⟨KC|K⟩ University of Gdańsk International Centre for Theory of Quantum Technologies

National Quantum Information Centre in Gdańsk (KCIK) & International Centre for Theory of Quantum Technologies (ICTQT)

XVII

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BOOK OF ABSTRACTS

Presented in alphabetical order

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INVITED SPEAKERS

Mohamed Bourennane

Stockhom University, Sweden

Topological quantum photonics

Abstract: Quantum photonic technologies offer a powerful platform for quantum communication, computation, and sensing, but their scalability is fundamentally limited by the fragility of quantum states in the presence of disorder, fabrication imperfections, and environmental noise. Overcoming this challenge is essential for realizing practical quantum systems. In this talk, I will present a new approach based on topological quantum photonics, where photonic structures are engineered to provide intrinsic robustness to quantum states of light. By combining quantum optics with topological photonic design, we move beyond conventional implementations toward noise-resilient quantum platforms. I will discuss our experimental efforts to generate and manipulate single photons and entangled states in integrated and laser-written photonic circuits. In particular, I will show how topological and non-Hermitian structures can enable protected transport, localization, and interference of quantum light. We investigate the robustness of entanglement and high-visibility quantum interference under controlled disorder, providing a pathway toward stable and scalable quantum photonic systems. This work establishes a bridge between topological wave physics and quantum information science, open ing new opportunities for robust quantum technologies, including secure communication and scalable quantum processing.

Andre Chailloux

Centre Inria de l'Université Grenoble Alpes, France

Quantum algorithms for decoding problems inspired by Regev's reduction

Abstract: Chen, Liu and Zhandry introduced a new family of quantum algorithms for decoding problems, inspired by Regev's reduction. The idea is to solve a decoding problem in a linear code in order to solve a corresponding decoding problem in the corresponding dual code. This approach has already provided convincing quantum advantage. In this talk I will briefly present this family of quantum algorithms and the applications for post-quantum cryptography and more generally for finding quantum advantage. I will then focus on links to quantum state discrimination problems and the open questions in this field.

Ignacio Cirac

Max Planck Institute of Quantum Optics, Germany

Efficient Preparation and manipulation of Tensor Network Quantum States

Abstract: Tensor Network States, like matrix product or projected entangled pair states play an important role in both, quantum information theory and many-body physics. They offer a compact and efficient representation, enabling accelerated numerical computations and providing intuitive insights into many-body phenomena. In this talk, I will discuss how certain states can be efficiently prepared and manipulated using quantum devices, highlighting the use of local operations and classical communication.

Nilanjana Datta

University of Cambridge, the UK

A reversible quantum resource theory for classical-quantum channels

Abstract: We prove the asymptotic reversibility of quantum resource theories of classical-quantum channels in a natural framework, where the distance between channels (and hence also the notion of approximate interconvertibility of channels) is measured in diamond norm, and the set of free operations is the set of all asymptotically resource non-generating superchannels. The result relies on a generalized quantum Stein's lemma for classical-quantum channels that we prove. This is joint work with Bjarne Bergh and Anirudh Khaitan (arXiv:2509.13280).

Khrystyna Gnatenko

Ivan Franko National University of Lviv, Ukraine

Properties of Multiqubit Quantum States Representing n-Partite Graphs and Their Quantification Using Quantum Computing

Abstract: Quantum states representing complex structures have recently attracted significant attention due to their wide-ranging applications in quantum information science and quantum computing. These states play an essential role in various quantum technologies, including quantum error correction, quantum cryptography, and quantum machine learning. In addition, studying these states opens up the possibility of constructing quantum protocols for detecting properties of complex systems using quantum programming. We investigate multi-qubit quantum states associated with bipartite graphs $G(U,V,E)$. For a general quantum state defined on a bipartite graph with arbitrary structure, we derive an analytical expression for the entanglement distance [1]. Furthermore, we establish a relationship between quantum correlators and the number of vertices with odd and even degrees in the subsets U and V. These quantities are essential for understanding the structure of bipartite graphs and for identifying possible matchings. Building on these theoretical results, we propose quantum protocols that allow one to determine the number of vertices with odd and even degrees in both partitions of a bipartite graph. As a specific example, we analyze a bipartite star graph. For this case, the entanglement distance and the number of odd-degree vertices in the sets U and V are evaluated using quantum programming [1]. We also extend our analysis to multi-qubit states corresponding to tripartite graphs. These states are generated by applying RXX, RYY, and RZZ gates to an arbitrary separable n-qubit state. We derive the entanglement distance for such states and study its dependence on both the state parameters and the structural properties of the corresponding tripartite graphs. In addition, we introduce a quantum protocol for counting closed cycles of length four in a tripartite graph, which suggests the potential for achieving quantum advantage in solving this problem. Finally, we examine quantum states that can be represented by weighted graphs [2,3]. These states also correspond to single-layer variational quantum states [2], which are important in quantum machine learning. The entanglement of these states is calculated both analytically and using quantum programming for graph states with arbitrary structure.

References:

1. Gnatenko Kh. P. Studies of properties of bipartite graphs with quantum programming // Phys. Lett. A. — 2026. — Vol. 566. — Art. 131191. — 7 p.
2. Gnatenko Kh. Quantum and classical calculations of the entanglement distance of multi-qubit one-layer variational quantum states // 2025 IEEE International Conference on Quantum Computing and Engineering (QCE), Albuquerque, NM, USA, 2025,. — P. 470–471
3. Gnatenko Kh. P. Relation of curvature and torsion of weighted graph states with graph properties and its studies on a quantum computer // Eur. Phys. J. Plus. — 2025. — Vol. 140, — Art. 241. — 7 p.

Philippe Grangier

Laboratoire Charles Fabry, IOGS, CNRS, France

Heading towards an Algebraic Heisenberg Cut

Abstract: Following an article by John von Neumann on infinite tensor products, we develop the idea that the usual formalism of quantum mechanics, associated with unitary equivalence of representations, stops working when countable infinities of particles (or degrees of freedom) are encountered. This is because the dimension of the corresponding Hilbert space becomes uncountably infinite, leading to the loss of unitary equivalence, and to sectorization. By interpreting physically this mathematical fact, we show that it provides a natural way to describe the "Heisenberg cut", as well as a unified mathematical model including both quantum and classical physics. By considering simple examples we also show that although the full force of the sectorisation theorems requires taking the infinite limit, early signs of the macroscopic behaviour appear before infinity. Such an approach can make sense of the quantum-classical transition as a primarily algebraic one.

References:

M. Van Den Bossche & P. Grangier, Foundations of Physics 53:45 (2023) [https://arxiv.org/abs/2209.01463]

Barbara Kraus

TUM School of Natural Sciences at the Technical University of Munich, Germany

Phases of matrix-product states with symmetries and measurements

Abstract: Two matrix product states (MPS) are in the same phase in the presence of symmetries if they can be transformed into one another via symmetric short-depth circuits. We consider how symmetry-preserving measurements with feedforward alter the phase classification of MPS in the presence of global on-site symmetries. We demonstrate that, for all finite abelian symmetries, any two symmetric MPS belong to the same phase. We give an explicit protocol that achieves a transformation between any two phases and that uses only a depth-two symmetric circuit. In the case of non-abelian symmetries, symmetry protection prevents one from deterministically transforming symmetry-protected topological (SPT) states to product states directly via measurements, thereby complicating the analysis. Nonetheless, we provide protocols that allow for asymptotically deterministic transformations between the trivial phase and certain SPT phases [1]. We extend this analysis and the protocols to nilpotent groups [2].

Josef Lazar

Academy of Sciences of the Czech Republic, Czech Republic

Quantum Technology Landscape at the Czech Academy of Sciences and Beyond

Abstract: This contribution outlines the current state and future trajectory of quantum technologies within the Institute of Scientific Instruments and the Czech Academy of Sciences. As a key player in the multidisciplinary programme of the AV21 Strategy of the Academy of Sciences, putting together a number of institutions we focus on interinstitutional synergies bridging the gap between basic and applied science in the quantum field. The topics cover Quantum Metrology and Communications: Development of cold quantum objects for frequency/time metrology and the creation of a national time scale for synchronizing not only data networks. Experimental milestones include progress in trapping and laser-cooling Calcium ions and also hybrid systems with Aluminum ions for optical quantum clocks. Infrastructure and larger collaborations cover integration into European initiatives such as EuroQCI and FOREST to build secure quantum communication backbones and fiber-based distribution of precise time across borders. Among future frontiers is and

emerging research into hybrid quantum gates combining trapped atoms, molecules, and nanoparticles. The topic of quantum computing is addressed by a deployment of the LUMI-Q consortium's quantum computer in the Czech Republic. Aligned with the European Chips Act and the Quantum Europe Strategy, the Czech scientific community set a national Strategy for Quantum Technologies with the prospect to contribute to the European digital security and industrial competitiveness.

Giovanna Morigi

Saarland University, Germany

Time complexity of a monitored quantum search with resetting

Abstract: Searching a database is a central task in computer science and is paradigmatic of transport and optimization problems in physics. For an unstructured search, Grover's algorithm predicts a quadratic speedup, with the search time $\tau(N) = \Theta(\sqrt{N})$ and N the database size. Numerical studies suggest that the time complexity can change in the presence of feedback, injecting information during the search. Here, we determine the time complexity of the quantum analog of a randomized algorithm, which implements feedback in a simple form. The search is a continuous-time quantum walk on a complete graph, where the target is continuously monitored by a detector. Additionally, the quantum state is reset if the detector does not click within a specified time interval. This yields a non-unitary, non-Markovian dynamics. We optimize the search time as a function of the hopping amplitude, detection rate, and resetting rate, and identify the conditions under which time complexity could outperform Grover's scaling. The overall search time does not violate Grover's optimality bound when including the time budget of the physical implementation of the measurement. For databases of finite sizes monitoring can warrant rapid convergence and provides a promising avenue for fault-tolerant quantum searches.

Gniewomir Sarbicki

Nicolaus Copernicus University

Spin chirality across quantum state copies detects hidden entanglement

Abstract: Entanglement can hide from standard detection in two fundamentally different ways: as multicopy correlations invisible to any single-copy measurement on an unknown state, and as bound entanglement invisible to the Peres–Horodecki criterion. We show that both forms share a common origin in spectral structures accessible only through joint measurements on multiple state copies and can be detected by a unified architecture built on controlled-SWAP circuits. We prove that the difference between partial transpose moments and purity moments, $C_k = \mu_k - I_k$, decomposes exactly as a chirality–chirality correlator—the same scalar spin chirality that governs chiral spin liquids and the topological Hall effect—revealing the specific physical content that multi-copy entanglement detection probes. For two-qubit states, chirality measures the signed volume of the correlation tensor parallelepiped, providing a geometric entanglement signature from just two measurements. Using the same circuit infrastructure, we develop a multi-channel spectral classifier for bound entanglement that combines realignment spectral features with chirality corrections. This classifier achieves 100% recall at zero false positives across all known 3×3 bound entangled families—compared with ∼50% for the computable cross-norm or realignment (CCNR) criterion, which certifies entanglement when the trace norm of the realignment matrix exceeds unity, and ∼58% for the range criterion, which certifies entanglement through the structure of product vectors in the state's range. A new marginal-noise construction produces states where the CCNR trace norm drops below the detection threshold, rendering them invisible to CCNR and to all other single-parameter criteria, while the non-Hermiticity gap between singular values and eigenvalues of the realignment matrix persists—enabling detection through the multi-channel approach. These CCNR-invisible states are still detected by the range criterion, but evade the PPT test and all moment-based witnesses. We demonstrate both capabilities experimentally on IBM Quantum processors: negativity reconstruction with mean errors of 0.002–0.027, chirality detection for pure and mixed states, and bound entanglement

detection across two structurally distinct families (Horodecki and chessboard) using a single family-agnostic classifier on a gate-based superconducting processor.

Sergii Strelchuk

University of Oxford, the UK

From Classical to Quantum Learning Theory: Learnability, Boosting and Quantum Advantage

Abstract: Learning theory has been a transformative force in modern computer science; its conceptual and mathematical tools - from the foundations of PAC learning and VC dimension to boosting, compression, generalization bounds - have reshaped algorithms, complexity theory, and statistics. At the frontier of Quantum Machine Learning, Quantum Learning Theory investigates the mathematical limits and capabilities of quantum algorithms. It explores the learnability of concepts under quantum access models, defining the sample complexity and query efficiency that distinguish quantum learners from their classical counterparts. At the same time, it addresses questions motivated by physics: how efficiently can we predict properties of complex quantum systems, and how does quantum information alter the principles of inference and generalization? Where, and under what assumptions, can we expect to obtain quantum advantage? In this talk, starting from classical learning theory I will introduce the foundations of quantum learning theory and its various access models which include both working with classical and quantum data. I will explain how what is known about efficient learnability in these models and when can one 'boost' the performance of a weak learner of quantum properties.

Volodymyr Tkachuk

Ivan Franko National University of Lviv, Ukraine

Encoding the Decision Partition Problem in Central-Spin Hamiltonians and Solving It on Quantum Processors

Abstract: The decision version of the integer number partition problem asks whether a given set of positive integers can be divided into two groups whose sums are exactly equal. This classical problem is known to be NP-complete, yet it appears naturally in an unexpected place in physics: the central-spin decoherence model. In this model, a single "central" spin interacts with many surrounding bath spins, and the total effect of the bath on the central system is determined by the weighted sum of their orientations. If the weights of these interactions are chosen to match the integers of a partition instance, then finding a bath configuration that produces zero net influence on the central spin is precisely equivalent to finding a perfect partition. In other words, the physical question "Is there a bath state that cancels the field on the central spin?" is exactly the same as the computational question "Does a perfect partition exist?" This correspondence builds a bridge between a fundamental decoherence model and a canonical NP-complete problem. It provides a physical interpretation of perfect partitions as "silent" bath configurations that do not affect the central spin. It also suggests practical ways to study the partition problem using quantum hardware. I will discuss how to explore partitioning via central-spin dynamics and how current quantum processors can be used to detect zero-field configurations and probe perfect partitions.

POSTER PRESENTERS