1970
University of Gdańsk 50th Anniversary
2020

INTERNATIONAL CENTRE FOR THEORY OF QUANTUM TECHNOLOGIES

International Centre for Theory of Quantum Technologies

Quantum Internships offer for Quantum Information Research Support Center

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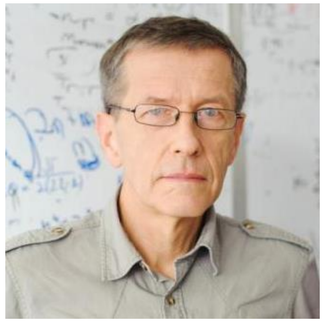
Research groups
Internships topics

Multiphoton Quantum Optics for Quantum Information Group

The broad aim of the group is to develop theoretical quantum information science of immediate experimental testability as well as to study the fundamental issues like causality, new concepts in theoretical quantum optics, and efficiency of quantum (optical) protocols.



Leader: **Marek Żukowski**

Specific goals of the group include:

- Operational translation of the schemes prosed by the other groups of ICTQT into experimental optical setups and feasibility studies.
- Direct collaboration with experimental teams of our IQOQI partner as well as other laboratories.
- Investigations concerning device-independent or self-testing quantum communication, quantum information processing schemes, aimed at commercialization.
- Search for new research avenues in quantum optics allowing demonstrations of quantum protocols or various kinds.
- New indicators of non-classicality in quantum optics.
- Application of theoretical/operational/experimental methods of quantum multiphoton interferometry to other processes of potential value for quantum communication and information processing.
- Quantum optical implementations of secure data transmission.
- Theory of optical test of quantum mechanics.

Keywords: quantum optics, multiphoton interferometry, reduction of communication complexity, foundations of quantum physics, quantum information, Bell's theorem, quantum optical circuits.

Quantum Cybersecurity and Communication Group

The broad aim of the group is to develop quantum solutions for problems in communication and information security.

Specific goals of the group include the development of:

- Quantum key distribution protocols with low hardware requirements.
- Quantum true random number generators.
- Existing and new quantum cryptographic primitives.
- Methods for secure communication and computation.
- Formal security proofs of quantum cryptographic protocols.
- Tools for cryptoanalysis.
- Commercialisation and industrial outreach.

Keywords: quantum cryptography, random number generation, cryptoanalysis, quantum communication, quantum key distribution, device-independent protocols.

Leader: **Marcin Pawłowski**

Research groups
Internships topics

Foundational Underpinnings of Quantum Technologies Group

The broad aim of the group is to understand the quantum manifestation of nonclassical phenomena, and how harness such nonclassicality for information processing. This is tackled from a novel perspective, combining an operational vision with the process-theoretic framework.

Leader: **Ana Belen Sainz**

Specific goals of the group include:

- Formulate candidate theories that supersede quantum.
- Study causality within and beyond quantum theory, from a process-theoretic perspective.
- Characterise the quantum manifestation of nonclassical phenomena.
- Develop resource theories to address quantification.
- Identify current and new forms of nonclassicality as resources for quantum technologies.
- Assess nonclassical speed-up for computation, within and beyond quantum theory.
- Contribute to the development of a systematic approach to quantum program optimisation based on the zx-calculus, by further developing the foundations of the latter.

Keywords: quantum contextuality, steering, causality, Bell's theorem, process theories, generalised probabilistic theories, quantum computational speedup, quantum networks, resource theories, post-quantum theories, post-quantum nonclassicality, zx-calculus.

New Quantum Resources Group

The broad aim of the group is research concerning quantum phenomena which could be used for quantum information processing.

Specific topics of the group include:

- Quantum randomness
- Causality and relativistic propagation of information
- Quantum non-Markovianity
- Quantum to classical transition including emergence of objectivity
- Nonstandard aspects of quantum metrology
- Quantum resources theory including multitasking
- Analysis of physical implementations of specific quantum tasks
- Bell inequalities and contextuality
- Ultimate limits of information processing based on physical principles

Leader: **Paweł Horodecki**

Keywords: quantum entanglement, quantum contextuality, quantum computational speedup, quantum capacity, quantum channels, communication complexity, violations of local realism, Bell's theorem, resource theories, quantum networks, quantum privacy, quantum randomness, randomness extraction.

Research groups Internships topics

Quantum Open Systems in Relation to Quantum Optics Group

The broad aim of the group is to build up understanding of the (quantum) thermodynamic properties of laser beams. The research will focus on analogies between open system dynamics and transmission of optical beams, and the thermodynamic context of indefinite causal order implemented in interferometric setups.

Leader: **Łukasz Rudnicki**

Specific goals of the group include:

- To study macroscopic models of evolution for laser beams, with special emphasis put on polarization, orbital angular momentum and spatial degrees of freedom.
- To study thermodynamic characterization of the optical beams.
- To reconsider known quantum thermodynamic models by adding the feature of indefinite causal order.
- To optimize metrological protocols leading to superresolution in spatial, spectral and temporal separation measurements.
- To improve the protocol of gate set tomography with regards to its intrinsic symmetries (so called gauge).

Keywords: open system dynamics, quantum optics, gate set tomography, indefinite causal order, laser beams, quantum metrology, superresolution, quantum random walks.

New Quantum Resources and Thermodynamics Group

The group deals with a broad spectrum of topics, related to such resources as „nonlocality”/contextuality, entanglement, randomness, athermality, and other related fundamental questions

Specific topics of the group include:

- Thermal operations
- The notion of work in micro regime
- Dynamical description of thermal quantum machines
- Limitations of Markovian evolution
- Contextuality/”nonlocality”
- Quantum gates, t-designs, random circuits
- Port based teleportation
- Quantum error correction
- Randomness amplification/extraction, secret key extraction
- Bell inequalities

Leader: **Michał Horodecki**

Keywords: quantum open systems, quantum thermodynamics, quantum resources, quantum computing, quantum communication, Bell inequalities.

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ICTQT emblematic goals

(1) Optimization of quantum setups

Experimentally friendly tests of quantumness

Efficient quantum tasks (communication, computing, metrology)

Self-testing devices for cybersecurity

(2) Unification of quantum thermodynamics

Thermodynamics in non-Markovian regime

Unambiguos notions of work and heat in micro-regime

Coarse grained thermodynamic description of quantum fields

(3) Development of quantum resources

Identification of new quantum resources

Quantification and resource conversion

Harnessing resources for efficient quantum tasks

(4) Towards the unknown

Creation and pursuit of new ideas beyond the current knowledge and beyond the agenda of ICTQT

ICTQT as an open forum for fundamental challenges.

Additional information

Offered internships:

- October/November 2021 (I round, 3 positions up to 6 months each),
- February/March 2022 (II round, 3 positions up to 6 months each).

ICTQT provides support in the field of organization of accommodation, administrative support with regard to the procedures necessary to admit a trainee and guarantees friendly, inspiring, interdisciplinary environment, including “entanglement” with National Centre for Quantum Information (KCIK) and Institute for Theoretical Physics and Astrophysics (IFTiA) at UG.

Host institution: International Centre for Theory of Quantum Technologies, University of Gdańsk, Wita Stwosza 63, Gdańsk, Poland

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