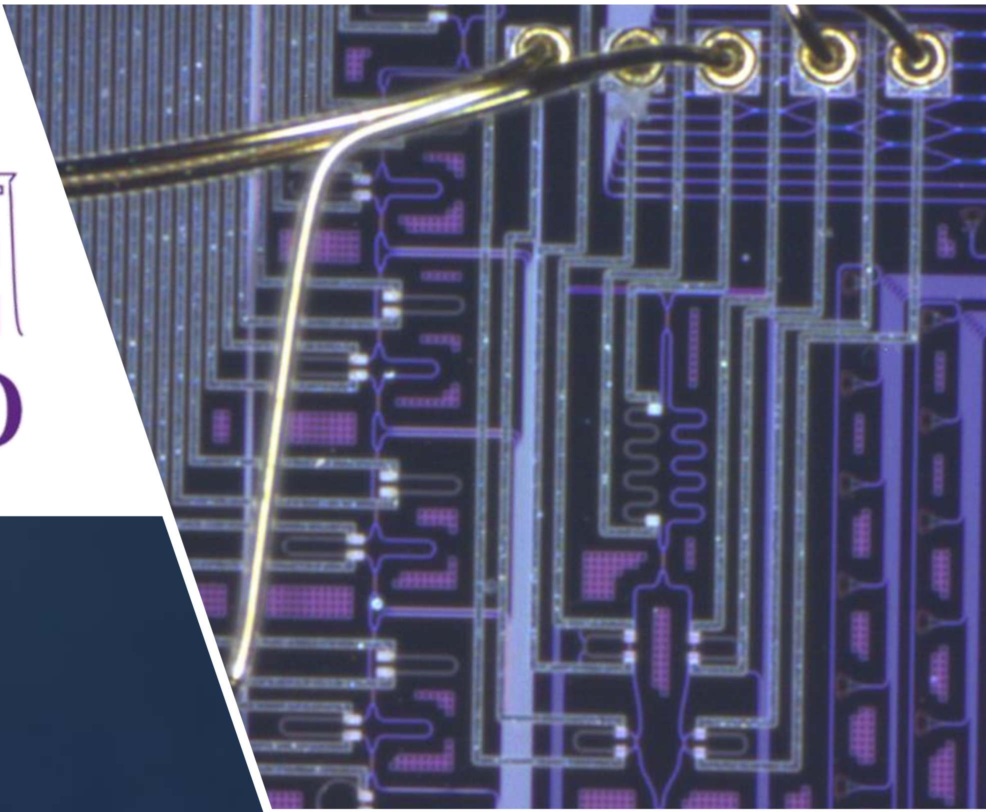
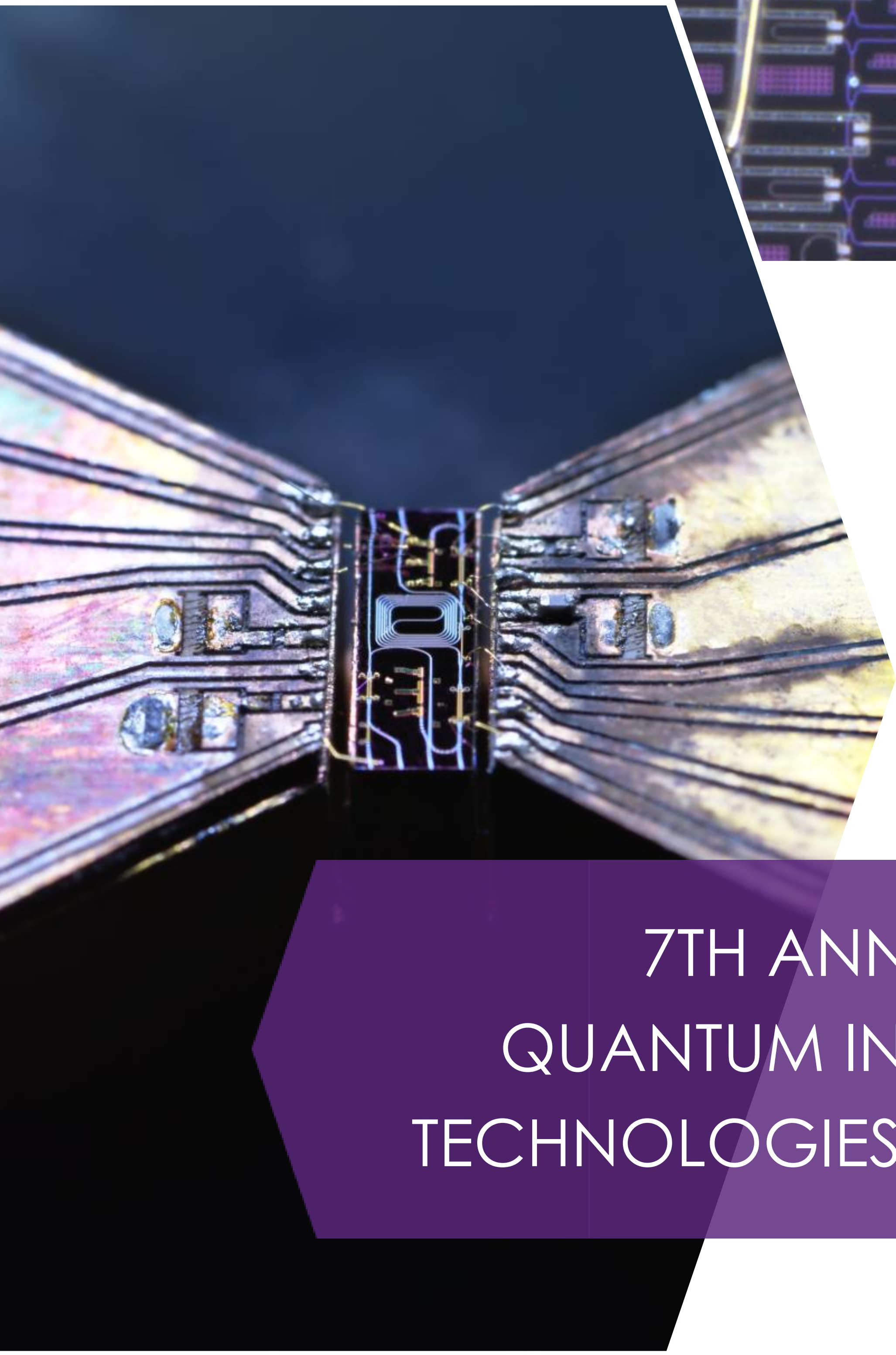
VIRTUAL

BQIT:20





QET Labs

Bristol, UK

27-30 April 2020

7TH ANNUAL BRISTOL QUANTUM INFORMATION TECHNOLOGIES WORKSHOP

University of Bristol

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CODE OF CONDUCT

The BQIT team is dedicated to providing a harassment-free online conference experience for everyone, regardless of gender, gender identity and expression, age, sexual orientation, disability, physical appearance, body size, race, ethnicity, religion (or lack thereof) or technology choices. We do not tolerate harassment of workshop participants in any form. Sexual language and imagery is not appropriate for any workshop platform, including talks, panels, dinners, Twitter and other online media. Workshop participants violating these rules may be sanctioned or expelled from Virtual BQIT:20 at the discretion of the workshop organisers.

WELCOME TO BQIT:20

Dear friends and colleagues,

The BQIT:20 team welcomes you to the seventh Bristol Quantum Information Technologies workshop.

Quantum physics is arguably the most accurate model of nature that we have. It also predicts we can adapt and greatly improve aspects of technology through the use of unique quantum phenomena. Our intention with BQIT over the years, has been to provide a sampling of the latest and most exciting results in foundational quantum information science and quantum technology, in a growingly diverse workshop that fosters a welcoming and creative atmosphere for all of its attendees. We plan to continue to deliver on these goals and to help us do this this year, we are extremely pleased to present to you this year an exciting technical program of invited speakers and poster presentations from across quantum information technologies. We very much hope every attendee gains something valuable from BQIT:20.

We had spent the best part of 12 months preparing BQIT:20 as a traditional (i.e. we-all-meet-up-in-the-same-room) workshop, in BQIT's home of Bristol, UK. However, the global circumstances that continue to impact us all professionally and personally, have forced BQIT in its new direction of being delivered as an all-virtual workshop for 2020. This is completely new to us from an organisational perspective, and we could not have made the change to an all-virtual workshop in five weeks without an increase in the technical team and extremely valuable advice from our colleagues who organised the inaugural Photonics Online Meetup (Jan 2020) and the recent QCTIP conference that took place online earlier this month hosted by Riverlane. In particular, we would like to thank Riccardo Sapienza (Imperial College London) and Amy Flower (Riverlane), and we point to [1] as a tremendous resource for anyone thinking of preparing a virtual conference.

We take this opportunity to thank Juani Bermejo Vega (University of Granada) and Josh Nunn (University of Bath) for their invaluable efforts as this year's external Board members. To each of our speakers and poster presenters, thank you for contributing your technical content. We are especially grateful to each of you for accommodating the change in circumstances and working with us to deliver your presentations online. In addition, the change to all-online in a short-time incurred expense, and so we are very grateful for the financial support from our sponsors. This enabled BQIT:20 to be free to all attendees.

It is our hope that you have a productive and enjoyable time while you engage and interact with BQIT:20. And to everyone that has helped take BQIT:20 online, thank you!

Best wishes,

Holly Caskie and Jonathan Matthews, on behalf of the BQIT board and organisation team

[1] Reshef, O., Aharonovich, I., Armani, A., Gigan, S., Grange, R., Kats, M. A. and Sapienza, R. "How to organize an online conference" Nature Reviews Materials, 5, 253-256 (2020)/ arXiv:2003.03219v2

DAY ONE AGENDA

MONDAY

APRIL 27

TIME	EVENT	LENGTH
09.00	Jonathan Matthews (University of Bristol) *Welcome and opening of the workshop*	15 min
Session One: chaired by Peter Turner (University of Bristol)		
09.15	Tim Ralph (University of Queensland) *Better Noiseless Amplifiers and CV Quantum Repeaters*	20 min (+ 5 min questions)
09.40	Jayne Thompson (National University of Singapore) *Causal Asymmetry in a Quantum World*	20 min (+ 5 min questions)
10.05	Steve Brierley (Riverlane) *Recent advances in Quantum software*	20 min (+ 5 min questions)
10.30	Yelena Guryanova (IQOQI Vienna) *Ideal Projective Measurements Have Infinite Resource Costs*	20 min (+ 5 min questions)
10.55	Sponsor demo: Nature Research COMMUNICATIONS PHYSICS SCIENTIFIC REPORTS natureresearch npj Quantum Information nature communications	10 min

Session Two: chaired by Josh Nunn (University of Bath)

12.30	Conor Bradley (TU Delft/QuTech) *Control, coherence and entanglement of nuclear spin registers in diamond*	20 min (+ 5 min questions)
12.55	Sonja Franke-Arnold (University of Glasgow) *Structured light - structured atoms*	20 min (+ 5 min questions)
13.20	Alex Clark (Imperial College London) *Single-Photon Spectroscopy of Atoms and Molecules*	20 min (+ 5 min questions)
13.45	Jorge Monroy Ruz (University of Bristol) *Encapsulated nanodiamonds for NV centre embedded silicon nitride quantum photonics*	20 min (+ 5 min questions)

Session Three: chaired by Jonathan Matthews (University of Bristol)

15.00	Alberto Politi (University of Southampton) *Generation of non-classical light in SiN devices*	20 min (+ 5 min questions)
15.25	Costanza Toninelli (CNR INO) *Scalable integration of Fourier-limited molecules in 3D polymeric photonic structures*	20 min (+ 5 min questions)
15.50	Omar Magana (Louisiana State University) *Multiphoton quantum-state engineering: Fundamentals and Applications*	20 min (+ 5 min questions)

16.15 DAY ONE CLOSE

17.30	Networking dinner - all attendees welcome to join!	120 min

DAY ONE ABSTRACTS

Tim Ralph

University of Queensland

Better Noiseless Amplifiers and CV Quantum Repeaters

We will discuss recent improvements to noiseless linear amplifiers and continuous variable quantum repeaters. Non-deterministic, heralded amplifiers can amplify unknown states without amplifying their quantum noise provided the alphabet of states to be amplified has an energy constraint. To date, practical protocols have had a very low energy constraint. We introduce a new linear optical protocol that can faithfully amplify states of significantly higher energy. We will also introduce a new quantum repeater scheme for distributing continuous variable entanglement which performs significantly better than previous schemes in terms of its ability to extend QKD protocols.

Jayne Thompson

National University of Singapore

Causal Asymmetry in a Quantum World

How can we observe an asymmetry in the temporal order of events when physics at the quantum level is time-symmetric? The source of time's barbed arrow is a longstanding puzzle. Causal asymmetry offers a provocative perspective. It asks how Occam's razor can privilege one temporal direction over another. That is, if we want to make statistically correct future predictions then what is the minimum past information we must store? Are we forced to store more data if we model events in one particular temporal order over the other?

Take a glass shattering upon impacting the floor. In one direction, the future distribution of shards depends only on the glass's initial position, velocity and orientation. In the opposite, we may need to track relevant information regarding each shard to infer the prior trajectory. Does this require more or less information? For stochastic processes, this potential divergence is quantified in the theory of computational mechanics. It is not only generally non-zero, but can also be unbounded. This phenomenon implies a simulator operating in the 'less natural' temporal direction is penalized with potentially unbounded memory overhead, and is cited as a candidate source of time's barbed arrow. However these studies assumed models were implemented via classical physics. Could the observed causal asymmetry have been a consequence of this classicality constraint?

In this presentation, we answer this question in the affirmative, by directly constructing a process where there is a classical arrow of time, but at the quantum level this arrow vanishes [1], and reporting on the experimental observation of this effect in a photonic quantum processor [2]. Our work suggests that causal asymmetry could be an artefact of forcing classical causal explanations in a fundamentally quantum world.

[1] Thompson et al., Phys. Rev. X 8, 031013
[2] Ghafari et al., Phys. Rev. X 9, 041013

Steve Brierley

Riverlane

Recent advances in Quantum software

The past 20 years has seen hugely impressive developments in quantum hardware with key milestones such as quantum computational advantage being met in 2019, but it is software that makes computers useful. Quantum computers perform calculations in a radically different way to traditional computers. They use counterintuitive notions such as superposition and entanglement and as a result it is subtle and challenging to develop applications that exploit this power. The expertise required is unique and specific.

I review recent advances in the field of quantum software and algorithm development made by Riverlane and discuss how we can get to commercial quantum advantage as soon as possible. These improve the way we use a quantum computer – dramatically lowing the cost of the first useful quantum computer by many orders of magnitude.

Yelena Guryanova

IQOQI Vienna

Ideal Projective Measurements Have Infinite Resource Costs

We show that it is impossible to perform ideal projective measurements on quantum systems using finite resources. We identify three fundamental features of ideal projective measurements and show that when limited by finite resources only one of these features can be salvaged. Our framework is general enough to accommodate any system and measuring device (pointer) models, but for illustration we use an explicit model of an N-particle pointer. For a pointer that perfectly reproduces the statistics of the system, we provide tight analytic expressions for the energy cost of performing the measurement. This cost may be broken down into two parts. First, the cost of preparing the pointer in a suitable state, and second, the cost of a global interaction between the system and pointer in order to correlate them. Our results show that, even under the assumption that the interaction can be controlled perfectly, achieving perfect correlation is infinitely expensive. We provide protocols for achieving optimal correlation given finite resources for the most general system and pointer Hamiltonians, phrasing our results as fundamental bounds in terms of the dimensions of these systems.

Connor Bradley

TU Delft/QuTech

Control, coherence and entanglement of nuclear spin registers in diamond

Spins associated to defects in solids are promising qubits for quantum information processing. The combination of an optical interface - enabling remote entanglement generation – with access to multi-qubit registers provides a basis for the realisation of quantum networks and modular quantum computation. Over the past years, essential components have been demonstrated, such as elementary quantum error correction [1] and entanglement distillation [2].

In this talk, I will present our efforts in realising the larger quantum registers that are needed for complex algorithms and larger networks. We have recently developed novel control techniques which enable control over a fully-connected ten-qubit register composed of the electron spin of an NV centre and nine associated nuclear spins [3]. I will present the benchmarks for this system, including two-qubit gate fidelities up to 99%, the demonstration of genuine 7-qubit entanglement, and the storage of arbitrary single-qubit states for up to 75 seconds. Finally, I will discuss our next steps towards larger numbers of qubits, where we have recently shown basic control and 3D imaging of 27 nuclear spin qubits [4].

[1] – J. Cramer, N. Kalb, M. A. Rol, B. Hensen, M. S. Blok, M. Markham, D. J. Twitchen, R. Hanson, and T. H. Taminiau, Nature Comm., 7(1), 1-7 (2016)

[2] – N. Kalb, A. A. Reiserer, P. C. Humphreys, J. J. Bakermans, S. J. Kamerling, N. H. Nickerson, S. C. Benjamin, D. J. Twitchen, M. Markham., and R. Hanson, Science, 356(6341), 928-932 (2017)

[3] – C. E. Bradley, J. Randall, M. H. Abobeih, R. C. Berrevoets, M. J. Degen, M. A. Bakker, M. Markham, D. J. Twitchen, and T. H. Taminiau, Phys. Rev. X 9, 031045 (2019)

[4] – M. H. Abobeih, J. Randall, C. E. Bradley, H. P. Bartling, M. A. Bakker, M. J. Degen, M. Markham, D. J. Twitchen, T. H. Taminiau, Nature 576, 411-415 (2019)

Sonja Franke-Arnold

University of Glasgow

Structured light - structured atoms

Complex vector light fields can show non-classical correlations in their spatial and polarisation degree of freedom, mimicking the behaviour of quantum entanglement.

I will introduce the concept of structured light, show how we generate and characterise it in the lab, and how it can be used to shape cold atomic samples.

Alex Clark

Imperial College London

Single-Photon Spectroscopy of Atoms and Molecules

Absorption, scattering, and fluorescence are just some of the ways we can use light to observe the world around us. I will present recent experiments in single-photon spectroscopy. The first used photon-pairs generated by four-wave mixing in optical fiber. Pump wavelength tuning scanned the idler wavelength across the band-edge absorption of gallium arsenide. The idler photons alone did not reveal the absorption due to Raman noise, but when correlated with signal photons the absorption was seen. The second experiment used a single dibenzoterrylene (DBT) molecule coupled to a gap between nanophotonic waveguides – a promising candidate for building an efficient photon source. We performed simultaneous single-molecule fluorescence and extinction spectroscopy, and used this to find the waveguide coupling efficiency. Interestingly, the asymmetry of the system results in a Fano-type lineshape in extinction. The final experiment used a bright pump laser to saturate rubidium atoms in a vapor cell, while a counter-propagating single-photon -level probe revealed narrow transmission peaks from the hyperfine-split excited state. The independently tunable pump and probe frequencies compensated for the Doppler shifts of all atoms in the beam. This experiment forms a basis for building an atomic quantum memory that can be used to store emission from DBT .

Jorge Monroy Ruz

University of Bristol

Encapsulated nanodiamonds for NV centre embedded silicon nitride quantum photonics

The design of optical interfaces to efficiently interact with solid state defects is challenging and an active area of research. Specifically, for colour centres in diamond, the high refractive index and the inert nature of diamond makes the collection of colour centre PL emission a challenging task. Even when nanofabrication of bulk diamond has been demonstrated, these nanostructures have restrictions many restrictions.

A versatile alternative to overcome these restrictions is to use nanodiamonds integrated with different photonic platforms. Here we show that nitrogen-rich silicon nitride is an ideal photonic platform for optically interfacing nanodiamonds containing NV centres. In addition, we present our recent progress on building scalable solid state quantum photonic platforms. We show deterministic positioning of nanodiamonds on a substrate to enable constructing fast sample maps to generate statistically significant data on the behaviour of NV centres pre and post encapsulation.

Alberto Politi

University of Southampton

Generation of non-classical light in SiN devices

The development of optical quantum technologies relies on the integration of different capabilities in monolithic devices. While silicon offers great advantages, among which exploiting the mature CMOS fabrication, it presents limitations due to the narrow transparency window. In this talk I will review progresses to increase the photonic capabilities offered by the silicon nitride platform. I will discuss the generation of non-classical states on-chip, including single photons and quadrature squeezing by four wave mixing, and the detection of single photons. I will discuss the current limitations in the generation of squeezing by self-phase modulation, and describe the how the current nanofabrication technology can provide squeezing levels comparable to the best free space OPO sources.

Costanza Toninelli

CNR INO

Scalable integration of Fourier-limited molecules in 3D polymeric photonic structures

The successful development of future photonic quantum technologies will much depend on the possibility of realizing robust and scalable nanophotonic devices. These should include quantum emitters like on-demand single-photon sources and non-linear elements, provided their transition linewidth is broadened only by spontaneous emission. However, conventional strategies to on-chip integration, based on lithographic processes in semiconductors, are typically detrimental for the coherence properties of the emitter. Moreover, such approaches are difficult to scale and bear limitations in terms of geometries. In the present contribution, we discuss an alternative platform, based on molecules that preserve near-Fourier-limited fluorescence even when embedded in polymeric photonic structures. Threedimensional patterns are achieved by Direct Laser Writing (DLW) of commercial photoresists around self-assembled organic nanocrystals containing fluorescent molecules. This method enables fast, inexpensive and scalable fabrication process, while offering unique advantages in terms of versatility and sub-micron resolution. In particular, Anthracene nanocrystals doped with dibenzoterrylene (DBT:Ac NCX) fluorescent molecules show unprecedented performances of singlephoton emission [1] and are naturally suitable both to deterministic positioning and to the integration in hybrid devices [2-3]. We demonstrate the integration DBT:Ac NCX via DLW at variable heights and well-defined locations in different architectures, from solid immersion lenses to waveguides, fabricated on different substrates. In particular, close-to Fourier limited emission is observed from on-chip molecules at cryogenic temperatures and enhanced light extraction is achieved in a micro -dome solid immersion lens design. By using an integrated polymeric design, detected photon counts of about 2.4 Mcps from a single cold molecule are reported [4]. The proposed technology will allow for competitive organic quantum devices, including integrated multi-photon interferometers, arrays of indistinguishable single-photon sources and hybrid electro-optical nanophotonic chips.

[1] S. Pazzagli, et al., ACS Nano 12, 4295-4303 (2018). [2] K. Schaedler, et al., Nano Letters 19, (2019). [3] P. Lombardi, et al., Adv. Quantum Technol. (2019), 1900083. [4] M. Colautti, et al., arXiv:1909.07334 (2019).

Omar Magana

Louisiana State University

Multiphoton quantum-state engineering: Fundamentals and Applications

The challenges involved in the preparation and characterization of photonic states with multiple particles, impose practical limitations to realistic quantum technologies. In this talk, I will report on our recent results on the preparation, manipulation and characterization of quantum states containing multiple photons. I will describe how the manipulation of the quantum electromagnetic fluctuations in two-mode squeezed vacuum states leads to a novel family of quantum-correlated multiphoton states with tunable mean photon numbers and degrees of correlations. Our technique relies on the use of conditional measurements to engineer the excitation mode of the field through the simultaneous subtraction of photons from two-mode squeezed vacuum states. In the second part of my talk, I will discuss two ongoing experiments that make use of multiphoton states. In this regard, I will describe the possibility of observing higher-order exceptional points in multiphoton systems and performing quantum phase estimation with multiphoton states.

NOTES

DAY TWO AGENDA

TUESDAY APRIL 28

TIME	EVENT	LENGTH
Session Four: chaired by John Rarity (University of Bristol)		
09.00	Daniel Oi (University of Strathclyde) *Quantum Research CubeSat (QUARC)*	20 min (+ 5 min questions)
09.25	Davide Bacco (Technical University of Denmark) *Fibre based quantum communications with multidimensional quantum states*	20 min (+ 5 min questions)
09.50	Mariella Minder (University of Cambridge/Toshiba CRL) *Advances in Experimental Twin-Field Quantum Key Distribution*	20 min (+ 5 min questions)
10.15	Siddarth Joshi (University of Bristol) *A trusted-node-free eight-user metropolitan quantum communication network*	20 min (+ 5 min questions)
10.40	Milica Prokic (European University Institute) *The Lights Keys: A Quantum Graphic Novel, Volume 2*	10 min
10.50	Sponsor demo: Quix	10 min

11.30	Networking lunch - all attendees welcome to join!	60 min

Session Five: EDI (Equality, Diversity & Inclusion) Panel chaired by Sabine Wollmann & Juani Bermejo Vega (University of Bristol)

12.30	**Working conditions in academia and its impact on mental health** Emma Chapman (Imperial) Carla Figueira De Morisson Faria (UCL) Rachel Herbert (Elsevier) Sofia Qvarfort (UCL)	90 min

Session Six: chaired by Juani Bermejo Vega (University of Granada)

15.00	Roope Uola (University of Geneva) *Quantifying quantum resources with conic programming*	20 min (+ 5 min questions)
15.25	Brian Flynn (University of Bristol) *Learning models of quantum systems from experiments*	20 min (+ 5 min questions)
15.50	Nadja Bernardes (Federal University of Pernambuco) *Correlation measures and non-Markovianity in open quantum systems dynamics*	20 min (+ 5 min questions)
16.15	Mercedes Gimeno Segovia (PsiQuantum) *Photonic Quantum Computing*	20 min (+ 5 min questions)

16.40 DAY TWO CLOSE

DAY TWO ABSTRACTS

Daniel Oi

University of Strathclyde

Quantum Research CubeSat (QUARC)

Quantum Key Distribution (QKD) can ensure the security of communication links in the face of the threat that large-scale quantum computing poses to currently deployed public key encryption. But the range of terrestrial QKD systems is limited by losses, either from exponential absorption in optical fibres or the limitations of horizontal free-space transmission through the atmosphere. Space-based quantum communication has the potential to extend the reach of QKD to global scales and may form the backbone for the quantum internet by distributing entanglement world-wide.

The MICIUS satellite achieved ground-breaking results, including QKD, teleportation, and entanglement distribution over large distances. However, the cost of such a large and conventional space platform is prohibitive for most nations attempting to achieve similar capability. Recent developments in the space industry, dubbed NewSpace, is revolutionising how satellite missions are conducted, reducing development time and costs. It provides a fast-track towards acquiring technical and operational expertise for advanced space systems such as satellite QKD (SatQKD). A central component of the NewSpace movement is the use of highly capable small satellites, most commonly CubeSats, that dramatically lowers the cost of entry compared with conventional satellites.

The Quantum Research CubeSat (QUARC) project is a part of the UK National Quantum Technology Programme and supported by the QT Hub in QComms and the UK Space Agency. QUARC aims to demonstrate and validate components and subsystems, and support efforts to deploy satellite constellation and corresponding ground networks for SatQKD. Here, we present the results of the architectural design and modelling of a CubeSat-based SatQKD system to secure links for critical infrastructure. We analyse the performance of a small constellation, utilising local weather and astronomical effects to ascertain the monthly secure rate achievable with currently available technology and to inform future development of SatQKD capabilities.

Davide Bacco

Technical University of Denmark

Fibre based quantum communications with multidimensional quantum states

Quantum communication represents a key enabler for many applications from secure communications to advanced quantum simulations on the cloud. However, multiple factors are limiting the development of this technology. The main technical limitations currently restricting the range of applicability are the intrinsic rate-distance limit and the extremely difficult coexistence with the present telecommunication infrastructure. Present quantum communication systems mainly use a two-dimensional encoding scheme (qubit) as information unit, which is very fragile and susceptible to external noise. On the contrary, adopting high-dimensional quantum states (qudit), which are intrinsically more robust to noise owing to their higher information efficiency, the potential to realise a fast and reliable quantum communication infrastructure is within our grasp. We here report our recent results on the generation, transmission and detection of high-dimensional quantum states in single-mode, multicore and multimode fibres.

Mariella Minder

University of Cambridge/ Toshiba CRL

Advances in Experimental Twin-Field Quantum Key Distribution

Quantum key distribution (QKD) allows users to generate shared encryption keys with information theoretic security guaranteed by the laws of quantum mechanics. Due to the use of dim optical pulses and losses in the quantum channel, there is a fundamental rate-distance limit in QKD that was thought to be unsurpassable with current technology [1, 2]. The proposal of the Twin-Field QKD (TF-QKD) protocol [3] offers a way to overcome this limit by showing the same square root dependence of key rate on channel loss that a quantum repeater shows, but solely utilising current technology. TF-QKD reached an essential milestone in the field of quantum cryptography and consequently it has since been rigorously explored, both theoretically [4, 5] and experimentally [6, 7, 8, 9]. Several variations of the scheme have been proposed, each with different benefits and drawbacks, while experimental demonstrations have obtained secure key rates using channels exceeding 500 km of total length. Here, we provide an overview of the developments in the area of TF-QKD research, including the most recent results by our group. [1] M. Takeoka, S. Guha, and M. M. Wilde, "Fundamental rate-loss tradeoff for optical quantum key distribution," Nat. Commun., vol. 5, p. 5235, oct 2014. [2] S. Pirandola, R. Laurenza, C. Ottaviani, and L. Banchi, "Fundamental limits of repeaterless quantum communications," Nat. Commun., vol. 8, p. 15043, apr 2017. [3] M. Lucamarini, Z. L. Yuan, J. F. Dynes, and A. J. Shields, "Overcoming the rate-distance limit of quantum key distribution without quantum repeaters: Supplementary material," Nature, vol. 557, no. 7705, pp. 400–403, 2018. [4] X.-B. Wang, Z.-W. Yu, and X.-L. Hu, "Twin-field quantum key distribution with large misalignment error," Phys. Rev. A, vol. 98, p. 062323, Dec 2018. [5] M. Curty, K. Azuma, and H.-K. Lo, "Simple security proof of twin-field type quantum key distribution protocol," npj Quantum Information, vol. 5, no. 1, p. 64, 2019. [6] M. Minder, M. Pittaluga, G. L. Roberts, M. Lucamarini, J. F. Dynes, Z. L. Yuan, and A. J. Shields, "Experimental quantum key distribution beyond the repeaterless secret key capacity," Nature Photonics, vol. 13, no. 5, pp. 334–338, 2019. [7] X. Zhong, J. Hu, M. Curty, L. Qian, and H. -K. Lo, "Proof-of-principle experimental demonstration of twin-field type quantum key distribution," Phys. Rev. Lett., vol. 123, p. 100506, Sep 2019.

Siddarth Joshi

University of Bristol

A trusted-node-free eight-user metropolitan quantum communication network

Quantum networks scale the advantages of quantum communication protocols to more than just two distant users. Here we present a fully connected quantum network architecture in which a single entangled photon source distributes quantum states to a multitude of users [1] and our work scaling the network to a complete end to end metropolitan quantum network with 8 users [2]. Our network architecture optimises the resources required by each user without sacrificing security or functionality. We established several long-distance loopback connections and demonstrated extended stable operation with high secure key rates. Unlike previous attempts at multi-user networks, which have been based on active components, and thus limited to some duty cycle, our implementation is fully passive and thus provides the potential for unprecedented quantum communication speeds. We experimentally demonstrate the feasibility of our approach using a single source of bi-partite polarization entanglement which is multiplexed into 16 wavelength channels and 2 beamsplitter channels to distribute 32 states between 8 users in a fully connected graph using only 1 fibre and polarisation analysis module per user. Four channels are used for network management and were configured to provide certain higher bandwidth premium links.

[1] S.Wengerowsky, et at., Nature, 564 (7735), 225–228 (2018).

[2] S.K. Joshi, et al. arXiv preprint arXiv:1907.08229 (2019).

Roope Uola

University of Geneva

Quantifying quantum resources with conic programming

Resource theories can be used to formalize the quantification and manipulation of resources in quantum information processing such as entanglement, asymmetry and coherence of quantum states, and incompatibility of quantum measurements. Given a certain state or measurement, one can ask whether there is a task in which it performs better than any resourceless state or measurement.
Using conic programming, we prove that any general robustness measure (with respect to a convex set of free states or measurements) can be seen as a quantifier of such outperformance in some discrimination task. We apply the technique to various examples, e.g. joint measurability, POVMs simulable by projective measurements, and state assemblages preparable with a given Schmidt number.

Brian Flynn

University of Bristol

Learning models of quantum systems from experiments

arXiv:2002.06169

An isolated system of interacting quantum particles is described by a Hamiltonian operator. Hamiltonian models underpin the study and analysis of physical and chemical processes throughout science and industry, so it is crucial they are faithful to the system they represent. However, formulating and testing Hamiltonian models of quantum systems from experimental data is difficult because it is impossible to directly observe which interactions the quantum system is subject to. Here, we propose and demonstrate an approach to retrieving a Hamiltonian model from experiments, using unsupervised machine learning. We test our methods experimentally on an electron spin in a nitrogen-vacancy interacting with its spin bath environment, and numerically, finding success rates up to 86%. By building agents capable of learning science, which recover meaningful representations, we can gain further insight on the physics of quantum systems.

Nadja Bernardes

Federal University of Pernambuco

Correlation measures and non-Markovianity in open quantum systems dynamics

We investigate the ability of correlation measures to witness non-Markovian open system dynamics. It is shown that that the quantum mutual information between system and ancilla as well as any entanglement measure, both commonly used for the characterization of non-Markovianity, are unable to witness all non-completely-positive-divisible dynamics. A new correlation measure for an enlarged setting with two ancillas is introduced, and it is shown that this measure witness non-Markovian dynamics for all bijective non-completely-positive-divisible evolutions.

Mercedes Gimeno Segovia

PsiQuantum

Photonic Quantum Computing

Photons make great qubits, they are cheap to produce, resilient to noise and the only known option for quantum communication. The two main traditional arguments against a fully linear-optical quantum computing architecture have been the lack of deterministic photonic entangling gates and the predisposition of photons to loss. However, a number of theoretical breakthroughs have made these arguments loose strength, while implementations in silicon photonics have opened the door to manufacturability at large scale. In this talk, I will describe an architecture for fault tolerant quantum computing based on linear optics, in the process I will explain how measurement-induced non-linearity can overcome the challenge of creating entanglement and how loss can be tackled with well-known error correcting codes.

NOTES

EDI PANEL

Pictured right: top to bottom

Emma Chapman

Imperial College London

Dr Emma Chapman is a Royal Society Dorothy Hodgkin Fellow based at Imperial College London where she researches the first stars to exist in our Universe, 13 billion years ago.

Emma has worked with individual institutions and the Institute of Physics to ensure the problem of bullying and harassment within STEM is taken seriously since the start of her postgraduate career. During that time, she lobbied for and helped introduce a new requirement for gender equality project JUNO to ensure physics departments have adequate policies for prevention and disciplinary processes surrounding bullying and harassment.

She works actively to improve workplace culture in academia as a member of the campaign organisation The 1752 Group. This research and lobby group works at a national level to end staff-student sexual misconduct, working with sector bodies such as Universities UK and NUS to research solutions and ensure new protections for students are disseminated nationwide.

Carla Figueira De Morisson Faria

UCL

Professor Carla Figueira de Morisson Faria from the Department of Physics and Astronomy, University College London (UCL), is one of the very few female Professors of mixed Black heritage in the UK, and, from 2016 to 2019, was the first female Undergraduate Admissions Tutor at UCL Physics and Astronomy. This has made her a trailblazer and facilitator of cultural change in several ways.

In 2018 she chaired the Power Hour at the Gordon Research Conference on Multiphoton Processes (Bryan University, USA), which aims at improving the conditions for Women in Science involving researchers from across the globe.

She is a regular speaker at TechGirls and In2science events, and the King's College Womxn in Physics conferences.

Carla leads the UCL Women in Physics group, and is a member of the Departmental Equality and Diversity committee and the Inclusion Group for Equity in Research (TIGERs) in STEMM.

Rachel Herbert

Elsevier

Rachel is the Senior Research Evaluation Manager at Elsevier and an associate of the International Center. Over the past five years, Rachel has specialised in the application of scientometric approaches to understand the world of research and was one of the analysts and authors of Elsevier's 2017 report, "Gender in the Global Research Landscape". Additionally, she is a member of Elsevier's Gender Working Group and is currently involved in initiatives focused on how insights from data, metrics and analytics could be applied to further our understanding of the role gender plays within research and for researchers.

Sofia Qvarfort

UCL

Dr Sofia Qvarfort is an EPSRC Doctoral Prize Fellow at both Imperial College and University College London researching noisy quantum metrology with optomechanical systems.

Sofia was born with a visual impairment. Since completing her undergraduate degree, she has worked towards improving the situation for visually impaired people (VIPs) at university. To help share the stories and experiences of visually impaired students, Sofia set up the website VIP@University (www.vipatuni.com) in 2017, where 'VIP' stands for 'visually impaired person', and a podcast called University InSight, interviewing visually impaired students about their experiences. Sofia is a new member of TIGERS in STEM, has taken part in a web-panel with the charity LOOK-UK to advise students during the COVID-19 crisis, and is developing guidelines for conference organisers on how to best accommodate visually impaired people.

DAY THREE AGENDA

WEDNESDAY APRIL 29

TIME	EVENT	LENGTH
Session Seven: chaired by Dara McCutcheon (University of Bristol)		
09.00	Maria Kieferova (Macquarie University) *Oblivious algorithmic cooling*	20 min (+ 5 min questions)
09.25	Barbara Kraus (University of Innsbruck) *Some aspects of quantum computing and its verification*	20 min (+ 5 min questions)
09.50	Michal Oszmaniec (CTP PAS) *Epsilon-nets, unitary t-designs and random quantum circuits*	20 min (+ 5 min questions)
10.15	Alexandra Moylett (University of Bristol) *Classically simulating near-term Boson Sampling*	20 min (+ 5 min questions)
10.40	Sponsor demo: PriTel PriTel	10 min

Session Eight: chaired by Jorge Barreto (University of Bristol)

12.30	Dominic Sulway (University of Bristol) *Engineering ultra-low-loss silicon quantum photonics in the mid-infrared*	20 min (+ 5 min questions)
12.55	Pete Mosley (University of Bath) *Photonic crystal fibre for quantum technologies: sources, networks, interfaces*	20 min (+ 5 min questions)
13.20	Natalia Herrera Valencia (Heriot Watt University) *Unscrambling entanglement through a complex medium*	20 min (+ 5 min questions)
13.45	Euan Allen (University of Bristol) *Quantum Optical Metrology of Correlated Phase and Loss*	20 min (+ 5 min questions)

Session Nine: chaired by Jake Bulmer (University of Bristol)

15.00	Lisa Ibberson (Hitachi Cambridge Laboratory) *Co-integrated superconducting-CMOS technology for fast gate-based dispersive readout*	20 min (+ 5 min questions)
15.25	Natalia Ares (University of Oxford) *Machine learning to efficiently characterise and tune quantum devices*	20 min (+ 5 min questions)
15.50	Matt Hutchings (Seeqc) *Seeqc - Digital Quantum Computing*	20 min (+ 5 min questions)
16.15	Sonia Buckley (NIST) *Progress in superconducting opto-electronic neuromorphic computing*	20 min (+ 5 min questions)

16.40 DAY THREE CLOSE

17.30	Networking dinner - all attendees welcome to join!	120 min

DAY THREE ABSTRACTS

Maria Kieferova

Macquarie University

Oblivious algorithmic cooling

Algorithmic cooling refers to protocols for extracting a very pure qubit out of an ensemble of qubits in thermal states. High purity can be achieved using heat-bath algorithmic cooling (HBAC) methods, which assume that parts of the cooling system can exchange heat with a heat bath. One of the main challenges with HBAC techniques is that they are highly sensitive to the state of the cooled qubits. In this work, we give an algorithm for reaching the asymptotic cooling state with a fixed, state-independent operation in each iteration.

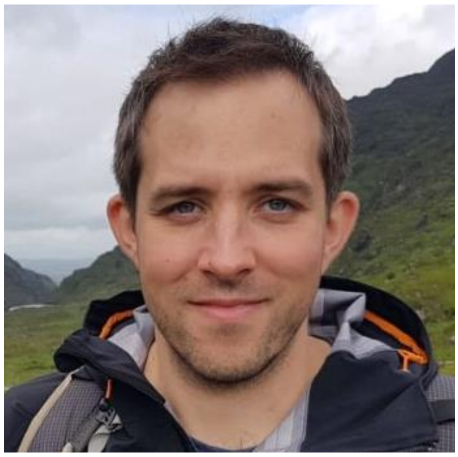
Based on "Novel Technique for Robust Optimal Algorithmic Cooling", S. Raeisi, MK, and M. Mosca, PRL 2019

Barbara Kraus

University of Innsbruck

Some aspects of quantum computing and its verification

I will present some results in the context of matchgate quantum computations and one some methods how to verify and validate quantum computations.



Michal Oszmaniec

CTP PAS

Epsilon-nets, unitary t-designs and random quantum circuits

Epsilon-nets and approximate unitary t-designs are natural notions that capture properties of general unitary operations relevant for numerous applications in quantum information and quantum computing. The former constitute subsets of unitary channels that are epsilon-close to every target unitary channel. The latter are ensembles of unitaries that (approximately) recover Haar averages of polynomials in entries of unitary channels up to order t.

In this work we establish quantitative connections between these two seemingly different notions. We apply our findings in conjunction with the recent results of Varju, 2013 in the context of quantum computing. First, we show that that approximate t-designs can be generated by shallow random circuits formed any from set of universal two-qudit gates in the parallel and sequential local architectures considered by Brandao-Harrow-Horodecki, 2016. Importantly, we do not require that the gate set is symmetric (i.e. contains gates together with their inverses) and consists of gates having algebraic entries. Second, we consider a problem of compilation of quantum gates and prove a non-constructive version of Solovay-Kitaev theorem for general universal gate sets.

Alexandra Moylett

University of Bristol

Classically simulating near-term Boson Sampling

Boson sampling is the problem of sampling from the same distribution as indistinguishable single photons at the output of a linear optical interferometer. It is an example of a non-universal quantum computation which is believed to be feasible in the near term and cannot be simulated on a classical machine. Like all purported demonstrations of 'quantum computational supremacy', this motivates optimising classical simulation schemes for a realistic model of the problem, in this case boson sampling when the implementations experience lost or distinguishable photons. Although current simulation schemes for sufficiently imperfect boson sampling are classically efficient, in principle the polynomial runtime can be infeasibly large. In this work, we develop a scheme for classical simulation of boson sampling under uniform distinguishability and loss, based on the idea of sampling from distributions where at most k photons are indistinguishable. We show that asymptotically this scheme can provide a polynomial improvement in the runtime compared to classically simulating idealised boson sampling. More significantly, we show that in the regime considered experimentally relevant, our approach gives an substantial improvement in runtime over other classical simulation approaches. Based on Quantum Science and Technology 5, 015001 (2020) [arXiv: 1907.00022].

Dominic Sulway

University of Bristol

Engineering ultra-low-loss silicon quantum photonics in the mid-infrared

Quantum silicon photonics must overcome considerable loss engineering challenges before it can scale to the thousands or millions of physical qubits required for fault tolerant quantum computation. The first such challenge is the intrinsic two-photon absorption (TPA), present in silicon at telecommunications wavelengths. This places fundamental limits on the heralding or Klyshko efficiency of silicon photon-pair sources based on spontaneous four-wave mixing (SFWM) [1]. We have recently shown [2] that by moving to a pump wavelength of 2-microns, in the mid-infrared (MIR), TPA in silicon can be curtailed, and by using 340-nm thick silicon waveguides, phase matching can be achieved for efficient SFWM. However phase-matching in more widely available 220-nm waveguides remains a challenge due to group-velocity dispersion limitations in the fundamental transverse electric (TE0) mode. Here, we demonstrate a new mid-infrared photon-pair source on 220-nm silicon which uses Type-0 SFWM in TE1 alone, which overcomes this limitation. Our source converts the TE0 pump fields into the TE1 mode, pumping a spiral waveguide, and then mode converting back to TE0 for off chip detection. We observe photon pairs with a peak net coincidence rate of 55.44 ± 0.06-Hz and a maximum coincidence-to-accidental ratio of 8.59 ± 0.06. For now, single photons must be routed off-chip for external detection, the necessary chip-to-fibre coupling is often a source of significant loss. We also demonstrate novel fibre-chip interface structures in the 2-micron band, via the adiabatic coupling of a nano-tapered silica fibre to a suspended and tapered silicon nanowire waveguide. We estimate the loss of a single coupler at –0.85 dB, with a 1-sigma confidence interval of 0.0-dB to -1.9-dB, and with a 3-dB bandwidth greater than 110-nm. Both of these advancements will be key enabling technologies for MIR quantum photonic resource generation and detection in the near future.

[1]- Husko, C. A. et al. Multi-photon absorption limits to heralded single photon sources. doi:10.1038/srep03087

[2]- L. M. Rosenfeld, D. A. Sulway, G. F. Sinclair, V. Anant, M. G. Thompson, J. G. Rarity, and J. W. Silverstone, "Mid-infrared quantum optics in silicon", 1906.10158, arXiv quant-ph, (2019).

Pete Mosley

University of Bath

Photonic crystal fibre for quantum technologies: sources, networks, interfaces

Photonic crystal fibre, in which light is guided by a microstructure of air holes in a glass matrix, enables control of fibre dispersion, tight modal confinement, long interaction lengths with atomic vapours, and low-loss integration with conventional fibre components.

I will present research conducted in the Centre for Photonics and Photonic Materials at the University of Bath towards applying these favourable characteristics to a range of applications within photonic quantum technologies. In particular, I will focus on enhancing heralded single-photon sources through active switching alongside engineered dispersion and loss, as well as creating frequency-conversion interfaces to link nodes in large-scale quantum networks.

Natalia Herrera Valencia

Heriot Watt University

Unscrambling entanglement through a complex medium

Photonic high-dimensional entanglement in the spatial degree of freedom has recently emerged as a practical way to enhance the capacity of quantum information systems, as well as increase their robustness to noise. However, while qubit-entanglement has been distributed over large distances through free-space and fibre, the transport of high-dimensional entanglement is hindered by the complexity of the channel, which encompasses effects such as free-space turbulence or mode-mixing in multi-mode waveguides. As a result, the transport of entangled states of light through highly complex media has never been achieved. This work demonstrates the transport of six-dimensional spatial-mode entanglement through a two-metre long, commercial multi-mode fibre with 84.43% fidelity. We show how the entanglement can itself be used to measure the transmission matrix of the complex medium, allowing the recovery of quantum correlations that were initially lost. Using a unique property of entangled states, the medium is rendered transparent to entanglement by carefully "scrambling" the photon that did not enter it, rather than unscrambling the photon that did. These results overcome a primary challenge in the fields of quantum communication and imaging, and opens a new pathway towards the control of complex scattering processes in the quantum regime.

Euan Allen

University of Bristol

Quantum Optical Metrology of Correlated Phase and Loss

Patrick M. Birchall, Euan J. Allen, Thomas M. Stace, Jeremy L. O'Brien, Jonathan C. F. Matthews, and Hugo Cable

Optical quantum metrology investigates how interrogating samples using quantum states of light can improve the precision with which parameters of the sample, such as the phase or loss, can be estimated. In many cases, phase and loss are applied simultaneously to the optical beam; either due to lossy optical elements in an interferometer, or due to the Kramers-Kronig relations which ensure changes in absorption are accompanied by a change in refractive index (phase). Examples include measurements of atomic gases and ring resonators.

Previous results [PRA 89 02345] have demonstrated that simultaneous estimation of both the phase and loss applied to a mode can never saturate the quantum Cramér-Rao bound (QCRB). In this work we show that if the phase and loss are correlated by an underlying physical parameter of interest then it is possible to saturate the QCRB. We derive this bound, which is independent of the input state and therefore bounds all quantum states, and introduce an experimental strategy using squeezed coherent states that saturates this bound. We investigate cases when the correlation is both known and unknown and look towards current achievable experimental parameters to see what improvement in precision can be found using current technology.

Work published at: PRL 124 140501 (2020)

Lisa Ibberson

Hitachi Cambridge Laboratory

Co-integrated superconducting-CMOS technology for fast gate-based dispersive readout

Silicon spin qubits are attractive candidates for solid state quantum computing applications, due to their long coherence times and compatibility with large scale manufacturing. Recent demonstrations of high-fidelity spin readout and one- and two- qubit gates are important milestones towards the successful realisation of a silicon quantum computer. Now, it is necessary to focus on scaling the technology to a number of qubits which is sufficiently large to perform computationally relevant calculations.

In our group, we investigate the use of silicon complementary metal-oxide-semiconductor (CMOS) technology as a platform for the implementation of scalable quantum circuits. Exploiting silicon transistors in this way allows us to benefit from the established technology used to fabricate large scale integrated circuits. Viable quantum computer implementations also require a scalable readout technique. In this talk I discuss the optimisation of gate based readout and demonstrate the rapid gate-based readout of the charge state in a silicon CMOS nanowire transistor, with an SNR of 3.3 in 50 ns. Finally, I present preliminary frequency multiplexing results to demonstrate the scalability of our approach.

Natalia Ares

University of Oxford

Machine learning to efficiently characterise and tune quantum devices

In a quantum device, a large set of parameters have to be carefully tuned to find the conditions in which it operates as a qubit. The difficulty in characterising and tuning each device has been so far a major hindrance for the scalability of quantum circuits, since these tasks quickly become intractable for large arrays of quantum devices. Automation is needed but device characteristics vary non-monotonically and not always predictably with control signals, making device characterisation and tuning extremely complex tasks to automate.

I will show how a machine learning algorithm can perform efficient quantum device measurements. This algorithm decides in real time which measurement would be the most informative to perform next, significantly reducing measurement times. I will also demonstrate how an algorithm can tune a 'virgin' double quantum dot device to operating conditions, without the need of specifying a device architecture, and in a fraction of the time that it requires manually.

Matt Hutchings

Seeqc

Seeqc - Digital Quantum Computing

Seeqc is developing the first digital quantum computing platform for global businesses. Seeqc combines classical and quantum technologies to address the efficiency, stability and cost issues endemic to quantum computing systems. The company applies classical and quantum technology through digital readout and control technology and through a unique chip-scale architecture. Seeqc's quantum system provides the energy- and cost-efficiency, speed and digital control required to make quantum computing useful and bring the first commercially-scalable, problem-specific quantum computing applications to market.

The company is one of the first companies to have built a superconductor multi-layer commercial chip foundry and through this experience has the infrastructure in place for design, testing and manufacturing of quantum-ready superconductors. Seeqc is a spin-out of Hypres, the world's leading developer of superconductor electronics. Seeqc's team of executives and scientists have deep expertise and experience in commercial superconductive computing solutions and quantum computing. Seeqc is based in Elmsford, NY with design and test facilities in the UK and EU.

Sonia Buckley

NIST

Progress in superconducting opto-electronic neuromorphic computing

The human brain exceeds the performance of computers at many tasks, and operates at orders of magnitude lower power while performing many others. Neuromorphic computing refers to compute hardware (rather than just software algorithms) taking inspiration from the hardware in the brain. CMOS hardware, which has been massively successful at traditional computation, may not prove to be the optimal hardware for neuromorphic computing. In this talk, we will discuss our proposed large-scale neuromorphic computing hardware platform. The platform has many similarities to those being considered for photonic quantum computing, without requiring quantum states. It combines semiconducting few-photon light-emitting diodes with superconducting-nanowire single-photon detectors to behave as spiking neurons. These neurons are connected via a network of optical waveguides. The use of light as a signaling mechanism overcomes fanout and parasitic constraints on electrical signals. The use of supercurrents achieves the low power density necessary for scaling. We will also present our experimental progress on the building blocks of this platform, including waveguide-integrated LEDs, multi-layer photonic waveguides, and superconducting detector circuits. Finally, we will discuss the next steps towards realizing this platform, which may lead to powerful supercomputing systems which are very different from the supercomputers we use today.

DAY FOUR AGENDA
THURSDAY
APRIL 30

TIME	EVENT	LENGTH
Session Ten: chaired by Joshua Silverstone (University of Bristol)		
09.00	Yasutomo Ota (University of Tokyo) *Hybrid integration based on transfer printing for scalable silicon quantum photonics*	20 min (+ 5 min questions)
09.25	Christine Silberhorn (Paderborn University) *Nonlinear integrated quantum optics*	20 min (+ 5 min questions)
09.50	Maria Chekhova (Max Planck Institute for the Science of Light) *Bright twin beams for quantum imaging and metrology*	20 min (+ 5 min questions)
10.15	Marco Bellini (Instituto Nazionale di Ottica CNR-INO) *Entanglement generation by coherent multimode photon addition*	20 min (+ 5 min questions)

10.40	BQIT sponsors exhibitor poster session	30 min

11.30	Networking lunch - all attendees welcome to join!	60 min

Session Eleven: chaired by Friederike Jöhlinger (University of Bristol)

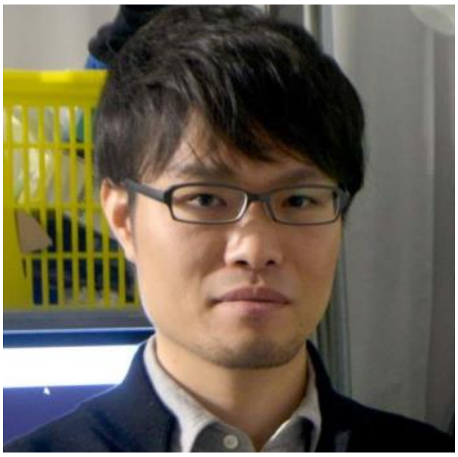
12.30	Vadim Makarov (Russian Quantum Centre) *Improving security of a QKD system via an external audit*	20 min (+ 5 min questions)
12.55	Sabine Wollmann (University of Bristol) *Experimental demonstration of robust quantum steering*	20 min (+ 5 min questions)
13.20	Glaucia Murta (Heinrich-Heine-Unversitat Dusseldorf) *Bounds on the information available to the eavesdropper in a multipartite device-independent scenario*	20 min (+ 5 min questions)
13.45	Ralf Riedinger (Harvard University) *Spin memory enhanced quantum communication*	20 min (+ 5 min questions)

Session Twelve: chaired by Cecile Skoryna Kline (University of Bristol)

15.00	Margherita Mazzera (Heriot Watt University) *New platforms for integrated solid-state quantum memories*	20 min (+ 5 min questions)
15.25	Christa Fluhmann (Yale Quantum Institute/ETH Zurich) *Encoding and control of a qubit in a trapped-ion mechanical oscillator*	20 min (+ 5 min questions)
15.50	Lindsay LeBlanc (University of Alberta) *Storage and manipulation of photonic signals using the Autler-Townes Splitting memory protocol*	20 min (+ 5 min questions)
16.15	Thanks and close - John Rarity (University of Bristol)	15 min

16.30 VIRTUAL BQIT:20 CLOSE

DAY FOUR ABSTRACTS



Yasutomo Ota

University of Tokyo

Hybrid integration based on transfer printing for scalable silicon quantum photonics

We discuss a novel way to perform hybrid integration of quantum photonic elements on chip. We employ transfer printing, which is based on pick-and-place assembly using a transparent rubber stamp under an optical microscope, and enables the transfer of processed devices from their mother wafers to target photonic chips prepared separately.

By carefully designing and operating the transfer-printing machine, it is possible to achieve positioning accuracy better than 100 nm, which is sufficient to ensure high coupling between optical components. We demonstrate transfer printing of InAs/GaAs quantum dot single photon sources on silicon optical circuits prepared by a CMOS process foundry.

We also show on-silicon integration of a quantum-dot-based cavity quantum electrodynamics system in strong coupling regime and of photonic
crystal nanocavity lasers.

Christine Silberhorn

Paderborn University

Nonlinear integrated quantum optics

Recent achievements in the area of integrated quantum optics and quantum information processing have shown impressive progress for the implementation of linear circuits based on monolithic waveguide structures. Most experiments are based on $\chi(3)$ -media, such as glas, silicon-on insulator or silica-on-silicon. In these platforms the implementation of highly efficient sources, frequency converters and fast active phase shifters and modulators pose severe challenges. The use of advanced waveguides structures, which harness a $\chi(2)$ –nonlinearity, allows for the realization various devices with multiple functionalities. These include single- and multi-channel sources with high brightness, quantum frequency conversion with tailored spectral-temporal properties, and circuits comprising degenerate pair generation in orthogonal polarization, linear elements, and active elements such as polarization rotators or an electro-optically controllable time delay. Here we present our latest progress for the implementation of integrated devices based on $\chi(2)$ – media for quantum circuits and quantum communication systems.

Maria Chekhova

Max-Planck Institute for the Science of Light

Bright twin beams for quantum imaging and metrology

High-gain parametric down-conversion (PDC) produces bright multimode radiation, known as bright squeezed vacuum. Despite the high mean photon number per mode, it has pronounced nonclassical features such as quadrature and twin-beam squeezing. The latter means that photon numbers in the signal and idler beams are perfectly correlated. These photon-number correlations have numerous applications in quantum metrology and imaging. In addition, the mean photon numbers of twin beams have a unique spectral distribution, determined by the `brightness of the vacuum'. We recently used this feature to measure the spectral sensitivity of a spectrometer [1]: as the frequencies of signal and idler beams are tuned, their peak values follow a parabola of a known shape. At high parametric gain, the shape of the parabola is changed, which allows the absolute measurement of the spectrometer sensitivity. Applications of bright twin beams are sometimes restricted by their strong photon-number fluctuations. Recently we found a way to avoid this problem. By tightly focusing the pump into periodically poled lithium niobate, we generated twin beams in an extremely efficient way. With picosecond pump pulses of only 100 nJ, we converted >30% of the pump energy into the twin beams. This caused considerable pump depletion; as a result, the thermal fluctuations normally present in the twin beams were to a large extent transferred to the pump radiation. In the twin beams, on the contrary, noise was considerably suppressed [2].

[1] S. Lemieux, E. Giese, R. Fickler, M. Chekhova, R. W. Boyd, Nature Physics 15, 529 (2019).

[2] J. Florez, J. Lundeen, M. Chekhova, to be submitted (2020).

Marco Bellini

Istituto Nazionale di Ottica CNR-INO

Entanglement generation by coherent multimode photon addition

In recent years, quantum state engineering has quickly evolved, with new tools and techniques, such as photon addition and subtraction, which have demonstrated their extreme versatility for performing operations normally unavailable in the realm of Gaussian quantum optics [1]. While photon subtraction can enhance nonclassicality and entanglement, the process of photon addition has the unique capability of creating nonclassicality and entanglement from scratch, whatever the input. Here, I will present the effects of coherent superpositions of single-photon additions [2], with a special regard to the generation of entanglement between macroscopically populated optical modes. In particular, I will show how the delocalized addition of a single photon does indeed entangle in a measurable way two weak laser pulses containing up to 60 photons each, on average [3]. Creating tunable entanglement between macroscopic systems is a fascinating goal that may help one understand how quantum mechanics blends into classical physics and provide new tools for enhanced communications and sensing.

[1] M. Bellini and A. Zavatta, Manipulating light states by single-photon addition and subtraction, Prog. Opt. 55, 41 (2010).

[2] H. Jeong, et al., Generation of hybrid entanglement of light, Nat. Photon. 8, 564 (2014).

[3] N. Biagi, et al., Entangling macroscopic light states by delocalized photon addition, Phys. Rev. Lett. 124, 033604 (2020).

Vadim Makarov

Russian Quantum Center

Improving security of a QKD system via an external audit

I report methodology for security evaluation that we have recently applied to several commercial devices. Results from one of them, a sub-carrier wave QKD system, will be outlined [arXiv:1909.07898].

Our audit and the follow-up work by the manufacturer have led to a marked improvement in implementation quality. We hope this methodology contributes to future standards for quantum cryptography.

Sabine Wollmann

University of Bristol

Experimental demonstration of robust quantum steering

Quantum communication protocols have come a long way from abstract theoretical models to everyday technological applications. Their verification is typically performed in a device-dependent manner, which implies trust in the measurement devices in the laboratory to perform precisely as their manufacturer promises.

However, there is no guarantee that these will function exactly as expected and will not be exploited by an adversary. Hence, one would like to entirely remove the level of trust on the devices requiring a completely trust-free protocol such as a Bell test [1,2]. However, the realization of such tests is experimentally challenging and extremely resource intensive, despite today's technology.

Quantum steering protocols provide an alternative which is robust to experimental imperfections and noise [3-7]. These semi-device independent tasks require to trust only one party's measurement devices while the other party's devices are treated as black boxes.

Here we experimentally demonstrate steering with minimal trust by simplifying one party's devices to the number of degrees of freedom they are monitoring [8,9]. Further, we investigate the robustness to measurement-reference-frames to test for applicability in near-term quantum applications such as quantum fibre networks [10]. This brings steering protocols much closer to Bell tests without the sacrifice of extremely high-end equipment.

[1] J. Bell, Phys. 1, 195 (1964).

[2] N. Brunner et al., Rev. Mod. Phys. 86, 419 (2014).

[3] H. M. Wiseman et al., Phys. Rev. Lett. 98, 140402 (2007).

[4] D. Cavalcanti, and P. Skrzypczyk, Rep. Prog. Phys. 80, 024001 (2017).

[5] R. Uola et al., arXiv:1903.06663.

[6] M. M. Weston et al., Sci. Adv. 4, e1701230 (2018).

[7] S. Wollmann et al., Phys. Rev. A 98, 022333 (2018).

[8] A. C. S. Costa et al., Phys. Rev. A 98, 050104 (R) (2018).

[9] T. Moroder et al., Phys. Rev. Lett. 116, 090403 (2016).

[10] S. Wollmann et al., arXiv:1909.04001

Glaucia Murta

Heinrich-Heine-Universität Düsseldorf

Bounds on the information available to the eavesdropper in a multipartite device-independent scenario

Going beyond the simple two-party scenario of quantum key distribution, we consider N parties who wish to certify security against a potential eavesdropper in a cryptographic task. Moreover, we consider the very adversarial scenario in which the parties make no assumption about the underlying quantum system or the internal working of their measurement devices. This is the device-independent scenario. In the device-independent scenario, security is certified by the violation of a Bell inequality. In this talk I will present tight bounds on the information available to the eavesdropper as a function of the violation of the multipartite MABK Bell inequality. I will discuss the implication of these results to cryptographic tasks, such as randomness expansion and conference key agreement. Finally, I discuss the challenges and possibilities to extend our results to other Bell inequalities, which can lead to better cryptographic protocols.

Ralf Riedinger

Harvard University

Spin memory enhanced quantum communication

Transmitting quantum information across long distances enables a variety of applications, such as quantum key distribution. However, the distance over which quantum information can be transmitted is currently limited by photon loss in the communication channel. This can be overcome with quantum repeaters, intermediate nodes which employ quantum memories and error correction to distribute entanglement over long distances. Their implementation, however, remains elusive, due to the challenge of interfacing photons with a well-controlled, long-lived quantum memory. Here, I will introduce an integrated diamond photonics platform that allows for efficient coupling of photons to the long-lived electron spin of a silicon vacancy color center. I will report on recent experimental progress, including the demonstration of Bell state measurements between asynchronously arriving photons, which enables quantum key distribution at rates exceeding the loss-limited rate of direct quantum communication.

Margherita Mazzera

Heriot Watt University

New platforms for integrated solid-state quantum memories

The coherent interaction between photons and atoms lays the bases of quantum information science, whose purpose is to open new possibilities for the transmission and the processing of information. It is crucial, for example, for the realisation of quantum networks. The first proof of principle demonstrations of quantum memories were carried out in ensembles of atomic gases, but recently, some solid -state systems have emerged as a promising alternative. More specifically the rare earth ion doped crystals are one of the most interesting candidates. In this contribution, I will present new strategies to develop integrated quantum devices using Pr^{3+}: YSO, a material that has demonstrated very promising properties for quantum light generation [1] and storage [2]. I will report on the demonstration of a novel platform for quantum light storage based on laser written waveguides in a new writing regime that enables improved confining capabilities compared to previous demonstrations [3]. I will show how, besides the remarkable advantages that this platform offers with respect to other integrated designs, such as the compatibility with fibre cords and the 3D capability, it also opens the way for spatial and frequency multiplexing in quantum storage protocol [4].

[1] A. Seri, et al., PRX 7 (2017) 021028

[2] K. Kutluer et al, PRL 118 (2017) 210502

[3] A. Seri, G. Corrielli, et al, Optica 5 (2018) 934

[4] A. Seri, D. Lago-Rivera, et al., PRL 123 (2019) 080502

Christa Fluhmann

Yale University

Encoding and control of a qubit in a trapped-ion mechanical oscillator

I will present experiments demonstrating a qubit encoded in the harmonic motion of a single trapped 40Ca+ ion [1]. The usage of the oscillator allows to study a logical qubit with a single quantum system, while in contrast commonly used error-correction schemes are based on arrays of many physical qubits. The approximate logical code states are formed from a periodically spaced superposition of displaced squeezed components, which has theoretically been shown to have optimal performance for a large set of oscillator errors [2, 3]. Our demonstration of these qubits is based on coupling the ion motional oscillator to an internal state qubit, which we can subsequently readout. We demonstrate logical state preparation and readout and analyse a complete single qubit gate set, including teleporting operations from the internal state qubit onto the oscillator code space.

[1] C. Fl¨uhmann, T. L. Nguyen, M. Marinelli, V. Negnevitsky, K. Mehta, and J. P. Home, Nature 566, 513 (2019).

[2] D. Gottesman, A. Kitaev, and J. Preskill, Phys. Rev. A 64, 012310 (2001).

[3] V. V. Albert, K. Noh, K. Duivenvoorden, D. J. Young, R. T. Brierley, P. Reinhold, C. Vuillot, L. Li, C. Shen, S. M. Girvin, B. M. Terhal, and L. Jiang, Phys. Rev. A 97, 032346 (2018).

Lindsay LeBlanc

University of Alberta

Storage and manipulation of photonic signals using the Autler-Townes Splitting memory protocol

The ability to store and manipulate quantum information encoded in electromagnetic (often optical) signals represents one of the key tasks for quantum communications and computation schemes. In the pursuit of a practical but efficient and broadband quantum memory, we make use of a three-level atomic system (in our case, laser-cooled rubidium atoms) and realize storage and photonic manipu- lations in the regime of Autler-Townes splitting (ATS), where a classical-level control field controls the absorption of an auxillary, possibly quantum, signal field. We demonstrate on-demand storage and retrieval of both high -power and less-than-one-photon optical signals with total efficiencies up to 30%, using the ground state spin-wave as our storage states. Recently, we began storing signals in much colder samples, approaching the transition to Bose-Einstein condensation. We also realize a number of photonic manipulations, including temporal beamsplitting, frequency conversion, and pulse shaping. The ATS memory scheme is inherently fast and broadband, and, in contrast to the related schemes, is less demanding in terms of technical resources, making it a leading candidate for practical quantum technologies.

NOTES

POSTER SESSION

01. SHIN-LIANG CHEN
QFort
Robust self-testing of steerable quantum assemblages

02. JONTE HANCE
University of Bristol
How Quantum is Quantum Counterfactual Communication?

03. VINDHIYA PRAKASH
ICFO
A versatile system to study light matter interactions at the level of single quanta

04. JEREMY ADCOCK
Denmark Technical University
Mapping graph state orbits under local complementation

05. FRANCESCO GRAFFITTI
Heriot Watt University
Tailored quantum light for novel quantum photonics applications

06. CHRISTOPHER MORRISON
Heriot Watt University
Quantum frequency conversion of a near-infrared quantum dot single photon source to the telecommunication C-band

07. ZHE XIAN KOONG
Heriot Watt University
Adiabatic Population Transfer in a Solid-state Biexciton-Exciton Cascade System

08. VIV KENDON
Durham University/EPSRC
Collaborative Computational Project - Quantum Computing

09. XUEMEI GU
Nanjing University
(Hyper)graph concepts in Quantum Experiments

10. SACHIN SHARMA
IIT Ropar India
Engineering the photonic environment to control the charge state of nitrogen vacancy centers in nanodiamond

11. DARIA KOWSARI
Washington University
Memory in Non-Markovain Open Quantum Systems

12. NILS GOEDECKE
Heidelberg Instruments Nano
NanoFrazor – A Nanolithography Tool for 2D & 3D devices

13. GRAHAM BRUCE
University of St Andrews
Speckle-based wavelength stabilization of lasers for quantum technology

14. ALBERTO DELGADO
National University of Colombia
Basic Quantum Circuits in Classical Control Systems

15. WILL DIXON
University of Bristol
The Impact of the Gradient Elastic Tensor on Electron Spin Coherence in Quantum Dots

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University of the Basque Country
Quantum Approximate Optimization of the Coset Leader Problem for Binary Linear Codes

17. ELIAS COMBARRO
University of Oviedo
Some experiments towards improving the uniformity of random bits generated with noisy quantum computers

18. AGUSTINA G. MAGNONI
CITEDEF-UNIDEF
Sub shot noise transmission measurement scheme using a time multiplexing single photon source

19. CHLOE CLEAR
University of Bristol
Phonon-induced optical dephasing in single organic molecules

20. LAWRENCE ROSENFELD & SEBASTIAN CURRIE
University of Bristol
Integrated Optical CHSH Violation in the Mid-Infrared

21. ROSS C. SCHOFIELD
Imperial College London
Polymer-encapsulated organic nanocrystals for single photon emission

22. BEN BURRIDGE
University of Bristol
Unbounded spectral purity from silicon micro-racetrack resonators

23. BEN SAYERS
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24. MIKHAIL PETROV
Russian Quantum Center
Independent security analysis of a commercial quantum random number generator

25. ALEXANDRE MAINOS
University of Bristol
Near-ideal spontaneous single photon source in silicon quantum photonics

26. JAKE BIELE

University of Bristol

The Effects of Saturation on Quantum Enhanced Absorption Spectroscopy

27. DAVID PAYNE

University of Bristol

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Active reset of a radiative cascade for superequilibrium entangled photon generation

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Process Tomography of a High Dimensional Quantum System

30. ANASTASIYA PONOSOVA

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Protection of fiber-based QKD sources against light-injection attacks

31. NICCOLO SOMASCHI

Quandela

Scaling-up quantum technologies with solid-state single-photon sources

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Russian Quantum Center

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34. NITICA SAKHARWADE

Perimeter Institute for Theoretical Physics

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Washington University St Louis

Encircling of exceptional points of a dissipative qubit

37. SOEREN WENGEROWSKY

Osterreichische Akademie der Wissenschaften

Distribution of polarization Entanglement over a 96 km-long deployed telecommunications fiber

38. YUTAKA SHIKANO

Keio University

Real-time in-vivo thermometry on worms by nitrogen-vacancy center in nanodiamond

39. MARTIN PLAVALA

Universitat Siegen

Jordan product of channels

40. ADETUNMISE DADA

University of Glasgow

Mid-infrared Two-Photon Interference and Entanglement

41. SARA RESTUCCIA

University of Glasgow

Using Hong-Ou-Mandel interference to test the role of relativity in quantum mechanics

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CODE OF CONDUCT

Virtual BQIT:20 is an online workshop intended for networking and collaboration in the quantum technology community. We value the engagement of each attendee and work to ensure all participants have an enjoyable and fulfilling experience. Accordingly, all attendees are expected to show respect and courtesy to other attendees throughout the workshop and at all workshop events. All attendees, speakers, sponsors and volunteers at Virtual BQIT:20 are required to agree with the following code of conduct. Organisers will enforce this code throughout the event. We expect cooperation from all participants to help ensure a safe environment for everybody. Thank you for helping make this a welcoming, friendly event for all.

THE SHORT VERSION

The BQIT team is dedicated to providing a harassment-free online conference experience for everyone, regardless of gender, gender identity and expression, age, sexual orientation, disability, physical appearance, body size, race, ethnicity, religion (or lack thereof), or technology choices. We do not tolerate harassment of workshop participants in any form. Sexual language and imagery is not appropriate for any workshop platform, including talks, panels, dinners, Twitter and other online media. Workshop participants violating these rules may be sanctioned or expelled from Virtual BQIT:20 at the discretion of the workshop organisers.

THE LONGER VERSION

Harassment includes, but is not limited to:

- Verbal comments that reinforce social structures of domination related to gender, gender identity and expression, sexual orientation, disability, physical appearance, body size, race, age, religion, or technology choices.
- Sexual images in public spaces.
- Deliberate intimidation, stalking, or following.
- Harassing photography or recording.
- Sustained disruption of talks or other events.
- Unwelcome sexual attention.
- Advocating for, or encouraging, any of the above behaviour.

Participants asked to stop any harassing behaviour are expected to comply immediately.

Sponsors are also subject to the anti-harassment policy. In particular, sponsors should not use sexualised images, activities, or other material.

If a participant engages in harassing behaviour, the workshop organisers may take any action they deem appropriate, including warning the offender or expulsion from the Virtual BQIT:20 platforms.

WHO TO CONTACT

If someone makes you or anyone else feel unsafe or unwelcome, please contact our team as soon as possible through our email bqit-admin@bristol.ac.uk. Harassment and other code of conduct violations reduce the value of our event for everyone. We want you to be happy at our event. People like you make our event a better place.

The BQIT team will be happy to help participants contact local law enforcement or otherwise assist those experiencing harassment to feel safe for the duration of the workshop.

We expect participants to follow these rules on all workshop platforms and workshop-related online social events.

ATTENDEE PROCEDURE FOR INCIDENT HANDLING

1. The BQIT team will be prepared to handle the incident. All our staff are informed of the code of conduct policy and guide for handling harassment at the workshop.

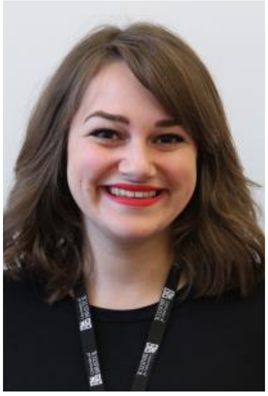
2. Report the harassment incident to a BQIT team member through email at bqit-admin@bristol.ac.uk (this inbox will be frequently checked for the duration of the event). All reports are confidential. When taking a personal report, our staff will ensure this is confidential. They may involve other event staff to ensure your report is managed properly. During the reporting process, we'll ask you to tell us about what happened. This can be upsetting, but we'll handle it as respectfully as possible. You won't be asked to confront anyone and we won't tell anyone who you are.

3. We will only involve law enforcement or security at a victim's request. If you do feel your safety is in jeopardy please do not hesitate to contact local law enforcement. If you do not have a phone please ask a member of the BQIT team who can call on your behalf.

ATTRIBUTION

This Code of Conduct was adapted from confcodeofconduct.com and Geek Feminism Wiki.

BQIT:20 BOARD



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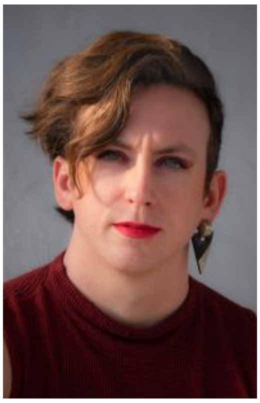
BQIT Board Chair, Organisation Lead & QET Labs Research Administrator

Jorge Barreto

Advisor to Tech and Programme teams, and Quantum Engineering CDT Lecturer



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External BQIT Board Advisor and Fellow at University of Granada

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Poster Session Lead and QET Labs PhD student

Will Dixon

Tech Team Advisor and Quantum Engineering CDT Student

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Pete Turner

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Sabine Wollmann

EDI Session Lead and QET Labs Research Associate

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Jake Biele

Advisor to EDI Session and Quantum Engineering CDT Student

Chloe Clear

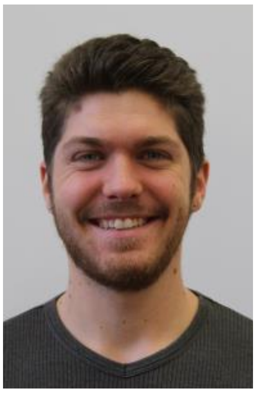
Advisor to EDI Session and Condensed Matter Physics CDT Student

Naomi Solomons

Advisor to EDI Session and Quantum Engineering CDT Student

Joseph Lennon

Tech Team Lead and QET Labs Research Associate



Jason Mueller

Tech Team Lead and QET Labs Research Associate

THE BQIT TEAM WOULD ALSO LIKE TO THANK:

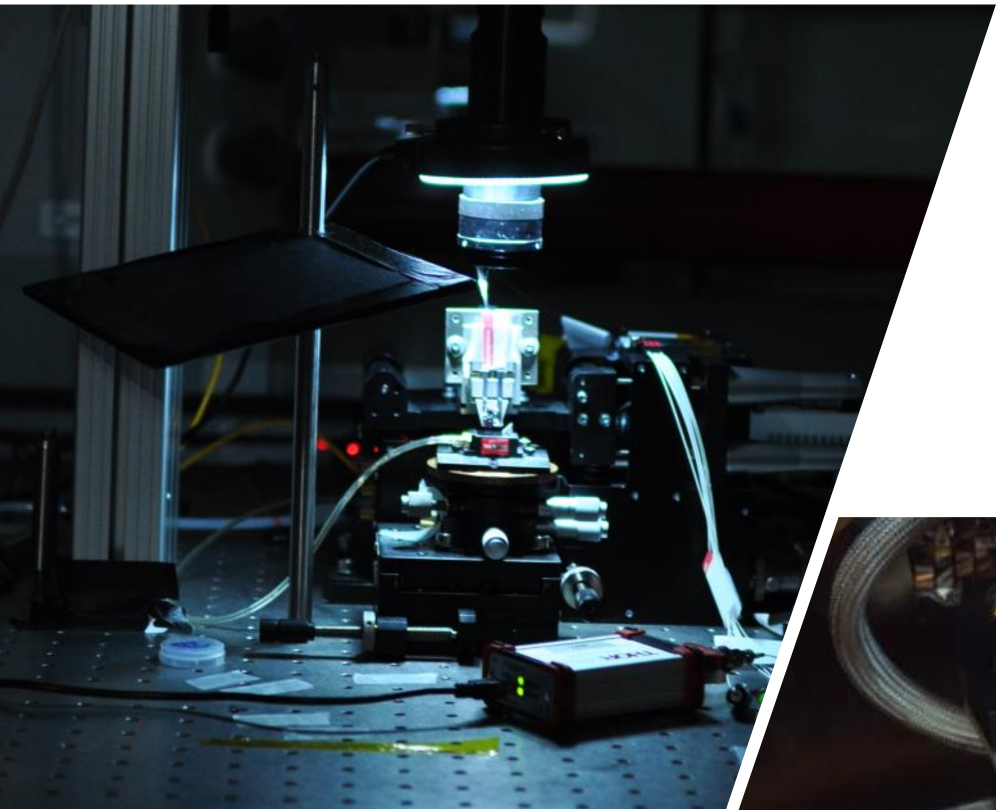
Our speakers and panellists for their flexibility in going online to share their work and opinions on an expansive range of topics.

Our sponsors for supporting our evolution to a virtual event and helping to make BQIT a continued success.

The BQIT board members, EDI team and tech team leads for their innovative ideas and diligent work throughout the year, and especially during the past few weeks. Thank you for adapting so quickly and for your support and enthusiasm during the move to an online platform.

Riccardo Sapienza (Imperial College London) and Amy Flower (Riverlane) for their sharing of expertise and invaluable advice during the evolution of Virtual BQIT:20. Riccardo is part of the organising committee of the POM (Photonics Online Meeting) and Amy Flower is the organiser of the 2020 QCTIP virtual conference.

And finally, all of our Virtual BQIT:20 attendees for participating. Thank you for signing on, and we look forward to welcoming you to Bristol soon.



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We look forward to
seeing you at:

BQIT:21

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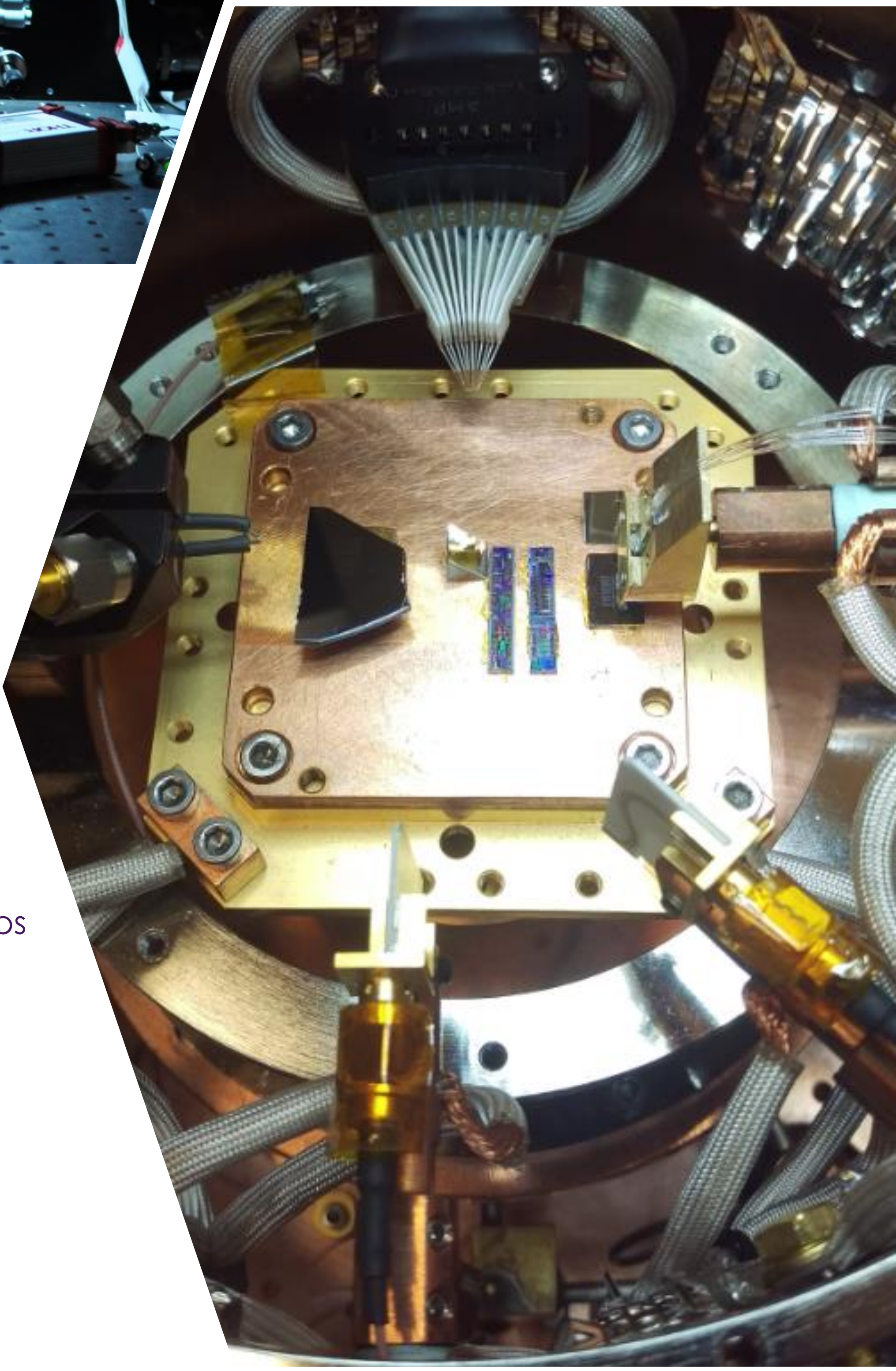

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