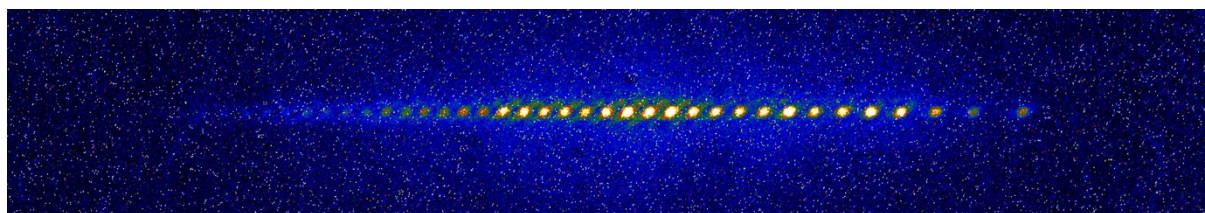


Asian Conference on Trapped Ions 2026

20 – 22 Apr 2026



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Poster ID: 1

#1 — Structural transitions and stochastic dynamics of 3D Coulomb clusters

Author(s): AYYADEVARA Akhil*; PRAKASH Anand; DUTTA Shovan; PARAMEKANTI Arun; RANGWALA S. A.

Affiliation(s): Raman Research Institute

Abstract:

We present structural transitions observed in clusters formed by a few laser-cooled 40Ca^+ ions confined in a three-dimensional (3D) end-cap type Paul trap [1, 2]. Numerical analysis of the clusters' vibrational modes reveals three distinct signatures of lattice dynamics at specific octupolar structural transitions [3]. We directly capture these signatures experimentally, including softening of a Higgs-like mode across a symmetry-breaking transition, stochastic switching between distinct symmetries at a discontinuous transition, and hysteresis across a spinodal point, where metastable minima vanish from the energy landscape. We also find a unique triple-point-like feature, where a symmetry-breaking transition and a symmetry-changing transition occur simultaneously.

In addition, we identify a few clusters with two symmetry-equivalent configurations. In real time, the ions reorient as the entire cluster alternates between the two potential energy minima, mimicking molecular isomerization [4]. To understand the transition pathway and the switch rate, we apply methods from quantum chemistry [5] and reaction rate theory [6, 7]. The theoretical predictions agree well with stochastic-dynamics simulations and experimental observations, pointing to a thermal-activation process driven by the photon bath used for Doppler-cooling of the cluster. Our experiments and analysis of tunable Coulomb clusters show how symmetries, energy landscapes, and dynamical pathways govern transitions in finite-sized systems.

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Poster ID: 2

#2 — Large associative ionization cross-section for low lying states of Li

Author(s): MAHENDRAKAR Vaibhav*; JOSHI Nisha; M Niranjana; YADAV Raghuveer Singh; E Krishnakumar; PANDY Amrendra; VEXIAU R; DULIEU Olivier; RANGWALA Sadiq

Affiliation(s): Raman Research Institute

Abstract:

We observe a high rate of Li_2^+ ion formation via resonant excitation of ^7Li atoms to low-lying 2P and 3S states. It was observed in a dilute Magneto-optical trap (MOT) (average atomic separation $\approx 10 \mu\text{m}$, $T \approx 500 \mu\text{K}$) of ^7Li formed at the center of a co-operational ion trap. The overlaps in the Potential Energy Curves (PECs) of neutral Li_2 and the Li_2^+ , together with the quadratic dependence of Li_2^+ formation rate on the density of MOT, point towards associative ionization (AI) as the formation pathway [1]. We use the parametric excitation technique to not only identify these ions as Li_2^+ but also decipher the entire chain reaction: $\text{Li}(3\text{S}) + \text{Li}(2\text{P}) \rightarrow \text{Li}_2^+ + e \rightarrow \text{Li}^+ + \text{Li} + e$.

We study the photo-dissociation (PD) of Li_2^+ in the presence of MOT light. Unlike the case of Rb_2^+ [2], we observe a few long-lived Li_2^+ in the ion trap. These ions are formed in the lower vibrational states of the $X^2\Sigma_g^+$ PEC, which have low PD rates towards the dissociation continuum of the lowest $^2\Sigma_u^+$ state for the 670nm wavelength. This observation offers an opportunity to co-trap Li_2^+ with other alkali species for further cold-chemistry studies. The significant AI rate of Li_2^+ suggests a large cross-section for this process. We carried out measurements to determine the AI cross-section to be very high ($\approx \pi (1000 \text{ ao})^2$) [1]. This is interesting, given that the participating atoms [$\text{Li}(2\text{P})$ & $\text{Li}(3\text{S})$] are not in high-lying Rydberg states [3].

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Poster ID: 3

#3 — Double-bracket quantum algorithms for quantum imaginary-time evolution

Author(s): GLUZA, Marek*; SON Jeongrak; TIANG Bi Hong; ZANDER Rene; SEIDEL Raphael; SUZUKI Yudai; HOLMES Zoe; NG Nelly

Affiliation(s): Nanyang Technological University

Abstract:

Efficiently preparing approximate ground-states of large, strongly correlated systems on quantum hardware is challenging and yet nature is innately adept at this. This has motivated the study of thermodynamically inspired approaches to ground-state preparation that aim to replicate cooling processes via imaginary-time evolution. However, synthesizing quantum circuits that efficiently implement imaginary-time evolution is itself difficult, with prior proposals generally adopting heuristic variational approaches or using deep block encodings.

Here, we use the insight that quantum imaginary-time evolution is a solution of Brockett's double-bracket flow and synthesize circuits that implement double-bracket flows coherently on the quantum computer. We prove that our Double-Bracket Quantum Imaginary-Time Evolution (DB-QITE) algorithm inherits the cooling guarantees of imaginary-time evolution.

Concretely, each step is guaranteed to i) decrease the energy of an initial approximate ground-state by an amount proportion to the energy fluctuations of the initial state and ii) increase the fidelity with the ground-state. We provide gate counts for DB-QITE through numerical simulations in Qrisp which demonstrate scenarios where DB-QITE outperforms quantum phase estimation. Thus DB-QITE provides a means to systematically improve the approximation of a ground-state using shallow circuits.

Poster ID: 4

#4 — Quantum Signal Processing Interferometry: Detecting rare events at the single-shot limit

Author(s): SCUCCIMARRA Frank*; CHALERMPUSITARAK Teerawat; MCGARRY Cameron; MILLICAN, Maverick; TAN Tingrei; VALAHU Christophe

Affiliation(s): The University of Sydney

Abstract:

Quantum sensing exploits quantum resources to enable measurement capabilities beyond classical limits [1,2]. While most work focuses on parameter estimation, an underexplored paradigm is single-shot binary decision-making. Here, the aim is to decide whether a signal has been detected, rather than estimating the signal's parameters. Single-shot sensing is particularly advantageous when the underlying event is rare, since we can't continuously interrogate the signal the way most parameter estimation schemes require.

Here, we implement a single-shot binary sensing protocol using Quantum Signal Processing Interferometry (QSPI) [3], on a trapped-ion system [4]. QSPI comprises sequences of single-qubit rotations and spin-dependent forces, transforming the signal sensed by the motional mode to a binary outcome readout using the ion's qubit.

We report experimental demonstrations of programmable single-shot phase-sensitive displacement sensing. Additionally, we extend existing QSPI theory to remove the requirement for prior knowledge about the displacement phase, and experimentally verify this phase-insensitive scheme.

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Poster ID: 5

#5 — Industrial $^{171}\text{Yb}^+$ single-ion optical clock with systematic uncertainty below 2×10^{-17}

Author(s): STUHLER Juergen*; FRIEDENAUER Axel; HEINRICH Daniel; RITTER Stephan; THOUMANY Pierre; TRESP Christoph

Affiliation(s): TOPTICA

Abstract:

Rapid advances in research on optical frequency standards (OFS) have enabled ultra-precise instruments and plans for a redefinition of the second. While most of the current OFS are highly specialized laboratory systems, development of commercially available optical clocks that are

robust and transportable with high uptime and high performance are crucial for applications such as timing, geodesy and navigation. Research projects involving both academic and industrial partners have realized such demonstrators surpassing the stability of current primary standards by more than an order of magnitude. Building on the expertise obtained within the collaborative funded research project “opticlock” coordinated by TOPTICA, we present here the setup of our commercially available industrial OFS prototype “TOPTICLOCK”. It is based on the $^2S_{1/2}$ ($F=0$) – $^2D_{3/2}$ ($F=2$) electric quadrupole transition at 435.5 nm of a single laser-cooled and trapped $^{171}\text{Yb}^+$ ion. All required subsystems are contained in two transportable 19” rack compartments.

We will show characterization results of our OFS, which had been transported to the German metrology institute PTB for metrological evaluation within the EU project Qu-Test. By comparison with the PTB laboratory-style OFS PTB-Yb1E3, which operates on the 467 nm electric octupole transition, using an optical difference frequency comb (TOPTICA DFC), a frequency instability of $5 \times 10^{-15}/\sqrt{t}$ with a total systematic uncertainty below 2×10^{-17} was demonstrated. The overall performance of the TOPTICLOCK OFS was also benchmarked by directly comparing it to the opticlock demonstrator, which is based on the same 435.5 nm clock transition. An agreement between both systems with a total uncertainty well below 10^{-17} was obtained from more than 10^6 s of measurement data.

Poster ID: 6

#6 — Towards Trapped-Ion Thermometry Using Cavity Induced EIT

Author(s): KUNDU ABHIJIT*; BHATT Vijay; SHARMA Arijit

Affiliation(s): Indian Institute of Technology Tirupati

Abstract:

Accurate thermometry of trapped ions is crucial for the advancement of ion-based quantum technologies. Precise temperature estimation enables reliable determination of motional heating rates, identification of unknown noise sources, and accurate measurement of motional state occupancy which is a key parameter for high-fidelity quantum computation and quantum networking.

Fine thermometry techniques operate in the sub-Doppler regime, after resolved sideband cooling has prepared the ion close to its motional ground state. In this regime, the motional state occupancy is directly measured. Well-established methods include resolved sideband thermometry [1] and analysis of Rabi oscillations on carrier and motional sideband transitions [2].

Here, we present a cavity-based electromagnetically induced transparency (EIT) technique for ion thermometry in cavity-QED systems. The method enables efficient extraction of the ion’s phonon occupation number following sub-Doppler cooling. Once cavity EIT is established using a control beam, the probe transmission through the cavity is monitored while scanning the probe frequency. The measured EIT linewidth carries information about the ion’s thermal state.

We develop a theoretical model that quantifies how thermal phonon occupation modifies the cavity-EIT transmission spectrum [3]. The technique allows determination of both ion temperature and motional state occupancy in the sub-Doppler regime. While ideally suited for cavity-qed system in the strong coupling regime, the proposed

method remains equally applicable for multi-ion cavity-qed systems in the weak coupling regime. The current method can only be used for operation in the resolved sideband regime, where individual motional states can be selectively addressed for all relevant transitions.

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Poster ID: 7

#7 — Helios: A 98 qubit trapped ion quantum computer

Author(s): RANSFORD Anthony*

Affiliation(s): Quantinuum

Abstract: TBC

Poster ID: 8

#8 — Proposal for macroscopic delocalisation of a large mass in a RF trap

Author(s): SCHUT Martine*; SCARANI Valerio

Affiliation(s): Centre for Quantum Technologies, NUS

Abstract:

Engineering coherent spatial superpositions of levitated large masses is an ongoing challenge. Borrowing from recent experimental work, we consider a charged mass of hundreds of nanometers size (“nanoparticle”) co-trapped with an ion in a Paul trap, and propose a scheme to manipulate its spatial state through the Coulomb interaction with the ion. Though the expected state-of-the-art displacement is smaller than the nanoparticle’s size, it is larger than the wavefunction of the trap’s ground state. Thus the co-trapping scheme is in principle able to demonstrate macroscopic delocalisation of a charged nanoparticle.

Poster ID: 9

#9 — A Charge-Particle-Free Atomic Source for Cryogenic Ion Traps Based on Microheater-Driven Reduction of SrCO₃

Author(s): MATSUMOTO Yuta*; NAKAMURA Ipei; NOGUCHI, Atsushi

Affiliation(s): KIS, The University of Tokyo

Abstract:

In surface-electrode iontraps for quantum information processing, anomalous heating caused is a major factor limiting quantum-gate fidelity and long coherence times. This effect is particularly severe when the ion–electrode distance is small. Cryogenic operation is known to be an effective approach to suppress anomalous heating. However, atomic sources used for ion generation and loading in cryostats must also satisfy strict requirements, including low thermal load and cleanliness.

Conventional resistively heated ovens can provide sufficient atomic flux, but their large heat dissipation makes them incompatible with cryogenic systems. In addition, strontium atoms rapidly oxidize in air, which complicates handling it in normal condition. Laser ablation enables fast and localized atomic delivery with a small average heat load, but it produces energetic charged particles that can charge or contaminate electrode surfaces. In our surface-electrode traps, this effect has led to severe difficulties for trapping ions.

In this work, we develop an atomic source suitable for cryogenic ion traps that operates with a low thermal load. We propose and demonstrate a method based on localized chemical reduction on a microfabricated heater. A solid-state mixture of strontium carbonate and aluminum is placed on the microheater, and neutral strontium atoms are generated through controlled local heating.

The emitted Sr atoms are detected using fluorescence spectroscopy on the 461 nm resonant transition. Fits to the measured fluorescence spectrum confirm that the atoms have a velocity distribution suitable for ion loading, and the fluorescence signal intensity indicates that the atomic flux is sufficient for photoionization-based loading. Repeated operation of the microheater shows that it can generate atoms thousands cycles.

These results show that the proposed microheater-based SrCO₃ reduction source is an effective atomic source for cryogenic surface-electrode ion traps. Direct measurements to verify the absence of charged-particle emission is currently in progress and will also be reported.

Poster ID: 10

#10 — Pulse-Shaped Mølmer-Sørensen Gates with Mode-Selective Control in ¹⁷¹Yb⁺ Ions

Author(s): KIM Hyerin*; KIM Yeongseo*; CHOI Taeyoung; GO Yerin; KIM Hyunsoo; KIM Minsu; YOO Jieun

Affiliation(s): Ewha Womans University

Abstract:

Trapped-ion system is one of the leading platforms for quantum computing, offering long coherence times and precise quantum control. We employed a home-built 4-rods trap to confine multiple ¹⁷¹Yb⁺ ions and perform coherent qubit manipulation using a 355 nm pulsed laser. After characterizing the collective motional modes of the ion chain and preparing the ions near the motional ground state via sideband cooling, we realize a high-fidelity two-qubit Mølmer-Sørensen (MS) entangling gate, which was verified through state population measurement and parity oscillations. To further enhance gate performance in the presence of multiple motional modes, we demonstrate two-qubit entangling gates using segmented amplitude pulse shaping. The entangling operation is realized via five-segment shaped pulse designed to tailor the temporal amplitude profile of the driving field. Compared to the

conventional single-pulse approach, the segmented pulse scheme yields a measurable improvement in gate fidelity by suppressing residual spin-motion entanglement and reducing sensitivity to motional mode coupling. Gate performance is further evaluated under different motional mode configurations in a two-ion system, including regimes where the transverse X and Y motional modes are closely spaced in frequency as well as well-separated regimes.

These configurations provide a test of gate robustness against multi-mode effects and spectral crowding. In both cases, the conventional single-pulse implementation achieves high fidelities, consistent with theoretical expectations for an ideally controlled system. The observed agreement between experiment and theory confirms the stable operation and precise control of the trapped ion platform. Moreover, the additional fidelity gains achieved through segmented pulse shaping demonstrate its effectiveness as a practical approach for enhancing two-qubit gate performance in complex multi-mode environments.

Poster ID: 11

#11 — Engineering High-Fidelity Gate Operations in a Trapped-Ion Platform: Scalable Laser Addressing and Detuning-Robust Pulse Shaping

Author(s): YOO Jieun*; KIM Hyunsoo*; KIM Minsu; KIM Hyerin; KIM Yeongseo; GO Yerin; AHN, Seongjin; CHOI Taeyoung

Affiliation(s): Ewha Womans University

Abstract:

Achieving high-fidelity quantum gate operations remains a key challenge in scalable trapped-ion quantum computing. In our platform development, we address this challenge along two complementary directions: scalable laser-based individual addressing and robust gate control strategies. For multi-qubit operation, we implement a crossed acousto-optic deflector (AOD) system to split and steer a 355 nm pulsed laser into independently controllable beams. This configuration enables flexible individual addressing with tight focusing and reduced crosstalk. We characterize beam alignment, intensity calibration, and gate optimization procedures, demonstrating its suitability for scalable multi-ion experiments. To enhance gate reliability under realistic experimental conditions, we also investigate frequency-detuning-tolerant control techniques using microwave-driven single-qubit transitions as a testbed. Employing an arbitrary waveform generator (AWG), we design a shaped π -pulse incorporating phase-inverted pulse segments to suppress infidelity arising from frequency detuning and fluctuations. By optimizing the relative duration of these segments based on measured gate fidelity, we demonstrate improved robustness compared to conventional square pulses and quantify the tolerable detuning range.

This combined approach advances high-fidelity gate engineering and provides practical insights for developing reliable and scalable trapped-ion quantum processors.

Acknowledgements

We acknowledge financial support from National Research Foundation of Korea RS-2025-NR068814, RS-2025-00442855, RS-2025-00466865

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Poster ID: 12

#12 — Towards Strong Ion–Photon Coupling with Trapped Barium Ions in a Fibre Microcavity

Author(s): WASAWO Tabijah*; DAKSHESH Natakala; DAS Diptaranjan; DUDOLADOV Savelli; GAO Shaobo; KASSA Ezra; KAVUNGA Vishnu; TAKAHASHI Hiroki; YUAN Zhenghan

Affiliation(s): Okinawa Institute of Science and Technology (OIST)

Abstract:

Efficient generation of photonic flying qubits from trapped-ion qubits is a central requirement for modular quantum computing and distributed quantum networks [1]. We report progress towards a barium ion–cavity platform designed to enable strong atom–photon coupling at the 493 nm S–P transition.

Barium provides a favourable platform for cavity QED through its strong dipole-allowed S–P transition at 493 nm, enabling large ion–photon cooperativity in a fibre-based microcavity [2]. Operation at this wavelength balances strong light–matter interaction with practical cavity stability in vacuum. We have verified long-term stability by tracking the finesse of a test cavity at 493 nm in vacuum for over one year, demonstrating sustained performance under experimental conditions [3].

Operation at short wavelengths also presents the challenge of cavity mirror degradation in vacuum. We outline our approach toward stable cavity operation at 493 nm under low circulating powers and describe ongoing efforts to achieve reliable ion–cavity integration. Characterization of the trap demonstrates stable confinement of barium ions, establishing the foundation for cavity-assisted experiments.

This architecture provides a pathway toward ion–cavity modules capable of fast atom–photon entanglement, cavity-assisted state readout, and photon-based interconnects between remote trapping nodes. Our work represents a concrete step toward shortwavelength cavity QED with trapped ions and photonic links between modular quantum processors.

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 [2] S. Gao, et al. Phys. Rev. Appl., 19(1), 2023;
 [3] Diptaranjan Das, et al. Manuscript in preparation.

Poster ID: 13

#13 — Numerical studies of the micromotion temperature of trapped ions and motional frequency shifts

Author(s): GHOSH, Amit*

Affiliation(s): IIT Kanpur

Abstract:

Among several other Quantum Computing simulation platforms, trapped-ion qubits offer several advantages, including long coherence times and very high gate fidelity. We will use a Paul trap for trapping 40Ca ions. The kinetic energy of an ion has three parts: One from secular motion, one from internal micromotion (IMM), and one from excess micromotion (EMM). Here, we will present a numerical simulation study of micromotion energies for ions and their effects on motional frequency shifts and cooling times. If there is a static external electric field, it will displace the ion position and can give rise to excess micromotion. Excess micromotion can also be caused by a phase difference between the RF blades or by trap blade misalignment. We will see the effect of all these on the ion's motional energy in our Paul trap.

Poster ID: 14

#14 — Heterodyne measurement of two 729-nm diode lasers at a linewidth of few Hertz

Author(s): LEE Hyegoo*; SHIN Yongha*; KIM Keumhyun; MOON Youngil; HAN Sangsoo; CHO Junhee; GWON Sehyun; KIM Myunghun; LEE Moonjoo

Affiliation(s): Pohang University of Science and Technology (POSTECH)

Abstract:

Decoherence induced by laser frequency noise remains one of the most critical obstacles in quantum information processing. Accurate characterization of the laser noise power spectral density (PSD) is essential to suppress this decoherence and enable high-fidelity qubit control. While qubit coherence-based noise spectroscopy provides ultimate system-level characterization, direct laser noise measurement offers complementary engineering insights. We stabilize two independent commercial external-cavity diode lasers (ECDLs) to high-finesse cavities using Pound-Drever-Hall (PDH) locking. Optical heterodyne beat spectroscopy between two independent master lasers, analyzed via Voigt profile fitting, yields individual linewidths below 10 Hz. PDH error signal analysis reveals comprehensive frequency noise PSD across 1 Hz–10 MHz, identifying diode laser specific servo bumps (100kHz~MHz regime) as dominant residual noise coupling intensity fluctuations into phase noise during multi-ion entanglement operations. Dual-port PDH characterization compares cavity reflection and transmission beams. The cavity transmission naturally filters servo bump components above cavity bandwidth while preserving sub-10 Hz core stability. This clean transmission beam injection-locks a high-power slave laser, producing high-power 729 nm output without MHz noise contamination. Transmission PSD confirms >10 dB servo bump suppression relative to reflection-locked performance. Our approach eliminates servo-induced decoherence, providing a complete engineering solution for commercial diode systems suitable for scalable trapped-ion quantum computing.

Poster ID: 15

#15 — Phononic frequency comb generation in a tunable trapped-ion nonlinear oscillator

Author(s): KIM Myunghun*; HAN Sangsoo; CHO Junhee; GWON Sehyeon; LEE Hyunjoon; MOON Youngil; SHIN Yongha; LEE Hyegoo; KIM Keumhyun; SUH Junho; LEE Moonjoo

Affiliation(s): Pohang University of Science and Technology (POSTECH)

Abstract:

Nonlinearity is a universal property of oscillators that underpins a wide spectrum of phenomena across fundamental science and practical applications. From macroscopic to microscopic vibrational systems, conservative and dissipative nonlinearities generate behaviors ranging from well-established bifurcations to exotic dynamics, while controlled access to these regimes remains elusive.

Here we present a trapped-ion mechanical oscillator with anharmonicity and dissipation arising from distinct physical mechanisms, demonstrating complete control of the nonlinear response and the generation of a phononic frequency comb. In the presence of engineered anharmonicity, the weakly driven ion exhibits Duffing-type oscillations, enabling a continuous transition from softening to hardening behavior. Beyond a critical ion velocity threshold at strong drive, the interplay between velocity-dependent anti-damping and the intrinsic nonlinearity gives rise to a new limit cycle, generating quasi-periodic motion and a mechanical frequency comb from a single driven mode. Our work establishes trapped-ion platforms as a versatile testbed for exploring scalable and collective dynamics.

Poster ID: 16

#16 — Quantum repeater applications with two co-trapped 40Ca^+ ions

Author(s): BERGERHOFF Max*, BAUMGART Pascal, ELSHEHY Omar, HAEN Christian, MEIERS Jonas, BAUER Tobias, BECHER Christoph, ESCHNER Jürgen

Affiliation(s): Saarland University, Germany

Abstract:

The quantum repeater (QR) [1] is a key building block for large quantum networks. Dividing a transmission link into segments of entangled quantum memories and cells of asynchronously entangled photons [2] overcomes the exponential loss of direct transmission.

We implement a QR cell using free-space coupled photons from two 40Ca^+ ions in the same Paul trap. Ion-photon entanglement (IPE) is generated asynchronously via controlled emission of single photons from individually addressed ions into separate single-mode fibers. Photon-photon entanglement with 77.8(6)% average fidelity is then produced by a Mølmer-Sørensen gate and state projection on the ions. This protocol increases the photon pair probability 100-fold compared to a synchronous QR cell, giving a single-attempt probability of $9.76(2)\times 10^{-5}$ and a detection rate of $11.34(2) \text{ s}^{-1}$ [3].

The QR segment connects QR cells to form a link. We demonstrate it using two 40Ca^+ quantum memories entangled via entanglement swapping of free-space coupled single photons at an optical distance of 440 m, following prior IPE generation, with photons converted to the telecom C band via polarization-preserving quantum frequency conversion

(QFC) [4]. Memory-memory entanglement is verified by a parity measurement after applying two $\pi/2$ pulses on the ions following photonic coincidence detection. The parity oscillation shows a peak-to-peak value of 1.36(15), corresponding to a fidelity above 68(8)%, with entangled memories produced at 4.7 per day.

In preparation for real-world quantum repeater applications, quantum communication protocols, including quantum state teleportation, have been demonstrated over the 14.4 km Saarbrücken urban fiber testbed using a spontaneous parametric down-conversion source of entangled photon pairs and a single 40Ca^+ ion, combined with QFC and polarization compensation [4].

In this context, a new ion trap setup with integrated sub-mm cavity for increased generation and collection probability of the photons is presented. It will improve the scaling behavior of the QR cell and enables quantum repeater protocols over the fiber link despite the losses of the link.

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- [3] M. Bergerhoff et al., Quantum repeater node with free-space coupled trapped ions, *Phys. Rev. A* 110, 032603 (2024)
- [4] S. Kucera et al., Demonstration of quantum network protocols over a 14-km urban fiber link, *npj Quant. Inf.* 10, 88 (2024)

Poster ID: 17

#17 — Quantum Process Tomography Analysis of Thermal Noise in Mølmer-Sørensen Gates for Quantum Error Correction

Author(s): HIRAI Noah*; KUDO Isamu; MIYANISHI Koichiro; NISHIO Shin; SATOH Takahiko; TAKAHASHI Hiroki; TAKEOKA Masahiro; TANJI Kazufumi

Affiliation(s): Department of Electronics and Electrical Engineering, Keio University

Abstract:

Trapped-ion quantum computers are a promising platform characterized by long coherence times and high-fidelity operations. The Mølmer-Sørensen (MS) gate is a widely used two-qubit entangling operation and a key primitive for stabilizer measurements in quantum error correction. Thus, improving its fidelity is a prerequisite for achieving fault-tolerance. Motional heating is a major error source in laser-based MS gates since the initial thermal state can amplify other errors such as motional dephasing. However, the effective error model in systems with limited cooling or high heating rates remains insufficiently understood.

In this study, we comprehensively analyze the impact of physical noise sources—including initial thermal states, heating, spin dephasing, motional dephasing, and photon scattering—on MS gate performance using the QuTiP simulator. Using quantum process tomography and Kraus operator decomposition, we quantify how each noise source contributes to specific Pauli error components as a function of the initial temperature. We find that in high temperature regimes, the dominant error is not an independent single-qubit error but random

over- or under-rotation errors, resulting in the correlated XX error (specifically of the form $I - i\epsilon XX$).

We further show that this error structure originates from the motional dephasing and the high-order Lamb-Dicke parameters, which induce the correlated error mediated by the motional modes. These results highlight the necessity of optimizing composite pulse sequences to suppress such errors. For quantum error correction codes, our error model can be compatible with stabilizer-based simulators through Pauli twirling. This study provides practical guidelines for hardware optimization, code selection, and assessment of logical error rate performance based on experimentally accessible parameters.

Poster ID: 18

#18 — In-situ control of cavity dissipation and a topological transition in an atom-nanotip-cavity system

Author(s): HA Taegyul*; GOUDARZI Kiyanoush; LEE Dowon; KIM Donggeon; JEONG Eunchul; KIM Uijin; KIM Myunghun; KIM Jinuk; LEE Moonjoo

Affiliation(s): Pohang University of Science and Technology (POSTECH)

Abstract:

We propose a method for tuning the cavity dissipation rate in an atom-cavity system. By inserting a nanotip into the cavity mode, we estimate that the cavity decay rate increases by a factor of approximately 20 due to the scattering and absorption losses at the tip. Applying this in-situ technique, we demonstrate that coupling a single atom or ion to the resonator enables the emergence of an exceptional line. Furthermore, the position of an exceptional point can be shifted by adjusting the decay rate, enabling a topological transition through dissipation control alone. Our work establishes a scattering-induced dissipation channel for probing the cavity field and enables controlled quantum state switching in cavity quantum electrodynamics.

Poster ID: 19

#19 — Field-space entanglement dynamics between tunnel-coupled Luttinger liquids

Author(s): DUPAYS Léonce; MURTADHO Taufiq; TIANG Bi Hong*; NG, Nelly H.Y.; RUGGIERO Paola

Affiliation(s): Department of Mathematics, King's College London, Centre for Quantum Technologies, Nanyang Technological University

Abstract:

We investigate the evolution of field-space entanglement between two Luttinger liquids (LL) after a quantum quench from decoupled to strongly tunnel-coupled scenarios. Here, field-space entanglement quantifies quantum correlations between the momentum modes of the two subsystem LLs. Whenever the quench preserves Gaussianity, the full correlation dynamics at finite temperature regime is analytically determined by the solution of a time-dependent quantum harmonic oscillator differential equation, which is known as “Ermakov equation”. This mapping enables a unified description of entanglement measures. As representative examples, we study both sudden and smooth linear quenches. For both cases, we derive (a) analytical expressions for the mutual information (MI), logarithmic negativity (LN), and Rényi

entropies; (b) long-time average values of both MI and LN in the zero-temperature limit, and (c) a proof that MI decreases monotonically with temperature. Moreover, for generic smooth quenches, MI and LN exhibit a quadratic early-time growth in the thermodynamic limit. Our analyses can be generalized to other smooth Gaussian-preserving quenches, and complement existing studies that have primarily focused on real-space entanglement or zero-temperature limit.

Poster ID: 20

#20 — Development of a trapped-ion based quantum computing platform

Author(s): ROY SHUVARATI*; A.S; SHARAN; MANGAONKAR; RAPOL

Affiliation(s): Indian Institute of Science Education and Research, Pune (IISER)

Abstract:

We aim to develop a 20-qubit quantum computing platform based on trapped calcium ions. Trapped ions provide one of the best platforms for developing a quantum computer because of the long coherence times of the qubit states and the highest quantum gate fidelities compared to all the existing platforms so far. We have designed and fabricated the individual components using in-house facilities and assembled a fully functional ion trap set-up that is capable of trapping up to 25 ions crystals. We implement the standard laser cooling and optical pumping schemes on the ions to prepare them in the initial state. We have performed spectroscopy on the quadrupole transition at 729 nm and observed Rabi oscillations for a single ion. This sets the stage for performing basic gate operations like single-qubit rotations and multi-qubit entanglement, using laser pulses, as our next step. Current efforts are focussed at characterizing our system and reducing noise, before performing gate operations. I will discuss the experimental setup, present our initial results, and outline our future research goals.

Poster ID: 21

#21 — Implementation of a Segmented Blade Trap with EMCCD-Based Real-Time Detection for Scalable Trapped-Ion Platforms

Author(s): GO Yerin*; KIM Minsu*; KIM Hyunsoo; YOO Jieun; KIM Yeongseo; KIM Hyerin; CHOI Taeyoung

Affiliation(s): Ewha Womans University

Abstract:

Trapped-ion platforms offer long coherence times and high-fidelity gate operations. In our previous work, we implemented single- and two-qubit gates using a four-rod trap with $^{171}\text{Yb}^+$ ions. However, the closed geometry limited optical addressing and precise ion control, restricting the reliable shuttling and uniform ion spacing essential for scalable multi-qubit operation.

To overcome these limitations, we designed and constructed a segmented blade trap with an open geometry that enhances optical access and laser interaction fidelity. The segmented DC electrodes enable fine control of the axial potential, allowing for uniform ion spacing and individual addressing.

In parallel, we developed a custom GUI-based control system for real-time state detection using an EMCCD camera. The system supports flexible parameter control and user-defined Regions of Interest (ROIs) for multi-ion readout. Realtime fluorescence buffering generates histograms for reliable state discrimination, while continuous brightness monitoring ensures detection stability. Future integration with ARTIQ via hardware triggering will enable automated experimental sequences.

These developments establish a scalable and integrated platform for precise control, individual addressing, and high-fidelity readout in multi-qubit trapped-ion quantum computing.

Acknowledgements

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Poster ID: 22

#22 — Trapped Ions: Scalable Architectures, Super-Heisenberg Sensors, and the Petz Map

Author(s): PNG, Wen Han*

Affiliation(s): Centre of Quantum Technologies, National University of Singapore

Abstract:

These works translate abstract concepts from quantum information theory into physical control protocols designed for quantum computation, error recovery, and quantum metrology. The physical platforms utilized are based on ion trap quantum information processor. In the first project, I propose a physical implementation of a symmetry-protected super-Heisenberg sensing protocol in trapped ion sensors. A key challenge in achieving the super-Heisenberg limit is designing nonlinear parametrization from a linear perturbing signal. We address this by pulse-engineering the signal onto a geometric phase, which is then encoded into qubits via spin-spin interaction. In the second project, I propose a quantum circuit implementation of the Petz recovery map for singlequbit decoherence, analyzing its resource requirements, performance under suboptimal priors, and resilience within noisy ion trap environments. Lastly, I proposed a novel scalable architecture Drive-Through Quantum Gate: Non-Stop Entangling a Mobile Ion Qubit with a Stationary One.

Poster ID: 23

#23 — Towards Cavity-Enhanced Efficient Single Photon Generation from an Ion in a Linear Trap

Author(s): YUAN Zhenghan*; OYA Shuma; TEH Soon; KAVUNGAL Vishnu; GAO Shaobo; KASSA Ezra; TAKAHASHI Hiroki

Affiliation(s): Okinawa Institute of Science and Technology (OIST)

Abstract:

This research represents a significant step towards the efficient generation of flying qubits

from stationary qubits, a key capability for enhancing the scalability and interconnectivity of modern quantum computers. We employ calcium ions as our stationary qubits and photons emitted by these ions serve as the interconnection medium for quantum communication.

The novelty of our approach lies in coupling a single ion within a linear chain to a FFPC, oriented with its cavity axis perpendicular to the trap axis to achieve individual ion–cavity coupling. To overcome the substantial disruption to the trapped ions induced by the nearby dielectric mirrors, we developed an active potential compensation method in combination with a dual-RF driving scheme, effectively mitigating the detrimental effects of stray charges on the cavity mirrors and suppressing motional heating caused by the dielectric proximity. [1]

To now, both the monolithic miniaturized linear Paul trap and the fibre-cavity holder, which integrate the compensation electrodes, were fabricated from glass using SLE technique.[2] The fibre mirror substrates were fabricated in-house via an automated CO₂ laser machining process and mirror-coated to the desired reflectivity. [3]

The assembled system exhibits a measured cavity finesse of approximately 30000, corresponding to a coupling strength of $g=2\pi\times 9.06$ MHz, which leads to a cooperativity larger than 1. Taking the efficiency parameters into account, a single-photon collection rate potentially up to 67.5 kHz can be achieved, which could be further improved by improving the experimental apparatus.

Looking forward, this work both enables the realization of a photonic-interconnected modular quantum computer, comprising multiple linear-trap modules linked via optical channels, thereby substantially increasing the accessible qubit number, and lays the foundation for a cavity-mediated, photon-based quantum network. Collectively, these advances represent a pivotal step toward the practical realization of a large-scale quantum computer.

[1]E.Kassa, et al. Phys. Rev. Applied 23, 024038

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[3]S.Gao, et al. Optics Express Vol. 33, Issue 18, pp. 39009-39022 (2025)

Poster ID: 24

#24 — Topological spin textures for quantum simulation in a Penning trap

Author(s): JEE Julian*; BIERCUK Michael; CAFE DE MIRANDA Gustavo; MAKADIA Nihar; PHAM Joseph; SHANKAR Athreya; WOLF, Robert

Affiliation(s): The University of Sydney

Abstract:

Engineered non-trivial spin textures offer a route to controlled studies of topology and out-of-equilibrium order, which governs the emergence of phenomena such as unconventional superconductivity, frustrated magnetism, and dynamical phases of matter. However, preparing such spatially structured states remains challenging in trapped-ion simulators. Here, we demonstrate a method to deterministically initialise spin textures in a two-dimensional Penning trap Coulomb crystal with more than 200 ions. By applying a spin-dependent force that varies with position, we engineer a spatially varying spin precession. Site-resolved spin-state detection is then used to reconstruct local Bloch vectors, which allows us to obtain quantitative

benchmarks of state preparation quality, including the winding number, order parameter, and texture fidelity relative to a target configuration. We experimentally demonstrate the preparation of skyrmion and domain wall textures, using single-site spin resets to initialise the latter. Additionally, we propose pulse sequences to initialise other spin textures, including anti-skyrmions, merons, bimerons and skyrmioniums. We investigate the impact of decoherence mechanisms to assess the feasibility of using these structured initial states in quantum simulation protocols. This work provides a route to engineering programmable spin textures, expanding the Penning trap’s capabilities for quantum simulation of non-equilibrium dynamics and emergent many-body phenomena.

Poster ID: 25

#25 — Algorithms Realized on the Quantinuum Helios Trapped-Ion Quantum Computer

Author(s): DECROSS, Matthew*

Affiliation(s): Quantinuum

Abstract:

We present recent experiments utilizing the unique capabilities of the Quantinuum Helios trapped-ion quantum computer. These experiments comprise important progress towards realizing applications across a diverse array of fields: materials science, cryptography, and quantum error correction. They include exploration of pairing correlations in the Fermi-Hubbard model of superconductivity, certified randomness amplification across a network, and the demonstration of break-even computations in high-rate QED and QEC codes. In the first case, development of new ground state preparation techniques, time evolution circuits, fermionic encodings, and error mitigation techniques allow non-equilibrium physics to be probed on a half-filled square lattice, as well as equilibrium physics in bilayer and doped checkboard models. In the second, we show how support for dynamical quantum-classical interactions within the coherence time (“gate streaming”) allows the effective latency in certified randomness experiments to be reduced by close to two orders of magnitude, bringing classical verification costs towards the realm of practical feasibility. In the third, we demonstrate encoding, QEC cycles, state preparation, gate benchmarking, and large-scale computation in high-rate codes using real-time quantum logic to achieve break-even performance. We focus on key enabling features of the trapped-ion platform, such as high fidelity, arbitrary qubit connectivity, leakage-heralded measurement, gate streaming, and on-the-fly transport compilation.

Poster ID: 26

#26 — Transport-Aware Syndrome Measurement Circuit Compiler for 1D QCCD Architecture

Author(s): ISHIKAWA Eitaro*; NISHIO Shin; MIYANISHI Koichiro; TANJI Kazufumi; KUDO Isamu; TAKEOKA Masahiro; TAKAHASHI Hiroki; SATOH Takahiko

Affiliation(s): Department of Information Engineering, Faculty of Science and Technology, Keio University

Abstract:

Trapped-ion platforms based on segmented traps require the repeated shuttling of ions between storage and interaction regions. As a result, the practical cost of quantum error correction (QEC) on such devices depends strongly on transport congestion rather than on gate counts alone. We present a compilation and execution-time estimation framework for the surface code syndrome measurement circuit on a strictly constrained one-dimensional quantum charge-coupled device (QCCD) architecture. To accurately model these costs, our framework compiles high-level quantum circuits into a QCCD-native instruction set, automatically inserting necessary transport operations—such as shuttling or physically swapping ions, and splitting or merging ion chains—to generate collision-free, executable operation sequences. Using rotated surface code as a representative workload, we evaluate the impact of scheduling strategies and zone-capacity constraints on a single-interaction-zone device. Our evaluation reveals a critical trade-off: strategies designed to increase logical parallelism, such as batch measurements or utilizing the maximum number of simultaneously active auxiliary qubits, often exacerbate traffic congestion and slow down the code cycle. Conversely, reusing auxiliary qubits across multiple stabilizer measurements reduces transport overhead, resulting in a faster overall QEC cycle. This framework quantifies the hidden costs of ion transport, demonstrating that future QEC compilers should explicitly treat routing latency as a primary cost metric for scalable trapped-ion fault-tolerant computing.

Poster ID: 27

#27 — Hour-scale ion confinement in a Paul trap via sympathetic cooling with ultracold atoms

Author(s): BAIDYA SATYABRATA*; DUTTA SOURAV

Affiliation(s): Tata Institute of Fundamental Research (TIFR)

Abstract:

We present a systematic study of ion-atom collisions conducted in a hybrid experimental apparatus consisting of a linear Paul trap for ion confinement and a magneto-optical trap for ultracold neutral atoms. The lifetime of trapped ions was characterized both in the presence and absence of ultracold atoms over a range of applied radio-frequency (rf) amplitudes and drive frequencies. We demonstrate that sympathetic cooling via collisions with ultracold atoms enables ion confinement times exceeding one hour in the Paul trap. Such prolonged trapping durations provide a robust platform for investigating low cross-section processes that are typically challenging to observe with conventional techniques.

Poster ID: 28

#28 — Decoherence Mechanisms Limiting the Generation of Nanoparticle Macroscopic Superpositions in RF traps

Author(s): JACKSON Tiong*; SCHUT Martine

Affiliation(s): Centre for Quantum Technologies, NUS

Abstract:

The preparation of nanoscale objects in coherent macroscopic superpositions remains an ongoing challenge. We examine one proposal to realise such states using a charged nanoparticle co-trapped with an ion in a linear Paul trap, in which the spatial state of the nanoparticle can be manipulated via the ion through Coloumb interactions. While a previous

study showed an achievable delocalization of the nanoparticle wavefunction that is much larger than that of its ground state, in this study we analyse in detail the dominant decoherence mechanisms that could limit the feasibility of the protocol. These mechanisms include air molecule scattering, blackbody radiation, and coupling to electric field noise sources.

Poster ID: 29

#29 — Development of an Ion-Trap System and a 674 nm Laser System towards Motional-State Control via Oscillating Electric-Field Gradients

Author(s): KINASE Tetsu*; KAWABE Komei; NAKAMURA Ippei; NOGUCHI Atsushi

Affiliation(s): KIS The University of Tokyo

Abstract:

Trapped ions are well isolated from the environment and can be controlled with lasers and microwaves, making them promising candidates for quantum computing. In trapped-ion systems, not only the electronic level structure of the ions but also their motional degrees of freedom are tools of quantum control. To achieve high-fidelity control of quantum states, ions must be cooled close to their motional ground state to minimize the influence of Doppler effects arising from their motion. However, cooling all motional modes requires optimization of laser parameters, which leads to significant temporal costs. In this study, we aim to overcome this challenge by applying oscillating electric field gradients to the ions to induce coherent interactions between multiple motional modes. To date, we developed an experimental setup to trap strontium ions and control their quantum states. To realize the observation and control of the motional state of strontium ions, it is necessary to excite the electric quadrupole transition with a laser to perform sideband spectroscopy. Since this electric quadrupole transition has a natural linewidth of approximately 0.4 Hz, the laser linewidth must be sufficiently narrow to efficiently drive the transition. To this end, we constructed an experimental setup where the 674 nm laser is stabilized to an ultra-low-expansion cavity to narrow its linewidth. Using this setup, we have succeeded in exciting the electric quadrupole transition of a strontium ion with the frequency-stabilized laser. We have observed Rabi oscillations and frequency spectra of sideband transitions and estimated the thermal phonon number of the motional state. In this poster presentation, we will introduce the details of our ion trap chip and frequency-stabilized laser system and present experimental results on quantum state control of strontium ions using these systems.

Poster ID: 30

#30 — Implementation of a 5-Qubit Trapped-Ion System with Arbitrary Individual Qubit Control

Author(s): SHON Hosung*; AHN Minjoo; CHA Yonghwan; CHO Beomgeun; CHOI Kwangyeul; CHUNG Daun; KIM Chiyoon; KIM Minjae; KIM Taehyun; PARK Junghyun

Affiliation(s): Seoul National University

Abstract:

Trapped-ion quantum computers offer a distinct advantage through all-to-all connectivity

mediated by collective motional modes. This connectivity permits not only arbitrary two-qubit gates between any pair of ions, but also the efficient generation of multi-qubit (Nbody) entanglement and parallel entangling gates within a single chain. However, full exploitation of this connectivity in practice requires simultaneous and individual control over the addressing beams driving each ion.

In this poster, we present the implementation of a 5-qubit trapped-ion system capable of arbitrary individual operations, utilizing a multi-channel acousto-optic modulator driven by a radio-frequency system-on-chip (RFSoc). In this architecture, the RFSoc provides multiple independent arbitrary waveform generator channels, enabling synchronized manipulation of the addressing beams for each qubit. We demonstrate the capability of our system to perform site-selective individual operations and implement precise pulse shaping for high-fidelity Mølmer-Sørensen gates. These capabilities pave the way for realizing complex multi-qubit operations and enable a broader range of trapped-ion quantum experiments.

This work is supported by a grant from NRF (Grants No. RS-2024-00442855, No. RS-2024-00413957) and IITP (Grant No. RS-2022-II221040), all of which are funded by the Korean government (MSIT).

Poster ID: 31

#31 — Integrated Photonics for Ba⁺ Surface Ion-Trap Chips

Author(s): KIM Chiyoon*; KIM Jaewoo; AHN Donghwan; CHO Youngjoon; CHOI Kwangyeul; JEONG Uihwan; KIM Changsoon; KIM Seung-Gun; KIM Taehyun; KIM Youngmin

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Abstract:

Trapped-ion quantum computing relies on metallic electrodes to confine ions while tightly controlled laser beams manipulate their quantum states. Conventional free-space optical systems, however, impose challenges in stability, scalability, and long-term alignment robustness. To address these limitations, we are developing in-house integrated photonics technology directly on surface ion-trap chips, replacing bulky external optics with on-chip optical routing and beam delivery. Our platform targets barium (Ba⁺) ion trapping and control. We are currently fabricating key photonic components including grating couplers, single-mode waveguides, and inverse taper edge couplers for efficient fiber-to-chip interfacing. These components are being integrated into a custom-designed surface ion-trap chip. Experimental characterization of the developed photonic components has been performed prior to full trap integration. For the grating couplers, out-coupling toward the target ion position was verified by scanning the focal plane of the imaging system upward from the waveguide. This method allowed us to confirm beam formation at the designed trapping height and to measure the relative intensity distribution of the emitted beam spot. Building upon these validated components, we are designing and fabricating an integrated ion-trap chip capable of delivering 493-nm and 650-nm laser light to three independent trapping sites. The chip integrates multiple routing paths to enable wavelength-specific delivery to designed ion positions. In this poster, we present our trap chip and integrated photonics fabrication process, photonic component characterization results, and the system-level integration strategy for combining surface ion traps with integrated photonics. Our approach aims to provide a scalable and alignment-robust platform for Ba⁺ trapped-ion quantum computing.

This work is supported by a grant from NRF (Grants No. RS-2024-00442855, No. RS-2024-00413957) and IITP (Grant No. RS-2022-II221040), all of which are funded by the Korean government (MSIT).

Poster ID: 32

#32 — Integrating a Toroidal RF Resonator for Cryogenic Ba-137 Ion Trapping and Qudit Operations

Author(s): OH Seunghoon*; KIM Junki

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Abstract:

We present the development of a cryogenic ion-trapping platform optimized for scalable qudit-based quantum computing using Ba-137. While the Optical-Microwave-Ground (OMG) architecture in Ba-137 offers a versatile and powerful pathway for qudit operations, integrating this system into a cryogenic environment presents significant experimental challenges. Our platform addresses these by utilizing a custom-modified low-vibration cryostat (Four9 Design) equipped with a robust metal barium ablation source.

A primary distinguishing feature of our setup is the RF delivery system. Diverging from conventional helical resonators, we integrated a compact toroidal RF resonator directly within the vacuum chamber. This design drastically shortens the wiring distance to the trap, minimizing RF loss and thermal load. Optically, all major components remain strictly outside the cryostat; we employ a long working distance objective lens to achieve high-resolution fluorescence collection while preserving internal thermal stability.

Currently, we have achieved reproducible trapping of Ba-138 and have successfully progressed to the trap loading stage for the Ba-137 isotope. Leading up to the conference, our immediate experimental focus is on observing 1762 nm Rabi oscillations and demonstrating ground-state hyperfine qubit control. These near-term milestones will establish the fundamental groundwork for executing high-fidelity D-state qudit operations within the OMG framework. Following the successful demonstration of these qudit operations, we plan to upgrade the system with a modular trap architecture to facilitate the testing of various 3D trap geometries in future experiments.

Poster ID: 33

#33 — Phase-space Topology in a Single-ion Synthetic Dimension

Author(s): LEE Kyungmin*; CHOI Wonhyeong; CHUNG Daun; KANG, Jiyong; KIM Taehyun; PARK Sumin; YU Seungwoo; YU Sunkyu

Affiliation(s): Seoul National University

Abstract:

We explore the topological properties of a synthetic Fock-state lattice (FSL) realized in a single-ion system described by the quantum Rabi model. By diagonalizing the Hamiltonian, we discover a zero-energy defect mode confined near a domain wall in the FSL, with its spin polarization protected topologically. Since the conventional band-topology approach is not

straightforward to apply to the FSL, we propose a physically motivated and directly observable topological invariant rooted in phase-space geometry—a phase-space winding number. We show that this phase-space invariant is connected to the Zak phase of the FSL, a quantized geometric phase that encodes the defect mode’s spin polarization, thereby establishing a bulk–boundary correspondence.

From this phase-space topological perspective, our results reveal single-ion dressed states with sharply contrasting behaviors: topologically protected spin states and bosonic states whose properties can be tuned by external driving. This framework enables the realization of the zero-energy defect state in a single-ion system using three-tone laser interactions. We present preliminary experimental results demonstrating the realization of this defect mode and the measurement of the phase-space invariant via Wigner tomography of the ion’s motional mode.

This work is supported by a grant from NRF (Grants No. RS-2024-00442855, No. RS-2024-00413957) and IITP (Grant No. RS-2022-II221040), all of which are funded by the Korean government (MSIT).

[1] K. Lee et al., “Phase-space topology in a single-atom synthetic dimension”, Phys. Rev. A 113, L010401 (2026).

Poster ID: 34

#34 — Development of Scalable Quantum Network Nodes with Trapped-171Yb+ Ions and Quantum Frequency Conversion

Author(s): KIM Minjae*; KIM Taehyun; LEE Kyungmin; PARK Sumin; YU, Seungwoo

Affiliation(s): Seoul National University

Abstract:

Trapped-ion systems offer a promising route to a scalable quantum network via photonic interconnects [1,2]. We report recent progress in developing quantum-network nodes based on trapped 171Yb+ ions entangled with a photon frequency qubit. We generate heralded remote entanglement between two ions confined in spatially separated microfabricated surface traps via a Bell-state measurement on the photon frequency qubits emitted by each ion. Following two-photon interference on a 50:50 non-polarizing beam splitter (NPBS), coincidence detection events at two single-photon detectors placed at the NPBS output ports herald entanglement between the distant atomic qubits. We measure a Bell-state fidelity of $F \geq 0.67 \pm 0.05$ by observing parity oscillations of the two-ion state as a function of the analysis microwave phase.

The photons entangled with the hyperfine levels of a 171Yb+ ion are in the ultraviolet (UV) range, which leads to high loss in optical fibers and limits long-distance transmission. This challenge can be addressed by quantum frequency conversion (QFC), which converts the emitted UV photons to fiber-optic communication bands [3]. We present recent experimental progress on our three-stage QFC setup, along with future directions toward efficient, low-noise conversion for fiber-based quantum networking.

This work is supported by a grant from IITP (Grant No. RS-2022-II221040) and NRF (Grants No. RS-2024-00442855, No. RS-2024-00413957), all of which are funded by the Korean government (MSIT).

- [1] D. Moehring et al., "Entanglement of single-atom quantum bits at a distance". Nature 449, 68–71 (2007).
- [2] D. Hucul et al., "Modular entanglement of atomic qubits using photons and phonons", Nat. Phys. 11, 37-42 (2015).
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Poster ID: 35

#35 — Results and future prospects from the first year of hybrid classical-quantum operations between RIKEN 'Fugaku' and Quantinuum 'Reimei'

Author(s): Nathan LYSNE *, Craig HOLLIMAN, Daichi OKUNO, Yuga KODAMA, Tomohiro MURATA, Kentaro YAMAMOTO, Riku MASUI, Takahito NAKAJIMA, Miwako TSUJI, Mitsuhsa SATO, Peter SCHOW, Lukas HEIDEMANN, Matthew BURKE, Philipp SEITZ, Oliver J. BACKHOUSE, Juan W. PEDERSEN, John CHILDRE, Seyon SIVARAJAH, David Munoz RAMO, Alex CHERNOGUZOV, Ross DUNCAN, Grahame VITTORINI

Affiliation(s): Quantinuum Tokyo, JPN

Abstract:

Quantum computing hardware has matured to the point where significant investment is being made to leverage them for augmenting existing classical compute. One prominent project is Japan's New Energy and Industrial Technology Development Organization (NEDO) JHPC-Quantum Project. Started in 2023, its goal was to create and evaluate a first-of-its-kind system integrating quantum compute directly into the workflow of a classical supercomputer. Connecting with RIKEN's flagship supercomputer 'Fugaku,' a Quantinuum System Model H1 trapped-ion quantum computer known as 'Reimei' was installed in Japan and brought online in February 2025, forming one of the world's first supercomputer-QPU hybrid systems. In this work, we will discuss performance and insights from operating a trapped-ion quantum computer in this new context. We will highlight initial results exploring hybrid classical-quantum workflows, including a recent end-to-end biomolecular simulation that was able to efficiently extend the simulation into configurations not accessible by the HPC alone[1]. Looking ahead, we will share potential future applications for this hybrid compute environment and comment on future directions for these systems.

1. Yamamoto et al, Quantum-HPC hybrid computation of biomolecular excited-state energies. <https://arxiv.org/pdf/2601.15677>

Poster ID: 36

#36 — An Integrated Trapped-ion Quantum Computer Controller

Author(s): KIM Minjae*; CHA Yonghwan; CHUNG Daun; KIM Taehyun; PARK Junghyun; SHON Hosung

Affiliation(s): Seoul National University

Abstract:

Manipulation of qubits in trapped-ion quantum computing systems relies on laser beams modulated by precise, arbitrary radio-frequency (RF) waveforms. Beyond direct qubit control,

the entire experimental sequence requires deterministic and precisely timed synchronization of all associated hardware and electronics, thereby necessitating a high-performance real-time control system. In this poster, we present a fully custom-developed control system for trapped-ion quantum computing that enables simultaneous manipulation of up to 8 ions via an integrated multi-channel arbitrary waveform generator. The core architecture is built on a commercial AMD radio-frequency system-on-chip platform, while all other auxiliary PCBs, including the DAC subsystem, were designed and assembled in-house. The system provides deterministic TTL control of external devices, performs state detection by counting pulses from photomultiplier tubes, and regulates DAC outputs for ion shuttling, all orchestrated with nanosecond-level timing resolution. The heart of the system is its capability to generate independent, arbitrary RF waveforms for eight channels. Using this platform, we also demonstrate the experimental results of single- and two-qubit gate operations on a 5-qubit trapped-ion system.

This work is supported by a grant from NRF (Grants No. RS-2024-00442855, No. RS-2024-00413957) and IITP (Grant No. RS-2022-II221040), all of which are funded by the Korean government (MSIT).

Poster ID: 37

#37 — Design study on a Compact Radio-Frequency Toroidal Resonator for Cryogenic Ion Trap

Author(s): Hyeri SONG*; Seunghoon OH, Junki KIM

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Abstract:

In cryogenic ion-trap system, a low resonator quality factor Q lead higher drive power to reach the same trap voltage, which may increase RF loss and thermal load. This can also potentially worsen ion motional heating. These considerations motivate resonator designs that provide adequate Q and V_{trap} at the target frequency. In this work, we study resonator design for cryogenic ion-trap RF driving. We first examine how the inductance of a toroidal inductor depends on its geometry. We then analyze a capacitively coupled single-resonator system by deriving expressions for V_{trap} and Q and using them to discuss the influence of key design parameters. Because V_{trap} and Q vary with C_c , an appropriate C_c should be chosen to achieve the required V_{trap} while keeping Q within an acceptable range at the target frequency. Because V_{trap} and Q vary with C_c , an appropriate C_c should be chosen to achieve the required V_{trap} while keeping Q within an acceptable range at the target frequency. From the inductor design perspective, improving both Q and V_{trap} is associated with obtaining the required inductance L while keeping RF loss and capacitance low. For a toroidal resonator, adjusting the turn density, defined as the number of turns per unit length, can serve as an effective design knob. At the same time, the increase in wire length and high-frequency resistance should be kept moderate by accounting for the skin-depth effect in a low-loss winding design. Based on these results, we expect that a compact resonator can be designed to meet the target Q and V_{trap} requirements for cryogenic ion-trap RF systems.

Poster ID: 38

#38 — Reducing Ion Heating in Quantum Computing: A Novel 3D-Printed Micro Ion Trap with Skeleton Structure

Author(s): Chon-Teng Belmiro Chu*; Hao-Chung Chen; Ting Hsu Hsiang-Yu Lo; Ming-Shien Chang; Guin-Dar Lin

Affiliation(s): Department of Physics and Center for Quantum Technology, National Tsing-Hua University, Foxconn

Abstract:

Electric-field-induced ion heating is a major obstacle in scalable trapped-ion quantum computing. We present a theoretical study of a novel 3D-printed ion trap with a skeleton electrode structure, designed to reduce heating by minimizing surface area near the ion. Compared to a conventional blade trap with identical confinement parameters, the skeleton trap achieves over 50% reduction in total heating rate. Patch-by-patch analysis reveals that heating is dominated by surfaces within 500 μm of the ion. For axial motion, the peak heating occurs approximately 110 μm away due to electric field directionality. We demonstrate that minor geometric optimization, in which the electrode gaps are realigned with these hotspots, can further suppress heating despite the associated increase in surface area. A linear relationship between ion-to-electrode distance and peak heating location is also established. These results highlight the potential of 3D-printed electrode designs for achieving both strong confinement and reduced noise in future quantum systems.

Poster ID: 39

#39 — PDH Feedforward Method for Improving Coherence and Gate Fidelity in Optical Qubits

Author(s): Jia-Yang Gao*; Clarence Liu Huihong; Jasper Phua Sing Cheng; Jianwei Lee; Morteza Ahmadi; Pei Jiang Low; Subhadeep Chakraborty; Manas Mukherjee

Affiliation(s): Centre for Quantum Technologies, NUS

Abstract:

Laser phase noise is one of the limiting factors that dictate the gate fidelities and coherence time in trapped-ion quantum systems. Previously, it has been reported that when the Rabi frequency of the ion qubit is close to the servo bump phase-noise frequency, the driving laser limits the fidelity and coherence time. This issue has typically been mitigated by setting the Rabi frequency away from the bump frequency, at the expense of limited servo bandwidth and ultimate fidelity. To address this issue, we developed an active phase-noise stabilization for the barium ion optical qubit laser at 1762 nm, employing a fiber electro-optic modulator (EOM) with an electrical feedforward servo. Our results demonstrate that this setup based on PDH feedforward method can suppress 15 dB servo bump phase noise near the bump peak frequency in our locking system. The laser phase noise is analyzed using delayed self-heterodyne interferometry (DSHI). We further tested the stabilized laser on the optical qubit, observing a clear improvement in coherence time based on the measured amplitude decay of Rabi oscillations even when the Rabi frequency lies within the servo bump bandwidth. This technique can be readily adapted to other optical qubits with minimal modifications.

Funding acknowledgement:

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Poster ID: 40

#40 — Implementation of a background-free measurement protocol for trapped barium ions

Author(s): Clarence Liu*; Jasper Phua Sing Cheng; Pei Jiang Low; Manas Mukherjee

Affiliation(s): Centre for Quantum Technologies, NUS

Abstract:

We implement a background-free, fast measurement protocol in trapped barium ions, where state detection is performed by measuring the atomic fluorescence from barium ions that spontaneously decay to the ground state after being driven by a laser at a different wavelength. This can be accomplished in barium ions if we exploit the non-zero spontaneous decay branching ratio of the $6P_{1/2}$ state into the $6S_{1/2}$ and $5D_{3/2}$ energy levels. This unconventional measurement protocol allows us to effectively distinguish atomic fluorescence from background scattered light due to the incident laser, thereby improving signal-to-noise-ratio. We present our work in progress in implementing this newly proposed measurement protocol and compare it with the conventional method.

Poster ID: 41

#41 — Scaling, Generalization and Robustness of Quantum Machine Learning Models

Author(s): Alex Jin; Jia-yang Gao*; Jasper Phua; Manas Mukherjee

Affiliation(s): Centre for Quantum Technologies, NUS

Abstract:

Classification is a fundamental task in machine learning, typically performed using classical models. Quantum machine learning (QML), however, offers distinct advantages, such as enhanced representational power through high-dimensional Hilbert spaces and energy-efficient reversible gate operations. Despite these theoretical benefits, bridging the gap between theoretical potential and real-world deployment requires rigorously validating both empirical generalization and robustness to noise on non-trivial and non-synthetic datasets.

In this work, we conduct our evaluations directly on several raw image datasets. We compare quantum models against modern classical baselines using matched-parameter neural models under strictly controlled, repeated-seed protocols. Our evaluations demonstrate that these quantum models are capable at extracting predictive signal directly from raw images, giving on-par performance as modern vision models. We further characterize quantum models' small-data behavior and report the scaling trend of the generalization gap versus $\sqrt{T/N}$ under controlled optimization settings. Additionally, we evaluate the robustness and reliability of these classifiers, both theoretically and on ion-trap quantum processors. We assess the resilience against adversarial attacks on raw image datasets and rigorously quantify the impact of realistic polarization (both bit and phase) noise.

Poster ID: 42

#42 — Long-lived Remote Ion-Ion Entanglement for Scalable Quantum Repeaters

Author(s): Wen-Zhao Liu, Ya-Bin Zhou*, Jiu-Peng Chen, Bin Wang, Ao Teng, Xiao-Wen Han, Guang-Cheng Liu, Zhi-Jiong Zhang, Yi Yang, Feng-Guang Liu, Chao-Hui Xue, Bo-Wen Yang, Jin Yang, Chao Zeng, Du-Ruo Pan, Ming-Yang Zheng, Xingjian Zhang, Shen Cao, Yi-Zheng Zhen, You Xiao, Hao Li, Lixing You, Xiongfeng Ma, Qi Zhao, Feihu Xu, Ye Wang, Yong Wan, Qiang Zhang, Jian-Wei Pan

Affiliation(s): University of Science and Technology of China

Abstract:

The fundamental unit for realizing quantum networks is entanglement between two distant quantum memories. Ion trap systems are excellent candidates for establishing long-distance entanglement due to their high-fidelity, long coherence times, deterministic logical gates, and scalability. We have constructed two $^{40}\text{Ca}^+$ ion trap systems, each achieving long coherence times and high-fidelity operations. Additionally, we employed a nonlinear waveguide to convert the ion-emitted wavelengths to the 1550 nm telecom wavelength, thereby extending the transmission distance. To establish entanglement between the two traps, we implemented global photon phase control over the optical fiber link and used a single-photon interference protocol to generate long-distance entanglement. We demonstrate memory-memory entanglement between two nodes connected by 10 km of spooled fiber, with coherence exceeding the entanglement generation time. This is enabled by long-lived trapped-ion memories, an efficient telecom interface, and a high-visibility single-photon entanglement protocol. As a demonstration, we show a proof-of-principle device-independent quantum key distribution (DI-QKD) experiment, with finite-size analysis over 10 km of fiber and a positive key rate over 101 km, surpassing previous work by two orders of magnitude. Our work represents a critical step toward scalable quantum networks and quantum repeaters. d

Poster ID: 43

#43 — Geometric Phase Gates for Trapped Ions Using Structured Light

Author(s): Subhadeep Chakraborty*; Prayas Sandeep Sarkar; Manas Mukherjee

Affiliation(s): Centre for Quantum Technologies, NUS

Abstract:

We consider a scheme for implementing a geometric phase gate for trapped ions using structured light, with qubits encoded in the $S_{1/2}$ ground state and the metastable $D_{5/2}$ state. The approach is based on a position-dependent ac Stark shift that gives rise to a state-dependent optical dipole force on the optical transition. The role of the spatial mode and polarization structure of the beam, including scalar, vector, and tensor Stark contributions, is analyzed. We discuss the operating conditions and evaluate spontaneous scattering within a frequency-dependent model. Possible experimental imperfections, such as beam misalignment, are also taken into account, along with considerations related to individual ion addressing.