QUANTUMSPEEDUP

February 12-13, 2026, Gdańsk

Book of Abstracts

(updated 12.02.2026)

International Centre for Theory of Quantum Technologies

Uniwersytet Gdański

Wydział Matematyki, Fizyki i Informatyki Uniwersytetu Gdańskiego

Centre for Quantum Optical Technologies

University of Warsaw

FRUG Fundacja Rozwoju Uniwersytetu Gdańskiego

QUANTUMSPEEDUP

February 12-13, 2026, Gdańsk

Venue: University of Gdańsk, Faculty of Mathematics, Physics, and Informatics, Wita Stwosza street, 57, Gdańsk, Poland
Auditorium: D005

Conference Programme
12 February 2026

Thursday, February 12, 2026		
09:30	Registration & Welcome Coffee	
10:45	**Opening**	
	Thursday SpeedTalk Sessions	
10:50 – 11:20	**SpeedTalks I**	
	Amrapali Sen (ICTQT, UG)	**Matthias Salzger** (ICTQT, UG)
	Fernando Almaguer Angeles (ICTQT, UG)	**Agniszka Schlichtholz** (WMFiI, UG)
	Leonard Sikorski (WMFiI, UG)	**Abhyoudai Sajeevkumar Shaleena** (ICTQT, UG)
	Rashi Adhikari (ICTQT, UG)	**Sumit Rout** (ICTQT, UG)
	Jędrzej Stempin (WMFiI, UG)	
	Break & Discussion time	
12:00 – 12:30	**SpeedTalks II**	
	Maria Popławska (QOT, UW)	**Michał Banacki** (ICTQT, UG)
	Felix Huber (WMFiI, UG)	**Jorge Escandón-Monardes** (ICTQT, UG)
	Gerard Anglès Munné (WMFiI, UG)	**Robert Okuła** (GUT)
	Paweł Cieśliński (ICTQT, UG)	**Rishav Sagar** (ICTQT, UG)
	Andre Hernandes Alves Malavazi (ICTQT, UG)	**Voting for Talk of the Day**
	Lunch Break (not provided by the organizers)	
15:00 – 17:00	**Thursday Poster Session**	

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Conference Programme
13 February 2026

Friday, February 13, 2026		
10:00	Registration & Morning Coffee	
10:30	**Announcements**	
	Friday SpeedTalk Sessions	
10:35 – 11:05	**SpeedTalks III**	
	Marcin Jarzyna (QOT, UW)	**Akshata Shenoy** (ICTQT, UG)
	Vera Uzunova (QOT, UW)	**Tomasz Linowski** (ICTQT, UG)
	Alexandre Orthey (MIM, UW)	**Konrad Schlichtholz** (ICTQT, UG)
	Antonio Mandarino (ICTQT, UG)	**Borhan Ahmadi** (ICTQT, UG)
	Gerardo Suarez Vargas (ICTQT UG)	**Piotr Mironowicz** (ICTQT, UG/ GUT)
	Break & Discussion time	
11:45 – 12:15	**SpeedTalks IV**	
	Marcin Marciniak (WMFiI, UG)	**Beata Zjawin** (ICTQT, UG)
	Ana Belen Sainz (ICTQT, UG)	**John H. Selby** (ICTQT, UG)
	Arturo Konderak (CFT, PAN)	**Karthik Hosapete Seshadri** (ICTQT, UG)
	Firat Diker (ICTQT, UG / SU)	**Giovanni Scala** (PB / INFN)
	Vinicius Rossi (ICTQT, UG)	**Voting for Talk of the Day**
	Lunch Break (not provided by the organizers)	
14:30 – 16:30	**Friday Poster Session**	
16:30	Closing remarks	

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List of speed talks / poster sessions – 12 February

Thursday Sessions	
Rashi Adhikari (ICTQT, UG)	Optimal Universal Higher-Order Quantum Networks for Multi-Copy Unitary Complex Conjugation
Fernando Almaguer Angeles (ICTQT, UG)	Hacking quantum computer with row hammer attack
Gerard Anglès Munné (WMFiI, UG)	Holographic quantum codes with trapped ions
Michał Banacki (ICTQT, UG)	Unitary induced channels and Tsirelson's problem
Paweł Cieśliński (ICTQT, UG)	The Incredible Richness of Bell Nonlocality
Felix Huber (WMFiI, UG)	A Lovász theta lower bound on quantum max cut
Jorge Escandón-Monardes (ICTQT, UG)	Multiparameter estimation with a photonic quantum switch
Andre Hernandes Alves Malavazi (ICTQT, UG)	cQED-Based Quantum Power Plant
Robert Okuła (GUT)	Mapping Quantum Discord for different Bell violations
Maria Popławska (QOT, UW)	Information capacity of multi-mode quantum Gaussian channels
Sumit Rout (ICTQT, UG)	Facets of Non-locality and Advantage in Entanglement-Assisted Classical Communication Tasks
Rishav Sagar (ICTQT, UG)	Ergotropy Protection via Two-Time Weak-Measurement (TWM) Protocol
Abhyoudai Sajeevkumar Shaleena (ICTQT, UG)	Understanding Bell inequality violations in 2-2-d and 2-d-2systems
Matthias Salzger (ICTQT, UG)	On the physical realisability of indefinite causal order process in classical spacetime
Agniszka Schlichtholz (WMFiI, UG)	Förster Resonance Energy Transfer in cylindrical nanostructures
Amrapali Sen (ICTQT, UG)	Superluminal Transformations and Indeterminism
Leonard Sikorski (WMFiI, UG)	Quantum waste management: Utilizing residual states in quantum information processing
Jędrzej Stempin (WMFiI, UG)	Quantum Capacity of a Graph

List of speed talks / poster sessions – 13 February

Friday Sessions	
Borhan Ahmadi (ICTQT, UG)	Reservoir-Engineered Exceptional Points for Quantum Energy Storage
Firat Diker (ICTQT, UG / SU)	Deterministic generation of a four-qubit W state using one- and two-qubit gates
Karthik Hosapete Seshadri (ICTQT, UG)	Quantum coherence leveraged agnostic phase estimation
Marcin Jarzyna (QOT, UW)	Optical Communication Receiver Based on Single Photon Coherent Beam Combination
Arturo Konderak (CFT, PAN)	Full nonlocality of partially entangled states
Tomasz Linowski (ICTQT, UG)	Quantum-inspired exoplanet detection in the presence of experimental imperfections
Antonio Mandarino (ICTQT, UG)	Statistics of topological defects across a phase transition in a digital superconducting quantum processor
Marcin Marciniak (WMFiI, UG)	Equiangular systems of vectors
Piotr Mironowicz (ICTQT, UG/ GUT)	Long-range device-independent quantum key distribution
Alexandre Orthey (MIM, UW)	Optimality of universal conclusive entanglement purification protocols
Vinicius Rossi (ICTQT, UG)	How typical is contextuality?
Ana Belen Sainz (ICTQT, UG)	Linear Program Witness for Network Nonlocality in Arbitrary Networks
Giovanni Scala (PB / INFN)	Measurable Third-Order Detection from an Affine Reduction Moment Matrix
Konrad Schlichtholz (ICTQT, UG)	Enhancing SPADE-based source discrimination through frequency measurements
John H. Selby (ICTQT, UG)	Generalised Process Theories
Akshata Shenoy (ICTQT, UG)	Quantum-Inspired Approaches for Bloch Surface Wave–Based Sensing
Gerardo Suarez Vargas (ICTQT UG)	Non-Markovian equations and approximate environments
Vera Uzunova (QOT, UW)	Photon Efficiency of high-dimensional Quantum Key Distribution
Beata Zjawin (ICTQT, UG)	The resource theory of causal influence and knowledge of causal influence

Acronyms

UG – University of Gdańsk, Poland
ICTQT – International Centre for Theory of Quantum Technologies
WMFiI - Department of Mathematics, Physics and Informatics

UW – University of Warsaw, Poland
QOT – Centre for Quantum Optical Technologies, Centre of New Technologies
MIM - Faculty of Mathematics, Informatics and Mechanics

CFT PAN – Center for Theoretical Physics, Polish Academy of Sciences, Poland

GUT – Gdańsk University of Technology, Poland

PB - Politecnico di Bari, Italy

INFN - Istituto Nazionale di Fisica Nucleare - Sezione di Bari, Italy

SU - Sabanci University, Turkey

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SpeedTalk Speakers / Poster Presenters

Speakers and Poster Presenters' Sessions
– 12 February 2026 (Alphabetical Order)

Optimal Universal Higher-Order Quantum Networks for Multi-Copy Unitary Complex Conjugation

Rashi Adhikari
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
While the optimal transformation of k copies of an unknown unitary U into a single instance of its complex conjugate U* is well-understood, the general k to l transformation, generating multiple target instances remains an open frontier in higher-order quantum computation. This project investigates the optimal universal quantum strategies for implementing the map U^{\otimes k} \to U*^{\otimes l} where l > 1.

Hacking quantum computer with row hammer attack

Fernando Almaguer Angeles
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
We demonstrate a hardware vulnerability in quantum computing systems by exploiting cross-talk effects on an available commercial quantum computers (IBM). Specifically, based on the cross-talk produced by certain quantum gates, we implement a row hammer attack that ultimately allows us to flip a qubit. Both single-qubit and two-qubit operations were performed and analyzed. Our findings reveal that two-qubit operations applied near a target qubit significantly influence it through cross-talk, thereby effectively compromising its state.

https://arxiv.org/abs/2503.21650

Holographic quantum codes with trapped ions

Gerard Anglès Munné
Faculty of Mathematics, Physics and Informatics (WMFiI), University of Gdańsk, Poland

Abstract:
Holography is a central concept at the intersection of gravity, condensed matter theory, and quantum information, linking the bulk of a system to its boundary. A model realizing key features of holographic systems is the holographic pentagon code by Pastawski et al. Here we experimentally implement small instances of the holographic pentagon and heptagon codes with trapped ions and test their properties: For the pentagon code, we recover logical bulk qubits from their nearby boundary and test the Ryu-Takayanagi entanglement area law. For the heptagon code, we show that the transversal Hadamard gate native to the constituent Steane codes induces a one-qubit error in the holographic code. Our implementation paves the way towards the use of holographic quantum codes for quantum information processing.

Unitary induced channels and Tsirelson's problem

Michał Banacki
International Centre for Theory of Quantum Technologies (ICTQT) and Faculty of Mathematics, Physics and Informatics (WMFiI), University of Gdańsk, Poland

Abstract:
Motivated by recent progress concerning quantum commuting and quantum tensor models of composed systems, we investigate a notion of (generalized) unitary induced quantum channel. Using properties of Brown algebras, we provide an equivalent characterization of the discussed families in both tensor and commuting frameworks. In particular, we introduce an equivalent formulation of Tsirelson's conjecture (Connes' embedding problem) in terms of the considered paradigms based on protocols that do not require measurements performed on infinite-dimensional subsystems. As a result, we show that there is a difference between quantum commuting and quantum tensor models for (generalized) unitary induced channels. Specifically, such a difference can be seen by parties who have direct access only to finite-dimensional subsystems.

https://arxiv.org/abs/2508.21808

The Incredible Richness of Bell Nonlocality

Paweł Cieśliński
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland, Poland
Ludwig Maximilian University, Germany

Abstract:
Non-classical quantum correlations underpin both the foundations of quantum mechanics and modern quantum technologies. Among them, Bell nonlocality is a central example. For bipartite Bell inequalities, nonlocal correlations obey strict monogamy: a violation of one inequality precludes violations of other inequalities on the overlapping subsystems. In the multipartite setting, however, Bell nonlocality becomes inherently polygamous. This was previously shown for subsystems obtained by removing a single particle from an N-partite system. Here, we generalize this result to arbitrary $(N-k)$-partite subsystems with $k>0$. We demonstrate that a single N-qubit state can violate all $\binom{N}{k}$ relevant Bell inequalities simultaneously. We further construct an N-qubit Bell inequality, obtained by symmetrizing the $(N-k)$-qubit ones, that is maximally violated by states exhibiting this generalized polygamy. We compare these violations with those achievable by GHZ states and show that polygamy offers an advantage in multipartite scenarios, providing new insights into scalable certification of non-classicality in quantum devices. Our analysis relies on symmetry properties of the MABK inequalities. Finally, we show that this behavior can occur across multiple subsystem sizes, a phenomenon we call hyper-polygamy. These structures reveal the remarkable abundance of nonlocality present in multipartite quantum states and offer perspectives for their applications in quantum technologies.

https://arxiv.org/abs/2512.09034

Multiparameter estimation with a photonic quantum switch

Jorge Escandón-Monardes
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
Several experiments have demonstrated the advantages that indefinite causal order offers for quantum information. For instance, the quantum switch, which is the most prominent example of an indefinite causal order process, has been shown to enhance the precision of some metrological tasks compared to fixed order strategies.

In this work, we experimentally demonstrate the advantages of indefinite causal order for multiparameter estimation in a photonic quantum switch. Our setup uses multicore optical fibers technology to coherently control the order of three quantum operations, two of them being noisy channels with variable noise strength. Our setup can estimate parameters even in noisy regimes where the consecutive application of the operations in a fixed order would make it unattainable. Additionally, we assess the Fisher information matrix for different configurations of the setup and different amounts of noise, showing that the best configuration of the quantum switch depends on a priori information and weighing of the parameters. Our results highlight the pertinence of indefinite causal order for quantum information under noisy conditions.

cQED-Based Quantum Power Plant

André Hernandes Alves Malavazi
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
Here, we introduce a quantum thermal power plant capable of autonomously charging a quantum battery and employing its charge to cool a qubit. The device consists of two independent modules, each comprising a qubit, a qutrit, and a harmonic oscillator within the same architecture. The engine module pumps energy into the oscillator, while the refrigerator module uses it to power the cooling process. The proposed device can be experimentally realized with state-of-the-art superconducting devices.

A Lovász theta lower bound on quantum max cut

Felix Huber
Faculty of Mathematics, Physics and Informatics (WMFiI), University of Gdańsk, Poland

Abstract:
Quantum Max Cut is a problem relevant to computer science and many-body quantum physics, due to its links to classical Max Cut and the anti-ferromagnetic Heisenberg Hamiltonian. We prove a lower bound to quantum Max Cut of a graph in terms of the Lovász theta function of its complement. For a graph with m edges, $\text{qmc}(G) \geq \tfrac{m}{4}\big(1 + \tfrac{8}{3\pi}\tfrac{1} \vartheta(\overbar{G}) -1} \big)$, with the bound achieved by a product state. For graphs with maximum degree Δ a relaxed bound follows from $\vartheta(\overbar{G}) - 1 \leq \Delta$, making it interesting for practically relevant quantum many-body systems. The proof extends a result by Balla, Janzer, and Sudakov on classical Max Cut and is inspired by the randomized rounding method of Gharibian and Parekh. It outperforms the classical bound when applied to quantum Max Cut.

https://arxiv.org/abs/2512.20326

Mapping Quantum Discord for different Bell violations

Robert Okuła
Gdańsk University of Technology (GUT), Poland

Abstract:
This work characterizes the relationship between quantum discord and Bell non-locality. We determine the range of admissible discord values—establishing both minimal and maximal limits—for entangled states exhibiting specific magnitudes of Bell violation. This comparison illuminates the hierarchy between general quantum correlations and non-locality, clarifying the extent to which discord is a prerequisite for observing non-classical statistics.

Information capacity of multi-mode quantum Gaussian channels

Maria Popławska
Centre for Quantum Optical Technologies (QOT), Centre of New Technologies (CeNT), University of Warsaw, Poland

Abstract:
Classical multiple-input multiple-output (MIMO) technology has revolutionized radio-frequency communication by exploiting spatial multiplexing to increase channel capacity. Inspired by this idea, we investigate how an analogous concept can be realized in multimode quantum optical communication. We study multi-mode quantum Gaussian channels described by linear optical transformations acting on many bosonic modes, providing a natural quantum counterpart of classical MIMO channels. Restricting to Gaussian modulation of coherent states, we express the achievable information rate in terms of the Holevo quantity and show that, after an appropriate mode decomposition, the capacity reduces to a sum over effective parallel channels. An explicit analogy with Rayleigh fading — a phenomenon arising from scattering during signal propagation in classical wireless channels — is established. Using tools from random matrix theory, we derive an analytical expression for the expected channel capacity of random multi-mode passive quantum Gaussian channels. Our results elucidate how randomness and the number of optical modes determine the scaling of information capacity, providing guidance for the design of high-capacity quantum optical links.

Facets of Non-locality and Advantage in Entanglement-Assisted Classical Communication Tasks

Sumit Rout
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
We reveal key connections between non-locality and advantage in correlation-assisted classical communication. First, using the wire-cutting technique, we provide a Bell inequality tailored to any correlation-assisted bounded classical communication task. The violation of this inequality by a quantum correlation is equivalent to its quantum-assisted advantage in the corresponding communication task. Next, we introduce wire-reading, which leverages the readability of classical messages to demonstrate advantageous assistance of non-local correlations in setups where no such advantage can be otherwise observed. Building on this, we introduce families of classical communication tasks in a Bob-without-input prepare-and-measure scenario, where non-local correlation enhances bounded classical communication while shared randomness assistance yields strictly suboptimal payoff. For the first family of tasks, assistance from any non-local facet leads to optimal payoff, while each task in the second family is tailored to a non-local facet. We reveal quantum advantage in these tasks, including qutrit over qubit entanglement advantage.

https://arxiv.org/abs/2507.10830

Ergotropy Protection via Two-Time Weak-Measurement (TWM) Protocol

Rishav Sagar
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
Quantum batteries (QBs) offer the potential for high-efficiency energy storage, but their performance is often degraded by environmental decoherence leading to unwanted discharging. In this work, we present a protocol utilizing selective two-time weak measurements to stabilize the stored energy and ergotropy in open quantum

systems. We establish the thermodynamic constraints that allow this protection to occur without requiring external recharging. Our results demonstrate that by tuning the measurement intensity, we can significantly mitigate discharging effects and improve the stability of both single-cell and N-cell quantum batteries. This protocol is feasible with current state-of-the-art quantum technologies and provides a path toward robust quantum energy storage.

https://arxiv.org/abs/2411.16633

Understanding Bell inequality violations in 2-2-d and 2-d-2systems

Abhyoudai Sajeevkumar Shaleena
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
Motivated by the previous semi-analytical optimization of tight bounds for Bell inequalities in the tripartite case corresponding to the $4 \times 4 \times 2$ scenario with three qubit subsystems, we consider a similar task in a more complicated setting involving d-dimensional subsystem. In particular, using approaches based on the Schmidt decomposition and recent results on optimal violation of the CHSH inequality, we provide a semi-analytical expression for the maximal violation of certain tripartite Bell inequalities for $2-2$-d and 2-d $-$ 2-dimensional subsystems. Specifically, the obtained results open the way to witnessing nonlocality for a certain family of states arising from a three-body decay beyond the qubit setting.

On the physical realisability of indefinite causal order process in classical spacetime

Matthias Salzger
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
In recent years there has been growing interest in quantum processes without a definite acyclic causal order. However, it is an open question which of these processes can be physically realised under which assumptions and in what regime. In this work, we show that almost any process in a classical spacetime corresponds to a quantum circuit with quantum control of causal order (QC-QC).

Förster Resonance Energy Transfer in cylindrical nanostructures

Agnieszka Schlichtholz
Faculty of Mathematics, Physics and Informatics (WMFiI), University of Gdańsk, Poland

Abstract:
A theory describing for the first time Förster Resonance Energy Transfer in cylindrical nanostructures is presented. We consider cylindrical structures including plate-like structures, nanocoins, nanorods, nanoroots, and (approximately) infinite nanowires. Beginning with a set of master equations, we obtain formulas characterizing the intensity of donor emission. Our approach, combining an analytical model with numerical calculations, contributes to a significantly improved understanding of FRET phenomena in cylindrical nanostructures as observed experimentally.

Superluminal Transformations and Indeterminism

Amrapali Sen
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
Quantum theory is widely regarded as fundamentally indeterministic, yet classical frameworks can also exhibit indeterminism once infinite information is abandoned. At the same time, relativity is usually taken to forbid superluminal signalling, yet Lorentz symmetry formally admits superluminal transformations (SpTs). Dragan and Ekert have argued that SpTs entail indeterminism analogous to the quantum one. Here, we derive a no-go theorem from natural assumptions, which can be interpreted as: superluminal transformations (SpTs) and finite information cannot coexist. Any theory accommodating SpTs must therefore allow unbounded information content, leading to a deterministic ontology akin to that of classical theories formulated over the real numbers. Thus, any apparent indeterminism arising from superluminal transformations reflects only probabilities arising from subjective ignorance, unlike the objective nature of probabilities in quantum theory, indicating that the claimed indeterminacy from superluminal extensions is not quantum.

https://arxiv.org/html/2601.15263v1

Quantum waste management: Utilizing residual states in quantum information processing

Leonard Sikorski
Faculty of Mathematics, Physics and Informatics (WMFiI), University of Gdańsk, Poland

Abstract:
We propose a framework for quantum residual management, in which states discarded after a resource distillation process are repurposed as inputs for subsequent quantum information tasks. This approach extends conventional quantum resource theories by incorporating secondary resource extraction from residual states, thereby enhancing overall resource utility. As a concrete example, we investigate the distillation of private randomness from the residual states remaining after quantum key distribution (QKD). More specifically, we quantitatively show that after performing a well-known coherent Devetak-Winter protocol one can locally extract private randomness from its residual. We further consider the Gottesman-Lo QKD protocol, and provide the achievable rate of private randomness from the discarded states that are left after its performance. We also provide a formal framework that highlights a general principle for improving quantum resource utilization across sequential information processing tasks.

https://arxiv.org/html/2510.27687

Quantum Capacity of a Graph

Jędrzej Stempin
Faculty of Mathematics, Physics and Informatics (WMFiI), University of Gdańsk, Poland

Abstract:
The classical capacity of a graph is a graph invariant that describes the asymptotic rate at which information can be transmitted through a noisy communication channel whose confusability structure is represented by a graph.
In this work, we propose an analogous notion of quantum capacity for quantum graphs, extending the classical framework to settings relevant for quantum communication. We show that computing this quantity is computationally hard and can be connected to another NP-hard combinatorial problem, the dominating set

problem. This connection suggests that many of the challenges appearing in classical zero-error information theory persist in the quantum setting, though with new structural features.

We further discuss possible approaches for studying and approximating the quantum capacity. In particular, we explore the use of semidefinite programming relaxations together with graph operations such as the XOR product to obtain computable bounds. These methods provide a promising direction for developing systematic tools to analyze quantum capacities of graphs and for better understanding the parallels and differences between classical and quantum information transmission.

Speakers and Poster Presenters' Sessions
– 13 February 2026 (Alphabetical Order)

Reservoir-Engineered Exceptional Points for Quantum Energy Storage

Borhan Ahmadi
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
Exceptional points are spectral singularities where both eigenvalues and eigenvectors collapse onto a single mode, causing the system's behavior to shift abruptly and making it highly responsive to even small perturbations. Although widely studied in optical and quantum systems, using them for energy storage in quantum systems has been difficult because existing approaches rely on gain, precise balanced loss, or explicitly non-Hermitian Hamiltonians. Here we introduce a new quantum energy-storage mechanism that realizes exceptional-point physics in a fully passive, physically consistent open quantum system. Instead of amplification, we use trace-preserving reservoir engineering to create an effective complex interaction between a charging mode and a storage mode through a dissipative mediator, generating an exceptional point directly in the drift matrix of the Heisenberg–Langevin equations while preserving complete positivity. The resulting dynamics exhibit two regimes: a stable phase where the stored energy saturates, and a broken phase where energy grows exponentially under a bounded coherent drive. This rapid charging arises from dissipative interference that greatly boosts energy flow between the modes without gain media or nonlinear amplification. The mechanism is compatible with optomechanical devices, superconducting circuits, and magnonic systems, offering a practical route to fast, robust, and scalable quantum energy-storage technologies and new directions in quantum thermodynamics.

Deterministic generation of a four-qubit W state using one- and two-qubit gates

Firat Diker
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland
Faculty of Engineering and Natural Sciences, Sabanci University, Turkey

Abstract:
We propose an optical scheme to build an entangled network composed of W state based on polarization encoded qubits (photons). This new setup consists of 2 cNOT gates, 4 V gates, 2 Hadamard gates and basic optical tools such as polarizing beamsplitters (PBSs) and path couplers (PCs). V gate is a specially-designed tool acting as a two-qubit gate which is composed of a cNOT gate, 3 PBSs and a PC. By using this gate, one benefits from the temporarily generated optical degree of freedom, which is the spatial mode of a photon in the proposed scheme. Using an extra degree of freedom allows us to perform more capable processing for W-state creation protocols. We use four photons as input, which means we do not need entanglement as a resource.

Quantum coherence leveraged agnostic phase estimation

Karthik Hosapete Seshadri
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
Quantum metrology concerns improving the estimation of an unknown parameter using an optimal measurement scheme on the quantum system. More the optimality of the measurement, the better will be the improvement in

sensing the value of the unknown parameter. Pertaining to the case of a two level system (qubit) undergoing rotation, a typical metrological task concerns the estimation of the angle of rotation (\tau) given the information about the axis of rotation (\theta, \phi). The method for garnering information about (\tau) is through maximizing the Fisher information. In the absence of the axis-knowledge, the optimality of the metrological task reduces drastically. Drawing inspiration from recent works leveraging entanglement to connect closed time-like curves and metrology, we overcome this limitation (lack of the knowledge of the rotation axis) using an ancilla assisted protocol. Here, the probe and the ancilla interact through a coherently controlled superposition of unitary evolutions. The quantum coherence in the initial state of the ancilla forms as the resource aiding the protocol. By measuring the ancilla in the same coherent basis in which it was prepared, we achieve optimal Fisher information about the rotation angle, independent of the axis parameters. Notably, this resource-efficient and operationally simple agnostic sensing alternative is independent of requiring entanglement in the initial joint state of the probe and the ancilla or entangling measurements, yet accounts for maximum Fisher information about the angle of rotation.

https://arxiv.org/abs/2507.21736

Optical Communication Receiver Based on Single Photon Coherent Beam Combination

Marcin Jarzyna
Centre for Quantum Optical Technologies (QOT), Centre of New Technologies (CeNT), University of Warsaw, Poland

Abstract:
We introduce an alternative receiver architecture for optical communication in the photon starved regime, in which a single large aperture is replaced by an array of smaller ones with outputs combined coherently, employing phase stabilization based on photon counting events. We show that it can attain high combination efficiency and reduce the signal to noise ratio, thus allowing for improved communication performance in the weak signal regime. We simulate the latter in a practical scenario and show that under weak-noise nighttime conditions the achieved performance is comparable to that offered by a single large aperture, whereas in daytime conditions, characterized by large noise, the single photon coherent beam combination architecture provides an advantage in the information transmission rate.

Full nonlocality of partially entangled states

Arturo Konderak
Center for Theoretical Physic, Polish Academy of Sciences (CFT PAS), Poland

Abstract:
Full nonlocality is a stronger form of nonlocality, in which every single realization of an experiment cannot be obtained with a classical setting, while in the standard nonlocality, it is only the complete statistic that cannot be reproduced classically. Despite several examples of fully nonlocal statistics are present in literature, achieving it with less and less resources, it is still unclear weather full nonlocality can be obtain without having maximally entangled states. In our work, we were able to obtain a examples of fully nonlocal states which are partially entangled. In particular, we proved that such examples only exist for dimensions greater than 3.

Quantum-inspired exoplanet detection in the presence of experimental imperfections

Tomasz Linowski
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Abstract:
Ideal spatial demultiplexing (SPADE) is proven to be a quantum-optimal tool for exoplanet detection, i.e., asymmetric source discrimination. However, recent investigations into the related problems of separation estimation and symmetric source discrimination showed its efficiency to be limited in the presence of noise. In this work, we use analytical tools to scrutinize the practical applicability of SPADE and derive the associated optimal decision strategy for exoplanet detection in the presence of experimental imperfections. On the one hand, we find that the probability of detection of noisy SPADE has the same scaling with planet-star separation and relative brightness as conventional techniques, such as direct imaging and coronagraphs. On the other hand, we prove that, due to a superior scaling coefficient under realistic noise conditions, SPADE remains the most efficient method for practical exoplanet detection in the sub-Rayleigh regime.

https://arxiv.org/abs/2505.00064

Statistics of topological defects across a phase transition in a digital superconducting quantum processor

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Abstract:
When a quantum phase transition is crossed within a finite time, critical slowing down disrupts adiabatic dynamics, resulting in the formation of topological defects. The average density of these defects scales with the quench rate, adhering to a universal power law as predicted by the Kibble–Zurek mechanism (KZM). In this study, we aim to investigate the counting statistics of kink density in the 1D transverse-field quantum Ising model. We demonstrate on multiple quantum processing units up to 100 qubits, that higher-order cumulants follow a universal power law scaling as a function of the quench time. We also show the breakdown of the KZM for short quenches for finite-size systems. Tensor network simulations corroborate our quantum simulation results for bigger systems not in the asymptotic limit.

https://arxiv.org/abs/2410.06250

Equiangular systems of vectors

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Abstract:
We present some results conserning equiangular systems of vectors in d-dimensional Hilbert space. The most improtant of them is a possibility to reduct the problem of finding SIC-POVM to the problem of finding an equiangular system of vectors with smaller cardinality.

Long-range device-independent quantum key distribution

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Abstract:
We study how long-distance device-independent quantum key distribution (DI QKD) can be implemented using realistic laboratory technology. Out approach exhibits favorable scaling of the secret key rate with channel loss, comparable to the advantages known from twin-field–type protocols. Our results indicate that device-independent key generation is achievable with detector performance available in modern superconducting platforms. The security analysis is carried out using the Entropy Accumulation Theorem, which allows us to obtain rigorous finite-size security guarantees. Importantly, we use a dedicated numerical tool based on this theorem that enables convenient security evaluation through a user-friendly, low-overhead workflow.

https://arxiv.org/abs/2507.23254
https://arxiv.org/abs/2506.18888

Optimality of universal conclusive entanglement purification protocols

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Abstract:
Entanglement purification is essential for quantum technologies; yet, rigorous bounds on the success probability for universal protocols -- those requiring no prior knowledge about the input state -- have remained underexplored. We establish such fundamental limits for conclusive protocols distilling perfect Bell states from pure two-qubit states by deriving the optimal success probability starting with: two copies of a state with known Schmidt basis, and four copies of a state with unknown Schmidt basis. We prove that a known protocol achieves these bounds, confirming its optimality. Crucially, universality imposes an inherent efficiency trade-off, yielding an average success probability of just 2/105 over Haar measure.

https://arxiv.org/abs/2509.09423

How typical is contextuality?

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Abstract:
Identifying when observed statistics cannot be explained by any reasonable classical model is a central problem in quantum foundations. A principled and universally applicable approach to defining and identifying nonclassicality is given by the notion of generalized noncontextuality. Here, we study the typicality of contextuality -- namely, the likelihood that randomly chosen quantum preparations and measurements produce nonclassical statistics. Using numerical linear programs to test for the existence of a generalized-noncontextual model, we find that contextuality is fairly common: even in experiments with only a modest number of random preparations and measurements, contextuality arises with probability over 99%. We also show that while typicality of contextuality decreases as the purity (sharpness) of the preparations (measurements) decreases, this dependence is not especially pronounced, so contextuality is fairly typical even in settings with realistic noise. Finally, we show that although nonzero contextuality is quite typical, quantitatively high degrees of contextuality are not as typical, and so large quantum advantages (like

for parity-oblivious multiplexing, which we take as a case study) are not as typical. We provide an open-source toolbox that outputs the typicality of contextuality as a function of tunable parameters (such as lower and upper bounds on purity and other constraints on states and measurements). This toolbox can inform the design of experiments that achieve the desired typicality of contextuality for specified experimental constraints.

https://arxiv.org/abs/2510.20722

Linear Program Witness for Network Nonlocality in Arbitrary Networks

Ana Belen Sainz
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Abstract:
Entanglement purification is essential for quantum technologies; yet, rigorous bounds on the success probability for universal protocols -- those requiring no prior knowledge about the input state -- have remained underexplored. We establish such fundamental limits for conclusive protocols distilling perfect Bell states from pure two-qubit states by deriving the optimal success probability starting with: two copies of a state with known Schmidt basis, and four copies of a state with unknown Schmidt basis. We prove that a known protocol achieves these bounds, confirming its optimality. Crucially, universality imposes an inherent efficiency trade-off, yielding an average success probability of just 2/105 over Haar measure.

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Measurable Third-Order Detection from an Affine Reduction Moment Matrix

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Abstract:
Randomized measurements make nonlinear state functionals accessible at non-tomographic cost, but the usefulness of low-order data for certifying entanglement is limited. We introduce a measurable third-order separability criterion obtained by a partial reduction acting on squre of affine sum of operators. It yields a compact 4×4 PT-symmetrized reduction--moment matrix $\bar M(\rho)$ built from second- and third-order invariants (including a PT-symmetrized cubic moment) and a single decision statistic $\mathcal{E}_4(\rho):=\lambda_{\min}(\bar M(\rho))$. We prove $\bar M(\rho)\succeq0$ for all separable states and show that $\mathcal{E}_4(\rho)$ can be estimated from single-copy randomized measurements with shot complexity $O(d_{\rm eff}^3/\epsilon^2)$. On $d\times d$ isotropic states we obtain a dimension-resolved moment-order separation: the best purely second-order purity test detects entanglement only for noise scaling $\sim d^{-1/2}$, whereas our third-order SOS criterion reaches $\sim 2/d$, approaching the PPT/separability boundary $\sim 1/d$.

Enhancing SPADE-based source discrimination through frequency measurements

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Abstract:
In recent years, spatial-mode demultiplexing has become a candidate for the practical implementation of quantum optimal measurement for source discrimination. This problem is relevant both in astronomy where one is interested in exoplanet detection and in microscopy where, e.g., one wants to distinguish different molecules with similar spectral properties. In our work, we examine the possibility of utilizing for this task not only spatial degrees of freedom of a photon but also its frequency. Our results show that for microscopic scenarios one can obtain a significant advantage over the typically considered quantum limit (obtained based on spatial degrees of freedom). However, the gain for exoplanet detection is minimal.

Generalised Process Theories

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Abstract:
Process theories provide a powerful framework for describing compositional structures across diverse fields, from quantum mechanics to computational linguistics. Traditionally, they have been formalized using symmetric monoidal categories (SMCs). However, various generalizations, including time-neutral, higher-order, and enriched process theories, do not naturally conform to this structure. In this work, we propose an alternative formalization using operad algebras, motivated by recent results connecting SMCs to operadic structures, which captures a broader class of process theories. By leveraging the string-diagrammatic language, we provide an accessible yet rigorous formulation that unifies and extends traditional process-theoretic approaches. Our operadic framework not only recovers standard process theories as a special case but also enables new insights into quantum foundations and compositional structures. This work paves the way for further investigations into the algebraic and operational properties of generalised process theories within an operadic setting.

https://arxiv.org/pdf/2502.10368

Quantum-Inspired Approaches for Bloch Surface Wave–Based Sensing

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Abstract:
Bloch Surface Waves (BSWs) supported by dielectric multilayer structures provide an attractive platform for sensing refractive index with high sensitivity, low loss and high-Q resonances. In this work, we examine the reflectance from a BSW multilayer stack designed for analyte (gas or liquid) sensing. The structure employs a Kretschmann configuration consisting of a substrate, eight alternating dielectric layers and a truncated top layer to support BSW excitation. The top layer interfaces the multilayer stack with the surrounding analyte medium.
Distinct and narrow reflectance dips corresponding to phase-matched excitation of the BSW are observed. The angular position of the resonance dip exhibits a measurable shift in response to variations in the real part of the refractive index of the analyte, enabling sensitive detection. In contrast, changes in the imaginary part of the refractive index influence the depth of resonance, providing additional information about the absorptive properties of the analyte. Our results demonstrate that wavelength-selective operation allows detection of specific gases or

liquids, with each wavelength corresponding to a particular analyte. Furthermore, we propose applying concepts from quantum metrology to improve resolution limits, enabling the detection of trace-level concentrations.

https://doi.org/10.3390/s130202011
https://doi.org/10.1364/OE.21.023331

Non-Markovian equations and approximate environments

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Abstract:
Accurate and efficient simulation of open quantum systems remains a significant challenge, particularly for Non-Markovian dynamics. We demonstrate the profound utility of expressing the environmental correlation function as a sum of damped sinusoidals within master equations. While not strictly required, this decomposition offers substantial benefits, crucially reducing the cost of Lamb-shift and decay rates calculations without sacrificing accuracy. Furthermore, this approach enables straightforward calculation of Lamb-shift corrections, bypassing the need for complex principal value integration. We show that these Lamb-shift effects are demonstrably non-negligible in heat transport scenarios, and are needed for an accurate description. Unlike in the Gorini-Kossakowski-Lindblad-Sudarshan(GKLS) master equation, the non-commuting nature of the Lamb-shift with the Hamiltonian in non-Markovian descriptions, coupled with GKLS's inaccuracies at early times, brings the necessity of Non-Markovian descriptions for finite-time thermodynamics. In the weak coupling regime, our Master Equation formulations with exponential decomposition achieve accuracy comparable to numerically exact methods. This methodology significantly simplifies and accelerates the simulation of non-Markovian dynamics in open quantum systems, offering a more reliable and computationally tractable alternative akin to a Global Master Equation.

https://arxiv.org/abs/2412.04705v2
https://arxiv.org/abs/2506.22346

Photon Efficiency of high-dimensional Quantum Key Distribution

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Abstract:
We theoretically analyze the extraction of multiple secret key bits from individual photon-pair detections using multiqubit QKD protocols.This is particularly relevant for photon-starved regime, where performance is limited by low source brightness and background radiation. By optimizing over the source intensity and the number of encoded qubits, we show that we show the finite limit of the photon efficiency. The multiqubit encoding can enhance the secret key rate by up to an order of magnitude compared to single-qubit schemes.

The resource theory of causal influence and knowledge of causal influence

Beata Zjawin
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Abstract:
Understanding and quantifying causal relationships between variables is essential for reasoning about the physical world. In this work, we develop a resource-theoretic framework to do so. Here, we focus on the simplest nontrivial setting--- two (classical) variables that are causally ordered, meaning that the first has the potential to influence the second. First, we introduce the resource theory that directly quantifies causal influence of a functional dependence in this setting and show that the problem of deciding convertibility of resources and identifying a complete set of monotones has a straightforward solution. Then, we introduce the resource theory that arises naturally when one has uncertainty about the functional dependence. We describe a linear program for deciding the question of whether one resource (i.e., probability distribution over functions) can be converted to another. Moreover, for the case where the variables are binary, we identify a triple of monotones that are complete. We provide an interpretation of these monotones and show that resourcefulness consists both of knowledge of the functional relations and of the degree of causal connectivity of the function relating the variables. Finally, we discuss how our resource theory connects to standard methods for quantifying cause-effect relations and Shannon theory, as well as its possible quantum generalization.

https://arxiv.org/abs/2512.11209