International Centre for Theory of Quantum Technologies

Uniwersytet Gdański

CENTRE FOR QUANTUM OPTICAL TECHNOLOGIES

UNIVERSITY OF WARSAW

QUANTUMSPEEDUP

November 20th-22nd, 2023, Gdańsk

Book of Abstracts

European Funds Smart Growth

Republic of Poland

FNP Foundation for Polish Science

European Union European Regional Development Fund

QUANTUMSPEEDUP

November 20th-22nd, 2023, Gdańsk

Venue: University of Gdańsk, Kładki Street, 24, 80-822 Gdańsk

Programme

Monday, November 20th, 2023		
16:30	Registration	
18:00	**Official opening**	
18:30	Welcome dinner	
Tuesday, November 21st, 2023		
9:30	Registration & Morning coffee	
10:30	**Organizational announcements**	
	Tuesday SpeedTalk Sessions	
10:35 – 11:00	**SpeedTalks I**	
	Tomasz Linowski (ICTQT, UG)	**Seungbeom Chin** (ICTQT, UG / SKKU)
	Ekta Panwar (ICTQT, UG)	**Piotr Mironowicz** (US)
	Anubhav Chaturvedi (ICTQT, UG / GUT)	**Konrad Schlichtholz** (ICTQT, UG)
	Vinicius Rossi (ICTQT, UG)	**Giuseppe Viola** (ICTQT, UG)
	Break & Discussion time	
11:20 – 11:45	**SpeedTalks II**	
	Ankit Kumar (ICTQT, UG)	**Matheus Eiji Ohno Bezerra** (UF do ABC/ UW)
	Pawel Halavach (QOT, UW)	**Robert Okuła** (GUT)
	Bartosz Kasza (QOT, UW)	**Otavio A. D. Molitor** (ICTQT, UG)
	Sumit Rout (ICTQT, UG)	**Michał Banacki** (ICTQT, UG)
	Break & Discussion time	
12:05 – 12:30	**SpeedTalks III**	
	Marcin Pawłowski (ICTQT, UG)	**Borhan Ahmadi** (ICTQT, UG)
	Marcin Jarzyna (QOT, UW)	**Nitica Sakharwade** (ICTQT, UG)
	Alejandro Jenkins (ICTQT, UG)	**Karol Horodecki** (ICTQT / IFTiA, UG)
	Marcin Markiewicz (ICTQT, UG)	**Rishav Sagar** (ICTQT, UG)
	Lunch Break	
15:00 – 17:30	**Tuesday Poster Session**	

Wednesday, November 22nd, 2023		
9:30	Registration & Morning coffee	
10:30	**Organizational announcements**	
	Wednesday SpeedTalk Sessions	
10:35 – 11:00	**SpeedTalks IV**	
	Marek Winczewski (ICTQT, UG)	**Crislane de Brito** (WFAiIS, NCU)
	Wojciech Bruzda (CFT PAN)	**Giovanni Scala** (ICTQT, UG)
	Marcin Wieśniak (ICTQT / IFTiA, UG)	**Some Sankar Bhattacharya** (ICTQT, UG)
	Marcin Łobejko (ICTQT / IFTiA, UG)	**Fattah Sakuldee** (ICTQT, UG)
	Break & Discussion time	
11:20 – 11:50	**SpeedTalks V**	
	Pedro Dieguez (ICTQT, UG)	**Susane Calegari** (CFT PAN)
	Roberto Dobal Baldijão (ICTQT, UG)	**Paweł Mazurek** (ICTQT, UG)
	Andre Hernandes Alves Malavazi (ICTQT, UG)	**Akshata Shenoy** (ICTQT, UG)
	Marcin Karczewski (ICTQT, UG)	**Last minute speedtalk!**
	Alexandre Orthey (CFT PAN)	**Last minute speedtalk!**
11:50	**Group photo**	
	Lunch Break	
14:30 – 17:00	**Wednesday Poster Session**	
17:00	Closing remarks	

Acronyms

UG – University of Gdańsk
ICTQT – International Centre for Theory of Quantum Technologies
IFTiA – Institute of Theoretical Physics and Astrophysics
WMFiI - Department of Mathematics, Physics and Informatics
UW – University of Warsaw
QOT – Centre for Quantum Optical Technologies, Centre of New Technologies
NCU - Nicolaus Copernicus University in Toruń
WFAiIS - Faculty of Physics, Astronomy and Informatics
CFT PAN – Center for Theoretical Physics, Polish Academy of Sciences
KCIK – National Quantum Information Centre
SKKU – Sungkyunkwan University, South Korea
UF do ABC - Universidade Federal do ABC, Brazil
US - University of Stockholm, Sweden

Committees

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SpeedTalk Session I – 21/11/2023

Dissipative evolution of quantum Gaussian states

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

Abstract:
Recent works on quantum resource theories of non-Gaussianity, which are based upon the type of tools available in contemporary experimental settings, put Gaussian states and their convex combinations on equal footing. Motivated by this, in this article, we derive a new model of dissipative time evolution based on unitary Lindblad operators which, while it does not preserve the set of Gaussian states, preserves the set of their convex combinations, i.e. so-called quantum Gaussian states. As we demonstrate, the considered evolution proves useful both as a description for random scattering and as a tool in dissipator engineering.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2105.12644

Robust self-testing of Bell inequalities tilted for maximal loophole-free nonlocality

Ekta Panwar
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
The amount of nonlocality measured by the violation of Bell inequalities is crucial to real-world applications. In the presence of inefficient detectors, for any given Bell inequality, the quantum strategies which maximally violate its tilted (based on detection efficiencies) version attain the maximum (detection) loophole-free nonlocality. We study the self-testing properties of the tilted versions of the CHSH inequality. Even high levels of the Navascu\'es--Pironio--Ac\'in hierarchy are insufficient to saturate the maximum quantum violation of the titled CHSH inequalities for all detection efficiencies. Consequently, self-testing via the standard sum of squares decomposition method is arduous and impractical. Instead, we obtain self-testing statements and the analytical form of optimal strategies via a novel Jordan's lemma-based proof technique. Finally, we demonstrate the robustness of these self-testing statements. Our results shed new light on the geometry of the quantum set of nonlocal correlations in the simplest scenario, highlighting the complexity of its characterization.

Extending loophole-free nonlocal correlations to arbitrarily large distances

Anubhav Chaturvedi
Gdańsk University of Technology
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
The detection loophole, particularly the critical detection efficiencies of the spatially separated measurement devices, severely limit the distances over which nonlocal quantum correlations can be sustained in state-of-the-art

Bell experiments. Instead of looking for quantum strategies with marginally lower threshold requirements, we exploit the properties of loophole-free nonlocal correlations, which are experimentally attainable today, albeit at short distances, to extend them over arbitrarily large distances. Specifically, we consider Bell experiments wherein the spatially separated parties randomly choose the location of their measurement devices in addition to their measurement settings. We demonstrate that when devices close to the source are perfect and witness extremal loophole-free nonlocal correlations, such correlations can be extended to devices with almost-zero detection efficiency and visibility placed arbitrarily far from the source. We then derive an analytic trade-off specific to the Clauser-Horne-Shimony-Holt Bell inequality: the higher the loophole-free nonlocality close to the source, the lower the threshold requirements away from the source. We utilize this trade-off and optimal quantum strategies to estimate the critical requirements of a measurement device placed away from the source. Finally, we formulate a versatile numerical method utilizing certifiable randomness to measure the nonlocal behaviour of individual measurement devices and estimate their critical parameters in generic network scenarios entailing several spatially separated measurement devices.

https://doi.org/10.48550/arXiv.2211.14231

A linear program for testing nonclassicality, its implementation and an application

Vinicius Rossi
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
A well-motivated method for demonstrating that an experiment resists any classical explanation is to show that its statistics violate generalized noncontextuality. We formulate this problem as a linear program and provide an open-source implementation of it which tests whether or not any given prepare-measure experiment is classically-explainable in this sense. If it is not, the implementation computes the minimal amount of noise that must be added such that a noncontextual ontological model does exist and then provides this model. We then apply this program to the investigation of the robustness of contextuality to partially dephasing noise in a scenario related to state discrimination (for which contextuality is a resource). We find that a vanishing amount of coherence is sufficient to demonstrate the failure of noncontextuality in this scenario, and we give a proof of contextuality that is robust to arbitrary amounts of partially dephasing noise. This is in stark contrast to partially depolarizing noise, which is always sufficient to destroy contextuality.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2204.11905, https://arxiv.org/abs/2212.06856

Graph Picture for the Heralded Non-Destructive Generation of Bosonic N-partite Entanglement

Seungbeom Chin
Sungkyunkwan University, South Korea
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
Heralded entanglement generated among identical particles is a useful resource for quantum computations, as heralded schemes distinguish experimental runs producing target states without direct measurement. Nonetheless, these heralded schemes generally entail the incorporation of supplementary particles and modes, thus amplifying

the design intricacy. In response to this challenge, our recent work (arXiv:2211.04042) introduced a graph approach for systematic heralded scheme design, which provided several graphical schemes (dubbed “sculpting bigraphs”) for creating multipartite boson entanglement with boson subtractions. However, an indispensable intermediate step remains essential to transmute these sculpting bigraphs into practical heralded entanglement generation circuits: the proposition of heralded subtraction operators (herein dubbed “subtractors”). Assembling the subtractors under the guidence of the sculpting bigraphs, we can seamlessly design heralded schemes for multipartite entangled states.
Our study establishes a set of translation rules, enabling the mapping of sculpting bigraph elements into linear optical networks through the incorporation of heralded subtractors. Consequently, we devise heralded schemes for the N-partite GHZ state with 2N photons, N-partite W state with (2N+1) photons, and N=3 Type 5 state (the superpostion of N=3 GHZ and W states) with 9 photons. Our results demonstrate that the process of designing heralded schemes for generating entanglement is simplified into the task of searching for suitable sculpting bigraphs.

https://arxiv.org/pdf/2310.10291.pdf

Experimental certification of more than one bit of quantum randomness in the two inputs and two outputs scenario

Piotr Mironowicz
University of Stockholm, Sweden

Abstract:
One of the striking properties of quantum mechanics is the occurrence of the Bell-type non-locality. They are a fundamental feature of the theory that allows two parties that share an entangled quantum system to observe correlations stronger than possible in classical physics. In addition to their theoretical significance, non-local correlations have practical applications, such as device-independent randomness generation, providing private unpredictable numbers even when they are obtained using devices delivered by an untrusted vendor. Thus, determining the quantity of certifiable randomness that can be produced using a specific set of non-local correlations is of significant interest. In this paper, we present an experimental realization of recent Bell-type operators designed to provide private random numbers that are secure against adversaries with quantum resources. We use semi-definite programming to provide lower bounds on the generated randomness in terms of both min-entropy and von Neumann entropy in a device-independent scenario. We compare experimental setups providing Bell violations close to the Tsirelson's bound with lower rates of events, with setups having slightly worse levels of violation but higher event rates. Our results demonstrate the first experiment that certifies close to two bits of randomness from binary measurements of two parties. Apart from single-round certification, we provide an analysis of finite-key protocol for quantum randomness expansion using the Entropy Accumulation Theorem and show its advantages compared to existing solutions.

https://arxiv.org/abs/2303.07460

Single-photon based Quantum Key Distribution secure against no-signaling eavesdropping

Konrad Schlichtholz
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
The problem of secure communication is one of the most important ones when aiming at providing safety to modern society. In our work we present a single-photon based device-independent quantum key distribution scheme secure

even against no-signaling eavesdropping. Our protocol links basic features of the first two emblematic protocols, BB84 and Ekert91, namely the secret key is distributed by a single photon, however, the security is provided by the observation of Bell non-classicality in the setup. The security analysis in the proposed scheme is based on a decomposition of the correlations into extremal points of a non-signaling polytope which allows for identification of the optimal strategy of eavesdropping. Upon this strategy, the key rate is calculated, which is then connected with the violation of a specific Clauser-Horne inequality.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

Quantum Advantage for Rendezvous and Domination Tasks on Graphs with Mobile Agents

Giuseppe Viola
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
This work explores the application of quantum non-locality, a renowned and unique phenomenon acknowledged as a valuable resource. Focusing on a novel application, we demonstrate its quantum advantage for mobile agents engaged in specific distributed tasks without communication. The research addresses the significant challenge of rendezvous on graphs and introduces a new distributed task for mobile agents grounded in the graph domination problem. Through a thorough investigation across various graph scenarios, we showcase the quantum advantage. Additionally, we scrutinize deterministic strategies, highlighting their comparatively lower efficiency compared to quantum strategies. This work concludes with a detailed numerical analysis, providing further insights into our findings.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

SpeedTalk Session II – 21/11/2023

Probing Modified Gravity with Entanglement of Microspheres

Ankit Kumar
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
While a wide variety of astrophysical and cosmological phenomena suggest the presence of Dark Matter, all evidence remains via its gravitational effect on the known matter. As such, it is conceivable that a modification to gravitation or concepts of inertia could explain the observations. Since quantum particles naturally source weak gravitation, their non-relativistic dynamics offers opportunities to test this small acceleration regime. We show that two nearby quantum particles accumulate a significantly larger position-momentum entanglement in modified gravity models. We demonstrate how the temperature can be fine-tuned such that these effects are certified simply by witnessing the entanglement generated from uncorrelated thermal states, eliminating the need for precise noise characterisation.

https://arxiv.org/abs/2306.14938

Construction of diode laser system with generation of pulses for optical-microwave converter

Pawel Halavach
Centre for Quantum Optical Technologies (QOT), Centre of New Technologies, University of Warsaw

Abstract:
My work presents an instruction for constructing a diode laser system with pulse generation capability. This system is a component of an optical-microwave converter, operating on Rydberg atoms and laser pulses, enabling the combination of microwave radiation with infrared radiation. By definition, Rydberg atoms have at least one electron that is excited to a very high energy level. Atoms at this level become sensitive to a microwave field, which excites them to a higher Rydberg level. An optical-microwave converter works on this principle. It consists of a vacuum cell with warm Rubidium atoms and three lasers illuminating it. The first two lasers excite the Rubidium atoms to Rydberg levels. As soon as the excited atoms absorb microwave radiation, the third laser causes forced emission of an infrared wave. The purpose of my work is to modify one of the Rubid excitation lasers to the Rydberg level with the ability to generate pulses. It will be used in an optical-microwave converter, operating on laser pulses. This will accurately time the finding of Rubidium atoms at each energy level. Also this will increase conversion efficiency by reducing the exposure of atoms. For the laser setup and configuration of the of the beam coming out of it, I calibrated and used an instrument for measuring and controlling beam parameters, which consists of a Raspberry Pi 4 model B platform and an HQ Camera V1.0. Using a lens system and anamorphic prisms, I corrected the beam size and it propagation in space. I then set up the acousto-optic modulator, which generates laser pulses, and I made its frequency characteristics. Finally, a diode laser system was obtained with three fiber optic outputs: two unmodulated beam outputs for laser calibration or reference, and one modulated beam output with pulse generation capability, which will be used in an optical-microwave converter. My work was done under the guidance of Wojciech Wasilewski and Michał Parniak.
The “Quantum Optical Technologies” (MAB/2018/4) project is carried out within the International Research Agendas programme of the Foundation for Polish Science co-financed by the European Unionunder the European Regional Development Fund.

Simultaneous estimation of loss and phase delay in quantum optical interferometry

Bartosz Kasza
Centre for Quantum Optical Technologies (QOT), Centre of New Technologies, University of Warsaw

Abstract:
In this work, I studied simultaneous estimation, which is a procedure where we estimate multiple parameters within a single measurement. The object of study was a Mach-Zehnder interferometer with losses and phase shift in one arm and a second ideal reference arm. I showed that for a Mach-Zehnder interferometer, taking as the total cost the sum of the variance of the loss estimators and the phase delay, we are able to find a certain regime of parameters as well as experimental conditions in which the simultaneous strategy allows estimation with less variance than in the resource-sharing strategy, where we estimate separately with the same average number of photons used.

A Novel Instance of Unbounded Quantum Advantage

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

Abstract:
We investigate the one-way zero-error classical and quantum communication complexities for a class of relations induced by a distributed clique labelling problem. We consider two variants: 1) the receiver outputs an answer

satisfying the relation - the traditional communication complexity of relations (CCR) and 2) the receiver has non-zero probabilities of outputting every valid answer satisfying the relation (equivalently, the relation can be fully reconstructed), that we denote the strong communication complexity of the relation (S-CCR). We prove that for the specific class of relations considered here when the players do not share any resources, there is no quantum advantage in the CCR task for any graph. On the other hand, we show that there exist, classes of graphs for which the separation between one-way classical and quantum communication in the S-CCR task grows with the order of the graph m, specifically, the quantum complexity is O(1) while the classical complexity is Ω(log m). Secondly, we prove a lower bound (that is linear in the number of cliques) on the amount of shared randomness necessary to overcome the separation in the scenario of fixed restricted communication and connect this to the existence of Orthogonal Arrays. Finally, we highlight some applications of this task to semi-device-independent dimension witnessing and the detection of Mutually Unbiased Bases.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2305.10372

Families of bosonic suppression laws beyond the permutation symmetry principle

Matheus Eiji Ohno Bezerra
Universidade Federal do ABC, Brazil
University of Warsaw

Abstract:
Exact cancellation of quantum amplitudes in multiphoton interferences with Fock states at input, the so-called suppression or zero transmission laws generalizing the Hong-Ou-Mandel dip, are useful tool in quantum information and computation. It was recently suggested that all bosonic suppression laws follow from a common permutation symmetry in the input quantum state and the unitary matrix of interferometer. By using the recurrence relations for interference of Fock states, we find a wealth of suppression laws on the beamsplitter and tritter which are not explained by the permutation symmetry principle. Our results reveal that in interference with Fock states on unitary multiports there are whole families of suppression laws for arbitrary total number of bosons even on asymmetric unitary multiports, beyond the previously formulated permutation symmetry principle.

https://arxiv.org/abs/2301.02192

How decoherence impact the security of BB84

Robert Okuła
Gdańsk University of Technology

Abstract:
We present how the mechanisms of quantum Darwinism should allow for the leakage of information in standard BB84 quantum transmission and measurement process. We investigate how much of the information about the results crucial for the cryptographic key to be kept unknown can be leaked during the process and subsequently how much of that information can be later used by the third party to obtain such information using a type of Van Eck side-channel wiretapping. We also show how this can be affected by the way different environmental layers (e.g. rooms or other divisions that can affect the spread in the environment) and their interaction.

Salient signatures of entanglement in the surrounding environment

Otavio A. D. Molitor
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
We develop a model in which presence of entanglement in a quantum system can be confirmed through coarse observations of the environment surrounding the system. This counter-intuitive effect becomes possible when interaction between the system and its environment is proportional to an observable being an entanglement witness. While presenting intuitive examples we show that:

i) a cloud of an ideal gas, when subject to a linear potential coupled with the entanglement witness, accelerates in the direction dictated by the sign of the witness;
ii) ii) when the environment is a radiation field, the direction of dielectric polarization depends on the presence of entanglement;
iii) iii) quadratures of electromagnetic field in a cavity coupled with two qubits (or a four-level atom) are displaced in the same manner.

The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2209.05197

On steering in the C*-algebraic framework

Michał Banacki
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
We discuss a scenario of bipartite steering with local subsystems of the parties modeled by certain operator algebras. In particular, we formalize the notion of quantum assemblages in a commuting observables paradigm and focus on equivalent descriptions of such objects providing a systematic analysis of previously scattered approaches. We provide necessary and sufficient conditions for the equivalence of quantum commuting and tensor models that is stable under extensions of the trusted subsystem by arbitrary finite-dimensional ancillae. Finally, we provide no-go results concerning the possibility of post-quantum steering in this most general bipartite paradigm and discuss related corollaries concerning free probability and operator system approach.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2306.14344

SpeedTalk Session III – 21/11/2023

New paradigms for device inependent security

Marcin Pawłowski
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk
Abstract:
Device Independent (DI) cryptography claims to provide secure communication without any trust in the devices that the parties are using. It is a beautiful concept but hardly practical. Current experimental realizations are very slow and have limited range, which makes them useless in real-life applications. Moreover, there are no possibilities in sight that would change this in foreseeable future. One of possible solutions lies in Semi-DI cryptography, which makes some assumptions about the devices used. These can include a bound on the dimension of the Hilbert space of system communicated or trust in some of the devices used. However, such assumptions are very difficult to justify. In this presentation I propose two different DI protocols which have assumptions that are easy to justify in practice. These solutions combine security of full DI with the greater ease of implementation of Semi-DI.
The work was partially supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

Signal amplification in quantum key distribution

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

Abstract:
Transmission losses through optical fibers are one of the main obstacles preventing both long-distance quantum communications and continuous-variable quantum key distribution. A standard way to restore the signal in conventional classical communication is optical amplification. In this work, we address a quantum key distribution protocol over a multispan link employing either phase-insensitive or phase-sensitive amplifiers. We perform security analysis under both unconditional and practical security frameworks by assuming in the latter case only a single span of the whole communication link to be untrusted. We identify the enhancement in key generation rate introduced by optical amplification in both scenarios.

https://arxiv.org/pdf/2309.08041.pdf

The Josephson junction as a quantum engine

Alejandro Jenkins
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
We treat the Cooper pairs in the superconducting electrodes of a Josephson junction (JJ) as an open system, coupled via Andreev scattering to external baths of electrons. The disequilibrium between the baths generates the direct-current bias applied to the JJ. In the weak-coupling limit we obtain a Markovian master equation that provides a simple dynamical description consistent with the main features of the JJ, including the form of the current-voltage characteristic, its hysteresis, and the appearance under periodic voltage driving of discrete Shapiro steps. For small dissipation, our model also exhibits a self-oscillation of the JJ's electrical dipole with frequency $\Omega=2eV/\hbar$ around

mean voltage V. This self-oscillation, associated with "hidden attractors" of the nonlinear equations of motion, explains the observed production of monochromatic radiation with frequency Ω and its harmonics. We argue that this picture of the JJ as a quantum engine resolves open questions about the Josephson effect as an irreversible process and could open new perspectives in quantum thermodynamics and in the theory of dynamical systems.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2302.04762

Generalization of Gisin's Theorem to Quantum Fields

Marcin Markiewicz
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
We generalize Gisin's theorem on the relation between the entanglement of pure states and Bell non-classicality to the case of mode entanglement of separated groups of modes of quantum fields extending the theorem to cover also states with undefined particle number. We show that any pure state of the field which contains entanglement between two groups of separated modes violates some Clauser-Horne inequality. In order to construct the observables leading to a violation in the first step, we show an isomorphism between the Fock space built from a single-particle space involving two separated groups of modes and a tensor product of two abstract separable Hilbert spaces spanned by formal monomials of creation operators. In the second step, we perform a Schmidt decomposition of a given entangled state mapped to this tensor product space and then we map back the obtained Schmidt decomposition to the original Fock space of the system under consideration. Such obtained Schmidt decomposition in Fock space allows for construction of observables leading to a violation of the Clauser-Horne inequality. We also show that our generalization of Gisin's theorem holds for the case of states on non-separable Hilbert spaces, which physically represent states with actually infinite number of particles. Such states emerge, for example, in the discussion of quantum phase transitions. Finally, we discuss the experimental feasibility of constructed Bell test and provide a necessary condition for realizability of this test within the realm of passive linear optics.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2308.14913

Non-reciprocal Quantum Batteries

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

Abstract:
Non-reciprocal approach has found many promising applications in distinct fields of quantum technologies. Here, we examine its application in the performance improvement of charging process of a quantum battery. By breaking the time-reversal symmetry of the evolution we activate nonreciprocal flow of energy from the quantum charger to the quantum which allows for considerable enhancement of accumulation of energy in the quantum battery. To

establish the non-reciprocity in the evolution of the charging process we use a waveguide connecting the charger to the battery. We prove that when no dissipation is present in the charging process the presence of non-reciprocity causes a substantial increase in the energy of the battery by 4 times and interestingly this positive effect of non-reciprocity remains noticeable even when the dissipation rates of energy of the charger and the battery increase. More interestingly, we show that to obtain the maximum accumulation of energy in the battery the dissipation rate of the waveguide must be equal to the square root of the product of the dissipation rates of the charger and the battery.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

How can models of Indefinite Causality be understood within the Causaloid Framework

Nitica Sakharwade
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
Towards the studies of Indefinite Causality from a post-quantum lens, a few frameworks have been proposed and studied. The Process Matrix Framework is one such framework that generalises quantum channels to process matrices. This framework has been vastly studied due to the direct applicability of known quantum information tools. Another framework, that chronologically preceded the process matrices is the Causaloid Framework which starts from a more general starting point and can be thought of as incorporating Generalised Probability Theories as well as Indefinite Causality. The Framework has been worked on more recently in my PhD thesis to be made more accessible. Further a hierarchy within the Causaloid Framework that is distinct from Sorkin's hierarchy, that depends on composition has been introduced. A natural question arises as to how the Process Matrix Formalism and the Causaloid Framework are related and how they can be understood through the introduced hierarchy. We answer this question by showing how the bipartite Process Matrices are a special instance in the Causaloid Framework. This ongoing work helps fill a theoretical gap in the literature and understanding Indefinite Causality from the lens of Generalised Probability Theories helps us make attempts towards an axiomatic approach to Indefinite Causality. Based on N. Sakharwade, An Operational Road towards Understanding Causal Indefiniteness within Post-Quantum Theories, 2022 and ongoing work.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://uwspace.uwaterloo.ca/handle/10012/17841

The rank of contextuality

Karol Horodecki
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk
Institute of Theoretical Physics and Astrophysics, Department of Mathematics, Physics and Informatics, University of Gdańsk

Abstract:
Quantum contextuality is one of the most recognized resources in quantum communication and computing scenarios. We provide a new quantifier of this resource, the rank of contextuality (RC). We define RC as the minimum number of non-contextual behaviors that are needed to simulate a contextual behavior. We show that the logarithm

of RC is a natural contextuality measure satisfying several properties considered in the spirit of the resource-theoretic approach. The properties include faithfulness, monotonicity, and additivity under tensor product. We also give examples of how to construct contextual behaviors with an arbitrary value of RC exhibiting a natural connection between this quantifier and the arboricity of an underlying hypergraph. We also discuss exemplary areas of research in which the new measure appears as a natural quantifier.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2205.10307

Fluctuation in Quantum Critical Heat Engine

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

Abstract:
Small thermal quantum machines and systems are typical subjects to non-negligible fluctuations, which can be both of thermal and quantum nature. It no longer suffices to study the mean values but one has to take their fluctuations into account. Characterizing fluctuations in the output of thermal machines is an important requirement in quantum technology. In this study, we shed some new light on the universal behavior of fluctuations in a many-body quantum Otto cycle in which the working medium is driven across quantum critical points during the unitary strokes. Under general conditions, we show that fluctuations in output work follow the Kibble-Zurek mechanism,i.e, it follows universal power-law scaling with the driving speed through the critical points.

SpeedTalk Session IV – 22/11/2023

V-type Open Quantum System Driven by Incoherent Light in Transient Regime

Marek Winczewski
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
We consider a nearly degenerate V-type system interacting with natural light. It is suggested that such a system would exhibit so-called Fano coherences. The correct description of these is essential for understanding such phenomena as photosynthesis and vision. However, different approaches to the reduced dynamics of open quantum systems suggest different evolution of coherences. We compare descriptions given by quasi- and fully-secular Markovian master equations with the evolution provided by the cumulant equation and its filtered approximation (FA equation).
The work was partially supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

Two-Unitary Complex Hadamard Matrices

Wojciech Bruzda
Center for Theoretical Physics, Polish Academy of Sciences

Abstract:
A unitary matrix U of order d^2 is called two-unitary, if the partially transposed matrix U^{Γ} and the reshuffled matrix $U^{\rm R}$ are also unitary. Such a matrix determines quantum orthogonal Latin squares, perfect tensor and an absolutely maximally entangled state of a quantum system composed of four subsystems with d levels each. Two-unitary Hadamard matrix H_{36} of size 6^2 constructed in this work provides a solution to the quantum version of the Euler problem, in which each field of the Latin square of size six contains a symmetric superposition of all 36 officers, with phases being multiples of sixth root of unity. Such a matrix provides a strongly distinguished point in the set of complex Hadamard matrices of order 36. Furthermore, the solution of the quantum Euler problem is much simpler that these previously known, as all amplitudes of the superposition are equal and the set of phases consists of six elements only.

Multiparty entanglement or multiparticle entanglement

Marcin Wieśniak
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk
Institute of Theoretical Physics and Astrophysics, Department of Mathematics, Physics and Informatics, University of Gdańsk

Abstract:
Entanglement is recognized as a communication resource distinguished from correlations obtained by local actions and classical communication. Its generalization, genuine multipartite entanglement is defined by the lack of the bipartite decomposition. However, I consider two simple examples of states with no GME. However, taking two copies and performing joint measurements (considered local) reveals GME. Therefore it is reasonable to ask at which stage GME is born.
The work was partially supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

Beating the Otto efficiency with a two-stroke engine assisted by a catalyst

Marcin Łobejko
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk
Institute of Theoretical Physics and Astrophysics, Department of Mathematics, Physics and Informatics, University of Gdańsk

Abstract:
We exceeded the Otto efficiency in one of the simplest heat engines acting only in two strokes and consisting of a pair of two-level systems assisted by a d-dimensional catalyst. The resulting efficiency takes a simple form as a generalization of the Otto's formula: $1 - \frac{1}{d} \frac{\omega_c}{\omega_h}$. Generally, an increase in an engine's efficiency comes at the cost of work production, which tends to zero as the system approaches the Carnot efficiency. The provided example opens a new range of possibilities how to boost the performance of thermal machines via finite-dimensional ancillary systems.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

Quantum Oct sensing with OAM-entangled light

Crislane de Brito (NCU)
Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Toruń

Abstract:
Quantum Optical Coherence Tomography (Q-OCT) is a non-classical counterpart of Optical Coherence Tomography (OCT), immune to the image-degrading chromatic dispersion and providing an enhanced resolution. In this approach, the traditional light source is replaced with a source of frequency-entangled photon pairs, and the traditional Michelson interferometer by the Hong-Ou-Mandel interferometer. We will show experimental results using SPDC entagled photons to image pieces of glass. Moreover, Furthermore, we will introduce the commencement of calculations for the utilization of Orbital Angular Momentum (OAM) entangled light, beneficial for noise-resilience due to the multitude of degrees of freedom involved, in sensing applications.

Revisiting Hyperbit Limitations unveils Quantum Communication Advantages

Giovanni Scala
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
Introduced by Pawłowski and Winter in 2012, Hyperbit Theory emerged as an intriguing alternative to quantum theory, hinting at new possibilities for reshaping entanglement and classical communication paradigms. In this study, we embark on a rigorous reassessment of Hyperbit Theory, revealing crucial operational limitations that challenge its equivalence to quantum mechanics.
The work was supported by QuantERA/2/2020, an ERA-Net co-fund in Quantum Technologies, under the eDICT project and by NCN SHENG grant UMO2018/30/Q/ST2/00625.

https://arxiv.org/abs/2308.16114

Local Inaccessibility of Random Classical Information & Entanglement

Some Sankar Bhattacharya
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
Discrimination of quantum states under local operations and classical communication (LOCC) is an intriguing question in the context of local retrieval of classical information, encoded in the multipartite quantum systems. All the local quantum state discrimination premises, considered so far, mimic a basic communication set-up, where the spatially separated decoding devices are independent of any additional input. Here, exploring a generalized communication scenario we introduce a framework for input-dependent local quantum state discrimination, called local random authentication (LRA). Referring to the term nonlocality, often used to indicate the impossibility of local state discrimination, we coin 'conditional nonlocality' for the impossibility associated with the task LRA. We report that conditional nonlocality necessitates the presence of entangled states in the ensemble, a feature absent from

erstwhile nonlocality arguments based on local state discrimination. Conversely, all the states in a complete basis set being entangled implies conditional nonlocality. However, the impossibility of LRA also exhibits more conditional nonlocality with less entanglement. The relation between the possibility of LRA and local state discrimination for sets of multipartite quantum states, both in perfect and conclusive cases, has also been established. The results highlight a completely new aspect of the interplay between the security of information in a network and quantum entanglement under the LOCC paradigm.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2307.08457

On the Applications of Noise Decoupling Principle in Continuous Variable Systems

Fattah Sakuldee
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
We consider a toy model of noise channels, given by a random mixture of unitary operations, in two situations concerning continuous variables, namely, state transfer problems, and superresolution quantum metrology. For the state transfer, assuming that the path between the transmitter node and the receiver node can be intervened, we propose a noise decoupling protocol to manipulate the noise channels generated by linear and quadratic polynomials of creation and annihilation operators, to achieve an identity channel, hence the term noise decoupling. For random constant noise, the target state can be recovered while for the general noise profile, the decoupling can be done when the interventions are fast compared to the noise. We show that the state at the transmitter can be written as a convolution of the target state and a filter function characterizing the noise and the manipulation scheme. We also briefly discuss that a similar analysis can be extended to the case of higher-order polynomial generators. For superresolution metrology, we apply a similar procedure to suppress the destructive effect of the noise for a measurement of spatial variables. We demonstrate that perfect noise decoupling can be reached by repeating the mode separators and intervening them by a group of rotations, in the limit of a large number of repetitions and small noise strength. For a special case of displacement noise, the problem is simplified. By reusing the modes separator twice, interlacing by a parity operator, given that the noise configuration is frozen between the first and the second steps, a perfect decoupling can be achieved, which allows for recovery of superresolution for a special class of noise generated by displacement operators. Furthermore, for a strong noise correlation between those two steps, our protocol provides a better measurement resolution compared to the non-modified case.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2307.02059

SpeedTalk Session V – 22/11/2023

Unveiling quantum complementarity trade-offs in relativistic scenarios

Pedro Dieguez
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
Complementarity is a cornerstone of quantum theory, assisting in the analysis and understanding of various quantum phenomena. This concept has even been assumed in theoretical studies in relativistic regimes. Here, we conduct a study of two generalized delayed-choice interferometers traveled by a system with an internal spin. We show how a complete complementarity relation can be indeed applied in these two setups and how the trade-off between the quantities in this relation, namely, path coherence, von Neumann predictability, and entropy of entanglement, is affected by special and general time dilation in an arbitrary spacetime. These modifications originate from Wigner rotations, which couple the spin to the external degrees of freedom of the system and do not rely on the spin acting as a clock. Despite having different complementarity trade-offs, both arrangements have the same interferometric visibility, as we unveil. To give a concrete example, we analyze the Newtonian limit of these results.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

https://arxiv.org/abs/2306.08136

Can multiple observers detect KS-contextuality?

Roberto Dobal Baldijão
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
KS-contextuality is a crucial feature of quantum theory. Previous research demonstrated the vanishing of N-cycle KS-contextuality in setups where multiple independent observers measure sequentially on the same system, which we call Public Systems. This phenomenon can be explained as the additional observers' measurements degrading the state and depleting the quantum resource. This explanation would imply that state-independent contextuality should survive in such a system. In this paper, we show that this is not the case. We achieved this result by simulating an observer trying to violate the Peres-Mermin noncontextuality inequality in a Public System. Additionally, we provide an analytical description of our setup, explaining the loss of contextuality even in the state-independent case. Ultimately, these results show that state-independent contextuality is not independent of what happens to the system in-between the measurements of a context.

https://arxiv.org/pdf/2310.19564.pdf

Modeling quantum thermal devices

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

Abstract:
On the one hand, the current technological status allows the precise design, control, and measurement of truly quantum systems in several physical platforms, e.g., solid-state systems, quantum gases, optical setups, etc. On the other, the emergent development of a thermodynamic theory for quantum systems brought new tools and a thermodynamic language to characterize the functioning of quantum devices. Here, I will present two ongoing projects that fit this context: (i) a continuous quantum heat engine that consists of two TLS, individually coupled to thermal baths, interacting with a single-mode harmonic oscillator working as a battery. In particular, I will present its dynamic behavior, considering both the local and global approaches. (ii) a quantum thermal transistor consisting of two TLS interacting with a qutrit, individually connected to thermal baths. More specifically, I will show its functioning regime and present how the qutrit's third level can affect it.

Generation of totally antisymmetric states

Marcin Karczewski
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
Description of evolution on multiports is, in general, a difficult task. However, some of its features can sometimes be predicted with relative ease. For instance, a substantial part of prohibited output events can be obtained with so-called "suppression laws" derived from the symmetries of the problem. I am going to show how to use these laws to construct an optical scheme for generating multipartite singlet states.
The work was supported by the ’International Centre for Theory of Quantum Technologies’ project (contract no. MAB/2018/5). The project is carried out 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).

Semi Device-Independent Certification of Generalized Measurements

Alexandre Orthey*, Remigiusz Augusiak
Center for Theoretical Physics, Polish Academy of Sciences
***speaker**

Abstract:
In semi device-independent certification of bipartite quantum systems, one subsystem's measurement operators remain unknown, while the measurements on the other subsystem are characterized. This can be done by assessing the maximal violation of Steering inequalities, rather than Bell inequalities, utilizing the self-testing approach. Recent advancements [Sarkar et al., PRA 106, L040402, (2022)] have introduced a framework for certifying genuinely incompatible d-outcome projective measurements. Here, we extend this methodology to encompass a large set of linear combinations of operators from the Heisenberg-Weyl basis. In particular, for the case of $d=3$, we present numerical results delineating the classical bound of the Steering operator as a function of the coefficients governing the linear combination defining the measurement to be certified in the untrusted party. This extension broadens the scope of semi device-independent certification, paving the way for more general and versatile quantum certification protocols.

Contextuality (and Pfaffian graphs) for Majorana Fermions

Susane Calegari
Center for Theoretical Physics, Polish Academy of Sciences

Abstract:
Majorana Fermions are promising building blocks for a quantum computer robust against local experimental imperfections. In this work, we prove state-independent contextuality for Majorana fermions in the fixed-parity sector using the sheaf-theoretic approach introduced by Abramsky and Brandenburger. We represent pairs of Majorana operators as edges in a graph and demonstrate that a set of Majorana measurements of degree 2 exhibits contextuality if and only if the corresponding graph is non-Pfaffian. Our analysis identifies the minimal proof of contextuality, given by a set of 9 Majorana observables forming a magic square, which can be represented as a 3 by 3 complete bipartiste graph. Our results bring light to a richer and larger structure of contextuality proves that go beyond the magic square and can be found in any dimension n>2. Moreover, we propose an experimentally testable contextuality witness that provides an inequality violated by any quantum state in the subtheory. Our results highlight the potential of Majorana fermions for quantum computation and provide a framework for future experimental implementations.

Waveguide-assisted Quantum Batteries

Paweł Mazurek
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
Non-reciprocal approach has found many promising applications in distinct fields of quantum technologies. Here, we examine its application in the performance improvement of charging process of a quantum battery. By breaking the symmetry of the evolution we activate nonreciprocal flow of energy from the quantum charger to the quantum which allows for considerable enhancement of accumulation of energy in the quantum battery. To establish the non-reciprocity in the evolution of the charging process we use a waveguide connecting the charger to the battery. We prove that when no dissipation is present in the charging process, non-reciprocity causes a substantial increase in the energy of the battery by 4 times and interestingly the positive effect remains noticeable even when the dissipation rates of energy of the charger and the battery increase. Therefore, the waveguide-enabled non-reciprocal approach constitutes a reliable alternative to the standard, waveguide-free setting. Importantly, the non-reciprocal approach optimal operation is achieved in the stationary limit, eliminating the need for fine time-control of the evolution parameters.
The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).

Steering enabled quantum metrology

Akshata Shenoy
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk

Abstract:
Quantum steering for metrological purposes enables the estimation of a local phase shift and its generating Hamiltonian with precision [NComm12, 2410(2021)]. We formulate the quantum metrological steering for noisy transmission channels to exhibit an enhancement in steering using stochastic operations. We show that there exists

noisy, unsteerable channels which, with stochastic operations, reveal hidden steerability and thus revive their applicability for metrology. Furthermore, the optimality of the stochastic operations is also discussed.

The work was supported by the 'International Centre for Theory of Quantum Technologies' project (contract no. MAB/2018/5). The project is carried out 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).