STIPEND OFFER no. PhD_student_MH_2024_2

Position in the project:	**PhD position in project OPUS no. 2021/41/B/ST2/03207**
Scientific discipline:	quantum physics
Involvement type:	Stipend contract
Number of positions offered:	2
Remuneration:	**monthly stipend** (scholarship amount not lower than PLN 1,000, awarded in accordance with the regulations for awarding scholarships in the project: https://ncn.gov.pl/sites/default/files/pliki/uchwaly-rady/2019/uchwala25_2019-zal1_ang.pdf)
Position starts on:	For candidates who are already doctoral students the starting date is negotiable (the fastest possible date for starting work on the project is April 2024). For candidates who aren't doctoral students and already have an MSc degree and candidates who plan to defend their MSc thesis no later than July 31, 2024, position starts on October 1st 2024.
Maximum period of contract	12 months (with possibility of extension)
Institution:	**International Centre for Theory of Quantum Technologies,** **University of Gdansk, Poland**
Project leader:	**Prof. dr hab. Michał Horodecki**
Project title:	**"Quantum open systems and thermodynamical resource theory"** *The project is financed within the OPUS 21 program by the National Science Center.*
Offer description:	We are looking for **two PhD students** to work in the New Quantum Resources and Thermodynamics Group of the International Centre for Theory of Quantum Technologies (ICTQT), hosted by the University of Gdansk (UG) – a pioneering and leading center of quantum information research in Poland. The positions are offered within the implementation of the OPUS 21 project entitled "Quantum open systems and thermodynamical resource theory (Polish: Kwantowe układy otwarte i termodynamiczna teoria zasobów)". The project is financed by the National Science Centre (NCN). **<u>About the "Quantum open systems and thermodynamical resource theory" project</u>** The aim of the project is to develop dynamical and kinematic approaches to quantum thermal machines. In dynamical approach, evolution is described by Hamiltonian (or derived from it evolution equations) while in kinematic approach the processes are described by discrete unitary transformations, or completely positive maps executed by external agent, belonging to a suitable (thermodynamically motivated) class. I.e. by kinematic approach we mean resource theoretic approach to quantum thermodynamics. The two approaches are complementary. The dynamical approach is close to the physical realm of quantum thermal machines, but often requires numerics, and usually does not

allow for proving general statements – one has to usually confine to specific models. The kinematic approach – inheriting methods from quantum information - although often does not refer to common experimental situations, allows to obtain analytical results, especially concerning limitations as well as optimization over possible processes. Thus is it important to develop both approaches and possible interconnections. The main objectives will be contained in the following tasks: dynamics, kinematics and interconnections.

Dynamics

We plan to re-examine the present results on thermodynamics of microscopic systems in the weak coupling non-Markovian regime. Our main tool is newly developed weak coupling non-Markovian dynamical equation (regularized cumulant equation). In particular, we want to solve an open problem of a description of heat flow for two systems coupled to two baths, so that it is consistent with thermodynamics (e.g. reproducing the known truth that heat flows from the hot bath to cold bath) for full range of coupling between the systems. Our working hypothesis is that the regularized cumulant equation will properly describe the thermodynamics of such scenario. Another topic is to analyse two systems operating as a heat engine, again, for parameters, for which no description consistent with thermodynamics is known. One of basic challenges will be to find proper description of heat currents in the non-Markovian weak coupling regime.

Kinematics

We plan to develop understanding of thermodynamical processes within the resource-theoretic approach. This includes: the relations between fluctuations and dissipation in the second order asymptotic limit; the problem of definition of work for explicit work reservoir possessing ground state; the long-standing unsolved problem of embezzling (related to Planck-Kelvin formulation of the Second Law). Selected working hypotheses are:

(i) the resource-theoretic fluctuation-dissipation relation identified recently by PI and coworkers holds for general states,

(ii) for states of work reservoir flat enough far from ground state average energy change give appropriate description work; while this hypothesis is implicitly assumed, apart from initial study by PI and coworkers no quantitative results are known – our main task will be to provide ones,

(iii) for suitable scaling of catalyst error, the catalytic processes with small error on catalyst, will obey near identical laws as without error on catalyst at all.

Interconnections

We plan to seek for a connection between resource theoretic and dynamical models of quantum thermal machines. This includes seeking for a mapping from discrete models of thermal machines to autonomous ones. We want also to seek for a connection between fluctuation-dissipation theorem in open systems and the resourcetheoretic fluctuation dissipation relations. We shall also aim at developing foundations for definition of work within resource-theoretic picture, and apply the results in dynamical picture.

Keywords: quantum thermodynamics, open systems, quantum heat engines, thermal operations, resource theory, quantum batteries.

If you would like any further details about the project, the advertised positions, or life in Gdańsk then please feel free to get in contact michal.horodecki@ug.edu.pl for a chat.

	About the group The group New Quantum Resources and Thermodynamics deals with a broad spectrum of topics, related to such resources as nonlocality/contextuality, entanglement, randomness, athermality, and others. broad aim of the New Quantum Resources Group would be to perform research concerning quantum phenomena that could be used for quantum information processing. **Specific research tasks of the group include:** 1. Quantum open systems and quantum thermodynamics a. Open problems on Thermal Operations. b. Efficiencies of engines based on Thermal Operations. c. The notion of work in micro regime; quantum batteries. d. Dynamical description of thermal quantum machines in various systems, including solar cells, thermoelectric generators, life-harvesting systems. e. Thermodynamics with explicit battery; fluctuation relations. f. Study limitations of Markovian evolution in thermodynamical context. 2. Resources for quantum computing: a. Contextuality/nonlocality, their relation to quantum speedup (in collaboration with NRQ). b. Quantum gates, t-designs, random circuits. c. POVMs – their power versus von Neumann measurements and application to quantum algorithms. 3. Quantum communication: a. Port based teleportation – various variants, related group representation problems. b. Quantum error correction. c. Randomness amplification/extraction, secret key extraction (in collaboration with NRQ). 4. Bell inequalities a. Employing graph theoretic tools. b. Large violation. **About ICTQT** ICTQT was created in 2018 within the International Research Agendas Programme of the Foundation for Polish Science co-financed by the European Union from the funds of the Smart Growth Operational Programme, axis IV: Increasing the research potential (Measure 4.3). The founders of ICTQT are Marek Żukowski (the director) and Paweł Horodecki (the research group leader). The Centre's official partner is IQOQI-Vienna of the Austrian Academy of Sciences. **The Centre consists of 6 groups:** Multiphoton Quantum Optics for Quantum Information (leader Marek Żukowski); New Quantum Resources (leader Paweł Horodecki); Foundational Underpinnings of Quantum Technologies (leader Ana Belen Sainz); New Quantum Resources and Thermodynamics (leader Michał Horodecki); Quantum Cybersecurity and Communication (leader Marcin Pawłowski); Quantum Open Systems in Relation to Quantum Optics (leader Łukasz Rudnicki). More about the research groups please find at you will find here: https://ictqt.ug.edu.pl.
Key responsibilities include:	1. Fulfilling the duties of a doctoral school participant following the study program. 2. Active scientific research. 3. Presentation and discussion of ideas and results with a diverse audience at the ICTQT and the external events. 4. Active participation in seminars, group meetings, etc. organized by the ICTQT.

Profile of candidates/requirement	1. The candidate should hold a MSc degree in physics. 2. The candidate should be interested in quantum open systems. 3. The candidate should be committed to working collaboratively within an inclusive and diverse environment. 4. Basic knowledge of quantum theory is required. 5. Experience in numerical simulations of physical system is appreciated.
We offer:	1. Monthly stipend. 2. Work in a rapidly developing unit the International Centre for Theory of Quantum Technologies at the University of Gdansk. 3. Scientific and organizational support. 4. Basic equipment and core facilities. 5. Travel funds for scientific collaboration and participation in conferences. 6. Friendly, inspiring, interdisciplinary environment.
Required documents:	All required documents should be prepared in English: 1. Recruitment form. 2. Curriculum vitae. 3. Motivation letter (including a statement of current scientific interests) – up to 2 pages. 4. Documents confirming scientific degrees (scan of diploma); 5. The reference letter about the candidate sent directly by one senior researcher (the candidate is expected to contact the referee and ask him/her to send the reference letter directly to ictqt-careers@ug.edu.pl. The letter must be sent before the deadline).
Recruitment process:	1. The recruitment procedure has three stages: ○ Pre-selection candidates by the Selection Commission (SC), based on sent documents; ○ Interview of pre-selected candidates by SC; ○ Recruitment to the UG Doctoral School of Natural Sciences or the UG Doctoral School of Quantum Information Theory (a formal procedure). 2. A PhD student position is offered to candidates who have received an MSc degree and who are already PhD students at Universities/Institutions. 3. A PhD student position is also offered to candidates who plan to defend their MSc thesis no later than July 2024. 4. An interview is expected in March 2024. 5. ICTQT Selecting Commission (SC) reserves the right to invite for the interview only pre-selected candidates. 6. SC's decision is final and is not subject to appeal. 7. SC reserves the right to close the competition without selecting a candidate. 8. The decision will be made by SC within 1 month from the date of recruitment completion. 9. In the event of resignation from accepting the position of the selected candidate, the SC has the right to send the offer to the person placed on the reserve list, and in the absence of such a list, the SC has the right to reconsider the applications submitted to the competition and to indicate a new candidate application submitted to the competition and to indicate a new candidate.
Submit application to:	ictqt-careers@ug.edu.pl
Application deadline:	March 11, 2024