BRISTOL QUANTUM INFORMATION TECHNOLOGIES WORKSHOP

5th annual conference

M Shed, Bristol

April 18-20
2018

BQIT:18

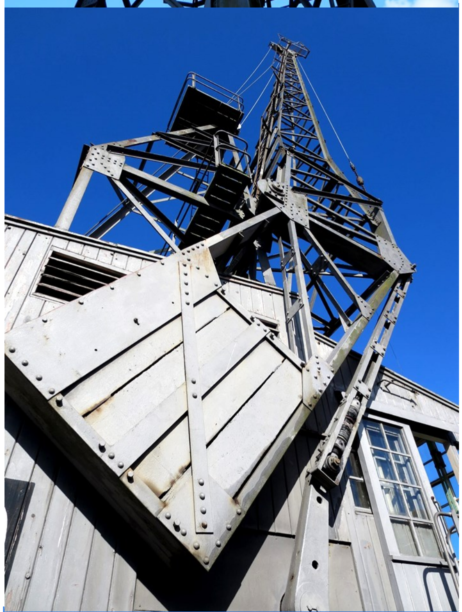
QET Labs

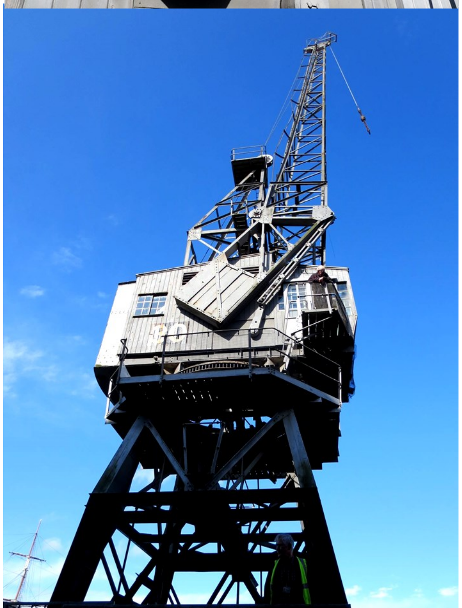
University of Bristol

PROGRAMME

Contents

BQIT:18





WELCOME TO BQIT:18

Dear colleagues and friends,

On behalf of the BQIT:18 team, I am delighted to welcome you to the fifth annual Bristol Quantum Information Technologies workshop.

We hope to replicate the success of past years this week by having a wide range of talks in quantum communications, theory, imaging, enhanced measurements, control, integrated quantum photonics (of course), dots, detectors and simulations. An industry focus session, including innovation and future funding opportunities completes this programme.

BQIT is a venture by the University of Bristol's QET (Quantum Engineering Technology) Labs, whose aim is to deliver a radically new generation of machines that exploit quantum physics to transform our lives, society and economy. QET Labs is a global centre for research, development and entrepreneurship in the emerging quantum technology industry, an international node for collaboration with industrial and academic world leaders, and a leading contributor to the EPSRC UK Quantum Technology Hub Network.

We sincerely hope you enjoy your time with us in Bristol and hope to see you back at next year's workshop.

Yours sincerely,

Professor John Rarity FRS (on behalf of the BQIT team)

VENUE & PARKING

M Shed

Princes Wharf, Wapping Rd, Bristol BS1 4RN

The main workshop will be held in the event suite on the top floor, with break out space and an exhibition area in the adjoining rooms. Guests are invited to explore the museum situated within the M Shed for the duration of the conference.

Parking is available in Wapping Wharf car park behind the M Shed at a rate of £9 per day.

DAY ONE AGENDA
WEDNESDAY APRIL 18

TIME	EVENT	LENGTH
09.30	**Arrivals and Registration**	**30 min**
10.00	Ruth Oulton (Deputy Director of QET Labs - University of Bristol) *Welcome and opening of the workshop*	5 min
Quantum Communications		
10.05	John Rarity (University of Bristol) *Next generation communication networks*	20 min (+ 5 min questions)
10.30	Christoph Marquardt (Max Planck Institute for the Science of Light) *Worldwide secure communication - quantum key distribution in space and on ground*	25 min (+ 5 min questions)
11.00	**Coffee Break**	**20 min**
Quantum Theory		
11.20	Elham Kashefi (University of Edinburgh & CNRS Sorbone Universites) *Delegated pseudo-secret random qubit generator*	25 min (+ 5 min questions)
11.50	Mio Murao (University of Tokyo) *Using quantum computers for manipulating and analysing quantum systems*	25 min (+ 5 min questions)
12.20	Terry Rudolph (Imperial College London) *Why I am optimistic about the silicon photonic architecture for quantum computing*	25 min (+ 5 min questions)
12.50	**Lunch**	**60 min**

Integrated Quantum Photonics

13.50	Mark Thompson (University of Bristol) *Silicon photonic quantum technologies*	25 min (+ 5 min questions)
14.20	Jacques Carolan (MIT) *Large-scale silicon-based quantum photonic processors*	25 min (+ 5 min questions)
14.50	Andrea Fiore (Eindhoven University of Technology) *Controlling exciton-photon coupling for quantum photonics*	25 min (+ 5 min questions)
15.20	**Coffee Break**	**20 min**

Quantum Enhanced Measurement and Quantum Control

15.40	Maria Chekhova (Max Planck Institute for the Science and Technology of Light) *SU(1,1) nonlinear interferometer*	25 min (+ 5 min questions)
16.10	Radek Lapkiewicz (University of Warsaw) *Photon correlations: a tool for imaging*	25 min (+ 5 min questions)
16.40	Alex Clark (Imperial College London) *Molecular quantum photonics*	25 min (+ 5 min questions)
17.10	**Thanks & close**	**5 min**

BRISTOL PACKET BOAT TOUR AND DINNER AT GLASSBOAT

Bristol Packet & Glassboat

Our drinks reception will take place aboard the Tower Belle, as we tour the Bristol harbour.

Pick up from the Arnolfini at 5.50pm, depart at 6pm.

We will disembark at the Glassboat Brasserie, situated on Welshback in Bristol's historic floating harbour, for our welcome banquet.

Dinner will be served at 7pm.

Welsh Back, Bristol BS1 4SB

DAY ONE Abstracts

Ruth Oulton

University of Bristol

Welcome and opening of the workshop

Welcome to BQIT 2018! We hope you will enjoy the programme we have put together, and find plenty of time for stimulating discussions and future collaborations.

Welcome to Bristol!

John Rarity

University of Bristol

Next generation communication networks

Photons are well known as carriers of information in quantum secured key distribution, as gatherers of information in quantum metrology and processors of information in quantum computing. In Bristol we have made great strides in linear optics quantum information processing particularly in the integration onto complex chip scale circuits.

Looking to the future we are working to build devices that deterministically generate spin-photon entanglement in solid state systems to solve the scaling challenges of linear optics schemes.

Our work in the quantum technology hubs has led to novel integrated and miniature quantum communications systems while imaging below the quantum limit has made dramatic progress.

I will try to highlight progress across these varied areas pointing to specialist BQIT talks and posters for the details.

Christoph Marquardt

Max Planck Institute for the Science of Light

Worldwide secure communication—quantum key distribution in space and on ground

Worldwide secure communication is important for an increasingly connected international society. Currently deployed cryptographic methods are at risk by future attacks e.g. by quantum computer algorithms. Quantum Key Distribution will offer provable long-term security for critical infrastructure and secure communication. Today several approaches are being developed. I will review concepts that combine ground-based and space optical quantum communication links to achieve world-wide coverage.

Optical free space communication is a reliable means to transmit classical and quantum information. Free space links offer ad-hoc establishment in intra-city communication, air-to-ground or satellite-to-ground scenarios. Quantum communication in space offers a fast route to global coverage [1]. I will discuss current activities, including the development of quantum key distribution with coherent optical communication in satellite systems, employing both discrete and continuous variable detection.

[1] I. Khan et al., “Satellite-Based QKD”, Optics & Photonics News, 2/2018

Elham Kashefi

University of Edinburgh & CNRS Sorbone Universites

Delegated pseudo-secret random qubit generator

The recent progress in quantum technologies has brought forward a vision of quantum internet that could implement a collection of known protocols for enhanced security or communication complexity. On the other hand the rapid development of quantum hardware has increased the computational capacity of quantum servers that could be linked in such a communicating network. This has raised the necessity of privacy preserving functionalities for the quantum cloud computing. In this talk I present our recent work on both possibility and impossibility results concerning secure delegated quantum computing on encrypted data.

Based on the following joint works:

Delegated Pseudo-Secret Random Qubit Generator
Alexandru Cojocaru, Léo Colisson, Elham Kashefi, Petros Wallden

On the implausibility of classical client blind quantum computing
Scott Aaronson, Alexandru Cojocaru, Alexandru Gheorghiu, Elham Kashefi

Mio Murao

University of Tokyo

Using quantum computers for manipulating and analysing quantum systems

Quantum computers can be used as manipulators of quantum systems including their dynamics. They can be also used to study the characteristic properties of quantum mechanics, such as entanglement, in addition to quantum simulation.

In this talk, two "applications" of quantum computers for analyzing properties of quantum physics are presented. One is to perform projective measurement of the energy eigenbasis on a system evolving under an unknown Hamiltonian system. A quantum computer is used to transform an unknown quantum dynamics to one of its eigenstates associated with an eigenenergy in this application. Another application is to understand counterintuitive spacetime properties related to entanglement by analyzing a class of distributed quantum information processing tasks called separable maps. We show that entanglement -assisted classical communication can simulate classical communication without causal order in this class of tasks.

Terry Rudolph

Imperial College London

Why I am optimistic about the silicon photonic architecture for quantum computing

I will overview some of the reasons why I believe silicon photonics is the only route to building a quantum computer of a million physical qubits.

DAY ONE Abstracts

Mark Thompson

University of Bristol

Silicon photonic quantum technologies

Generating, controlling and detecting quantum states of light within silicon photonic circuits opens the way to realising complex large-scale quantum photonic technologies for applications in computing and communications.

Here we overview recent developments presenting circuits comprising hundreds of photonics components and discussing routes towards scalable quantum computing.

Jacques Carolan

MIT

Large-scale silicon-based quantum photonic processors

Photons play a central role in many areas of quantum information science, either as qubit themselves or to mediate interactions between long-lived matter based qubits. Techniques for (1) high-fidelity generation, (2) precise manipulation and (3) ultra-efficient detection of quantum states of light are therefore a prerequisite for virtually all quantum technologies. A quantum photonics processor is the union of these three core technologies into a single system, and, bolstered by advances in integrated photonics, promises to be a versatile platform for quantum information science. In this talk we present recent progress towards large - scale silicon-based quantum photonic processors, leveraging the platform of silicon photonics which provides unrivalled performance in terms of component density, large-scale manufacturability and compatibility with CMOS electronics. We demonstrate protocols in quantum computing, quantum simulation, and classical deep learning; and point towards systems engineering challenges in scaling such systems up. These results demonstrate quantum photonic processors as both a versatile testbed for prototyping new linear optical protocols and as a route towards large -scale quantum information processing, pointing the way to applications across fundamental science and quantum technologies.

Andrea Fiore

Eindhoven University of Technology

Controlling exciton-photon coupling for quantum photonics

The radiative coupling between excitons and the optical mode of semiconductor microcavities is the basis for efficient solid-state quantum light sources and generally a tool for coupling photonic to solid-state qubits. Varying this coupling in time would enable controlling photon emission and absorption processes, and thereby the temporal waveform of single photons and vacuum Rabi oscillations.

In this talk a method to deterministically control the exciton-photon coupling will be discussed, which relies on the tailoring of the electromagnetic field seen by the emitters in systems of coupled cavities. Its application to the control of the spontaneous emission rate will be demonstrated and potential extensions will be discussed.

Maria Chekhova

Max Planck Institute for the Science of Light

SU(1,1) nonlinear interferometer

A nonlinear SU(1,1) interferometer is a sequence of two coherently pumped high-gain parametric amplifiers, realized through parametric down-conversion or four-wave mixing. The radiation emitted by the first amplifier can be amplified or deamplified in the second one, depending on the phase shifts acquired on the way. This makes the interferometer extremely sensitive to phase shifts, its sensitivity reaching the Heisenberg limit in the lossless case.

Losses certainly reduce the phase sensitivity; however, detection loss can be overcome by making the interferometer gain-unbalanced. As we have shown theoretically [1] and experimentally [2], phase sensitivity below the shot-noise level can be achieved even with very inefficient detection provided that the second amplifier is pumped sufficiently strong.

This can be considered as part of the general strategy of phase sensitive amplification prior to detection. In particular, phase sensitive amplification can be used to protect from loss the protocol of sub-shot-noise imaging, in which an object is placed into one of twin beams and the image is restored in the difference intensity distribution [3]. By amplifying the image before detection, the limitations imposed by losses can be lifted, and the protocol can be extended to 'difficult' spectral ranges such as infrared.

[1] M. Manceau et al., New Journal of Physics 19, 013014 (2017).

[2] M. Manceau et al., Phys. Rev. Lett. 119, 223604 (2017).

[3] G. Brida et al, Nature Photonics 4, 227 (2010).

Radek Lapkiewicz

University of Warsaw

Photon correlations: a tool for imaging

I will discuss a few experiments with photons, trying to convince you that:

1. It is possible to image objects without detecting the light scattered by them.

2. Correlations between two particles can be witnessed by detecting one particle.

3. Spatial phase of a light beam can be reconstructed in the presence of phase fluctuations.

4. Emitters within a diffraction limited region in a fluorescence microscope can be counted.

The experiments share the idea of replacing single pixel detectors with cameras in the classic setups of Leonard Mandel.

Alex Clark

Imperial College London

Molecular quantum photonics

Photons lie at the heart of many quantum technologies, but to date they are difficult to generate and collect with high efficiency. In this talk I will discuss the use of organic molecules for generating single photons. When dibenzoterrylene (DBT) is embedded in anthracene it is photostable and forms a two-level system which when excited will emit a photon at a wavelength of ~780 nm. Room temperature fluorescence from DBT can be used for communication and sensing, and cryogenic cooling leads to the generation of coherent, lifetime-limited photons required for quantum interference applications.

In this talk I will present our work in characterising single DBT molecules at various temperatures, and discuss recent developments in coupling DBT emission, both into optical fibres using a microcavity and into photonic and plasmonic waveguides using nano-fabricated devices. Such devices not only form the basis for building efficient photon sources, but can also be used for other applications where a strong light-matter interaction is required. These include photon switching, number filtering, photon -photon interactions, and quantum memories. I will present routes towards demonstrating these applications, and challenges that must be overcome in doing so.

DAY TWO AGENDA
THURSDAY
APRIL 19

TIME	EVENT	LENGTH
09.30	**Tea and coffee**	**30 min**
Quantum in Industry		
10.00	Andy Collins (QTEC) *Start-up by proxy - a second hand account of high tech start ups*	20 min (+ 5 min questions)
10.25	Jelena Trbovic (Zurich Instruments) *Zurich Instruments solutions for quantum control and measurements*	20 min (+ 5 min questions)
10.50	Luke Dandy & Cris Quintana (Airbus) *QDOS Lite*	25 min (+ 5 min questions)
11.20	**Coffee Break**	**20 min**
Industry and Innovation		
11.40	Mustafa Rampuri (University of Bristol) *Quantum Technologies Innovation Centre*	20 min (+ 5 min questions)
12.05	John Azariah (Microsoft) *QDK and Q# tutorial*	25 min (+ 5 min questions)
12.35	**Lunch**	**60 min**
13.35	Poster session (sponsored by KETS) *In main event suite* and Interactive Tutorial (Microsoft) *In Studios 1 & 2 - to continue until 16.30.* *Timetable on Page 14*	60 min

Future Funding and Research to Industry

14.35	Liam Blackwell (EPSRC) *Future of the quantum technology research portfolio*	25 min (+ 5 min questions)
15.05	Niccolo Somaschi (Quandela) *Efficient solid-state quantum light sources for quantum technologies*	20 min (+ 5 min questions)
15.30	**Coffee Break**	**20 min**

Dots

15.50	Mete Atature (University of Cambridge) *Solid-state quantum networks with spin-photon interfaces*	25 min (+ 5 min questions)
16.20	Chaoyang Lu (University of Science and Technology of China) *Two photon interference between independent sources*	25 min (+ 5 min questions)
16.50	Andrew Young (University of Bristol) *Quantum dots and quantum technology*	20 min (+ 5 min questions)
17.15	**Thanks & close**	**5 min**

DINNER AT THE SS GREAT BRITAIN

SS Great Britain

Our drinks reception and dinner will be served on board the SS Great Britain, one of the most important historic ships in the world.

Guests will have access to the entire ship during their visit, with the option to attend a guided tour. Access to the museum and dry dock from 5pm.

Drinks will be served at 6pm and dinner at 7pm.

Great Western Dockyard, Gas Ferry Road, Bristol BS1 6TY

DAY TWO Abstracts

Andy Collins

QTEC

Start-up by proxy - a second hand account of high tech start ups

Working in research is a joy and a privilege where, after years of exams and hard work, you can explore your ideas and ideally become a world expert in something. At the outset of a research career it's arguably the goal to go for tenure, or something like it, and the dream to make a big impact with your discoveries. However, impact can be so much more than just papers, talks and grant money. A scientific discovery can rapidly become a daily influence or disruptive change in everyday life. For an increasing number of scientists there is a passion to see something they have created making a difference in society.

I manage a programme aimed at commercialising Quantum Technology and have seen up close the early part of the journey from scientist to entrepreneur. In this talk I will present case studies and observations of the talented people building an industry that, until very recently, did not exist.

Jelena Trbovic

Zurich Instruments

Zurich Instruments solutions for quantum control and measurements

High-fidelity qubit state measurements, reliable qubit state control, and fast feedback are essential elements needed for operating quantum processors. The interfacing classical technology is often the bottleneck on the way towards larger system size because of the lack of the system integration and multi-channel synchronization.

In this talk I will present how Zurich Instruments ultra-high-frequency lock-in amplifiers and arbitrary waveform generators are used through LabOne software and programming platforms in characterizing and fast feedback control of superconducting qubits. Furthermore I will present solutions for increasing system complexity applicable to other technologies such as trapped ions, or semiconductor spin qubits.

Luke Dandy & Cris Quintana

Airbus

QDOS Lite

The security of highly-sensitive information exchange has become a major topic in recent years. Encryption techniques require the shared use of strong keys and Quantum Key Distribution (QKD) ensures this by using the unbreakable quantum nature of light. The underlying quantum processes involved in QKD also enable eavesdropper detection, which cannot be achieved using non-quantum methods. QKD has been implemented using photonic modules and demonstrated successfully in different environments (fibre-to-fibre, in free-space ground-to-ground and ground-to-air). However, Size, Weight and Power (SWaP) constraints have limited previous implementations, and a commercially available payload with low SWaP does not yet exist. Project Q-DOS Light aims to deliver a QKD module using compact, cutting-edge photonic waveguide technology which will allow low-SWaP requirements to be met. Using this module, Q-DOS Light will demonstrate a secure, high data rate optical communications datalink (~1 Gbps) between a commercially available airborne platform and a ground base station.

Airbus are leading the development and the outdoor demonstration of a low-SWaP wireless optical QKD data link at a range of 1+ km. This includes the design and implementation of an airborne pod with a mass below 5kg and high-performance tracking capabilities. Airbus are also involved in the base station development, which main challenge is to cope with the atmospheric turbulences and coupling the qubits into a Single Mode Fibre (SMF) efficiently.

Mustafa Rampuri

University of Bristol

Quantum Technologies Innovation Centre

The University of Bristol has an ambition to support the UK's £270m investment in QT by nurturing the emergent QT industry.

The Quantum Technologies Innovation Centre (QTIC) is a national resource that supports all business from small QT supply chain start-ups to global corporations, helping them to develop and grow in an environment that will provide affordable access to state-of-the-art equipment and talent.

This talk will describe the motivation behind the centre, the plans and explain ways to engage.

John Azariah

Microsoft

QDK and Q# tutorial

Microsoft has announced that efforts are underway to build the world's first complete, scalable and industry-ready quantum computer. To that end, significant work continues on building the topologically protected qubit, but that's not where the story ends.

The Quantum Architecture and Computing team at Microsoft have released a new Quantum Development Kit – including a new purpose-built language with integrated tooling, several simulators, and an extensive library of algorithms and routines – to facilitate a broad audience in developing and characterizing their own quantum programs.

John Azariah, the lead of the Q# development language, will introduce the development kit and demonstrate the language in action in this talk aimed at software developers and quantum computer scientists alike.

BQIT:18

|KETS⟩

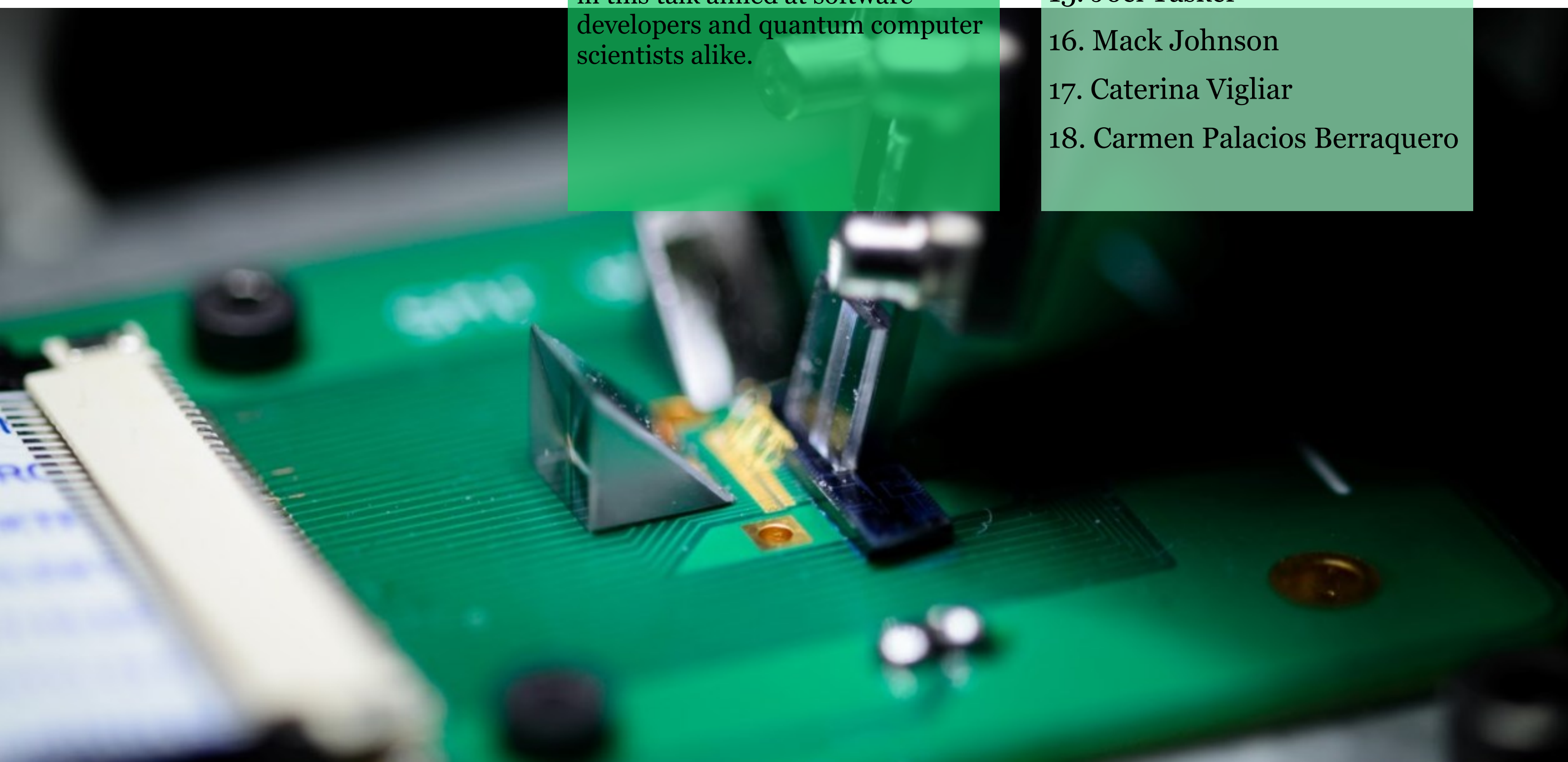
QUANTUM SECURITY

BQIT:18 poster session

Sponsored by KETS

In main event suite

1. Alex Moylett
2. Michael Lubasch
3. Felipe Ortiz-Huerta
4. Matt Day
5. Mikhail Saygin
6. Antonio Andreas Gentile
7. Jorge Monroy Ruz & Joe Smith
8. Alasdair Price
9. Imad Faruque
10. Stefano Paesani
11. Stasja Stanisic
12. Ross Donaldson
13. Alex Clark
14. George Atkinson
15. Joel Tasker
16. Mack Johnson
17. Caterina Vigliar
18. Carmen Palacios Berraquero



DAY TWO Abstracts

Interactive Tutorial

Microsoft

In Studios 1 & 2

13:35-14.05: Setup and Introduction

14.05-14.35: Introduction to Q#

14.35-15.30: Hands on performance of code Katas

15.30-15.50: Break

15.50-16.30: Entanglement and teleportation in Q#

16.30-17.00: Software Engineering in Q#

Liam Blackwell

EPSRC

Future of the quantum technology research portfolio

A summary of current thinking and plans for the future of the UK National Quantum Technology Programme.

Covering the Industrial Strategy Challenge Fund Pioneer Programme, work on identifying research priorities for Quantum Technology Research Hubs, and the development of the portfolio in the longer term.

Niccolo Somaschi

Quandela

Efficient solid-state quantum light sources for quantum technologies

Quandela is a spinoff company from the Center of Nanosciences and Nanotechnologies (CNRS/UPSud) founded in 2017. Our objective is to commercialize top-class quantum light sources to boost the research in quantum optics, to allow the emergence of further innovations in the field of photonics and scale up quantum technologies outside the academic world.

One of our first products is Delight, a single-photon source device based on solid-state technology with exceptional single-photon emission efficiency - typically 75% against few percent for competitive technologies. By providing an effective rate of single-photons up to 300 MHz counts-per-seconds this technology can be implemented in quantum imaging & sensing application as well as point-to-point quantum communication.

By designing a unique photonic structure architecture, which allows for the insertion of electrical contacts, we also built eDelight: an electrically controlled source of ultra-pure photons. By means of the applied voltage, eDelight guarantees bright emission of highly identical photons, essential requirement for the development of the most advanced quantum applications: quantum simulation & computation, complex quantum networks.

In this talk I will give a brief overview about the technology at the core of Quandela and discuss how our devices can allow scaling up optical quantum technologies confirming the importance of solid-state single-photon sources as cornerstone for the forthcoming developments of quantum technologies.

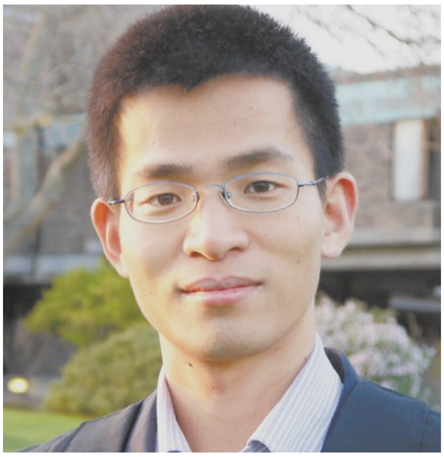
Mete Atature

University of Cambridge

Solid-state quantum networks with spin-photon interfaces

Optically active spins confined in solids, such as semiconductor quantum dots, offer realistic opportunities for realizing stationary and flying qubits within the context of spin-based quantum information science, particularly for distributed quantum network architectures. Their inherently mesoscopic nature leads to a multitude of dynamics within the solid-state environment of spins, charges, vibrations and light, but implementing a high level of control on these constituents and their interactions with each other creates tailored spin-photon quantum interfaces with optimal properties.

In this talk, I will provide a snapshot of the progress and challenges for quantum optically interconnected solid-state spins, with focus on generating high-bandwidth nonlocal quantum correlations in self-assembled quantum dots via coherently scattered single photons. I will also discuss current steps towards improving both the spin coherence and the entanglement generation rate in the very near future, as well as the routes to cluster-state based quantum networks.



Chaoyang Lu

University of Science and Technology of China

Two photon interference between independent sources

We develop single-photon sources that simultaneously combines high purity, efficiency, and indistinguishability.

We demonstrate entanglement among ten single photons. We construct high-performance multi-photon boson sampling machines to race against classical computers.

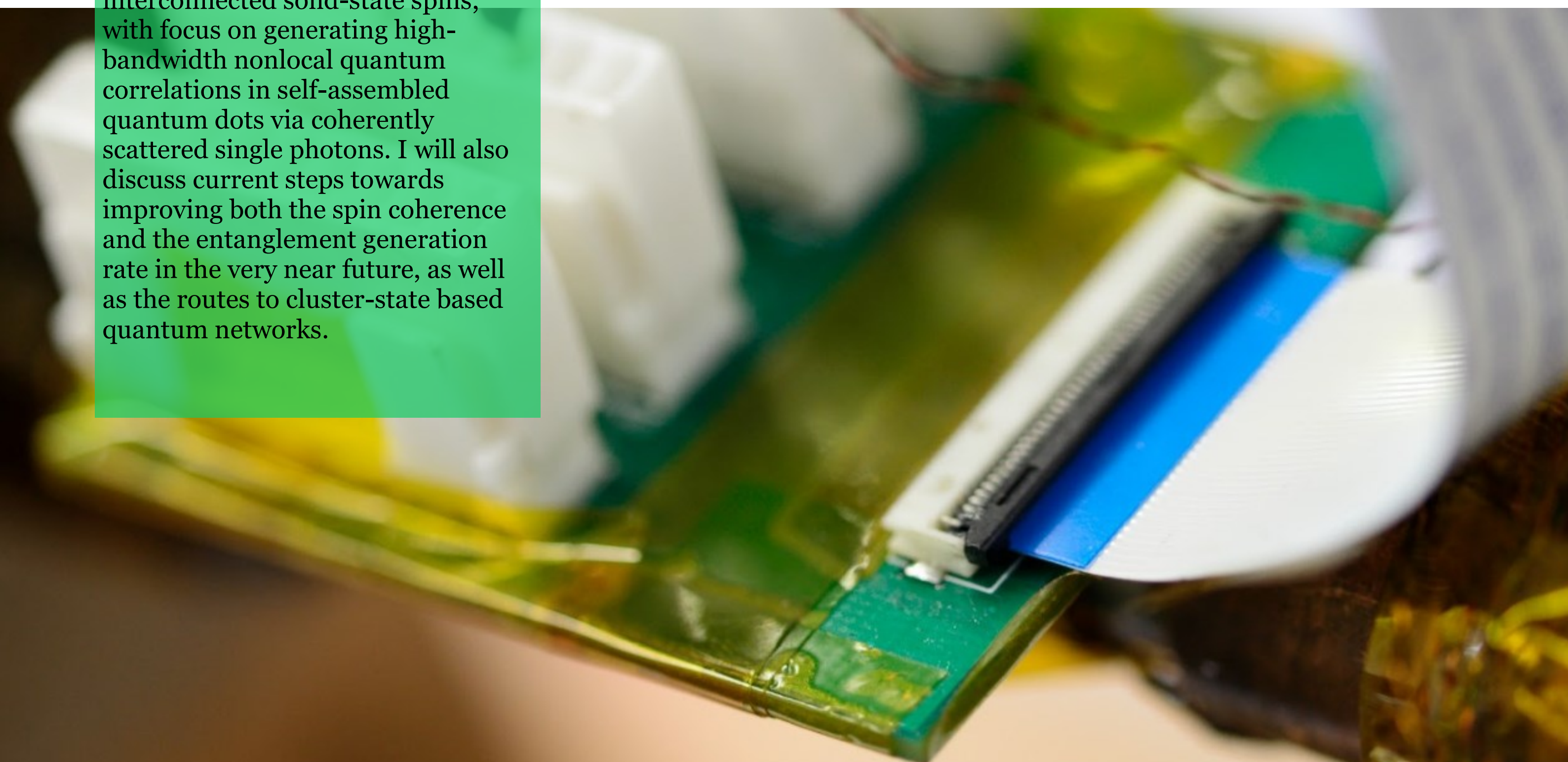
Andrew Young

University of Bristol

Quantum dots and quantum technology

Quantum photonics is currently limited to the few photon regime. This is largely a result of inefficient spontaneous parametric down conversion sources, but perhaps more significantly the lack of deterministic two photon entangling gates. Quantum dots have the potential to provide a step change in the scalability of quantum photonic architectures, providing both next generation sources, and gates for quantum photonics.

In this talk I discuss some of the work that we carry out in Bristol with quantum dots, and focus on the prospects for quantum dots as a viable quantum technology. I will discuss the current limitations that are universal in all quantum dot labs and what we are doing to try and combat these.



DAY THREE AGENDA
FRIDAY APRIL 20

TIME	EVENT	LENGTH
09.30	**Tea and coffee**	**30 min**
Detectors and Simulations		
10.00	Val Zwiller (TU Delft and KTH) *Photons alone in the dark*	25 min (+ 5 min questions)
10.30	Dondu Sahin (University of Bristol) *Designing single photon detectors in a waveguide cavity*	20 min (+ 5 min questions)
10.55	Anthony Laing (University of Bristol) *Photonic simulations of molecular quantum dynamics*	20 min (+ 5 min questions)
11.20	**Coffee Break**	**20 min**
Quantum Communications and Networks		
11.40	Xiao Yuan (University of Oxford) *Variational quantum simulation of imaginary time evolution and its applications*	25 min (+ 5 min questions)
12.10	Eleni Diamanti (CNRS, Sorbonne Universite) *Practical challenges in quantum cryptography*	25 min (+ 5 min questions)
12.40	**Lunch**	**60 min**

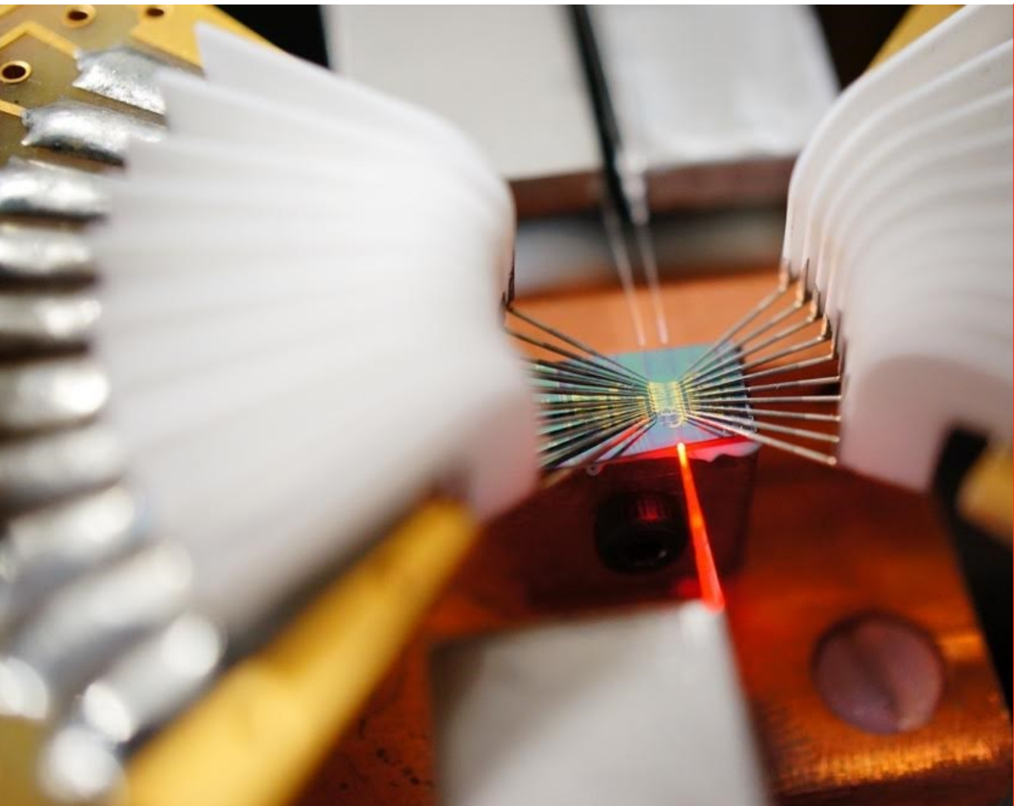
Quantum Theory

13.40	Peter Knight (National Physical Laboratory) *Nondestructive detection of a single optical photon*	25 min (+ 5 min questions)
14.10	Pieter Kok (University of Sheffield) *Optimal imaging of distant black bodies*	25 min (+ 5 min questions)
14.40	Sam Pallister (University of Bristol) *Verifying quantum states*	20 min (+ 5 min questions)
15.05	**Coffee Break**	**20 min**

Quantum Theory cont. and Imaging

15.25	Irene D'Amico (University of York) *Robust Entanglement Generation with Spin Chains*	25 min (+ 5 min questions)
15.55	Lorenzo Maccone (University of Pavia) *Digital quantum metrology*	25 min (+ 5 min questions)
16.25	Miles Padgett (University of Glasgow) *Resolution limits of ghost imaging*	25 min (+ 5 min questions)
16.55	John Rarity (Director of QET Labs - University of Bristol) *Close and thanks*	5 min

CLOSE



BQIT:19

Thank you for attending this year's Bristol Quantum Information Technologies workshop.

Please save the date for our next conference:

3-5 April 2019

DAY THREE Abstracts

Val Zwiller

TU Delft and KTH

Photons alone in the dark

Detecting light is central for a wide range of scientific and technological activities, operating at the quantum limit, at the single photon level is an enabling technology for a wide range of emerging quantum technologies. Superconducting nanowires were shown in 2001 by the Goltsman group in Moscow to be able to detect single photons, triggering an intense experimental effort worldwide. The physical limit of these detectors remains to be identified but is clearly very close from the quantum limit, something that was never thought possible with previous detection techniques.

One obvious figure of merit is the detection efficiency, high detection efficiency results in short measurement times and can drastically shorten complex measurements. Besides detection efficiency, time resolution is another crucial parameter, often more important than detection efficiency. We are now able to reach time resolutions in the order of 10 ps while the physical limit remains to be identified. Time resolution is crucial when performing quantum measurements such as antibunching, or entanglement measurements to observe the highest possible fidelities. We will show that often, the detector time resolution is the limiting factor in an experiment. Another crucial specification for a photon detector is its dark count rate, we will show that our detectors can give mHz of dark counts which allows for very clean optical measurements.

Dondu Sahin

University of Bristol

Designing single photon detectors in a waveguide cavity

I will discuss our work on single photon detectors, based on superconducting nanowires. They are designed to operate at 1550 nm and 2100 nm with calculated efficiencies > 90%.

I will also present our compact, CMOS compatible waveguide crossings with a small footprint, which are promising for scaling integrated quantum photonic interconnections.

Anthony Laing

University of Bristol

Photonic simulations of molecular quantum dynamics

Modelling the dynamics of quantum mechanical systems, including molecules, is generally intractable to classical computational techniques. Such computational overheads may be overcome by utilising quantum simulation techniques, in which a well-controlled quantum system is programmed to mimic the quantum behaviour of another.

Recent progress in integrated photonics has seen the advent of high fidelity on-chip processing of photonic quantum information and fully programmable circuitry to establish devices that are universal for linear optics.

Here we discuss proof-of-principle experimental demonstrations of quantum photonics as a simulation platform for molecular quantum dynamical behaviour.

Xiao Yuan

University of Oxford

Variational quantum simulation of imaginary time evolution and its applications

Imaginary time evolution, as a powerful tool in physics, materials science, etc, can be simulated with a classical computer based on its mathematical definition. However, the power of classical simulation of many body physics is generally limited due to the exponential growth of the Hilbert space to the system size. Meanwhile quantum simulation can in principle efficiently simulate many-body quantum systems, but it cannot be directly applied to the unphysical imaginary time evolution. In this work, we propose a variational method for simulating imaginary time evolution via a hybrid algorithm that combines quantum and classical computing. Then, we apply our simulation method to variational quantum eigensolver in finding the ground state energy of Hamiltonians. We test our method in quantum computational chemistry, specifically in finding the ground state energy of the H2 molecule.

The method can be also applied to general optimisation problems, such as 3-satisfiability and MaxCut, and extended to Gibbs sampling and quantum machine learning. As our algorithm is hybrid and can exploit a shallow quantum circuits, it can be implemented with current and near-term quantum computers with experimental errors suppressed by the recently proposed error mitigation methods.

Eleni Diamanti

CNRS, Sorbonne Universite

Practical challenges in quantum cryptography

In this talk, we discuss the current landscape in quantum cryptography in the context of future quantum-safe communications and describe the state-of-the-art and practical challenges in this field.

To illustrate these challenges, we focus in particular on recent practical photonic implementations, using encodings in discrete or continuous variables of light, of central quantum network protocols, enabling secret key distribution, quantum coin flipping, verification of entangled resources and transactions with quantum money, with maximal security guarantees.

Peter Knight

National Physical Laboratory

Nondestructive detection of a single optical photon

Unlike “demolition,” detection quantum nondemolition (QND) or “nondestructive” photon detection ideally avoids any absorption of the photons during the measurement. It is essential for applications in quantum information processing. Detecting a single photon without absorbing it is a long-standing challenge in quantum optics. All experiments demonstrating the nondestructive detection of a photon make use of a high quality cavity.

We present a cavity-free scheme for nondestructive single-photon detection. By pumping a nonlinear medium we implement an interfield Rabi oscillation which leads to a $\sim\pi$ phase shift on a weak probe coherent laser field in the presence of a single signal photon without destroying the signal photon. Our cavity-free scheme operates with a fast intrinsic time scale in comparison with similar cavity-based schemes. We implement a full real-space multimode numerical analysis of the interacting photonic modes and confirm the validity of our nondestructive scheme in the multimode case. Many researchers have previously unsuccessfully tried to apply cross-Kerr-based schemes using the “Ising”-type interaction for QND single-photon detection in the multimode picture. Our scheme can circumvent such complications using a Rabi-like oscillation in a cavity-free scheme to detect a single optical photon without destroying it. In our setup we have induced a π phase shift in a weak probe field by a traveling single photon in a nonlinear medium with this single photon remaining largely unchanged. This may well have significance for possible all-optical quantum gates.

Pieter Kok
University of Sheffield

Optimal imaging of distant black bodies

The measurement of an object's spatial configuration is important in many disciplines, from astronomy to engineering. We present the quantum optimal estimator for the spatial configuration of a distant body based on the black body radiation received in the far-field—this can be considered a form of reconstructive imaging. In doing so we must deal with multi-parameter quantum estimation of incompatible observables, a problem that is thus far not very well understood.

We compare our optimal observables to the two mode analogue of lensed imaging and find that the latter is far from optimal, even when compared to measurements which are separable.

To prove the optimality of the estimators we show that they minimise the cost function weighted by the quantum Fisher information—this is equivalent to maximising the average fidelity between the actual state and the estimated one.

Sam Pallister
University of Bristol

Verifying quantum states

The goal of a large fraction of quantum experiments is to produce a certain quantum state, to use as a resource for a particular task. However, checking which state is being produced by an experiment requires full state tomography, which takes a prohibitively long time for contemporary experiments.

In this talk, it will be argued that there are lots of contexts where tomography is not necessary, and verification can instead be incredibly quick. We'll cover both the theoretical basis for such verification protocols, and apply it to verify a photonic chip based in Bristol.

Irene D'Amico
University of York

Robust Entanglement Generation with Spin Chains

Reliable quantum communication/ processing links between modules are a necessary building block for various quantum processing architectures. A candidate for these links is the use of spin chains: these can be embodied by very different types of physical system and so potentially embedded in different types of hardware.

In this presentation I will review our recent proposals for generation, distribution and storage of quantum entanglement using spin chains [1],[2], [3]. These are based on spin chain inspired by the SSH model, with alternating strength couplings and containing a set of defects, that lead to domain walls between topologically distinct regions of the chains. Our results show that these protocols are very robust against perturbations such as fabrication defects or static fields.

[1] "Topologically protected localised states in spin chains", M.P. Estarellas, I. D'Amico, T.P. Spiller, Scientific Reports 7, Article number: 42904 (2017)

[2] "Robust Quantum Entanglement Generation and Generation-plus-Storage Protocols with Spin Chains", M.P. Estarellas, I. D'Amico, T.P. Spiller, Phys. Rev. A 95, 042335 (2017)

[3] "Rapid and robust generation and distribution of EPR pairs with spin chains", K. N. Wilkinson, M. P. Estarellas, T. P. Spiller and I. D'Amico, to appear in Quantum Information & Computation (2018) "arXiv:1708.05650"

Lorenzo Maccone

University of Pavia

Digital quantum metrology

Modern cryptography is about much more than sending secret messages, and quantum features can enable us to do also other things than share secret keys.

This talk will consider examples of using quantum key distribution setups, with minimal changes, for different functionalities. One example is transferrable message authentication, which enables a sender to send tamper-proof messages which cannot be forged, and where messages can also be forwarded from one recipient to another. Another example is a quantum scheme for oblivious transfer, which is a universal primitive for multiparty computation.

Miles Padgett

University of Glasgow

Resolution limits of ghost imaging

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Since the inception of ghost imaging in the 1990s there have been investigations into the applications of this technique. Here we present an examination of the resolution limits of ghost imaging and ghost diffraction.

Beyond consideration of these limits, our ghost diffraction is an implementation of Popper's thought experiment, and while our results agree with his experimental predictions, we show how these results do not contradict the Copenhagen Interpretation.

John Rarity

University of Bristol

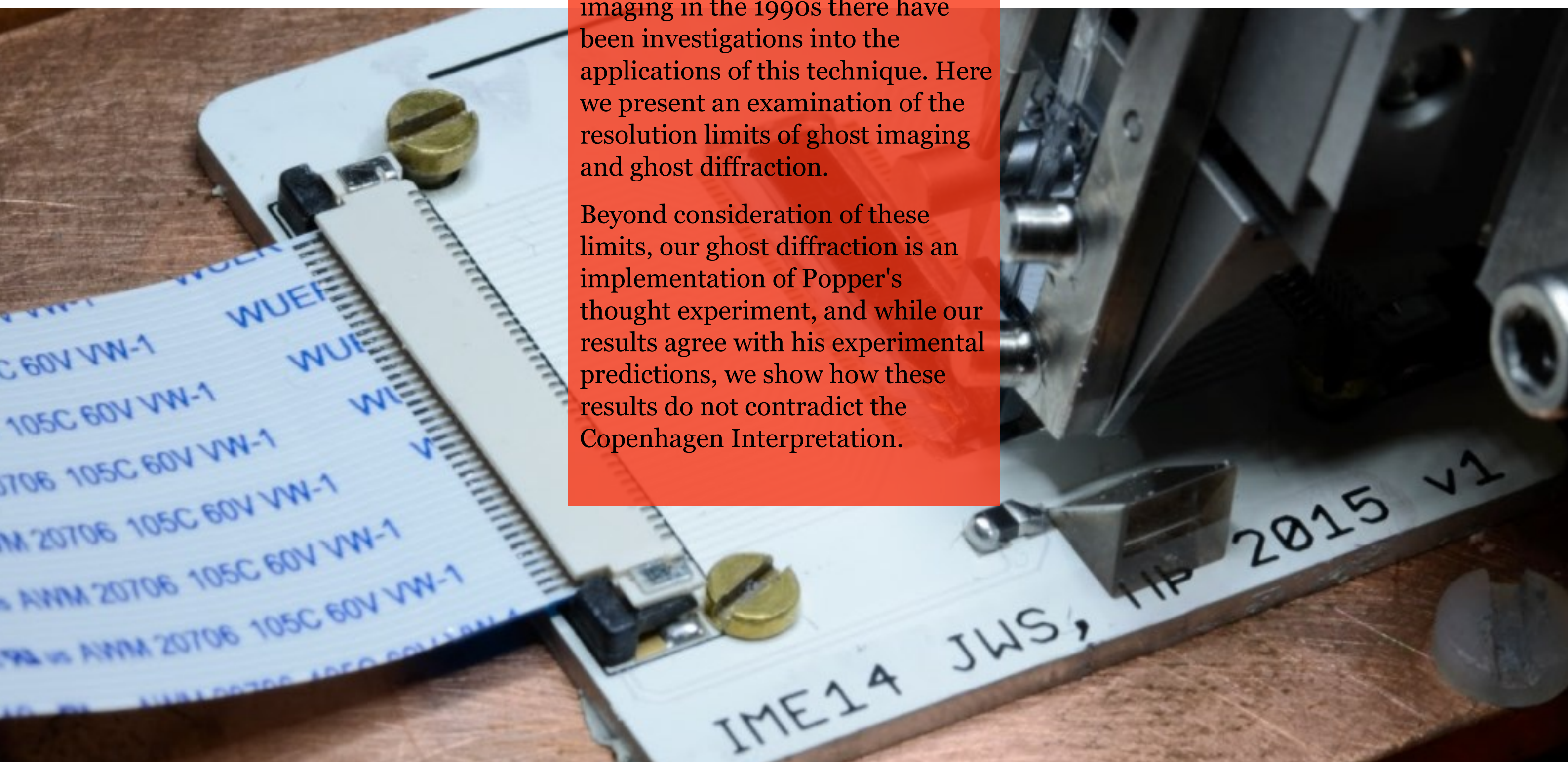
Thanks and close

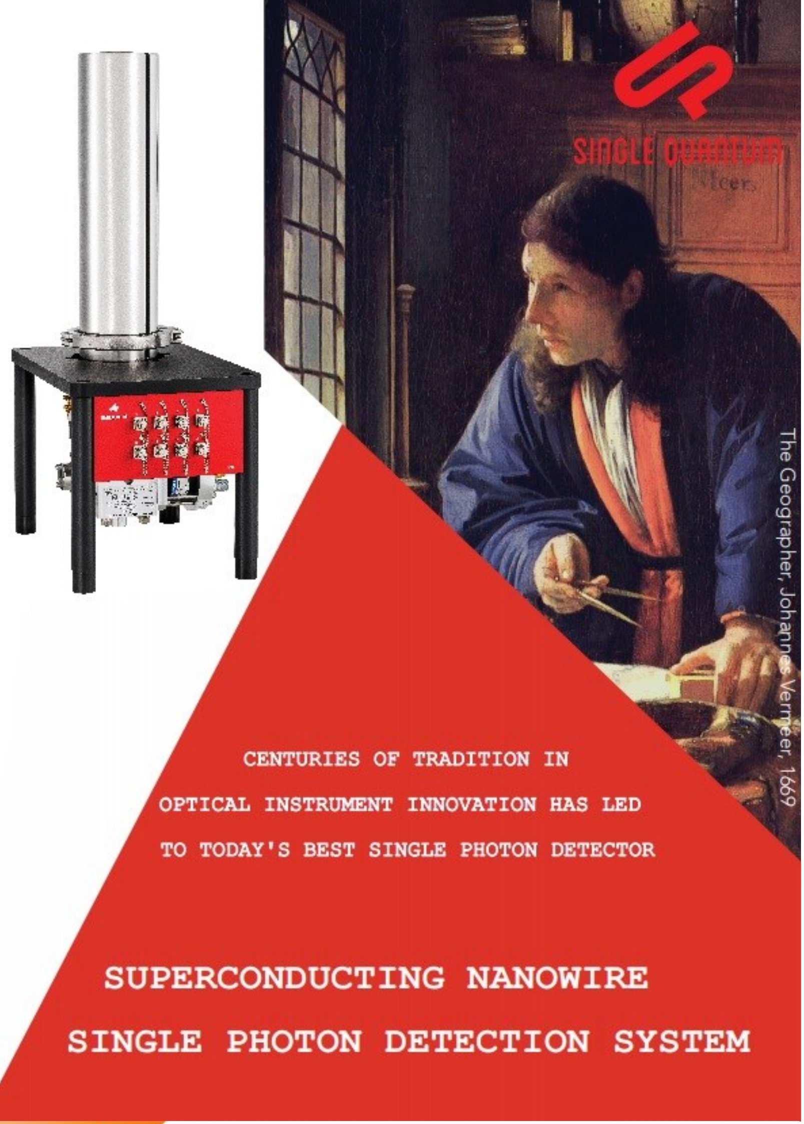
Thank you for attending this year's BQIT workshop.

Please save the date for next year's workshop:

3-5 April 2019.

We look forward to seeing you there.





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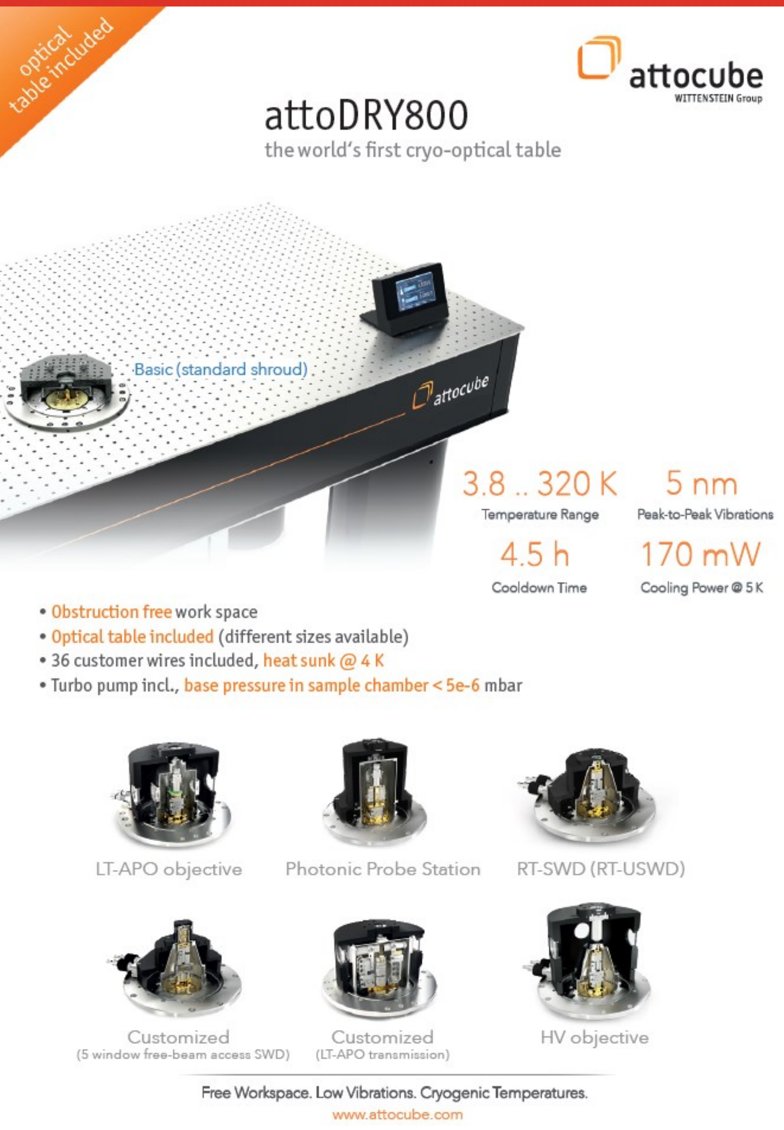

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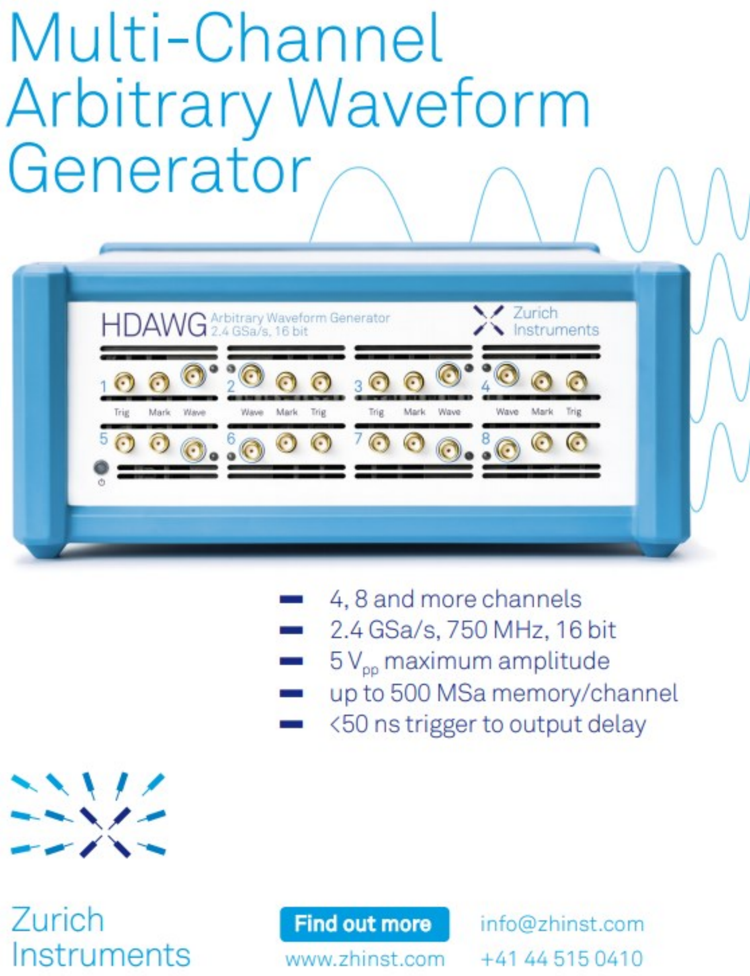

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