Q 67: Poster – Quantum Information

Computing and Simulation; Communication; Concepts and Methods

Time: Thursday 17:00–19:00 Location: Philo 2. OG

Q 67.1 Thu 17:00 Philo 2. OG

Preparation and Control of Logical Qubits in the Hyperfine Structure of ^{173}Yb^{+} — •Selena-Maria Bota, Monika Leibscher, and Christiane P. Koch — Freie Universität Berlin, Berlin, Germany

Recent research proposes robust encoding of quantum information in high angular momentum states of atoms or molecules, where the logical qubits are protected against most common errors [1]. Such codewords can be built in the hyperfine structure of trapped ^{173}Yb^{+}, namely using metastable states in the $^2F^0_{7/2}$ manifold [2]. This work focuses on the preparation of such robust qubits with sequences of microwave pulses, specifically on simulating the population dynamics driven by the pulses and optimising them for better fidelity and time duration. The future aim is to devise a protocol for operational gates using the proposed codewords.

[1] Jain, Shubham P., et al. "Absorption-Emission Codes for Atomic and Molecular Quantum Information Platforms". Phys. Rev. Lett. 133 (2024), p. 260601.

[2] Xiao, Di, et al. "Hyperfine structure of ^{173}Yb^{+}: Toward resolving the ^{173}Yb nuclear-octupole-moment puzzle." Phys. Rev. A 102 (2020), p. 022810.

Q 67.2 Thu 17:00 Philo 2. OG

Updates on the PTB two-qubit quantum computer — •Markus Duwe[1,2], Hardik Mendpara[1,2], Alexander Onkes[1,2], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch Technische Bundesanstalt, Braunschweig

We report the latest experimental results from the two-qubit quantum processor at PTB. We trap ^{9}Be$^+$ ions in a room temperature surface-electrode ion trap. We manipulate the qubits with microwaves generated by conductors embedded in the trap structure [1]. We describe updates to the experimental apparatus and present low heating rates. Individual ions are addressed via a micromotion sideband and the gate infidelity is characterized using randomized benchmarking [2]. We use a Mølmer-Sørensen type interaction to achieve Bell-state infidelities in the 10^{-3} range. Furthermore, we report progress towards combining these two gates to realize a universal gate set with improved performance compared with our previous measurements [3].

Q 67.3 Thu 17:00 Philo 2. OG

Grover Optimization for Lock Scheduling Problems — •Freyja Ullinger[1], Jannes Weghake[1], Oliver Sefrin[1], Sarah Kahlen[2], Lorenz Mumm[2], Tino Werner[2], Sabine Wölk[1], and Matthias Zimmermann[1] — [1]Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), Institut für Quantentechnologien, Ulm, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), Institut für Systems Engineering für zukünftige Mobilität, Oldenburg, Germany

There exist several quantum algorithms with a proven quantum advantage. One of them is the Grover Search Algorithm [1], which finds an item in an unordered database with quadratic speed-up. By mapping optimization problems to search problems, one is able to harvest this quantum advantage. A particularly interesting NP-hard problem explored in the project QCMobility is the lock scheduling problem. Here we aim at deriving an optimal schedule to lock the incoming ships, while minimizing for example waiting times or water consumption.

In this poster, we investigate the solution of the lock scheduling problem. For this purpose, we formulate it as a quadratic unconstrained binary optimization (QUBO) problem and find the global optimum with Grover Adaptive Search [2]. Our results are obtained on quantum hardware simulators.

[1] L. K. Grover, Proc. 28th Annu. ACM Symp. Theory Comput., 212 - 219 (1996).

[2] W. P. Baritompa, D. W. Bulger, and G. R. Wood, SIAM J. Optim. **15**, 1170 (2005).

Q 67.4 Thu 17:00 Philo 2. OG

A guide on Grover search algorithms for solving QUBO problems — •Jannes Weghake, Freyja Ullinger, and Matthias Zimmermann — Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Quantentechnologien, Ulm, Germany

Typical industry-related optimizations, like routing, packing, or scheduling, can be reformulated as a quadratic unconstrained binary optimization (QUBO) problem [1]. In the fault-tolerant quantum computing era, a promising approach to solve these problems is the Grover Adaptive Search [2]. The Grover Adaptive Search is able to solve QUBOs with a quadratic speed-up in comparison to classical algorithms. Here different Grover runs are chained together in order to identify the optimal solution.

In this poster, we present a comprehensive guide with intuitive visuals, a theoretical background and a walkthrough to help non-expert to apply the Grover Adaptive Search. In particular, we demonstrate how to parse the QUBOs into a Grover oracle - the quantum dictionary [3] - and what this implies for the different quantum registers involved.

[1] G. Kochenberger, J.-K. Hao, F. Glover, M. Lewis, Z. Lü, H. Wang, and Y. Wang, J. Comb. Optim. **28**, 58 (2014).

[2] W. P. Baritompa, D. W. Bulger, and G. R. Wood, SIAM J. Optim. **15**, 1170 (2005).

[3] A. Gilliam, C. Venci, S. Muralidharan, V. Dorum, E. May, R. Narasimhan, and C. Gonciulea, arXiv:1907.11513 (2019).

Q 67.5 Thu 17:00 Philo 2. OG

Quantum Information Processing with trapped-ion based Qudits — •Lukas Gerster, Peter Tirler, Manuel John, Keshav Pareek, Tim Gollerthan, Lisa Parigger, Raphael Poloczek, Timo Spalek, Michael Meth, and Martin Ringbauer — Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25/4, 6020 Innsbruck, Austria

Quantum Information Processing has been predominantly developed using qubits, two level quantum systems, as its fundamental building blocks. Most physical implementations of qubit-based quantum processors utilize multilevel systems, from which only two levels are selected for encoding the information. By encoding information in multi-level qudit basis states, one directly expands the Hilbert space available for computation, which promises more efficient compilation with respect to the number of required entangling gates. We experimentally demonstrate a set of local and entangling gate operations on a 10-qudit register, showing all necessary elements for performing qudit-based computation.

Q 67.6 Thu 17:00 Philo 2. OG

Quantum Simulation and Computation with Ytterbium Rydberg Atoms in Optical Tweezer Arrays — •Jonas Rauchfuss[1], Clara Schellong[1], Till Schacht[1], Ben Michaelis[1], Paul Callsen[1], Nejira Pintul[1], Tobias Petersen[1], Alexander Ilin[1], Christoph Becker[1,2], and Klaus Sengstock[1,2] — [1]Center of Optical Quantum Technologies University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Quantum Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

In recent years, neutral atoms have emerged as one of the most promising platforms for quantum computing and quantum simulation, characterised by scalability, large coherence times, high-fidelity single atom control as well as engineerable, strong, long-range interactions. In our project we use the alkaline-earth-like element ytterbium, whose fermionic isotope 171Yb features a rich level structure that allows for sophisticated qubit schemes including midcircuit read-out, advanced error correction, and optical trapping and manipulation of Rydberg states. Here, we introduce our experimental setup and present our current progress towards building a neutral-atom quantum simulator including characterisation measurements of tweezer loading, imaging, and qubit manipulation. We further present efforts to overcome known limitations of current quantum computation and simulation platforms, like arbitrary single atom addressing techniques, efficient suppression of servo induced laser noise for highest fidelity excitation schemes, and fast spatial light modulation techniques for scalable sorting algorithms.

Q 67.7 Thu 17:00 Philo 2. OG

Impact of electrode noise on qubit quality metrics in a 2D segmented ion trap — •Daniel Busch[1], Benjamin Bürger[1], Kais

Rejaibi[1], Ivan Boldin[1,2], Patrick Huber[1], Dorna Niroomand[1], and Christof Wunderlich[1] — [1]Universität Siegen, Walter-Flex-Straße 3, 57072 Siegen — [2]Present address: eleQtron GmbH, Heeserstraße 5, 57072 Siegen

Important requirements for the realisation of robust quantum computing are long qubit coherence times as well as high gate fidelities both of which suffer from uncontrolled parameter fluctuations (noise). Thus, eliminating and mitigating noise constitutes one of the major challenges to scalability. In the case of trapped-ion quantum computing, ion traps with segmented electrodes are one approach to scale up the number of qubits. However, electric field fluctuations at these DC electrodes lead to a further source of noise. We are currently setting up a cryogenic quantum demonstrator that will include a cryogenic digital-to-analog converter (DAC) combined with a switching matrix to tackle this issue.

To evaluate the strategy of using optical switches, we have installed proof-of-principle optical switches in a room temperature experiment using the first two copies of a micro-structured 2D segmented ion trap with built-in micromagnets. We show results of measurements of coherence time and gate fidelities, and discuss the effects of remaining electric noise at the electrodes.

Q 67.8 Thu 17:00 Philo 2. OG

High-fidelity quantum information processing with trapped barium ions via addressed off-resonant interactions — •Tommaso Faorlin[1], Lorenz Panzl[1], Phoebe Grosser[1], Walter Joseph Hörmann[1], Juris Ulmanis[2], Thomas Feldker[2], Alexander Erhard[2], Giovanni Cerchiari[1,3], Rainer Blatt[1,2,4], and Thomas Monz[1,2] — [1]Universität Innsbruck, Technikerstraße 25/4, Innsbruck, 6020, Austria — [2]Alpine Quantum Technologies (AQT) GmbH, 6020, Innsbruck, 6020, Austria — [3]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068, Siegen, Germany — [4]Institute for Quantum Optics and Quantum Information (IQOQI), 6020, Innsbruck, Austria

The Hyperion experiment aims at pushing the boundaries of coherent trapped-ion control. Our focus lies on improving gate fidelities and minimizing state-preparation and readout errors, in a quantum register of barium ions. Building on state preparation at the 1e-4 level, state readout at the 1e-5 level and single-ion addressing cross-talk on the 1e-4 level, I present a novel gate scheme, leveraging ground-state qubits with radially-addressed Raman interactions using 532 nm light. The entangling gates are mediated through the perpendicular, axial motional modes, utilizing the field gradient of the employed laser fields. This novel approach promises the low cross-talk from radial addressing in combination with improved gate performance offered by axial-mode mediated gates.

Q 67.9 Thu 17:00 Philo 2. OG

Raman addressing system for light-shift gates on Qudits in trapped ion quantum computer — •Raphael Poloczek, Tim Gollerthan, Manuel John, Peter Tirler, Michael Meth, Keshav Pareek, Lukas Gerster, Lisa Parigger, Timo Spalek, and Martin Ringbauer — Institut für Experimentalphysik, Universität Innsbruck, Austria

Qudits, the generalization of qubits to d-level quantum systems, offer a powerful extension of conventional two-level quantum computing. Trapped ions represent a platform for realizing such systems, as their intrinsic multilevel structure naturally supports qudit encoding, providing access to higher-dimensional Hilbert spaces and enabling enriched computational capabilities. Fully exploiting qudit-based architectures requires the realization of efficient quantum gates for qudits. A recently demonstrated light-shift gate mechanism constitutes such an operation, creating genuine entanglement between two qudits, while matching the system's local dimension [1].

We are developing an experimental setup to implement this entangling gate on a quantum computer using trapped $^{40}Ca^+$ ions as information carriers. The setup is designed to address single ions using a pair of counterpropagating Raman beams, which generate the state dependent dipole force required to operate this gate.

[1] P. Hrmo et al., Nat Commun 14, 2242 (2023)

Q 67.10 Thu 17:00 Philo 2. OG

Double side-addressed, high-NA ion trap system leveraging barium towards fault-tolerant quantum computing — Lorenz Panzl[1], Tommaso Faorlin[1], •Phoebe Grosser[1], Rainer Blatt[1,2,3], Thomas Feldker[3], Alexander Erhard[3], Georg Jacob[3], Giovanni Cerchiari[1,4], and Thomas Monz[1,3] — [1]Universität Innsbruck, Technikerstraße 25/4, Innsbruck, 6020, Austria — [2]Institute for Quantum Optics and Quantum Information (IQOQI), 6020, Innsbruck, Austria — [3]Alpine Quantum Technologies (AQT) GmbH, 6020, Innsbruck, 6020, Austria — [4]Naturwissenschaftlich- Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068, Siegen, Germany

We present a high-performance quantum information processing unit based on trapped atomic ions that is designed to push current limits of gate fidelities and SPAM errors to the 10^{-4} level and below. We utilise barium ions in our experiment due to the long lifetime of the metastable D5/2 state (leading to high readout fidelities) and the availability of hyperfine structure, providing access to the ground-state clock qubit. We demonstrate state preparation fidelity at the 10^{-4} level and high detection efficiencies. We combine off-resonant, addressed optical pulses and global microwave pulses to perform addressed single-qubit rotations, and demonstrate a novel procedure for implementing a two-qubit geometric phase gate that utilises a transverse gradient to coherently excite the axial modes. In doing so, our experiment is independent of any sub-Hz optical phase stability requirements, as it is outsourced to the RF control.

Q 67.11 Thu 17:00 Philo 2. OG

A Cryogenic Tweezer-Array Platform for Entangling Ytterbium-171 Nuclear Spins via the Optical Clock Transition — •Mohammad Soltani[1], Julian Feiler[1,2], Konrad Koenigsmann[3], Jin Yang[3], Max Hachmann[1,2], and Peter Schauss[1,2,3] — [1]Institute for Quantum Physics, University of Hamburg, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Department of Physics, University of Virginia, Charlottesville, USA

Neutral atom platforms based on ytterbium have emerged as a promising architecture for quantum computing, particularly in scalable optical tweezer arrays that enable individual trapping and control of atoms. Specifically, the fermionic isotope Yb-171, with its nuclear spin of I = 1/2, provides a robust and natural qubit implementation.

In our project, we aim at realizing large-scale robust entanglement in the nuclear spin of ytterbium atoms trapped in a tweezer array with a cryogenic shield. For our entanglement scheme, we plan to rely on spin-exchange in combination with coherent driving of the clock transition. Therefore, we need a highly stable laser system to address the clock transition in Yb-171.

We will report on the progress in setting up the experiment and on our efforts to stabilize the clock laser to an ultra-stable reference cavity. To characterize the stability and accuracy of the laser system, we are preparing a comparison to other clock lasers at the Institute for Quantum Physics in Hamburg.

Q 67.12 Thu 17:00 Philo 2. OG

Integrated Quantum Information Processing with Novel Photonic Interfaces — •Louis L. Hohmann[1,2], Jeldrik Huster[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST)

Integrated quantum photonics has achieved significant progress in quantum computing, providing low-loss connections, a compact size, and high phase stability. These features enable reliable and space-efficient control of photonic qubits. Multipartite entangled states, such as GHZ and linear cluster states, are particularly important for quantum photonics as they serve as essential resource states for photonic quantum computing. We demonstrate our advancements in generating multipartite entangled states on a silicon-on-insulator photonic quantum circuit powered by spontaneous parametric down-conversion single-photon sources. The fiber-to-chip interface employs 3D-printed photonic wirebonds, a new, highly stable connection method between single-mode fibers and on-chip edge couplers, enabling a fully integrated quantum photonic circuit.

Q 67.13 Thu 17:00 Philo 2. OG

Faster, more efficient loading of Yb^+ and Ba^+ ions for mixed-species cryogenic trapped ion quantum computers — •Marwan Mohammed[1,2], Michael Johanning[2], and Christof Wunderlich[1] — [1]Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany — [2]eleQtron GmbH, 57072 Siegen, Germany

Trapped ion quantum computers (TIQCs) in cryogenic vacuum facilitate both longer lifetimes and reduced motional heating of Coulomb crystals. However, keeping a low heat load typically necessitates pulsed laser ablation for ion loading. Only a small fraction of slow-moving ablated atoms are trappable by surface trap chips, but capturing faster-moving ablated atoms by increasing trap depth would increase the laser cooling time and therefore loading time significantly, whereas using higher pulse fluences to trap more ions risks chip contamination.

To this end, we present improvements to the ion loading process for two cryogenic quantum demonstrators that utilise Yb^+–Ba^+ mixed crystals. Two-photon photoionisation schemes shall use autoionizing transitions with larger absorption cross-sections; we will investigate a 531 nm transition for Ba^+ and use autoionization spectroscopy to discover and characterise suitable Yb^+ transitions. In addition, we realise a fiber-coupled pulsed ablation laser for more consistent shot-to-shot loading, and investigate a loading scheme using a compact effusive atomic source. Overall, this will yield faster, more efficient ion loading, benefitting both TIQCs of larger ion numbers and trapping of low-abundance ionic species.

Q 67.14 Thu 17:00 Philo 2. OG

A cryo-compatible optical system for addressing and achromatic imaging of trapped Yb^+ and Ba^+ ions — •Ernst Alfred Hackler, Daniel Busch, Kunal Kumbhar, Marwan Mohammed, Patrick H. Huber, Dorna Niroomand, and Christof Wunderlich — Walter-Flex-Straße 3, 57072 Siegen

To interface with the ions in a cryogenic ion trap quantum computer, we need to guide different laser wavelengths to trapped ions inside a cryogenic vacuum chamber and image the ions precisely and with high collection efficiencies.

Firstly, we have simulated and constructed a modular, compact overlapping unit comprising dichroic mirrors in order to produce a combined, collimated laser beam containing all the necessary wavelengths for state detection and preparation of Yb^+ and Ba^+ ions. By using off-the-shelf parts and an optimization algorithm for determining the optimal mirror choice, we achieve overlapping of 8 wavelengths used for Yb^+ and Ba^+ from 369–935 nm. The laser intensities are well-above the saturation intensities of the ions at the position of a 10-ion chain. Secondly, we developed and built a system for simultaneous imaging of both ion species, without chromaticity errors. A reflective objective lens, originally designed at Leibniz Universität Hannover, allows for in-vacuum, achromatic fluorescence imaging closer to the ions' position, increasing the light collection efficiency. We were able to image components inside the cryostat and demonstrate the system's general behaviour.

Q 67.15 Thu 17:00 Philo 2. OG

Programmable Quantum Computers and Teleportation: Theory and Experiment — Hans-Otto Carmesin[1,2,3] and •Jannes Ruder[3] — [1]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

We developed a quantum computer - demonstrator that can also work with laser light and that provides a universal set of quantum gates. It performs the operations of the gates with single photons or with coherent laser light. The quantum computer - demonstrator can be programmed by an electrooptical piezo based energy efficient polarizer POLARITE III, that is controlled by a Raspberry Pi 5. With it Qubits und optical quantum gates are controlled. Moreover, the quantum computer - demonstrator can illustrate the process of quantum teleportation, the transfer of a state of a qubit C to a qubit B via an entangled qubit A. This process represents a safe transfer of quantum information.

Q 67.16 Thu 17:00 Philo 2. OG

Utilizing TWA simulations as quantum inspired approximative solve for max-cut problems — •Dennis Breu[1], Tom Schlegel[1], Alexey Bochkarev[2], Simon Ohler[1], Michael Fleischhauer[1], and Maximilian Kiefer-Emmanouilidis[3] — [1]Department of Physics and Research Center OPTIMAS, RPTU-University of Kaiserslautern-Landau, D-67663 Kaiserslautern, Germany — [2]Department of Mathematics, RPTU Kaiserslautern-Landau — [3]DFKI Kaiserslautern and RPTU Kaiserslautern-Landau

There is still a big need to find classical algorithms to efficiently approximately solve NP-Hard problems, since near-term quantum computers are not up for the task yet. For the Max-Cut, a prototypical NP-Hard problem, we propose a method that models a Quantum Annealing (QA) protocol on a classical computer using the truncated Wigner approximation (TWA), achieving a runtime virtually competitive with existing solvers. The TWA is a semiclassical approximation that is able to take lowest order quantum-fluctuations into account. In the TWA simulation of Quantum Annealing quantum fluctuations are included through Monte-Carlo sampling of the initial state. The time evolution of these initial states is however described by ODEs only, which can easily be vectorized and accelerated through the use of GPUs. Moreover, our numerical experiments suggest that the number of trajectories required to model close-to-adiabatic schedules is relatively low. This fact, along with massive parallelization ability, allows us to outperform quantum computers available to us and get close to state of the art classical algorithms in terms of speed and accuracy.

Q 67.17 Thu 17:00 Philo 2. OG

Quantum Routing in Quantum Networks — •Johanna Seitz, Lukas Pausch, and Matthias Zimmermann — Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Quantum Technologies, Ulm, Germany

In the development of future quantum networks [1], investigating possible quantum-network applications beyond quantum key distribution protocols becomes more and more relevant, promising higher security over classical networks by communicating quantum information. Due to the no-cloning theorem, there is no direct quantum analogue to the classical network protocol of sending identical, unknown information to two receiving parties by creating copies before distribution. To overcome this, we develop a quantum routing scheme that takes an input state and sends partial information via superposition to two receiving parties (compare to: [2]). In this protocol, the amount of information distributed to each party is defined via an additional control qubit that is processed together with the input state. Furthermore, we analyze the reverse operation of quantum decoupling to recover the initial quantum state, which can be realized by non-deterministic operations. Research on quantum routing protocols like this could open up new applications for communication with quantum networks, going beyond the capabilities of current classical communication networks.

[1] S. Wehner, D. Elkouss, R. Hanson, Science **362**, eaam9288 (2018).

[2] B.K. Behera, T. Reza, A. Gupta et al., Quantum Inf. Process. **18**, 328 (2019).

Q 67.18 Thu 17:00 Philo 2. OG

Recent advances in the implementation of a post-processing pipeline for a star-shaped quantum key hub — •Tobias Liebmann and Thomas Walther — TU Darmstadt, Institute of Applied Physics, 64289 Darmstadt

Quantum computing threatens the security of widely used public-key cryptographic schemes such as the Rivest-Shamir-Adleman (RSA) protocol. As a countermeasure, quantum key distribution (QKD) enables the generation of symmetric keys with information-theoretic security, making it suitable for one-time-pad encryption. However, distilling secure keys from raw quantum measurement data requires a complex classical post-processing pipeline. We present recent advances in the post-processing system of our QKD network, with a focus on error correction, authentication, and privacy amplification. In particular, we employ protograph-based LDPC codes for error correction, allowing the code length and rate to be adapted to different links in our network. For authentication of the classical channel we use a Wegman-Carter scheme, and Toeplitz hashing for privacy amplification. We analyze these components with respect to common performance metrics and benchmark them against our previous implementations as well as other published approaches.

Q 67.19 Thu 17:00 Philo 2. OG

Implementation of unidirectional modulation of polarization squeezed states for an experimental free-space continuous-variable quantum key distribution scheme — •Jan Schreck[1,2], Kevin Jaksch[1,2], Thomas Dirmeier[1,2], Hüseyin Vural[1,2], and Christoph Marquardt[2,1] — [1]Max Planck Institute for the Science of Light, Staudtstr. 2, Erlangen, Germany — [2]Chair of Optical Quantum Technologies, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7 / A3, Erlangen

Continuous-variable quantum key distribution (CV-QKD) provides a pathway toward quantum-safe cryptography. Polarization is a promising degree of freedom for encoding QKD signals in free-space optical (FSO) channels. In this context, the unidirectional modulation of polarization-squeezed states of light constitutes an experimental CV-QKD scheme that may enhance robustness against channel noise and limitations in post-processing efficiency. In this work, we present our approach to generating squeezed states of light as the source of quantum signals, and describe the corresponding sender and receiver setups for information transfer. Experimental characterization of the encoding concept based on electro-optical modulation is reported, indicating the feasibility of QKD with our implementation.

Q 67.20 Thu 17:00 Philo 2. OG

Phase Measurements in a Highly Imbalanced Interferometer — •Maximilian Mengler, Sarah Wenk, and Thomas Walther — TU Darmstadt, Darmstadt, Germany

In entanglement-based quantum key distribution using phase-time coding, entangled photon pairs can be generated by passing a double pulse through a nonlinear crystal. To achieve consistently low error rates, the phase between these pulses must be stabilized, and their timing must be precise. This can be achieved utilizing a highly imbalanced interferometer that splits one incoming pulse into two outgoing ones. In a first step, such an interferometer is commonly stabilized in its temperature, as shifts therein change the interferometer's phase. To further reduce instabilities, an active stabilization utilizing phase measurements can be used. As a first step, we introduce a scheme that allows the measurement of the interferometer's phase without altering the pulses that run through it, but by referencing them to an external signal.

Q 67.21 Thu 17:00 Philo 2. OG

Floquet engineering in a dissipatively protected subspace — •Liz Burton and Francesco Petiziol — TU Berlin, Hardenbergstraße 36, Berlin

A possible approach to quantum error correction is to encode information in the degenerate ground state of a gapped physical system, where correctable errors correspond to excitations of the system and are thus energetically penalized. Error correction is realized "passively", without active manipulation of the system, through dissipation processes that relax the system to the ground state. In our work, we consider a physical realization of the three-qubit code as an Ising model coupled to a bath that implements the necessary dissipative channels. We investigate how to realize logical operations in the code space by means of Floquet engineering techniques. Moreover, one of our major goals is to shed light on the interplay between the Floquet scheme and dissipative protection, and how it impacts the efficiency of the quantum error correction code.

Q 67.22 Thu 17:00 Philo 2. OG

Quantum Kolmogorov-Arnold Networks for Interpretable Healthcare Models — •Vanessa Stein[1], Yannick Werner[1,2], Akash Malemath[1], Nikolaos Palaiodimopoulos[1,2], Paula Manso Zorilla[2], Hamraz Javaheri[2], Mengxi Liu[2], Paul Lukowicz[1,2], Vitor Fortes Rey[1,2], Gregor Alexander Stavrou[3], Omid Ghamarnejad[3], and Maximilian Kiefer-Emmanouilidis[1,2] — [1]RPTU Kaiserslautern-Landau — [2]DFKI Kaiserslautern — [3]Department of General, Visceral and Oncological Surgery, Klinikum Saarbrücken

Transparency remains a major challenge in applying machine learning to healthcare, where understanding model decisions is crucial for clinical trust and adoption. Kolmogorov-Arnold networks provide a structurally interpretable alternative to conventional neural architectures by placing learnable functions on edges rather than nodes. We explore quantum realizations of these architectures using Quantum Circuit Born Machines to create compact, expressive models with directly accessible functional components. Initial results indicate that the approach enables interpretable decision pathways without sacrificing predictive performance compared to established classical and quantum classifiers. This highlights the potential of quantum machine learning to support trustworthy AI in healthcare by combining strong performance with enhanced interpretability.

Q 67.23 Thu 17:00 Philo 2. OG

Evaluating the Impact of Expert-Curated vs. LLM-Generated Feedback on Novice Quantum Programmer Performance — •Lars Krupp[1,2], Jonas Bley[2], Smriti Sharma[1,2], Maximilian Kiefer-Emmanouilidis[1,2], Paul Lukowicz[1,2], and Jakob Karolus[1,2] — [1]DFKI Kaiserslautern — [2]RPTU Kaiserslautern-Landau

The field of quantum computing (QC) faces a significant barrier to adoption due to the shortage of qualified educators. While online resources provide foundational knowledge, students often encounter coding challenges where a lack of timely, personalized assistance can severely stifle their learning progress. We present a user study on the PennyLane website using a plugin to inject different types of assistance into their error messages and investigate the efficacy of these assistance mechanisms for introductory QC coding tasks. Our study compares three types of assistance provided when a student's code fails: standard error messages, expert-curated messages, and personalized, Large Language Model (LLM)-generated support. Unlike the non-personalized expert messages, the LLM-based system reads and interprets the student's code and provides targeted guidance aimed at successful task completion. Learning gain is evaluated using a pre- and post-test design to assess the impact of these distinct support modalities on student understanding.

Q 67.24 Thu 17:00 Philo 2. OG

Synthetic Data Generation for Healthcare Prediction — •Paula Manso Zorilla[1], Yannick Werner[1,2], Hamraz Javaheri[1,2], Gregor Alexander Stavrou[3], Omid Ghamarnejad[3], Paul Lukowicz[1,2], Maximilian Kiefer-Emmanouilidis[1,2], and Vitor Fortes Rey[1,2] — [1]DFKI Kaiserslautern — [2]RPTU Kaiserslautern-Landau — [3]Department of General, Visceral and Oncological Surgery, Klinikum Saarbrücken

Advancing machine learning in healthcare is often hindered by limited, imbalanced, and privacy-sensitive clinical datasets. To address these constraints, we investigate physics-inspired synthetic data generation using GANs, large language models, and a Quantum Circuit Born Machine trained with maximum mean discrepancy loss. We assess the resulting datasets in terms of fidelity, privacy preservation, and practical utility by training classical and quantum classifiers while evaluating performance exclusively on real patient data. Our findings show that synthetic clinical data can improve robustness and predictive capability in low-data settings. This demonstrates how quantum and classical generative models can help unlock reliable, privacy-preserving AI for real-world healthcare applications.

Q 67.25 Thu 17:00 Philo 2. OG

Quantum-Inspired Low-Entanglement Optimization Techniques for Image Segmentation — •Marie Gogolin[1], Richard Castro[1,2], Yannick Werner[1,3], Ali Mogisheh[2], Alexander Geng[2], Arcesio Castaneda Medina[2], Paul Lukowicz[1,3], and Maximilian Kiefer-Emmanouilidis[1,3] — [1]RPTU Kaiserslautern-Landau — [2]Fraunhofer ITWM Kaiserslautern — [3]DFKI Kaiserslautern

Optimization problems such as image segmentation can be mapped to ground-state computations in Ising-type models, allowing quantum and quantum-inspired methods to be applied to real-world tasks. In this work, we investigate a spectrum of approaches to solving such problems, starting from the Max-Cut formulation and comparing exact diagonalization, imaginary-time evolution, and quantum annealing techniques. The focus lies on tensor-network methods. Matrix Product States and Projected Entangled Pair States, which enable scalable simulations of one- and two-dimensional systems with controllable entanglement. We further integrate quantum annealing concepts with tensor-network optimization by combining generalized PEPS using the simple-update scheme with a Floquet-based adiabatic evolution approximation. Numerical experiments on image segmentation benchmark the strengths and limitations of these techniques across varying system sizes and problem structures. The results demonstrate the potential of low-entanglement tensor networks as powerful tools for quantum-inspired optimization, bridging theoretical developments with practical applications in computer vision.

Q 67.26 Thu 17:00 Philo 2. OG

First-detection return statistics in quantum walks with long-range hopping — •Sayan Roy[1], Shamik Gupta[2], Giovanna Morigi[1], and Gabriele Perfetto[3] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Department of Theoretical Physics, Tata Institute of Fundamental Research, 1 Homi Bhabha Road, Mumbai, 400005, India — [3]Institut für Theoretische Physik, ETH Zürich, Wolfgang-Pauli-Str. 27, 8093 Zürich, Switzerland

Quantum walks are paradigms for many-body dynamics and are analog realization of quantum algorithms such as the quantum search. Key characterizing concepts are quantum recurrence, which describes the ability of a quantum walker to return to its initial state, and the associated first-detection time, which is the time interval elapsed between the initial time and the recurrence. In this work, we analyze a quantum walk on a chain with long-range hopping , where the coupling between sites at distance d decays as $d^{-\alpha}$, with $\alpha \geq 0$. The walker evolves unitarily between stroboscopic projective measurements on the initial site performed at times $t_n = n\tau, n \in \mathbb{N}$. Our study shows that the nature of the walk is controlled by the hopping exponent α. In the strong long-range regime $\alpha < 1$, interference tends to localize the walker and the quantum walks are recurrent: the walker returns to the origin with probability one. For $\alpha > 1$, instead, the first-detection probability decays algebraically, with exponent depending on α, leading to a transient quantum walk. We connect these behaviors with the spectral features of the model.

Q 67.27 Thu 17:00 Philo 2. OG

Non-Exponential Decay in Finite Photonic Waveguide Arrays — •Florian Huber[1,2,3,4], Benedikt Braumandl[1,2,3,5], Johannes Knörzer[6], Jonas Himmel[7], Carlotta Versmold[1,2,3], Robert Jonsson[8], Alexander Szameit[7], and Jasmin Meinecke[1,2,3,4] — [1]Ludwig-Maximilians-Universität München — [2]Max-Planck Institut für Quantenoptik — [3]Munich Center for Quantum Science and Technology (MCQST) — [4]Technische Universität Berlin — [5]Technische Universität München — [6]ETH Zurich — [7]Universität Rostock — [8]Malmö University

Tight-binding models with a single defect at the edge of a lattice give rise to a variety of dynamical behaviors and provide a well controlled minimal setting to study decay in open quantum systems. Transitioning between exponential decay, non-exponential relaxation or oscillatory dynamics is possible by only varying a single parameter. To explore these effects experimentally, we use fused silica waveguide arrays providing a versatile yet well controllable platform and a natural realization of tight-binding models with varying coupling strengths and boundary conditions. To analyze the suitability of the experimental platform we characterize the waveguide arrays in detail and use the reconstructed refractive index profile for additional numerical eigenmode-expansion simulations. By comparing the analytic solution to our experimental data and additional numerical simulations and by taking finite-size effects into account we establish a general framework and benchmark for assessing how waveguide-based quantum simulator implementations can reliably emulate infinite or semi-infinite models.

Q 67.28 Thu 17:00 Philo 2. OG

Quantum searches as quantum walks on a graph with variable connectivity — •Giovanni Ragazzi[1], Emma King[2], Paolo Bordone[1], Giovanna Morigi[2,3], Matteo Paris[4], and Andrea Solfanelli[5] — [1]Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Università di Modena e Reggio Emilia, I-41125 Modena, Italy — [2]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [3]Center for Quantum Technologies (QuTe), Saarland University, Campus, 66123 Saarbruecken, Germany — [4]Dipartimento di Fisica Aldo Pontremoli, Università di Milano, I-20133 Milano, Italy — [5]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

A quantum walk on a lattice is a paradigm of a quantum search in a database. For quantum walks on a continuous time, the walker diffuses across the lattice and the search ends when it localizes at the target site. The search time T can exhibit Grover's optimal scaling with the lattice size N, namely, $T \sim \sqrt{N}$, on an all-connected, complete lattice. For finite-range tunneling between sites, instead, Grover's optimal scaling is warranted when the lattice is a hypercube of $d > 4$ dimensions. In a recent work, it was shown that Grover's optimum can be reached in lower dimensions on lattices of long-range interacting particles, when the interaction strength scales algebraically with the distance r as $1/r^\alpha$ and $0 < \alpha < 3d/2$. In this contribution, we extend the formalism to determine the computational time complexities of quantum walks on graph with different geometries, considering in particular sparse graphs and chiral effects.

Q 67.29 Thu 17:00 Philo 2. OG

Statistical properties of quantum ensembles on hyperspheres — •Max Tartler and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt, Hochschulstraße 4A, 64289, Darmstadt

Quantum states are described by density operators and carry the entire information of a physical system. The Bloch sphere provides a geometric representation of all possible quantum states for spin 1/2-systems [1]. The question arises how quantum systems of higher dimension, such as multipartite ones, can be understood geometrically.

In this contribution, we give a geometric representation of quantum states in arbitrary dimensions. The key to this approach is the Cholesky decomposition of positive definite matrices [2]. One finds that the entire Hilbert space of N dimensions can be mapped onto a sector of the real unit hypersphere in N^2 dimensions. We analyze where special classes of quantum states are located in this picture. Furthermore, the statistical properties of homogeneously distributed quantum states on the hypersphere are resolved through the computation of the probability distribution function of the density matrices.

[1] Quantum Computation and Quantum Information: 10th Anniversary Edition, Michael A. Nielsen, Isaac L. Chuang p. 105 (2010)
[2] Matrix Analysis, Roger A. Horn, Charles R. Johnson p. 441 (2013)

Q 67.30 Thu 17:00 Philo 2. OG

Quantum states on hyper-spheres — •Christian Schaub and Reinhold Walser — Institute for Applied Physics, TU Darmstadt, Germany

Quantum entanglement is a key resource in today's quantum technologies, making its reliable quantification fundamentally important. A powerful strategy for characterizing entanglement is to decompose a quantum state into its local building blocks and compare these components with the original state, naturally connecting to the underlying geometry of quantum states [1]. While the Schmidt decomposition provides a perfect factorization, it only applies to pure states.

In this contribution, decomposition-based methods are therefore introduced for the analysis of arbitrary mixed states, with the Cholesky decomposition as a central element. The Cholesky decomposition provides a unique and compact factorization of density matrices and serves as the foundation for a hyper-spherical representation, in which quantum states can be interpreted as points on the surface of a hypersphere. Within this framework, entanglement can be understood as the geodesic distance on the hyper-sphere between the original state and the nearest separable state on the submanifold. This distance is minimized to quantify entanglement, yielding a closer separable approximation than partial-trace-based factorizations.

[1] Ingemar Bengtsson et al. Geometry of Quantum States: An Introduction to Quantum Entanglement. 2nd ed. Cambridge University Press, 2017

Q 67.31 Thu 17:00 Philo 2. OG

Applications of Multi-Qubit Gates for Scalable Quantum Algorithms in Trapped-Ion Systems — Eoin Potts, Alexander Gresch, Soronzonbold Otgonbaatar, Marcel Seelbach, Dimitris Badounas und •Michael Fromm — eleQtron GmbH, Heeserstr. 5, 57072 Siegen, Germany

Multi-qubit entangling gates are a central resource for achieving scalable quantum algorithms, particularly in trapped-ion quantum computing platforms where long-range interactions and high-fidelity control are available. In particular, we examine the efficient layering of Givens rotations enabled by collective multi-qubit interactions. We further discuss Hamiltonian engineering techniques that leverage native multi-qubit gates to encode optimization problems directly into effective many-body interactions. Finally, we address strategies for scaling multi-qubit gates beyond a single register, including modular architectures and ion shuttling.