QWORLD

QUANTUM SCIENCE DAYS

The second scientific meeting organized by QWorld | June 1-3, 2022, Online

Program & List of Talks

All aspects of quantum information science and technology

Version: May 31, 2022

We are very excited to organize **the second edition of QWorld Quantum Science Days**, providing opportunities for researchers at all levels working on all aspects of quantum information science and technologies to present their work. We received many excellent submissions, and we are happy to have **a program of thirty-three contributed talks** over three days. We are also honored to have **nine distinguished speakers**. We hope that you find the meeting to be a place to meet with other researchers around the world, and we also hope that it provides a stimulating environment that can help you advance your research.

We especially thank **Stacey Jeffery** (CWI, QuSoft, & WIQD), **Elham Kashefi** (University of Edinburgh, CNRS Sorbonne Universite, & VeriQloud Ltd), **Aleksander A. Lasek** (QuICS & University of Maryland), **Paweł Gora** (QWorld, University of Warsaw, & Quantum AI Foundation), **Nathan Shammah** (Unitary Fund), **Shaeema Zaman Ahmed** (Science Melting Pot), **Andrii Semenov** (Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine), **Valeria Sequino** (Università degli Studi di Napoli "Federico II", INFN sezione di Napoli, membro della collaborazione Virgo), and **Oxana Mishina** (QTEdu CSA & Italian National Institute of Optics – CNR c/o SISSA) for honoring our event with their speech. We are very thankful to every author for submitting their work to the second edition of Quantum Science Days.

This event would not be possible without **Oxana Mishina** (National Institute of Optics – CNR, Trieste, Italy), **Robert Fickler** (Tampere University, Finland), **Adam Glos** (QWorld & Institute of Theoretical and Applied Informatics, Poland), **Aeysha Khalique** (QPakistan & National University of Sciences and Technology, Islamabad), **Andras Palyi** (QHungary & Budapest University of Technology and Economics), **Laura Piispanen** (Aalto University, Finland), Özlem Salehi (QWorld & Institute of Theoretical and Applied Informatics, Poland), **Travis L. Scholten** (IBM Quantum), **Nathan Shammah** (Unitary Fund), and **Marlou Slot** (Womanium & Georgetown University / National Institute of Standards and Technology) who generously devoted their time to serve on the program committee. We thank each of them for their significant contributions.

We cannot thank the organizing committee members **Adam Glos** (QWorld & Institute of Theoretical and Applied Informatics, Poland), **Akash Kundu** (QIndia & Institute of Theoretical and Applied Informatics, Poland), **Shantanu Misra** (QWorld), **Agnieszka Wolska** (QWorld) to make the event possible with their excellent work.

We are always thankful to **Unitary Fund** for believing in our mission from the very beginning. We especially thank them for their support of our event.

More than **600 people** have registered for our event. We are very grateful to each of them for showing us such a huge appreciation.

Abuzer Yakaryilmaz
Co-chair of the program committee
Co-chair of the organizing committee

Program

JUNE 1

Session 1 Abuzer Yakaryilmaz, 10:00 (UTC)

- Opening
- **Nathan Shammah: Quantum Error Mitigation on NISQ computers and simulators**
- Vishal Sharma: OpenQAOA: An open-source SDK for quantum optimisation (13)
- Utkarsh Azad: qLEET: A Visualization Library for Parameterized Quantum Circuit (14)
- Marco Fellous Asiani: Limitations in quantum computing from resource constraints (4)
- Taha Rouabah: Compiling topological qubit braiding-gates for Fibonacci anyons topological quantum computation (9)

12:30 – 13:00 | Break (30 min.)

Session 2 Aurél Gábris, 13:00 (UTC)

- Adam Glos: QIntern program by QWorld (30)
- **Paweł Gora: QIntern/QResearch Talk: "Solving Vehicle Routing Problems using Quantum Computing"**
- Ashish Arya, Ludmila Botelho, Fabiola Cañete: Music Composition Using Quantum Annealing (3)
- Ludmila Botelho: Music Reduction with Quantum Annealing (15)
- Akash Kundu: Optimizing the Production of Test Vehicles using Hybrid Constrained Quantum Annealing (17)

15:30 – 16:00 | Break (30 min.)

Session 3 Robert Fickler, 16:00 (UTC)

- **Andrii Semenov: Photocounting measurements with realistic photon-number resolution**
- Zoltán György: Parallelization of single-qubit gates with bichromatic driving (26)
- Shrobona Bagchi: IID and problem specific random samples of quantum states from quantum Wishart distributions (12)
- Olga Okrut: Calculating Nash Equilibrium on Quantum Annealers (19)

Program

JUNE 2

Session 4 Zoltán Zimborás, 10:00 (UTC)

- Manal Khawasik: Secured Quantum two-bit commitment protocol (22)
- **Stacey Jeffery: Quantum Walk Search Algorithms**
- Iskender Yalcinkaya: Disorder-free localization in quantum walks (18)
- Bence Bakó: Optimal QAOA design for the Max-K-Cut Problem (21)
- Adam Glos: Optimal QAOA design for the Traveling Salesman Problem (23)

12:30 – 13:00 | Break (30 min.)

Session 5 Özlem Salehi, 13:00 (UTC)

- Laura Piispanen, Daria Anttila: Aalto Quantum Games course nurturing the creative minds of physicists and game creators (33)
- **Oxana Mishina: Quantum Technology Education in Europe**
- Jibran Rashid: QCourses by QWorld (31)
- Daniel Strano: Metriq: a platform for community-driven quantum benchmarks (32)
- Zeki Seskir: The Landscape of the Quantum Start-up Ecosystem (5)

15:30 – 16:00 | Break (30 min.)

Session 6 Aeysha Khalique, 16:00 (UTC)

- Justin Li: Bit Commitment Schemes from Non-Local Games (7)
- Hafiza Rumlah Amer: Genuine Multipartite Nonlocality Bound for AND (24)
- Muhammad Adeel: Quantum computational contextuality (16)
- **Aleksander A. Lasek: Experimental observation of thermalisation with noncommuting charges**

Program

JUNE 3

Session 7 Oxana Mishina, 10:00 (UTC)

- **Elham Kashefi: Quantum Computing as a Service: Secure and Verifiable Multi-Tenant Quantum Data Centre**
- Shubhayan Sarkar: Certification of optimal randomness using quantum steering (2)
- Iris Michela Anna Paparelle: Introduction to quantum communication: a history of sharing secrets and keys (25)
- Iris Michela Anna Paparelle: Implementation and security analysis of continuous variable quantum secure direct communication channel (20)
- Sahar Ben Rached: Running Qiskit algorithms on a superconducting two-qubit quantum processor utilizing a custom hardware platform (29)

12:30 – 13:00 | Break (30 min.)

Session 8 Marlou Slot, 13:00 (UTC)

- **Shaeema Zaman: Quantum Games and Simulations**
- Laura Piispanen: Defining Quantum Games (27)
- Zeki Seskir: Quantum Games and Interactive Tools for Quantum Technologies Outreach and Education (6)
- Noora Heiskanen: Visualizing the Unseen: Game design and playful visuals in communicating quantum science (28)
- Lea Kopf: Endless Fun in high dimensions – A quantum card game (8)

15:30 – 16:00 | Break (30 min.)

Session 9 Oxana Mishina, 16:00 (UTC)

- **Valeria Sequino: Squeezing vacuum states for quantum noise reduction in gravitational wave detectors**
- Carlos L. Benavides-Riveros: Quantum Computing the Excitation Spectra of Quantum Many-Body Systems (via Purified Ensembles) (1)
- Marcin Jastrzębski: Measuring ultrafast light pulses with shearing interferometry (10)
- Muhammad Daud: A comparative study of network topologies in context of future quantum internet (11)

Invited speakers

Nathan Shammah (Unitary Fund)

Quantum Error Mitigation on NISQ computers and simulators

Abstract:

In this talk we'll review main topics in quantum error mitigation and how different techniques can be employed to reduce the error due to quantum noise in quantum intermediate scale quantum computing devices. We will show how Mitiq [1], an open-source toolkit in Python can be used to apply techniques such as zero noise extrapolation, probabilistic error cancellation, Clifford data regression, dynamical decoupling and more. We also analyze how quantum error mitigation is affected by time-correlated noise [2]. Finally, we discuss how other open-source software like qutip-qip [3] can be used to simulate hardware backends and several types of noise.

References:

[1] Mitiq: A software package for error mitigation on noisy quantum computers, Ryan LaRose, Andrea Mari, Sarah Kaiser, Peter J. Karalekas, Andre A. Alves, Piotr Czarnik, Mohamed El Mandouh, Max H. Gordon, Yousef Hindy, Aaron Robertson, Purva Thakre, Nathan Shammah, William J. Zeng, https://arxiv.org/abs/2009.04417

[2] Reducing the impact of time-correlated noise on zero-noise extrapolation, Kevin Schultz, Ryan LaRose, Andrea Mari, Gregory Quiroz, Nathan Shammah, B. David Clader, William J. Zeng, https://arxiv.org/abs/2201.11792

[3] Pulse-level noisy quantum circuits with QuTiP, Boxi Li, Shahnawaz Ahmed, Sidhant Saraogi, Neill Lambert, Franco Nori, Alexander Pitchford, and Nathan Shammah, Quantum 6, 630 (2022) https://quantum-journal.org/papers/q-2022-01-24-630/

Nathan Shammah

is a theoretical physicist working in quantum technology and open-source software and is interested in the interplay between collective effects and dissipative dynamics in many-body quantum systems. He is the Chief Technology Officer of Unitary Fund, a non-profit organization that performs in-house research in quantum tech and supports open-source software projects. At Unitary Fund, he leads the technical staff (Unitary Labs), which performs research in quantum computing developing open-source software. Unitary Labs two main projects are Mitiq, a Python quantum error mitigation toolkit, and Metriq, a platform for the community-driven benchmarking of quantum computing systems. Nathan is also Visiting Scientist at the University of Milan, Italy and at RIKEN, Japan's national lab. Previously, he was a postdoctoral research scientist at RIKEN, Japan, where he worked in the Theoretical Quantum Physics Laboratory. He holds a PhD in Physics from the University of Southampton, UK.

10:00 (UTC), June 1

Invited speakers

Paweł Gora (QWorld, University of Warsaw, and Quantum AI Foundation)

QIntern/QResearch Talk:

Solving Vehicle Routing Problems using Quantum Computing

Abstract:

In this talk, I will introduce a few approaches to solving the Vehicle Routing Problems and their variants using quantum computing. First, I will formally define the considered optimization problems and the corresponding QUBO formulations. Then, I will explain how these problems can be tackled using quantum annealing, QAOA and VQE, and present the results of experiments achieved in 2021 by an international group of students under my supervision within the QIntern program at QWorld. Finally, I will explain how we are planning to enhance these approaches, e.g., using graph coarsening and surrogate optimization, which is the goal of the current research carried out under the QResearch project.

Paweł Gora

is a scientist, IT specialist and entrepreneur working mostly on the applications of AI and quantum computing, especially in transportation and medicine. Graduated from the Faculty of Mathematics, Informatics and Mechanics of the University of Warsaw (M.Sc. in Mathematics and M.Sc. in Computer Science) and is now a PhD Candidate at that Faculty. In the past, he worked as a software engineering intern or research intern at Microsoft, Google, CERN and IBM Research. He is one of the organizers of 2 meetups in Warsaw: Warsaw.ai and Warsaw Quantum Computing Group, and a member of the Board of QWorld and QPoland. He is also a founder and CEO of the "Quantum AI Foundation" aiming to support the development of AI and quantum computing. He also co-founded the "Quantum AI" group aiming to facilitate education in the area of applications of AI in quantum computing and quantum computing in AI. He received several awards, e.g., "Lider ITS" award for the best R&D work in the intelligent transportation systems domain in Poland. "MIT Technology Review" recognized him as one of 10 Top Polish Talents in the "MIT Innovators Under 35" competition. In 2017, he was also placed on the "NEW EUROPE 100" list of emerging technology stars in Eastern Europe. He also collaborates with several startups serving as a technical and business advisor.

13:20 (UTC), June 1

Invited speakers

Andrii Semenov (Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine)

Photocounting measurements with realistic photon-number resolution

Abstract:

Photocounting is a basic measurement procedure used in many optical implementations of quantum-information technologies. It also plays a crucial role in a number of fundamental experiments. Modern photocounters enable to register even a single photon. However, distinguishing between adjacent numbers of photons is still a challenging task. There are several experimental tricks resolving this problem at least approximately: splitting a light beam on several spatial or temporal modes and then analyzing each of them separately with on/off detectors, counting photocurrent pulses in a measurement time window, etc. The latter case is strictly impacted by the detector dead time. In the case of superconducting nanowire single-photon detectors (SNSPD) additional influence is given by the recovering time.

In this talk I will discuss how the photodetection theory is modified to properly describe realistic photon-number-resolving detectors, particularly the SNSPD. Our theory includes three features of such a detection: detector dead time, relaxation time, and impact of previous measurement time windows. We discuss applications of this theory to quantum-optical experiments. In particular, we demonstrate how these detectors can be used for identifying nonclassicality of photocounting statistics, experimental observartions of generalized Hong-Ou-Mandel experiments, etc. We also discuss possible applications of our theory to boson-sampling experiments.

Andrii Semenov

received his doctoral degree from the Taras Shevchenko National University of Kyiv (Ukraine) in 2002. In 2018 he has received his habilitation degree from the University of Rostock (Germany). Between 2002 and 2019 Andrii Semenov was a postoctoral and senior researcher at the Institute of Physics of the National Academy of Sciences (NAS) of Ukraine and at the University of Rostock. Since 2019 he is a leading researcher at the Bogolyubov Institute for Theoretical Physics of the NAS of Ukraine. Andrii Semenov is also a part-time professor at the Taras Shevchenko National University of Kyiv and an associate professor at the Kyiv Academic University. The research activity of Andrii Semenov is mainly concentrated in the field of quantum optics. His main contributions are made in the theory of quantum-light transmission through the turbulent atmosphere, the theory of realistic photodetection, and the theory of nonclassical properties of radiation.

16:00 (UTC), June 1

Invited speakers

Stacey Jeffery (CWI, QuSoft, & WIQD)

Quantum Walk Search Algorithms

Abstract:

Grover's quantum search algorithm and its generalization, amplitude amplification, are ubiquitous in quantum applications because they are easily applied in a number of contexts: essentially anywhere that a classical brute-force search might be used. In this tutorial, I will describe how classical random walk search algorithms can more generally be sped up by quantum computers to get faster search algorithms.

Stacey Jeffery

has been a Senior Researcher at CWI since January 2017. Her main areas of interest are quantum algorithms and cryptographic protocols, and models of quantum computation. Before that, she was an IQIM Postdoctoral Fellow at the Institute for Quantum Information and Matter (IQIM) at Caltech. Stacey received her PhD from the University of Waterloo in 2014, where she was affiliated with the Institute for Quantum Computing (IQC), supervised by Michele Mosca, and informally co-advised by Frédéric Magniez. With Julia Cramer, Stacey co-founded WIQD (Women in Quantum Development), a professional network for women in all areas of quantum technology.

10:20 (UTC), June 2

Invited speakers

Oxana Mishina (QTEdu CSA & Italian National Institute of Optics – CNR c/o SISSA)

Quantum Technology Education in Europe

Abstract:

We are currently living through the Second Quantum Revolution, where the scientific knowledge based on Quantum Theory is used to develop new technologies. In 2018 European Commission launched the Quantum Flagship initiative to support the technology transfer from the research laboratories to industry. This challenging transition requires bringing together research institutes, universities, companies, and policy makers in a collaborative ecosystem. Its fundamental ingredient is education that starts from promoting the citizen awareness and engagement and continues with training programs for pupils, students and professionals. The European quantum technology community proposed a well defined education agenda [1] and the Coordination and Support Action for Quantum Technology Education (QTEdu CSA) was born within the Quantum Flagship to respond to its needs. I present the work done by the QTEdu CSA team that covers the building up the education community network, online repositories creation, construction of a competence framework for quantum technologies, and the development of pilot programs to support pan-European synergies. The QTEdu community keeps growing and welcomes new participants [2]!

References:

[1] Strategic Research Agenda y Quantum Flagship: Education and Trainig, p. 106. https://qt.eu//app/uploads/2020/04/Strategic_Research-_Agenda_d_FINAL.pdf

[2] QTEdu community portal – https://qtedu.eu/

13:20 (UTC), June 2

Oxana Mishina

- QT Research in Denmark, France, and Germany: Theoretical physicist in the quantum optics experimental labs of Niels Bohr Institute Quantop Lab (Copenhagen, DK) and Kastler-Brossel Laboratory (Paris, FR), and in a theoretical group at Saarland University (Saarbreucken, DE).
- Quantum ambassador at schools in Germany: Outreach and school labs from Saarland University (Saarbruecken, DE).
- Education Research in Germany: Physics education researcher at TU Braunschweig (Braunschweig, DE), collaborator at UniTS (Trieste, It).
- Coordination and support for QT education in Europe and Italy: Senior fellow at the National Institute of Optics – CNR (Trieste, IT) working in QFlag CSA and QTEdu CSA.
- Study: Graduated in Nuclear Physics for medical applications, and Ph.D. in Physics and mathematics at SPbSTU (St. Petersburg, RU).

13:20 (UTC), June 2

Invited speakers

Aleksander A. Lasek (QuICS & University of Maryland)

Experimental observation of thermalisation with noncommuting charges

Abstract:

Quantum simulators have recently enabled experimental observations of quantum many-body systems' internal thermalisation. Often, the global energy and particle number are conserved, and the system is prepared with a well-defined particle number—in a microcanonical subspace. However, quantum evolution can also conserve quantities, or charges, that fail to commute with each other. Noncommuting charges have recently emerged as a subfield at the intersection of quantum thermodynamics and quantum information. We initiate the experimental testing of its predictions, with a trapped-ion simulator. We prepare 6–15 spins in an approximate microcanonical subspace, a generalisation of the microcanonical subspace for accommodating noncommuting charges, which cannot necessarily have well-defined nontrivial values simultaneously. The noncommuting charges are the three spin components. We simulate a Heisenberg evolution using laser-induced entangling interactions and collective spin rotations. We report the first experimental observation of a novel non-Abelian thermal state, predicted by quantum thermodynamics. We observe reduced many-body thermalization in the presence of noncommuting charges. Quantum non-commutation effects are detectable and significant for relatively large realistic systems, despite decoherence. This work initiates the experimental testing of a subfield that has so far remained theoretical.

The preprint of the paper the talk is based on can be found on arxiv: https://arxiv.org/abs/2202.04652

Aleksander A. Lasek

is a postdoc at QuICS and University of Maryland. After finishing his PhD in Cambridge, UK, supervised by Crispin Barnes, he moved to Maryland to work on quantum thermodynamics with Nicole Yunger-Halpern. He has developed a GPU-accelerated quantum simulator during his doctorate, and is interested in quantum computing, thermodynamics, information, and numerical simulations.

17:00 (UTC), June 2

Invited speakers

Elham Kashefi (University of Edinburgh,
CNRS Sorbonne Universite, & VeriQloud Ltd)

Quantum Computing as a Service: Secure and Verifiable Multi-Tenant Quantum Data Centre

Abstract:

The development of quantum computing and quantum communication builds upon decades of analysis of their classical counterparts. The recent path taken by start-ups and large technological corporations points toward quantum technologies being mostly cloud-accessible. In future Quantum Data Centres using a combination of techniques in quantum and classical networking, as well as distributed quantum computing, will deliver the processing power of a many-qubit quantum computer by relying on a network of few-qubit processors. In this talk we present first steps towards a built-in design to provide service to multiple users/applications based on secure verifiable multi-party quantum computation.

Elham Kashefi

is Professor of Quantum Computing at the School of Informatics, University of Edinburgh, and Directeur de recherche au CNRS at LIP6 Sorbonne Universite. She co-founded the fields of quantum cloud computing and quantum computing verification, and has pioneered a trans-disciplinary interaction of hybrid quantum-classical solutions from theoretical investigation all the way to actual experimental and industrial commercialisation (Co-Founder of VeriQloud Ltd). She has been awarded several UK, EU and US grants and fellowships for her works in developing applications for quantum computing and communication and was awarded the French 2021 les Margaret Intrapreneur award. She is the senior science team leader of the quantum computing and simulation hub in the UK.

10:00 (UTC), June 3

Invited speakers

Shaeema Zaman Ahmed (Science Melting Pot)

Quantum Games and Simulations

Abstract:

In this talk, Shaeema Zaman Ahmed will introduce the use and impact of games and simulations in quantum physics education, outreach training, and quantum control research, which she explored during her PhD. One might wonder "why games and simulations?". There are indeed a couple of good reasons. Firstly, research shows that there is potential in crowdsourcing solutions to scientific problems through games. Secondly, studies also show that games and simulations can enhance learning, as seen in many scientific disciplines. During her PhD, Shaeema took forward this arena of tools and applied it in quantum physics to explore: (a) how simulations can improve student learning of quantum mechanics [1], (b) perspectives on crowdsourcing solutions for controlling atoms through a game [2], and (c) the impact of the use of simulations in quantum physics outreach training [3].

References:

[1] Shaeema Zaman Ahmed et al. "Quantum composer: A programmable quantum visualization and simulation tool for education and research". In: American Journal of Physics 89.3 (2021), pp. 307–316. https://aapt.scitation.org/doi/10.1119/10.0003396

[2] Jesper Hasseriis Mohr Jensen et al. "Crowdsourcing human common sense for quantum control". In: Phys. Rev. Research 3 (1 2021), p. 013057. https://journals.aps.org/prresearch/abstract/10.1103/PhysRevResearch.3.013057

[3] Shaeema Zaman Ahmed et al. "A training programme for early-stage researchers that focuses on developing personal science outreach portfolios". In: arXiv:2103.03109 (2021). https://arxiv.org/abs/2103.03109

Shaeema Zaman Ahmed

is a physicist and science communicator with research experience that spans quantum physics education and outreach using games and simulations, astrophysics and quantum control. She has also worked outside academia as a scientific content creator and science communicator both in India and Denmark. After completing her PhD at Aarhus University, Denmark, she started her startup, Science Melting Pot, driven by her passion for science outreach and her concern for the challenges in achieving diversity in the physics community. Furthermore, she also co-mentored a quantum physics outreach training program in an EU-H2020 research project, QuSCo, during her PhD. She was one of the nominees for the Kvinder i Fysik (KIF) / Danish Women in Physics 2021 prize for her dedication to physics teaching and outreach by the KIF network.

13:00 (UTC), June 3

Invited speakers

Valeria Sequino (Università degli Studi di Napoli "Federico II", "INFN sezione di Napoli", membro della collaborazione Virgo)

Squeezing vacuum states for quantum noise reduction in gravitational wave detectors

Abstract:

In recent years, interferometric gravitational wave detectors have been demonstrated to be able to measure very small distance variations induced by gravitational radiation. One of the main limits for such detectors is the so-called "quantum noise" due to vacuum fluctuations that enter the interferometer. This noise manifests itself as radiation pressure noise and as shot noise, depending on the observation frequency. The adopted solution for quantum noise reduction is the injection of squeezed vacuum states through the output port of the interferometer. This technique has been used during the last observation run in order to reduce shot noise; being the radiation pressure noise not disturbing the detector sensitivity.

At present a new generation of gravitational wave detectors are in phase of commissioning. Many upgrades have been done and this much improved the sensitivity in the low frequency part of the detection bandwidth, where radiation pressure noise now dominates. In order to have a broadband quantum noise reduction, a frequency-dependent squeezing technique has been implemented.

In this talk, I will introduce the problem of quantum noise in gravitational wave detectors, mostly considering that for such detectors audio-frequency squeezed vacuum states are needed. Moreover I will focus on the techniques used during the last observation run for Advanced Virgo and the one presently under commissioning for Advanced Virgo Plus.

References:

- CavesCM 1981 Quantum-mechanical noise in an interferometer Phys. Rev.D23 1693
- Acernese F et al 2019 Increasing the astrophysical reach of the advanced virgo detector via the application of squeezed vacuum states of light Phys. Rev. Lett. 123 231108
- TseMet al 2019 Quantum-enhanced advanced ligo detectors in the era of gravitational-wave astronomy Phys. Rev. Lett. 123 231107
- Zhao Y et al 2020 Frequency-dependent squeezed vacuum source for broadband quantum noise reduction in advanced gravitationalwave detectors Phys. Rev. Lett. 124 171101
- Sequino, Valeria. "Quantum noise reduction in Advanced Virgo." Physica Scripta 96.10 (2021): 104014.

16:00 (UTC), June 3

Valeria Sequino

I am a member of the Virgo collaboration starting from 2012 and, at present, I work at the University of Napoli "Federico II". Previously I worked at the University of Rome "Tor Vergata", where I also got my PhD, and for the Istituto di Fisica Nucleare (INFN) in Rome and Genova.

My career is fully devoted to quantum noise reduction in gravitational wave detectors, at present I am working for the commissioning of Advanced Virgo Plus and for the Einstein Telescope project.

16:00 (UTC), June 3

List of Talks

[In their submitted order]

1. Quantum Computing the Excitation Spectra of Quantum Many-Body Systems (via Purified Ensembles)

Session 9, June 3

Carlos L. Benavides-Riveros, Lipeng Chen, Christian Schilling, Sebastián Mantilla, Stefano Pittalis (Max Planck Institute for the Physics of Complex Systems; Ludwig-Maximilians-Universität München; CNR-Istituto Nanoscienze, Modena)

State-average calculations based on mixture of states are increasingly being exploited across chemistry and physics as versatile procedures for addressing excitations of quantum many-body systems. If not too many states should need to be addressed, calculations performed on individual states are also a common option. Here we show how the two approaches can be merged into one method, dealing with a generalized yet single pure state. Using the well-known Unitary Coupled Cluster ansatz, our approach allows to quantum compute the whole spectra of quantum many-fermion systems. By computing the spectrum of a Fermi-Hubbard model we show how this approach performs.

2. Certification of optimal randomness using quantum steering

Session 7, June 3

Shubhayan Sarkar, Jakub J. Borkała, Chellasamy Jebarathinam, Owidiusz Makuta, Debashis Saha, Remigiusz Augusiak (Center for Theoretical Physics, Polish Academy of Sciences, Warsaw)

Certification of quantum systems and their properties has become a field of intensive studies. Here, taking advantage of the one--sided device-independent scenario (known also as quantum steering scenario), we propose a self-testing scheme for all bipartite entangled states using a single family of steering inequalities with the minimal number of two measurements per party. Building on this scheme we then show how to certify all rank-one extremal measurements, including non-projective d2-outcome measurements, which in turn can be used for certification of the maximal amount of randomness, that is, 2log_2 d bits.

3. Music Composition Using Quantum Annealing

Session 2, June 1

Ashish Arya, Ludmila Botelho, Fabiola Cañete, Dhruvi Kapadia, Özlem Salehi
(ICT Academy, Indian Institute of Technology; Institute of Theoretical and Applied Informatics, Polish Academy of Sciences; Benemerita Universidad Autonoma de Puebla, Mexico)

With the emergence of quantum computers, a new field of algorithmic music composition has been initiated. The vast majority of previous work focuses on music generation using gate-based quantum computers. An alternative model of computation is adiabatic quantum computing (AQC), and a heuristic algorithm known as quantum annealing running in the framework of AQC is a promising method for solving optimization problems. In this talk, we lay the groundwork of music composition using quantum annealing. We approach the process of music composition as an optimization problem. We describe the fundamental methodologies needed for generating different aspects of music including melody, rhythm, and harmony. The discussed techniques are illustrated through examples to ease the understanding. The music pieces generated using D-Wave quantum annealers are among the first examples of their kind and presented within the scope of the chapter.

4. Limitations in quantum computing from resource constraints

Session 1, June 1

Marco Fellous Asiani, Jing Hao Chai, Robert S. Whitney, Alexia Auffèves, Hui Khoon Ng
(CNRS; Centre for Quantum Technologies, Singapore; Yale-NUS College, Singapore)

Fault-tolerant schemes can use error correction to make a quantum computation arbitrarily accurate, provided that errors per physical component are smaller than a certain threshold and independent of the computer size. However, in current experiments, physical resource limitations like energy, volume, or available bandwidth induce error rates that typically grow as the computer grows. Taking into account these constraints, we show that the amount of error correction can be optimized, leading to a maximum attainable computational accuracy. We find this maximum for generic situations where noise is scale-dependent. By inverting the logic, we provide experimenters with a tool for finding the minimum resources required to run an algorithm with a given computational accuracy. When combined with a full-stack quantum computing model, this provides the basis for energetic estimates of future large-scale quantum computers.

5. The Landscape of the Quantum Start-up Ecosystem

Session 5, June 2

Zeki Seskir, Ramis Korkmaz, Arsev Umur Aydinoglu (KIT-ITAS; METU)

The second quantum revolution has been producing groundbreaking scientific and technological outputs since the early 2000s; however, the scientific literature on the impact of this revolution on the industry, specifically on start-ups, is limited. In this paper, we present a landscaping study with a gathered dataset of 421 companies from 42 countries that we identify as quantum start-ups, meaning that they mainly focus on quantum technologies (QT) as their primary priority business. We answer the following questions: (1) What are the temporal and geographical distributions of the quantum start-ups? (2) How can we categorize them, and how are these categories populated? (3) Are there any patterns that we can derive from empirical data on trends? We found that more than 92% of the start-ups have been founded within the last 10 years, and more than 50% of the start-ups are located in the US, the UK, and Canada. We categorized the QT start-ups into six fields: (i) complementary technologies, (ii) quantum computing (hardware), (iii) quantum computing (software/application/simulation), (iv) quantum cryptography/communication, (v) quantum sensing and metrology, and (vi) supporting companies, and analyzed the population of each field both for countries, and temporally. Finally, we argue that low levels of quantum start-up activity in a country might be an indicator of a national initiative to be adopted afterwards, which later sees both an increase in the number of start-ups, and a diversification of activity in different QT fields.

6. Quantum Games and Interactive Tools for Quantum Technologies Outreach and Education

Session 8, June 3

Zeki Seskir (KIT-ITAS), et. al.

In this article, we provide an extensive overview of a wide range of quantum games and interactive tools that have been employed by the community in recent years. The paper presents selected tools, as described by their developers. The list includes Hello Quantum, Hello Qiskit, Particle in a Box, Psi and Delta, QPlayLearn, Virtual Lab by Quantum Flytrap, Quantum Odyssey, ScienceAtHome, and The Virtual Quantum Optics Laboratory. Additionally, we present events for quantum game development: hackathons, game jams, and semester projects. Furthermore, we discuss the Quantum Technologies Education for Everyone (QUTE4E) pilot project, which illustrates an effective integration of these interactive tools with quantum outreach and education activities. Finally, we aim at providing guidelines for incorporating quantum games and interactive tools in pedagogic materials to make quantum technologies more accessible for a wider population.

7. Bit Commitment Schemes from Non-Local Games

Session 6, June 2

Claude Crépeau, Justin Li (McGill University; Optable Inc)

A bit commitment scheme is a cryptographic primitive that acts as a digital safe for mutually mistrusted parties. Classically the security of the commitment is tied to the underlying computational assumption. We are instead interested in exploring com- mitment schemes whose security is guaranteed by physical laws. More specifically, we focus on bit commitment schemes built using nonlocal correlations, which are the joint probability distributions derived from measuring entangled quantum systems. These correlations can violate the Bell inequalities and still respect the relativistic causality of no faster-than-light communication. A pseudo-telepathy game provides an intuitive way to understand the nonlocal nature of entanglement, where multiple non-communicating players cooperate to answer challenges given by a verifier. The game cannot be won all the time for classical players without knowing each other's inputs, but players that share the appropriate entanglements can do so. In this work, we present a protocol to transform any pseudo-telepathy game into a classically secure bit commitment scheme. Players sharing nonlocal resources can cheat the binding property of the bit commit- ment scheme built using this protocol, while players that use strictly local strategies will not. This property paves the way for zero-knowledge protocols for quantum simu- lators without the need of signalling. We also introduce a new binding definition of bit commitment schemes that we call the non-binding game.

8. Endless Fun in high dimensions – A quantum card game

Session 8, June 3

Lea Kopf, Markus Hiekkamäki, Shashi Prabhakar and Robert Fickler
(Tampere University, Finland; Quantum Science and Technology Laboratory, Ahmedabad, India)

Quantum computing is a rapidly developing technology that uses peculiar quantum features to perform calculations that are impossible with classical schemes. The enormous progress over the last decades has also led to an urgent need for young professionals and new educational programs. Based on the Q-Cards game developed in 2019, we have created a strategic multi-player card game, Endless Fun in high dimensions, that introduces the players to the building blocks of a quantum computer, i.e., quantum gates. By playing physical cards acting as quantum gates, the players aim to increase their quantum state value and decrease the values of the other players. In the game, they encounter quantum features such as superposition, interference, and entanglement. The card game contributes to the ongoing efforts on gamifying quantum physics education with a particular focus on the counter-intuitive features on which quantum computing is based on.

9. Compiling topological qubit braiding-gates for Fibonacci anyons topological quantum computation

Session 1, June 1

Taha Rouabah, Nacer Eddine Belaloui, Abdellah Tounsi, Muhammad Masud Laouamri, Achour Benslama (University of Constantine 1, Algeria)

Topological quantum computation is an implementation of a quantum computer in a way that radically reduces decoherence. Topological qubits are encoded in the topological evolution of two-dimensional quasi-particles called anyons and universal set of quantum gates can be constructed by braiding these anyons yielding to a topologically protected circuit model. In the present study we remind the basics of this emerging quantum computation scheme and illustrate how a topological qubit built with three Fibonacci anyons might be adopted to achieve leakage free braiding gate by exchanging the anyons composing it. A single-qubit braiding gate that approximates the Hadamard quantum gate to a certain accuracy is numerically implemented using a brute force search method. The algorithms utilized for that purpose are explained and the numerical programs are publicly shared for reproduction and further use.

10. Measuring ultrafast light pulses with shearing interferometry

Session 9, June 3

Marcin Jastrzębski, Stanisław Kurzyna, Michał Lipka, Michał Parniak
(Centre for Quantum Optical Technologies (QOT); University of Warsaw)

Femtosecond light impulses have a variety of interesting applications. Such high time resolution is useful for experiments with atoms and molecules. They can also have some medical uses for example in surgery. The problem of characterizing ultrafast pulses has some already known solutions. It is not a trivial task since we do not have measuring devices faster than short laser pulses. Our method is able to determine both spectral and temporal width of the impulse without any nonlinear effects. This is relevant because nonlinear optics is very inefficient energetically so such methods are not suitable for single photon measure. We achieve this by measuring the interference visibility of two pulse copies. One shifted in time and the other in frequency domain. We use a custom spectrometer for calibration of the RF setup which was necessary since commercial devices are not precise enough. We also built a 4f setup to adjust the spectral width of the used laser. Spectral filters of some kind are a must-have since femtosecond impulses, following the uncertainty principle, have a very huge spectral width - even more than ten nanometers. The recent modification involved putting a special rubidium cell to the optical system. Rubidium atoms have very interesting properties which have a significant influence on the experimental results.

11. A comparative study of network topologies in context of future quantum internet

Session 9, June 3

Muhammad Daud, Aeysha Khalique, Peter P. Rohde (National University of Science and Technology, Pakistan; University of Technology Sydney)

Entanglement distribution in multi node networks can become the backbone for a future quantum internet, it will become a widely accepted phenomenon as quantum repeater networks become more and more efficient. Graph theoretic approaches to make a feasible multi-node quantum network for secure communication and distributed quantum computation are of particular interest as the classical internet was built on such theories. Unlike today's classical internet, quantum internet will most likely rely on more than one path between the source and destination. This multi-path routing paradigm allows the user-pair to establish entanglement, and send their Bell-pairs through paths other than shortest path and still get a single high fidelity Bell-pair at the end via entanglement purification. This study encompasses a quintessential comparative analysis of having more than the minimum required edges in networks to support multi-path routing with an added advantage of temporal layers from utilizing quantum memories. We provide an explanation for the benefits of having redundant edges in tree networks by adding rings of edges at each level and compare the idea of cost distances with lattice networks. Our analysis provides an understanding of fidelity-efficiency trade-offs in the context of user competition and path finding probabilities. We make an argument for network topologies playing an important role in serving the purpose whether it is for distributed quantum computation or for quantum key distribution. To show deployability of entanglement distribution networks with extra edges we present a wide area network for 14 selected universities in Islamabad in two different fiber-optic based network topologies. One being a minimal spanning tree network that costs around $61, 370.00 and the other being a completely connected network which costs about $1, 109, 670.00. Regardless of the monetary cost a clear advantage is shown in key generation rates for ideal nodes.

12. IID and problem specific random samples of quantum states from quantum Wishart distributions

Session 3, June 1

Han Rui, Weijun Li, Shrobona Bagchi, Hui Khoon Ng, Berthold Georg Englert (Center for Quantum Technologies, Singapore; University of Oxford; Korea Institute of Science and Technology, Seoul; Yale NUS College)

Random samples of quantum states are an important resource for various tasks in quantum information science, and samples in accordance with a problem-specific distribution can be indispensable ingredients. Some algorithms generate random samples by a lottery that follows certain rules and yield samples from the set of distributions that the lottery can access. Other algorithms, which use random walks in the state space, can be tailored to any distribution, at the price of autocorrelations in the sample and with restrictions to low-dimensional systems in practical implementations. In this work, we present a two-step algorithm for sampling from the quantum state space that overcomes some of these limitations.

We first produce a CPU-cheap large proposal sample, of uncorrelated entries, by drawing from the family of complex Wishart distributions, and then reject or accept the entries in the proposal sample such that the accepted sample is strictly in accordance with the target distribution. We establish the explicit form of the induced Wishart distribution for quantum states. This enables us to generate a proposal sample that mimics the target distribution and, therefore, the efficiency of the algorithm, measured by the acceptance rate, can be many orders of magnitude larger than that for a uniform sample as the proposal. We demonstrate that this sampling algorithm is very efficient for one-qubit and two-qubit states, and reasonably efficient for three-qubit states, while it suffers from the „curse of dimensionality" when sampling from structured distributions of four-qubit states.

13. OpenQAOA: An open-source SDK for quantum optimisation

Session 1, June 1

Vishal Sharma, Leonardo Disilvestro, Shao-Hen Chiew, Nur Shahidee, Ezequiel Rodriguez Chiacchio (Entropica Labs, Singapore)

In this talk, we present OpenQAOA, a Python open-source multi backend library to design and implement QAOA and its variations for optimisation on Noisy Intermediate-Scale Quantum (NISQ) devices and simulators with the goal of promoting research in the field.

14. qLEET: A Visualization Library for Parameterized Quantum Circuit

Utkarsh Azad, Animesh Sinha (International Institute of Information Technology Hyderabad)

Session 1, June 1

qLEET is an open-source Python package for studying parameterized quantum circuits (PQCs), which are widely used in various variational quantum algorithms (VQAs) and quantum machine learning (QML) algorithms. qLEET enables computation of properties such as expressibility and entangling power of a PQC by studying its entanglement spectrum and the distribution of parameterized states produced by it. Furthermore, it allows users to visualize the training trajectories of PQCs along with high-dimensional loss landscapes generated by them for different objective functions. It supports quantum circuits and noise models built using popular quantum computing libraries such as Qiskit, Cirq, and PyQuil. In our work, we demonstrate how qLEET provides opportunities to design and improve hybrid quantum-classical algorithms by utilizing intuitive insights from the ansatz capability and structure of the loss landscape.

15. Music Reduction with Quantum Annealing

Ludmila Botelho, Özlem Salehi (Institute of Theoretical and Applied Informatics, Polish Academy of Sciences)

Session 2, June 1

With the emergence of quantum computers, the class of combinatorial optimization problems is one of the potential targets to tackle. An alternative model of computation is adiabatic quantum computing (AQC), and a heuristic algorithm known as quantum annealing running in the framework of AQC is a promising method for solving optimization problems. With this in mind, we proposed a multiobjective optimization for a fixed interval scheduling problem with application for music reduction.

16. Quantum computational contextuality

Muhammad Adeel, Jibran Rashid (Institute of Business Administration, Karachi)

Session 6, June 2

Recently a new definition of qubit is proposed in terms of incompatible observables (anticommuting measurements). This definition allows self-testing a system whether it is indeed quantum based solely on observed statistics. Historically contextuality too is defined in terms of (in)compatible observables. Consequently some form of contextuality under judicious assumptions can be identified for quantum algorithms and automata. We label this form of contextuality as quantum computational contextuality. Moreover, we believe this contextuality is a resource for quantum advantage, as it speeds up memory efficiency. As a specific example we consider 2QCFA proposed by Ambainis and Watrous and build a promise problem PROMISEPAL for PALINDROME. Numerical simulations suggest a positive result in identifying a contextual behavior. A complete characterization of PROMISEPAL is yet to be attained.

17. Optimizing the Production of Test Vehicles using Hybrid Constrained Quantum Annealing

Session 2, June 1

Adam Glos, Akash Kundu, Özlem Salehi (Institute of Theoretical and Applied Informatics, Polish Academy of Sciences)

Optimization of pre-production vehicle configurations is one of the challenges in the automotive industry. Given a list of tests requiring cars with certain features, it is desirable to find the minimum number of cars that cover the tests and obey the configuration rules. In this paper, we model the problem in the framework of satisfiability and solve it by utilizing the newly introduced hybrid constrained quadratic model (CQM) solver provided by D-Wave. The problem definition is based on the "Optimizing the Production of Test Vehicles" use case given in the BMW Quantum Computing Challenge. We formulate a constrained quadratic model for the problem and use a greedy algorithm to configure the cars. We benchmark the results obtained from the CQM solver with the results from the classical solvers like CBC (Coin-or branch and cut) and Gurobi. We conclude that the performance of the CQM solver is comparable to classical solvers in optimizing the number of test vehicles. As an extension to the problem, we describe how the scheduling of the tests can be incorporated into the model.

18. Disorder-free localization in quantum walks

Session 4, June 2

B. Danaci, Iskender Yalcinkaya, B. Cakmak, G. Karpat, S. P. Kelly, A. L. Subasi (Istanbul Technical University, Czech Technical University in Prague, Bahcesehir University, Izmir University of Economics, Johannes Gutenberg University of Mainz)

The localization phenomenon usually happens due to the existence of disorder in a medium. Nevertheless, specific quantum systems allow dynamical localization solely due to internal interactions. We study a discrete-time quantum walker which exhibits disorder-free localization. The quantum walker moves on a one-dimensional lattice and interacts with on-site spins by coherently rotating them around a given axis at each step. Since the spins do not have their dynamics, the system poses the local spin components along the rotation axis as many conserved moments. When the interaction is weak, the spread of the walker shows sub diffusive behavior, having downscaled ballistic tails in the evolving probability distribution at intermediate time scales. However, as the interaction gets stronger, the walker gets exponentially localized in the complete absence of disorder in both lattice and initial state. Using a matrix--product-state ansatz, we investigate the relaxation and entanglement dynamics of the on-site spins due to their coupling with the quantum walker. Surprisingly, even in the delocalized regime, entanglement growth and relaxation occur slowly, unlike the majority of the other models displaying a localization transition.

19. Calculating Nash Equilibrium on Quantum Annealers

Session 3, June 1

Olga Okrut, Keith Cannon, Kareem H. El-Safty, Nada Elsokkary, Faisal Shah Khan (Dark Star Quantum Lab, Inc.)

Adiabatic quantum computing is implemented on specialized hardware using the heuristics of the quantum annealing algorithm. This setup requires the addressed problems to be formatted as discrete quadratic functions without constraints and the variables to take binary values only. The problem of finding Nash equilibrium in two-player, non-cooperative games is a two-fold quadratic optimization problem with constraints. This problem was formatted as a single, constrained quadratic optimization in 1964 by Mangasarian and Stone. Here, we show that adding penalty terms to the quadratic function formulation of Nash equilibrium gives a quadratic unconstrained binary optimization (QUBO) formulation of this problem that can be executed on quantum annealers. Three examples are discussed to highlight the success of the formulation, and an overall, time-to-solution (hardware + software processing) speed up of seven to ten times is reported on quantum annealers developed by D-Wave System.

20. Implementation and security analysis of continuous variable quantum secure direct communication channel

Session 7, June 3

Iris Michela Anna Paparelle, Alessandro Zavatta, Matteo Paris (CNR-INO, UniMi)

The development of supercomputers and quantum computers will threaten current secure communication protocols. However, quantum mechanics offers a solution guaranteeing physical layers and provable security of communications. In particular, quantum secure direct communication (QSDC) allows secret messages to be directly and securely communicated over a quantum channel. We investigate implementations of continuous variable QSDC using single-mode squeezed coherent states, and state of the art quantum optical technology. Indeed, the continuous variable regime can be well compatible with fully developed optical telecommunication technologies. The security of the protocols against different forms of attacks (e.g. intercept-resend attack and collective attack) and against losses and noise is investigated, both analytically and numerically.

21. Optimal QAOA design for the Max-K-Cut Problem

Session 4, June 2

Bence Bakó, Adam Glos, Özlem Salehi, Zoltán Zimborás (Eötvös Loránd University, Budapest; Institute of Theoretical and Applied Informatics, Polish Academy of Sciences; Wigner Research Centre for Physics, Budapest)

In the era of Noisy Intermediate Scale Quantum (NISQ) devices, variational quantum algorithms may offer a way of demonstrating useful quantum advantage. Combinatorial optimization is a particular class of problems, for which one could expect some benefits from quantum computing. These problems are usually formulated as Quadratic Unconstrained Binary Optimization (QUBO) problems that can be easily embedded into the ground state problem of an Ising Hamiltonian. However, this method results in high redundancy,

significantly increasing the resources required. There have been multiple attempts to reduce this redundancy and make the algorithm more suitable for near term devices. In this study, we further improve these methods and introduce the simulated Quantum Approximate Optimization Algorithm (SIM-QAOA), which significantly reduces the quantum resources needed for the Max-K-Cut problem.

22. Secured Quantum two-bit commitment protocol

Session 4, June 2

Manal Khawasik, Wagdy Elsayed, Magdi Rashad, Ahmed Younes (Faculty of Science, Alexandria University; Faculty of Computers and Information Systems, Mansoura University, Egypt)

Bit commitment (BC) is an extremely important primitive in quantum cryptography. It is the basic building block of many cryptographic protocols in which it provides security over distrustful parties. The literature included here presents a secured quantum two-bit commitment (Q2BC) protocol for any two classical bits. The protocol contains two parties - a committer and a receiver - who share both quantum and classical communication channels. The main phases of the Q2BC protocol are commitment and revealing phases where the concealing and binding conditions have to be proved in order to accept the commitment message. The proposed framework utilizes different security layers to hide specific quantum states in a superposition alongside trivial one qubit operations. The secured unitary transformations are applied by the two parties to meet the concealing and binding conditions. To verify the success of the proposed protocol, the measured output of the two parties are compared. The protocol operates under the assumption that the two parties might cheat and the possible existence of an eavesdropper.

23. Optimal QAOA design for the Traveling Salesman Problem

Session 4, June 2

Bence Bakó, Adam Glos, Özlem Salehi, Zoltán Zimborás (Eötvös Loránd University, Budapest; Institute of Theoretical and Applied Informatics, Polish Academy of Sciences; Wigner Research Centre for Physics, Budapest)

The current state-of-the-art quantum algorithms require representing the original problem as unconstrained binary optimization, where the objective function is a polynomial accepting binary string and outputting an objective value. Depending on the choice of the quantum algorithm, such representation is either embedded into a quantum annealer or simulated with a gate-based quantum computer. Unfortunately, such representation, especially when restricted to 2-local interactions, results in higher redundancy, significantly increasing the resources required. This is particularly important as the current and near-future quantum hardware is necessarily small and fragile to the noise.

We overcome this issue with an alternative way of encoding the Travelling Salesman Problem into a quantum computer. Why our representation still relies on the bitstring input, making it suitable for current quantum devices with qubits, we significantly reduce the number of quantum resources needed, reaching an almost optimal value for all cost measures simultaneously. These measures include but are not limited to a number of qubits, gates or the depth of the circuit. Our approach is generic and will be particularly suitable for complicated constrained optimization problems.

24. Genuine Multipartite Nonlocality Bound for AND

Hafiza Rumlah Amer, Jibran Rashid (Institute of Business Administration, Karachi)

Session 6, June 2

We develop a multipartite generalization of Tsirelson's bound. This yields a bound on nonlocal computation of n-bit AND function where n–1 parties are grouped together. The bound serves as a threshold for genuine n-partite nonlocality. We expect a similar approach is feasible for determining bounds for threshold functions in general.

25. Introduction to quantum communication: a history of sharing secrets and keys

Iris Michela Anna Paparelle (CNR-INO, Trieste)

Session 7, June 3

Being able to tell secret information to specific actors over long distances has always been important and decisive, from winning a battle to keep your credit card codes, from defending individual privacy to ensuring public infrastructures. Nowadays, communication is mainly secured through the complexity of certain computational tasks: stealing the data would take so much time and resources, with current computers, that it would lose its value. However, the development of supercomputers and quantum computers is going to threaten these protocols. Nevertheless, quantum mechanics also offers solutions, as no one can violate the physical laws of the quantum world, not even quantum computers. To understand the first and fundamental protocols of quantum secure communication, BB84 and DL04, a few of the quantum oddities have to be introduced: the notions of observables and collapse, quantum superposition, and the no-cloning theorem. In conclusion, the quantum information carriers will be introduced, to show how to bring to reality these protocols of key and message distribution.

26. Parallelization of single-qubit gates with bichromatic driving

Zoltán György, András Pályi, Gábor Széchenyi (Eötvös University, Budapest; Budapest University of Technology and Economics)

Session 3, June 1

We investigate in a simple model the selective addressing of flopping-mode spin qubits arranged in a crossbar architecture. With EDSR technique based on spin-orbit interaction, using bichromatic driving, Rabi oscillations can be induced, if the sum of the two ac electric fields matches with the splitting frequency of the qubit. In the weak driving regime we derive analytical formulas for the Rabi frequency and the Bloch-Siegert shift. We find that (i) the Rabi frequency will be zero in the charge degeneracy point, it has a maximal value at a finite detuning of the double quantum dot, (ii) the larger the difference between the ac driving frequencies, the larger is the Rabi frequency, (iii) the Bloch-Siegert shift is significant when there is g-factor antisymmetry between the quantum dots, (iv) the bichromatic Rabi frequency is typically 1-2 order of magnitude smaller than the monochromatic one. We also investigate the harmful effect of the charge noise and we find that reducing the g-factor antisymmetry makes the qubits more resistant to this noise. We present the advantages and the application of bichromatic driving and the crossbar architecture: selective addressing of qubits and the parallelization of single-qubit gates on the 2D qubit array, using frequency multiplexing. Our analytical results are supported by numerical simulations.

27. Defining Quantum Games

Laura Piispanen, Annakaisa Kultima (Aalto University), et. al.

Session 8, June 3

In this article, we explore the concept of quantum games and define quantum games as any type of games that are related to or reference quantum physics through any of three proposed aspects. The rise of the quantum computers has made it possible to think about a new wave of computer games, namely quantum computer games, games on quantum computers. But at the same time, there are also various games that are exploring quantum mechanics and related topics through digital, analogue and hybrid means. In this article we go through the emerging body of quantum games, the history of quantum games and the different ways a game may be considered a quantum game. For this we propose three dimensions for analysing and defining the phenomenon of quantum games: the perceivable dimension of quantum games, the dimension of quantum technologies and the dimension of scientific purposes.

28. Visualizing the Unseen: Game design and playful visuals in communicating quantum science

Noora Heiskanen (Aalto University of Art, design and architecture)

Session 8, June 3

In my thesis I look at aspects of communicating quantum physics and some of the key phenomenons of quantum physics through games and art. My aim is to redesign an exhibition of quantum technology and phenomenon called "Quantum Explorations" that was organized in Aalto University in 2019, to better answer the challenges and possibilities that well designed science exhibitions can offer to both scientist and non-scientist audiences. My research is based on the interviews with game designers, artists, quantum scientists and quantum technology professionals, as well as my own work of creating, playing, and researching creative quantum games and art projects. Through this process I'm developing a visual design manual for "Unseen exhibition" where I'm knitting together the best practices of how to create an exhibition to visualize some quantum phenomenon.

29. Running Qiskit algorithms on a superconducting two-qubit quantum processor utilizing a custom hardware platform

Sahar Ben Rached, Oliver Sander, Richard Gebauer, Mourad Telmini
(University of Tunis El Manar; Karlsruhe Institute of Technology)

Session 7, June 3

At the Institute for Data Processing and Electronics, Karlsruhe Institute of Technology, an FPGA-based system is developed for the control and readout of superconducting qubits, called the QiController. The goal of this master thesis is the integration of the QiController as an external quantum processor to IBM Qiskit. Thus, superconducting processors commanded by the QiController would enable the execution of circuits and algorithms designed by Qiskit. To achieve the project's goal, we design and calibrate quantum gates in QiCode, the native programming language of the QiController, and integrate the translation routine needed to convert Qiskit algorithms into QiCode instructions. In the second phase of the project, we tested running Qiskit algorithms on a single-qubit superconducting processor built at NIST and commanded by the QiController system.

30. QIntern program by QWorld

Adam Glos (QWorld)

Session 2, June 1

QIntern is the summer quantum internship program of the QWorld Association, hosted by the QResearch Department. The goal of QIntern is to encourage and support collaborative work in quantum information science and technology, bringing together more experienced people and those willing to learn more. During the presentation I'll show the results of our previous editions, and present the plan for upcoming QIntern 2022.

31. QCourses by QWorld

Jibran Rashid (QWorld)

Session 5, June 2

QCourses are university accredited graduate courses offered by QWorld Association. During the academic year 2021-22, we offered Quantum Computing and Programming (QCourse511) and Projects in Quantum (QCourse570) in collaboration with the University of Latvia. We will review outcomes from the courses as well as challenges in scaling up this model to a graduate degree program.

32. Metriq: a platform for community-driven quantum benchmarks

Daniel Strano, Vincent Russo (Unitary Fund)

Session 5, June 2

With the growth of quantum computing in academia and industry, it can be hard to keep track of the many new developments. The community lacks an open repository of "state-of-the-art" benchmark results, and it is difficult to know how to appropriately compare "like-to-like," across the breadth of published quantum benchmark results. Metriq is designed to address these challenges.

Metriq is an open source web application for reporting, presenting, analyzing, and tracking benchmarks in the domain of quantum technologies. "Submissions" to the app can be any URL that constitutes a source for quantum benchmarks, presenting "results" at the intersection of a “method” and a “task.” “Results” are reported by the community of users at the intersection of quantum technology “methods” performing desired “tasks,” or workloads of interest. Metriq publicly presents comparisons of “results” from “methods” across any given “task.”

We will briefly explain the motivating challenges of quantum benchmarks that Metriq is meant to address, followed by a “tour” of the live web application at https://metriq.info, explaining its taxonomy and workflows.

33. Aalto Quantum Games course nurturing the creative minds of physicists and game creators

Session 5, June 2

Laura Piispanen, Daria Anttila, Annakaisa Kultima (Aalto University, Finland; University of Turku, Finland)

We are presenting our experiences from organizing the online Quantum Games course at Aalto University. Quantum Games brings together students from bachelor’s, master’s and doctoral levels both from the school of Sciences and Art. Students form teams with backgrounds both from quantum physics as well as game design and through lectures, mentoring and set milestones develop ready games by the end of the course. Mentors have backgrounds both from professional game developing as well as university level research on quantum information, quantum technologies and related fields. Quantum Games has now been organized three times in a row and we will focus on the experiences and produced games of the latest iteration. In Spring 2022 Quantum Games brought together students from six different countries all over the world and together the teams developed ten quantum games.

Program committee

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