic CoFe as a ring electrode of the analysis trap [4]. This introduces residual magnetic field inhomogeneities at the precision trap (PT), where a homogeneous magnetic field is required. To control the magnetic inhomogeneities at the PT, four superconducting coils are used. By loading a certain current into the coils, the linear and quadratic components of the magnetic field can, in principle, be tuned to zero. However, because of the external magnetic field at the superconducting joints [5], the coils could maintain too small current for linear gradient compensation. We show that shielding the joints with Mu-metal increased the current limit by a factor of about 5. In addition, a compensation ring was implemented in the experiment. A ring made of cobalt-ferrite alloy is placed near the precision trap to generate a magnetic slope that compensates for the residual field inhomogeneity. The geometry of the ring was selected by analytical calculations, FEM simulations and measurements. Combining the features of the ring with the larger coil tuning range, the linear gradient of the PT was tuned to zero with superconducting coils. Recent results incorporating these improvements will be summarized and presented.

References: [1] Smorra, C., Sellner, S., Borchert, M. et al. A parts-per-billion measurement of the antiproton magnetic moment, Nature 550, 371–374 (2017) [2] Jack A. Devlin et al. Superconducting Solenoid System with Adjustable Shielding Factor for Precision Measurements of the Properties of the Antiproton, Phys. Rev. Applied 12, 044012 (2019) [3] H. Dehmelt, Continuous Stern-Gerlach effect: Principle and idealized apparatus, Proc. Natl. Acad. Sci. U.S.A. 83 (8) 2291-2294 (1986) [4] C. Smorra et al. Observation of individual spin quantum transitions of a single antiproton, Physics Letters B 769, 1-6 (2017) [5] W.A.Fietz, M.R.Beasley and J.Silcox, Magnetization of Superconducting Nb-25%Zr Wire, Phys. Rev. 136, A335 (1964)

Wednesday 9th September, Poster Session 2
Fabrication process for a micro structured Penning trap for (anti-)proton-beryllium coupling

Presenter: Philipp Luca Hoffmann
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In our cryogenic multi-Penning trap experiment, we focus on testing CPT symmetry [1] by performing high-precision measurements of the g-factor of protons [2] and antiprotons [3]. We aim to reach precision beyond the parts-per-billion level, by using quantum logic spectroscopy [4,5] that employs a single, laser-cooled $^{9}Be^{+}$ ion. With that ion sympathetic cooling and spin-state detection of the (anti-)proton can be archived by coupling the particle motion via Coulomb interaction in a double-well potential. We aim to employ a micro fabricated Penning trap with a double-well potential and an inner diameter of 800 µm and a tunable offset of the trapping potential. A small separation between the wells together with tailored curvature strengthen Coulomb coupling and shorten the exchange time. However this is only achieved if the geometry is aligned with high precision. The compact diameter provides strong, stable axial confinement at modest voltages, enabling deep, precisely-controlled wells. Simulations support a two-stage protocol for coupling: an initial frequency sweep followed by static near-harmonic coupling, that achieves efficient energy exchange under practically achievable stability constraints [6], motivating a small, highly precise trap for sympathetic cooling and quantum-logic readout of single (anti-)protons. We present the fabrication of such a micro-coupling trap. We design and fabricate this precise, small-diameter trap section with thin, segmented electrodes using microfabrication techniques. The three-dimensional electrode geometry is structured by selective laser-induced etching (SLE) [7] on fused silica wafers, followed by physical vapor deposition (PVD) of an seed layer stack and subsequent electroplating to obtain low-resistance, cryo-compatible electrodes.

References: [1] R. Lehnert, Symmetry 8 (2016) [2] G. Schneider et al., Science 358 (2017) [3] C. Smorra et al., Nature 550 (2017) [4] D. J. Heinzen and D. J. Wineland, Phys. Rev. A, 42 (1990) [5] P. O. Schmidt et al., Science 309 (2005) [6] N. Poljakov et al., arXiv:2602.22826 (2026) [7] A. Marcinkevicius et al., Opt. Lett. 26 (2001)