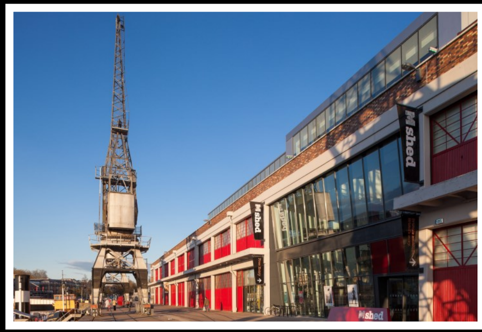
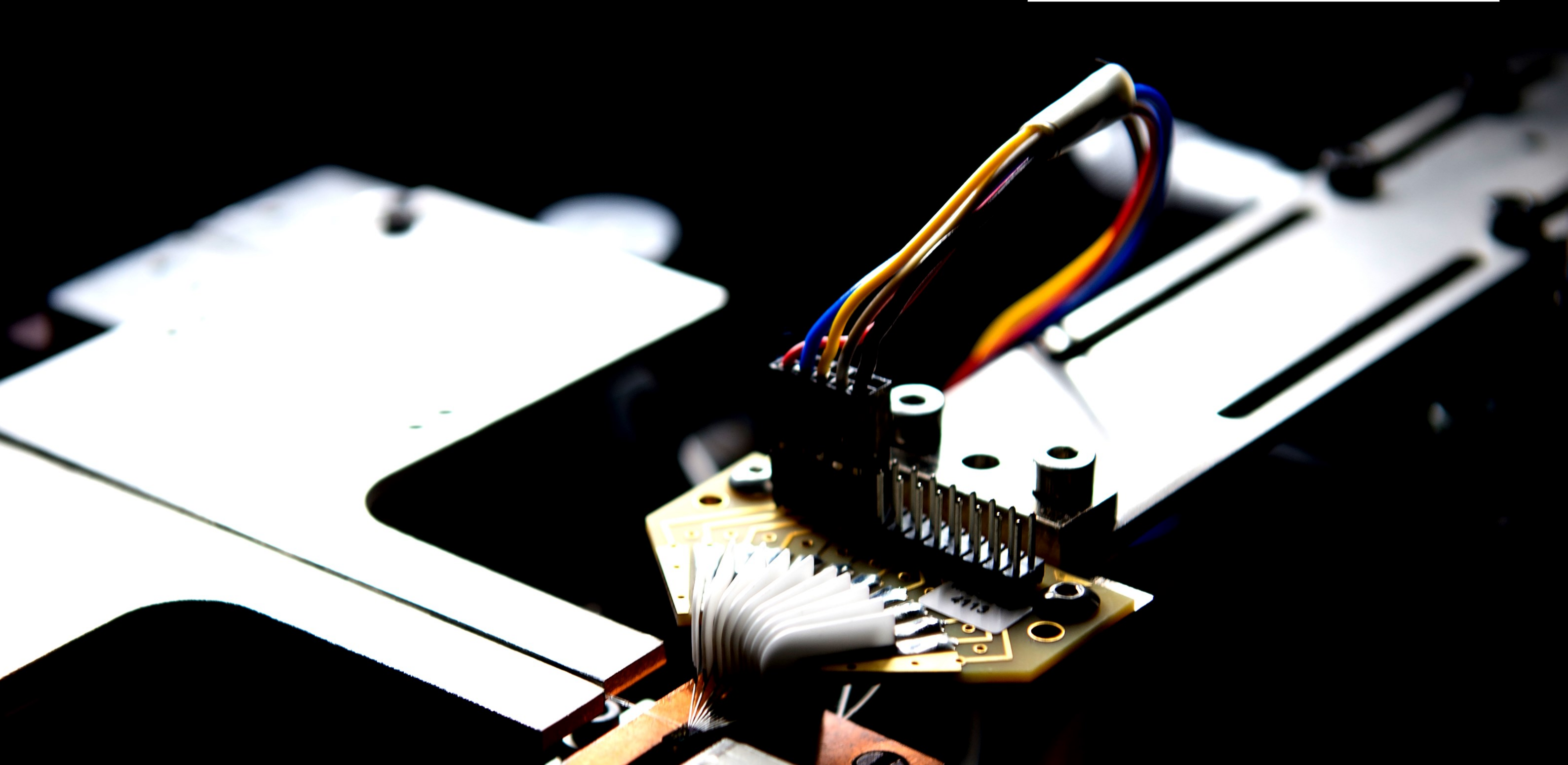
University of BRISTOL

QET Labs



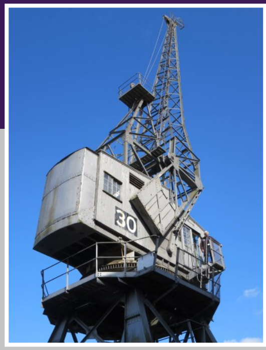
The Bristol Quantum Information Technologies Workshop

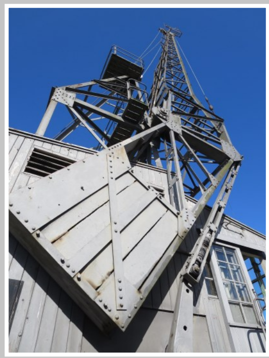
5-7 April 2017—M Shed, Bristol

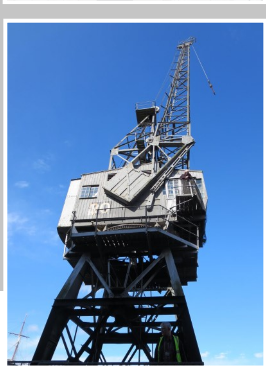


bqit-admin@bristol.ac.uk

Welcome to BQIT:17







CONTENTS

Dear colleagues and friends,

On behalf of the Programme Committee for the Bristol Quantum Information Technologies Workshop (BQIT), I am delighted to welcome you to BQIT:17.

We hope to replicate the success of past years this week by having talks in the areas ranging from entanglement foundations and quantum theory through platforms in ions, solid state, hybrid systems and integrated quantum photonics to technology challenges of scaling up and applications to quantum communications, metrology, and information processing. An industry focused session with panel discussion and future EU flagship funding opportunities completes this wide ranging programme.

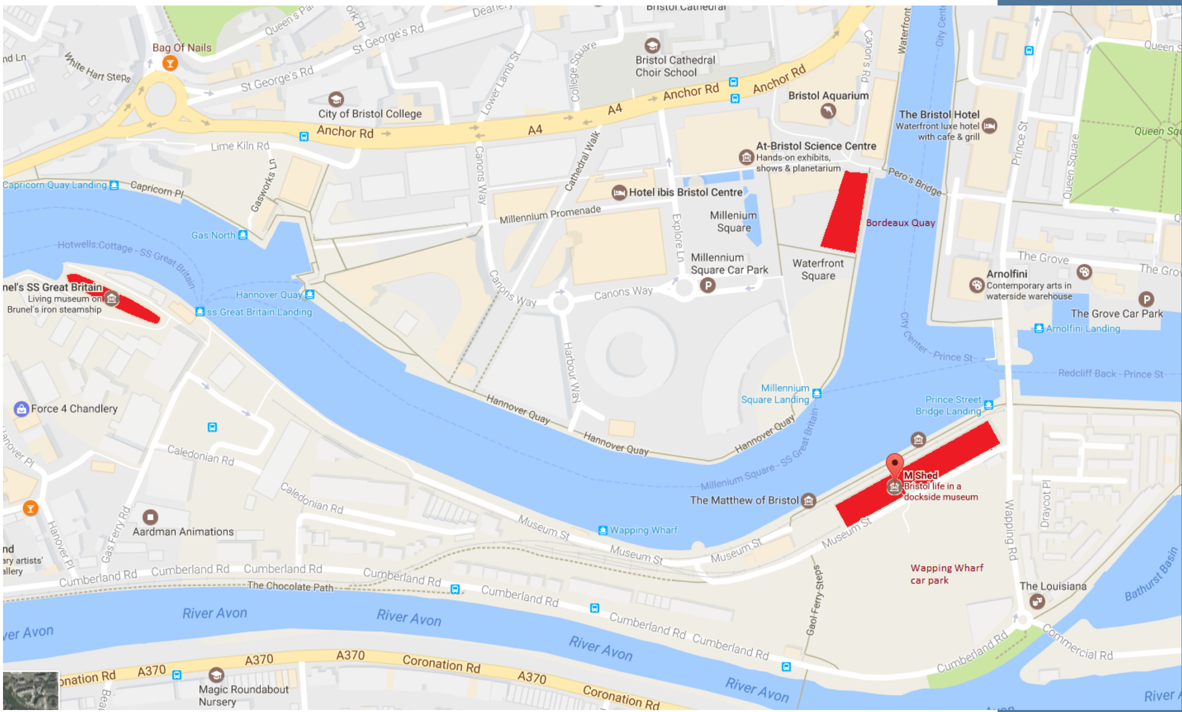
BQIT is a venture by the University of Bristol's QET Labs (Quantum Engineering Technology Labs), whose aim is to deliver a radically new generation of machines that exploit quantum physics to transform our lives, society and economy. QET Labs is a global centre for research, development and entrepreneurship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

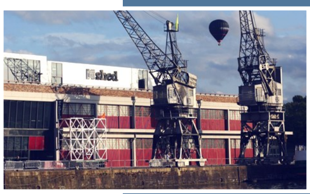
Professor John Rarity (on behalf of the Programme Committee)

Map & Parking information



M Shed

Princes Wharf, Wapping Rd, Bristol BS1 4RN



M Shed is a world-class cultural landmark set on the historic harbourside in the heart of Bristol, and showcases our engineering and industrial city in a beautiful setting.

Bristol's flagship museum has been designed to retain the character of the former 1950s transit shed and contains the Bristol Places gallery, focusing on our physical and dynamic city and the ways that people have shaped and experienced it and continue to do so. Some of the best engineering exhibits in Bristol are outside M Shed, including their cargo cranes and the banana-shaped steam crane which is the oldest surviving exhibit of its type.

The panoramic views from the event suite are unparalleled, and show off Bristol's harbourside in all its glory.

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 will also have the opportunity to view the museum situated within the M Shed.

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

Day One: Speakers

Wednesday 5th April

John Rarity

University of Bristol

Welcome

10:00 - 10:10

Entanglement Foundations

Aephraim Steinberg

University of Toronto

Novel quantum technologies: from making one photon act like eight to seeing two stars inside a single spot

10:10 - 10:45

Marek Zukowski

University of Gdansk

Entanglement and non-classicality indicators for optical interferometry with states of undefined photon numbers, and quantum Stokes parameters

10:45 - 11:20

Quantum Devices

Joshua Nunn

University of Oxford

Finally: a noise-free quantum memory

11:40 - 12:15

Marco Liscidini

University of Pavia

Generation of non-classical states of light via parametric fluorescence in integrated devices

12:15 - 12:50

Quantum Information Theory 1

Elizabeth Crosson

Caltech

Quantum annealing versus classical optimization

12:50 - 13:25

Lunch 13:25-14:55 (served in the foyer)

Quantum Communications

Jake Kennard

University of Bristol

Integrated Quantum Key Distribution

14:55 - 15:15

Robert Collins

Heriot Watt University

Quantum digital signatures in optical fibre networks

15:15 - 15:50

Yury Kurochkin

Russian Quantum Centre

Fast prototyping of QKD optical schemes with the use of the modular QKD setup

15:50 - 16:10

Funding Industry

Chris Erven

University of Bristol

Starting up the quantum industry and the importance of ethical tweeting

16:30 - 16:50

Chris Snelling

ICE Oxford

Design and scaling of cryogenics towards a quantum computer

16:50 - 17:10

Niki Haines

Keysight Technologies

Quantum technologies: today and tomorrow!

17:10 - 17:30

Industry Panel Session

17:30 - 18:00

Andy Collins
QTEC

Niki Haines
Keysight Technologies

Roberto Desimone
BAE Systems

Susannah Jones
DSTL

Bob Cockshott
KTN UK

Welcome Dinner: Bordeaux Quay

Wednesday 5th April

Bordeaux Quay

V-Shed, Canons Way, Bristol BS1 5UH

Our welcome dinner and drinks reception will take place at Bordeaux Quay on Bristol's Harbourside, just a short walk from our workshop venue.

Housed in an elegant, converted warehouse on the waterfront, Bordeaux Quay offers the very best in seasonal, regionally sourced food and drink. The restaurant is situated on the first floor and offers stunning views of the harbour.

Drinks reception will begin at 18:30, with dinner being served at 19:30.

Day One: Timetable

Wednesday 5th April

Time	Event	Length	Running alongside
09.30	Arrivals and Registration	30 min	
10.00	Welcome: John Rarity (University of Bristol)	10 min	
Entanglement Foundations			
10.10	Aephraim Steinberg (University of Toronto)	30 min (+ 5 min questions)	
10.45	Marek Zukowski (University of Gdansk)	30 min (+ 5 min questions)	
11.20	*Coffee Break*	*20 min*	
Quantum Devices			
11.40	Joshua Nunn (University of Oxford)	30 min (+ 5 min questions)	
12.15	Marco Liscidini (University of Pavia)	30 min (+ 5 min questions)	
Quantum Information Theory 1			
12.50	Elizabeth Crosson (Caltech)	30 min (+ 5 min questions)	
13.25	*Lunch*	*90 min*	
Quantum Communications			Poster session (sponsored by Quantum Engineering CDT)
14.55	Jake Kennard (University of Bristol)	20 min	
15.15	Robert Collins (Heriot Watt University)	30 min (+ 5 min questions)	
15.50	Yury Kurochkin (Russian Quantum Centre)	20 mins	
16.10	*Coffee Break*	*20 min*	
Funding Industry			
16.30	Chris Erven (University of Bristol)	20 min	
16:50	Chris Snelling (ICE Oxford)	20 min	
17:10	Niki Haines (Keysight Technologies)	20 min	
Panel Session			
17.30	Panel Members: - Andy Collins (Quantum Technology Enterprise Centre) - Niki Haines (Keysight Technologies) - Roberto Desimone (BAE Systems) - Susannah Jones (DSTL) - Bob Cockshott (KTN UK)	30 min	
18:00	Close & thanks	5 min	
Welcome dinner at Bordeaux Quay			

Day Two: Speakers

Thursday 6th April

Quantum Information Theory 2

Ashley Montanaro
University of Bristol
General-purpose quantum algorithms
09:30 - 09:55

Martin Plenio
University of Ulm
Efficient Quantum State Tomography in action
09:55 - 10:30

Laura Mancinska
University of Bristol
Harnessing quantum entanglement
10:30 - 10:55

Scaling Up

Winfried Hensinger
University of Sussex
Constructing a microwave trapped ion quantum computer
11:15 - 11:50

Michael Bremner
University of Technology Sydney
Beyond classical computing via low-depth quantum circuit sampling
11:50 - 12:25

Lunch 12:25-13:55 (served in the foyer)

Metrology

Morgan Mitchell
ICFO
Application-inspired quantum sensing and metrology
13:55 - 14:30

Alex Lvovsky
University of Calgary
Manipulating Schrödinger cats in quantum optics
14:30 - 15:05

Continuous Variables

Akira Furusawa
University of Tokyo
Hybrid quantum information processing: A way for large-scale optical quantum information processing
15:25 - 16:00

Dylan Mahler
University of Bristol
An integrated homodyne detector in Silicon
16:00 - 16:25

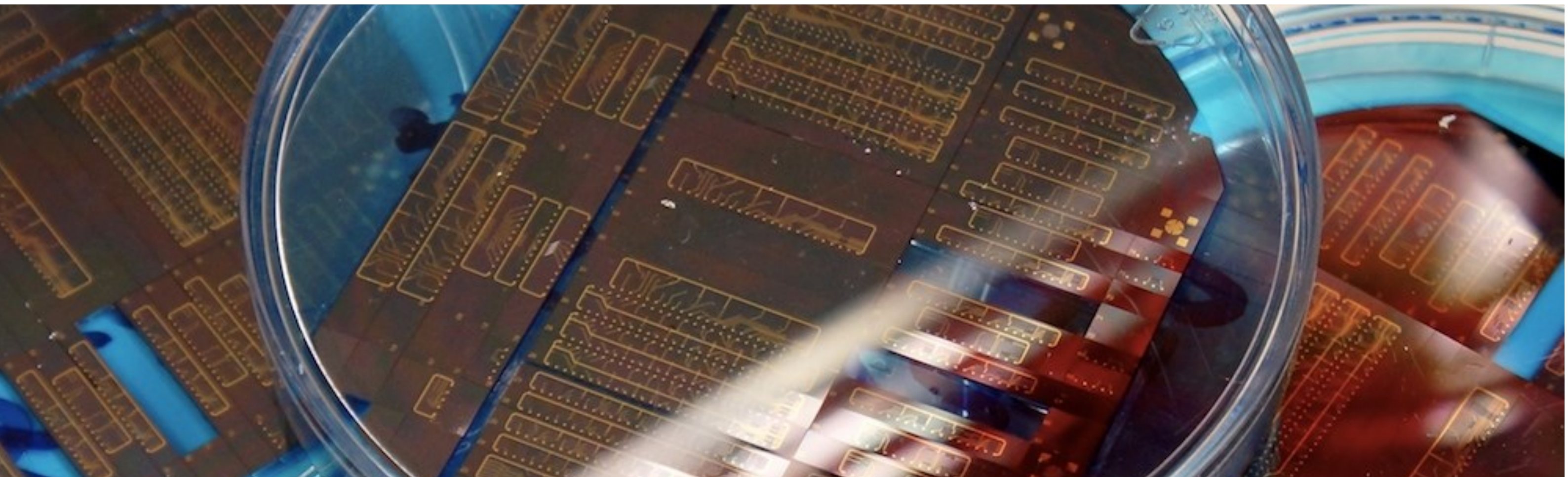
Flagship/Future Funding

Tommaso Calarco
University of Ulm
Towards a Quantum Flagship
16:25 - 17:00

Day Two: Timetable

Thursday 6th April

Time	Event	Length	Running alongside
09.00	*Tea and Coffee*	*30 min*	Poster session (sponsored by Quantum Engineering CDT)
Quantum Information Theory 2			
09.30	Ashley Montanaro (University of Bristol)	20 min (+ 5 min questions)	
09.55	Martin Plenio (University of Ulm)	30 min (+ 5 min questions)	
10.30	Laura Mancinska (University of Bristol)	20 min (+ 5 min questions)	
10.55	*Coffee Break*	*20 min*	
Scaling Up			
11.15	Winfried Hensinger (University of Sussex)	30 min (+ 5 min questions)	
11.50	Michael Bremner (University of Technology Sydney)	30 min (+ 5 min questions)	
12.25	*Lunch*	*90 min*	
Metrology			
13.55	Morgan Mitchell (ICFO)	30 min (+ 5 min questions)	
14.30	Alex Lvovsky (University of Calgary)	30 min (+ 5 min questions)	
15.05	*Coffee Break*	*20 min*	
Continuous Variables			
15.25	Akira Furusawa (University of Tokyo)	30 min (+ 5 min questions)	
16.00	Dylan Mahler (University of Bristol)	20 min (+ 5 min questions)	
Flagship/Future Funding			
16.25	Tommaso Calarco (University of Ulm)	30 min (+ 5 min questions)	
17.00	Close & thanks	5 min	
Dinner and drinks reception at SS Great Britain			



Dinner: SS Great Britain

Thursday 6th April

SS Great Britain

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

Brunel's SS Great Britain is one of the most important historic ships in the world. When she was launched in 1843 she was called 'the greatest experiment since the Creation'.

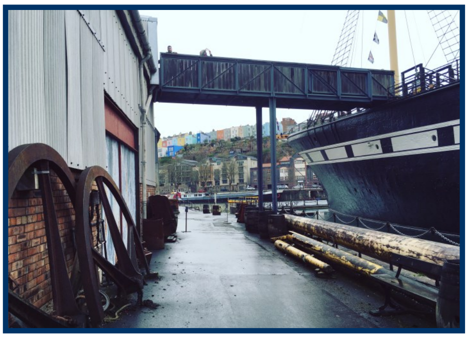
By combining size, power and innovative technology, Brunel created a ship that changed history. His vision for the SS Great Britain made her the great-great-grandmother for all modern ships.

Guests will have access to the entire ship during their visit, with the option to attend a guided tour, providing a fantastic opportunity to explore and learn about one of Bristol's greatest pieces of innovative design and technology.

The beautifully restored ship lies in the heart of Bristol's harbourside. Launched in 1843 as the world's first luxury ocean liner, the SS Great Britain is a truly unique venue.

Our dinner will be freshly cooked on board ship, and served in the First Class Dining Saloon.

Drinks reception will begin at 18:00, with dinner being served at 19:00.



Day Three: Speakers

Friday 7th April

Detectors

Sae Woo Nam

NIST

Superconducting nanowire detector developments at NIST

09:30 - 10:05

Wolfram Pernice

Munster University

Waveguide integrated superconducting single photon detectors

10:05 - 10:40

Solid State & Hybrid Systems 1

Almut Beige

University of Leeds

From optical cavities to cavity-fibre networks

11:00 - 11:35

Ruth Oulton

University of Bristol

Quantum dot spin-based photon phase shifts for photonic cluster states and photon switching

11:35 - 12:10

Sven Hofling

University of Wurzburg

High efficiency quantum dot single photon sources for quantum technologies

12:10 - 12:45

Lunch 12:45-13:45 (served in the foyer)

Integrated Quantum Photonics

Sebastien Tanzilli
University of Nice
Spectrally-resolved white-light quantum interferometry for high-accuracy optical measurements
13:45 - 14:20

Raffaele Santagati
University of Bristol
Quantum information processing and machine learning in silicon quantum photonics
14:20 - 14:45

Solid State & Hybrid Systems 2

Jason Smith
University of Oxford
Optical microcavities for quantum technologies
14:45 - 15:20

Peter Humphreys
Delft University of Technology
Quantum networks of diamond spins for computing and communication
15:20 - 15:55

John Rarity
University of Bristol
Close
15:55 - 16:00

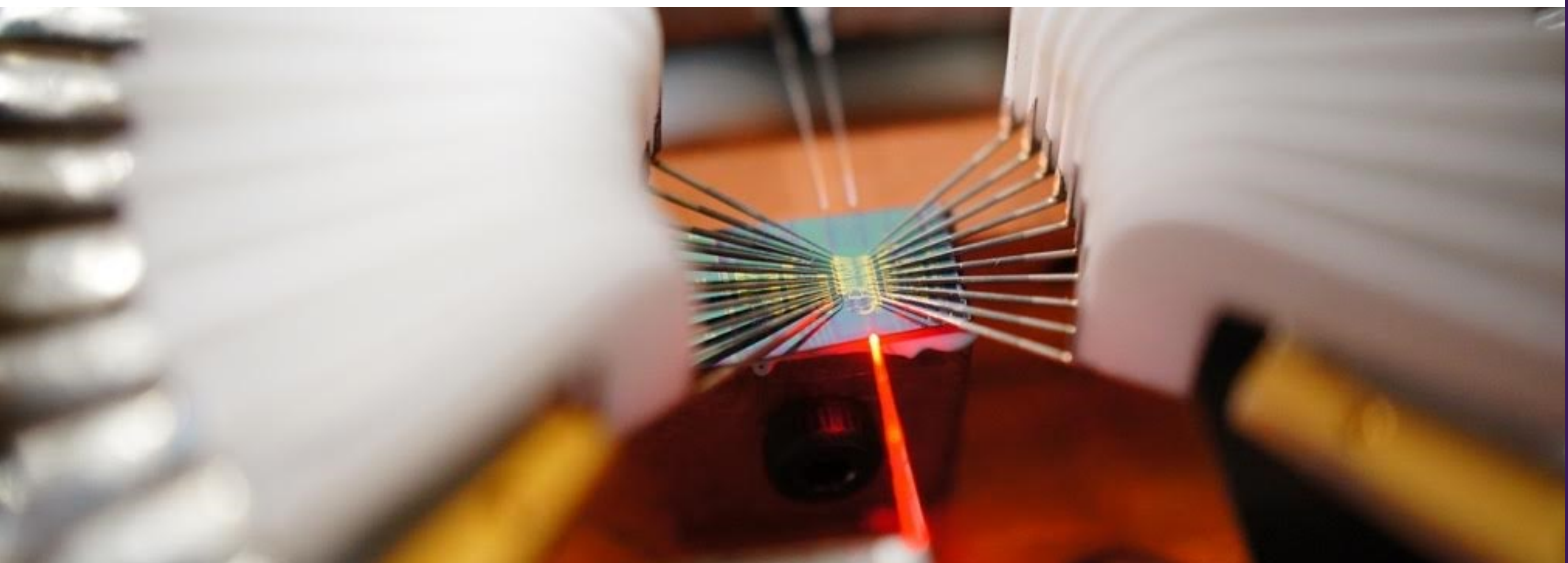
Thank you for joining us at this year's BQIT workshop. We hope you can join us next year. Please save the date:

18th-20th April 2018

Day Three: Timetable

Friday 7th April

Time	Event	Length	Running alongside
09.00	*Tea and coffee*	*30 min*	Poster Session (sponsored by Quantum Engineering CDT)
Detectors			
09.30	Sae Woo Nam (NIST)	30 min (+ 5 min questions)	
10.05	Wolfram Pernice (University of Münster)	30 min (+ 5 min questions)	
10.40	*Coffee Break*	*20 min*	
Solid State & Hybrid Systems (1)			
11.00	Almut Beige (University of Leeds)	30 min (+ 5 min questions)	
11.35	Ruth Oulton (University of Bristol)	30 min (+ 5 min questions)	
12.10	Sven Höfling (University of Würzburg)	30 min (+ 5 min questions)	
12.45	*Lunch*	*60 min*	
Integrated Quantum Photonics			
13.45	Sebastien Tanzilli (CNRS/Université Côte d'Azur)	30 min (+ 5 min questions)	
14.20	Raffaele Santagati (University of Bristol)	20 min (+ 5 min questions)	
Solid State & Hybrid Systems (2)			
14.45	Jason Smith (University of Oxford)	30 min (+ 5 min questions)	
15.20	Peter Humphreys (TU Delft)	30 min (+ 5 min questions)	
15:55	Thanks and close: John Rarity (University of Bristol)	5 min	
16.00 CLOSE			



Speaker Abstracts

Aephraim Steinberg (University of Toronto):

Novel quantum technologies: from making one photon act like eight to seeing two stars inside a single spot

I will give a brief overview of two of our recent experiments trying to push the boundaries of experimental quantum measurement.

In one, having developed a system in which we can measure the effect of individual photons on a second optical beam, we show how "weak value amplification" can be used to greatly enhance the nonlinear effect of a single postselected photon. In a very different experiment, we show how inspiration from quantum information has led to a new paradigm which promises to vastly improve the resolution of classical imaging systems, from microscopes to telescopes.

Joshua Nunn (University of Oxford):

Finally: a noise-free quantum memory

Photonic quantum computers are a tantalising prospect, but useful-scale devices cannot be achieved without some kind of active multiplexing to pick out successful logic operations. Quantum memories that can store photons could enable temporal multiplexing via repeat-until-success, but so far they have been too noisy. Here we present a new quantum memory protocol optimised for low-latency photonic synchronisation — the off-resonant cascaded absorption (ORCA) memory. We verify experimentally that the ORCA memory is entirely noise-free.

Marco Liscidini (University of Pavia):

Generation of non-classical states of light via parametric fluorescence in integrated devices

Light confinement in integrated micro- and nano-structures allows for the efficient generation of photon pairs via parametric fluorescence, thanks to the enhancement of the light-matter interaction associated with light confinement in small volumes. Yet, the advantages of integrated device go well beyond efficiency improvement, for micro structures grant an unprecedented control of the properties of the generated light. I will discuss how pairs generated by parametric fluorescence can be used as building blocks to produce a whole variety of states of non-classical light, from single heralded photons to multipartite states.

Elizabeth Crosson (Caltech):

Quantum annealing versus classical optimization

Quantum annealing is an analog form of quantum computation that proposes to solve classical optimization problems by attempting to prepare low energy states of quantum spin systems. Although empirical benchmarks of commercially available quantum annealers indicate that they are becoming competitive with classical single core CPUs, it remains mostly unknown whether quantum annealers can achieve a scaling advantage over classical methods when applied to difficult optimization instances. In this talk I will share a current theoretical perspective on the strengths of quantum annealing, as well as the prospects for overcoming its weaknesses to improve the performance of the method.

Robert Collins (Heriot Watt University):

Quantum digital signatures in optical fibre networks

To date, the field of quantum communications has mainly focused on quantum key distribution (QKD) – to the point where commercial systems are now available. By employing either single photons or weak coherent states as the information carriers, QKD allows the pairwise generation of secure keys for use in point-to-point encryption. Quantum digital signatures (QDS) offer complementary functionality to that of QKD to create secure digital signatures which provide information-theoretically secure guarantees of the authentication, non-repudiation and transferability of signed messages.

Early experimental demonstrations of QDS operated with highly specialized custom hardware in a laboratory environment and transmitted over short lengths of optical fibre in controlled conditions. The first experimental demonstration of QDS required quantum memory, operated over 5 meters of specialized optical fibre and required complex active feedback control systems and thermal isolation. Ongoing developments of the underlying theoretical protocols lead to many of these restrictive requirements being removed with each subsequent iteration of the experimental demonstrations. However, the previous demonstrations remained laboratory-based with specific optical configurations that offered limited compatibility with the global telecommunications optical fibre infrastructure.

More recently we have reported a QDS system operating over several tens of kilometres of dark installed standard telecommunications optical fibre. The QDS system employed a QKD system operating at a wavelength of 1550 nm and only modified the classical post-processing of the data, leaving the optical systems unchanged. Therefore, this experiment demonstrates the potential that commercially available QKD systems can be adapted for use with QDS with minimal changes –

Yury Kurochkin (Russian Quantum Centre):

Fast prototyping of QKD optical schemes with the use of the modular QKD setup

A. Duplinsky, A. Kanapin, A. Miller, A. Sokolov, A. Losev, V. Rodimin, A. Fedorov, V. Kurochkin and Y. Kurochkin
Russian Quantum Center, Skolkovo, Moscow 143025, Russia

There are number of technological challenges on the way to the implementation of quantum key distribution (QKD) [1]. An important ingredient of the technology is the QKD protocol. It should provide both guaranteed security of distributed keys and direct realizations on the physical level [2]. The optical scheme should be stable and give a level high of the bit rate. Another important requirement is that the raw key should be converted to the secret one in the fast and efficient way.

Here we present the results of the project aimed on the commercial QKD development. The first result is the design of the modular QKD device [3]. To make a fast prototyping we realize the plug&play optical scheme [4] with the use of the seminal BB84 QKD protocol and decoy-state protocol [5]. National Instruments cards with code and Python code for the post-processing procedure drive the designed setup [6, 7]. Platforms based on National Instruments are commonly used in research activity of the academic community.

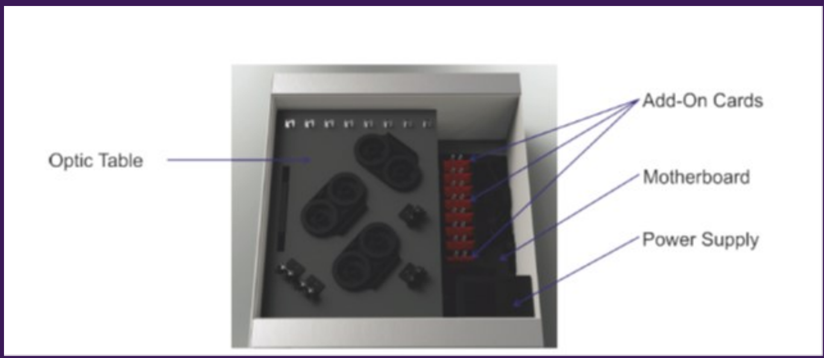


Figure 1. Design concept of Alice's unit in the developed modular QKD setup.

The system can operate with any type of free running single-photon detectors. We use ID230 detectors [8]. The external drivers of single-photon detectors, phase modulators and synchronization detector are realized as removable modules. Each device can drive up to 4 detectors and 6 universal ports for phase or amplitude modulators. Although the fact that the setup is oriented research and development applications, it demonstrates high degree of robustness beyond laboratory conditions.

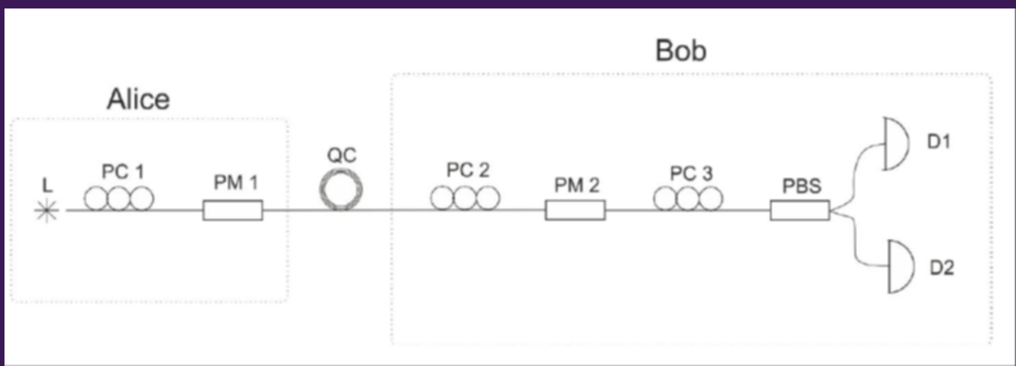


Figure 2. QKD scheme for the tests in the classical regime: L is the laser, PC is the polarization controller, PM is the electro-optical phase modulator, PBS is the polarization beam splitter, D is the detector, QC is the quantum channel.

We use the designed setup for generation of quantum keys over a distance of 30 km between two bank offices in Moscow with the final key generation rate on the level of 0.5 kbit/s. Due to the quantum basis and optical methods of information transfer, the developed modular QKD setup is suited pretty well for the education of undergraduate physics students.

The developed setup is well suits for the start of experimental research in QKD. The example is the application of the fiber-based polarization-encoding scheme with low voltage electro-optical phase modulators based on $LiNbO_3$ [9]. It allows one to use single laser source for polarization encoding implementation, while most polarization state implementations suffer from the pulse indistinguishability problem. Both Alice and Bob use phase electro-optical $LiNbO_3$ modulators for polarization modulation. Alice creates one of four polarization states, two diagonal and two circular. Bob uses his modulator for active choose of basis in which he measures the state, diagonal or circular. This allows Bob to use only two detectors except of four for BB84 protocol with Bob's passive choice. Use of phase modulators on both sides compensates polarization mode dispersion.

We acknowledge financial support from Ministry of Education and Science of the Russian Federation (Agreement 14.582.21.0009, ID RFMEFI58215X0009).
[1] E. Diamanti, H.-K. Lo, B. Qi, and Z. Yuan, npj Quant. Inf. 2, 16025 (2016).
[2] N. Gisin, G. Ribordy, W. Tittel, and H. Zbinden, Rev. Mod. Phys. 74, 145 (2002).
[3] A.S. Sokolov, A.V. Miller, A.A. Kanapin, V.E. Rodimin, A.V. Losev, A.S. Trushechkin, E.O. Kiktenko, A.K. Fedorov, V.L. Kurochkin, Y.V. Kurochkin, arXiv:1612.04168.
[4] A. Muller, T. Herzog, B. Huttner, W. Tittel, H. Zbinden, and N. Gisin, Appl. Phys. Lett. 70, 793-5 (1997).
[5] C.H. Bennet and G. Brassard, in Proceedings of IEEE International Conference on Computers, Systems and Signal Processing (Bangalore, India, December 9-12, 1984), p. 175.
[6] E.O. Kiktenko, A.S. Trushechkin, Y.V. Kurochkin, and A.K. Fedorov, J. Phys. Conf. Ser. 741, 012081 (2016).
[7] RQC QKD Software, https://github.com/RQC-QKD-Software
[8] ID Quantique, www.idquantique.com
[9] A. Duplinskiy, V. Ustimchik, A. Kanapin, Y. Kurochkin, Proc. SPIE 10224, International Conference on Micro- and Nano-Electronics 2016, 102242W (2016

Chris Erven (University of Bristol):

Starting up the Quantum Industry and the Importance of Ethical Tweeting

In this talk I'll briefly synopsize the recent flurry of quantum start-ups being announced, programmes around the world to support them, and our own efforts here in Bristol to grow a new quantum start-up ecosystem with our Quantum Technology Enterprise Centre – which is now recruiting for the 2017-18 year! I will also start a (likely lively, possibly heated) discussion on the important of "ethical tweeting" for both academics and companies if we want to avoid destructive interference between the two.

Niki Haines (Keysight Technologies):

Quantum Technologies: Today and Tomorrow!

Quantum Computing is promising to be an enabler for many technologies that are in development today, like 5G, IoT, cloud computing and Industry 4.0, but also technologies that we do not even know about, yet. Keysight Technologies is accompanying the research efforts of multiple physical implementations to realise a fault-tolerant and universal scalable quantum computing platform.
We are investing in supporting the rollout of such concepts by providing a growing portfolio of scalable modular platforms to validate and test some of the most popular quantum computing research efforts. (Including Superconducting qubits, Quantum Dots, Ion traps and photonic qubits etc.).

Ashley Montanaro (University of Bristol):

General-purpose quantum algorithms

Known quantum speedups over classical computation divide, roughly speaking, into two classes: exponential speedups for special-purpose problems such as integer factorisation and simulation of quantum systems; and polynomial speedups for more general problems such as unstructured search. In this talk I will discuss the latter kind of quantum algorithm, including recent work on algorithms for accelerating classical approaches towards constraint satisfaction problems and Monte Carlo methods.

Martin Plenio (University of Ulm):

Efficient Quantum State Tomography in Action

In this lecture I will introduce methods for the efficient verification of quantum properties as well as the efficient tomography of many-body quantum states. I will also present results of a recent experimental implementation of efficient quantum state tomography with trapped ions.

Laura Mančinska (University of Bristol):

Harnessing quantum entanglement

The phenomenon of entanglement is one the key features of quantum mechanics. It lies at of the heart of cryptographic applications of quantum technologies and is also necessary for computational speedups. I will overview some of the key scenarios where entanglement assistance leads to classically unattainable functionality. In particular, we will see how entanglement can be used to certify that a purported quantum device is acting according to its specification. I will end by pointing out that despite the existing applications of entanglement we still lack a full understanding of it and listing some of the most pressing open questions in this area.

Winfried K. Hensinger (University of Sussex):

Constructing a microwave trapped ion quantum computer

Sussex Centre for Quantum Technologies
Department of Physics & Astronomy, University of Sussex,
Brighton, East Sussex, BN1 9QH, United Kingdom
E-mail: w.k.hensinger@sussex.ac.uk
http://www.sussex.ac.uk/physics/iqt

Trapped ions are a promising tool for building a large-scale quantum computer. The number of radiation fields (such as lasers) required for the realisation of quantum gates in any proposed ion-based architecture scales with the number of ions inside the quantum computer, posing a major challenge when imagining a device with millions of qubits. Here I present a fundamentally different approach, where this scaling entirely vanishes. The method is based on individually controlled voltages applied to each logic gate location to facilitate the actual gate operation analogous to a traditional transistor architecture within a classical computer processor. Instead of aligning numerous laser beams into designated entanglement zones, the use of a single microwave source outside the vacuum system is sufficient. We have demonstrated the key principle of this approach by implementing a two-qubit quantum gate based on long-wavelength radiation where we generate a maximally entangled two-qubit state with fidelity 0.985(12). I will also discuss the engineering blueprint for a large-scale microwave trapped-ion quantum computer we have recently released. The work features a new invention permitting actual quantum bits to be transmitted between individual quantum computing modules using electric fields in order to obtain a fully modular large-scale machine.

Michael Bremner (University of Technology Sydney):

Beyond classical computing via low-depth quantum circuit sampling

Over the last few years there has been significant attention devoted to devising experimental demonstrations of quantum supremacy: namely a quantum computer solving a computational task that goes beyond what a classical machine could achieve. This is, in part, driven by the hope that a clear demonstration of post-classical can be performed with a device that is intermediate between the small quantum circuits that can currently be built and a full-scale quantum computer. The theoretical challenge that this poses is twofold: firstly we must identify the physically least expensive quantum computations that are classically unachievable; and we must also determine if this advantage can be maintained in the presence of physical noise. In this talk I will review the IQP and Boson Sampling approaches to quantum supremacy, how they can be generalized to other intermediate quantum computing models, and to what extent the experimental resource requirements of these problems can be reduced.

See:

- M. J. Bremner, A. Montanaro, and D. J. Shepherd "Achieving quantum supremacy with sparse and noisy commuting quantum computations", arXiv:1610.01808
- M. J. Bremner, A. Montanaro, and D. J. Shepherd "Average-case complexity versus approximate simulation of commuting quantum computations", Phys. Rev. Lett. 117, 080501 (2016). arXiv:1504.07999
- S. Boixo, et al, "Characterizing quantum supremacy in near-term devices", arXiv:1608.00263

Morgan Mitchell (ICFO):

Application-inspired quantum sensing and metrology

I will discuss two recent - and I hope surprising - results in quantum sensing. Both were found by considering the role of quantum noise in real-world optical and atomic instruments. The first concerns the ``tracking,'' i.e., continuous monitoring, of an evolving atomic ensemble, such as one finds in an optical magnetometer or magnetic resonance imager. If the continuous monitoring is done in a non-destructive way, something that is routine in optical magnetometry, then the combined atomic/optical system naturally evolves to a ``planar squeezed state'' with a sensitivity far below classical limits for both spin angle and spin amplitude, the only atomic degrees of freedom that enter the measurement record. In this way, a measurement that is already being used in magnetometry can almost completely evade quantum statistical noise, extending the quantum sensing limits by orders of magnitude. We demonstrate such dual-squeezed spin tracking using a cold atomic spin ensemble. The second result concerns the broad class of measurements that operate using an optimized, rather than constrained, number of particles. This class includes interferometric gravitational-wave detection and many atomic instruments, but is not well described by quantum-information-styled models of quantum sensing. By general arguments we show how the optimal working point is inevitably determined by interactions among the sensing particles, making most models of quantum sensing inapplicable to these sensors. Considering a simple but realistic model for spectroscopic sensing, we then show that optical squeezing remains effective in such optimized, nonlinear systems. As time permits, I will describe an experimental demonstration in spin noise spectroscopy.

Alex Lvovsky (University of Calgary):

Manipulating Schrödinger cats in quantum optics

Superpositions of macroscopically distinct quantum states, introduced in Schrödinger's famous Gedanken experiment, are an epitome of quantum ``strangeness" and a natural tool for determining the validity limits of quantum physics. The optical incarnation of Schrödinger's cat --- the superposition of two opposite-amplitude coherent states --- is also the backbone of quantum information processing in the continuous-variable domain. The talk will cover recent experimental progress on preparing such states, applying them in quantum technology and communications, and increasing their amplitude.

Akira Furusawa (University of Tokyo):

Hybrid Quantum Information Processing; A Way for Large-scale Optical Quantum Information Processing

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We are working on hybrid quantum information processing, which combines two methodologies of quantum information processing – qubit and continuous variable (CV) [1]. More precisely, we encode logical qubits by using CV methodology and utilize CV quantum processors for the realization of a fault-tolerant large-scale universal optical quantum computer. The advantage of this methodology is that we can have both high-fidelity nature of qubits and determinisity of CV quantum processors. In other words, we can enjoy both particle- and wave-nature of quantum mechanics. Towards this goal we performed various things, which include quantum error correction with nine-party CV entanglement [2], teleportation of Schrödinger's cat state [3], adaptive homodyne measurement with phase-squeezed states [4], deterministic teleportation of time-bin qubits [5], creation of ultra-large-scale CV cluster states [6], generation and measurement of CV entanglement on a chip [7], and synchronization of photons with cavity-based quantum memories [8].

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Sae Woo Nam (NIST):

Superconducting nanowire detector developments at NIST

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Single-photon detectors are an essential tool for a wide range of applications. Ideally, a single photon detector generates a measurable signal only when a single photon is absorbed. Since the first reported detection of a single photon using a superconducting nanowire in 2001, rapid progress has been made in the development and application of superconducting nanowire single photon detectors with ideal properties.

I will briefly describe recent progress in nanowire detector developments at NIST for both telecommunication wavelengths and UV wavelengths.

Almut Beige (University of Leeds):

From optical cavities to cavity-fiber networks

Many applications of quantum information processing, like the simulation of many-body quantum systems, require the construction of scalable qubit networks [1]. A prominent example of such networks are optical lattices with one atom per site and effective interactions induced by Bose-Hubbard-like Hamiltonians [2]. Alternatively one could couple on-demand single photon sources via linear optics elements [3,4]. In this talk, we discuss how to create coherent cavity networks with high or even complete connectivity in a large variety of configurations [5]. Predicting the dynamics of such networks requires the improvement of our understanding of the quantised electromagnetic field inside an optical cavity and near semitransparent mirrors [6,7].

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Raffaele Santagati (University of Bristol):

Quantum information processing and machine learning in silicon quantum photonics

Since the first demonstration of quantum interference in silicon waveguide, the field of silicon quantum photonics has seen a rapid development, with increasing complexity and functionality of the devices based on this technology.
In this talk I will review some of our most recent progress in the field of silicon quantum photonics and how we used this technology to implement new quantum information processing protocols, from quantum simulation to new methods for learning the properties of physical systems.

Peter Humphreys (Delft University of Technology):

Quantum networks of diamond spins for computing and communication

The realization of a highly connected network of qubit registers is a central challenge for quantum information processing and long-distance quantum communication. Diamond spins associated with NV centers are promising building blocks for such a network: they combine a coherent spin-photon interface that has already enabled creation of spin-spin entanglement over 1km [1] with a local register of robust and well-controlled nuclear spin qubits for information processing and error correction [2]. We are now entering a new research stage in which we can exploit these features simultaneously and build multi-qubit networks. I will present our latest results towards the first of such experiments: entanglement distillation between remote quantum network nodes. Finally, I will discuss the challenges and opportunities ahead on the road to large-scale networks of qubit registers for quantum computation and communication.

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Dylan Mahler (University of Bristol):

An integrated homodyne detector in Silicon

The homodyne detector is a primitive element in many quantum optics experiments. It is primarily a characterization device, used for measuring the quantum state of the electromagnetic vacuum field. Use of homodyne detectors on more than a small number of optical modes has so far been limited by the interferometric stability of quantum optical experiments. Quantum integrated photonics, in which optical sources, circuits, and detectors are monolithically integrated on a semi-conductor chip, solves this issue due to its inherent interferometric stability. Here we present the first quantum homodyne detector on a silicon chip. We demonstrate all of the characteristics required for detection of quantum states: high speed, signal-to-noise ratio, and common-mode rejection ratio., and use the detector to perform quantum state tomography of a coherent state.

Jake Kennard (University of Bristol):

Integrated Quantum Key Distribution

Quantum technologies are rapidly developing and have the potential to revolutionise the fields of computing and telecommunications. They have major implications for the security of many of our conventional cryptographic techniques which are known to be insecure against a quantum computer. Fortunately, quantum key distribution (QKD) provides a highly secure approach to sharing random encryption keys by transmitting single photons. QKD has advanced from simple proof-of-principle experiments towards robust long-term demonstrations, it has still not obtained wide-scale adoption. Integrated photonics provides a stable, compact, and robust platform to implement complex photonic circuits amenable to mass-manufacture, and therefore provides a compelling technology for optical quantum information devices.

Recent demonstrations include integrated devices for Reference-Frame-Independent QKD, planar waveguide components in transmitters and receivers, and chip-to-chip QKD using GHz clocked indium phosphide transmitters and silicon oxynitride receivers. Silicon photonics, in particular, is a leading platform for quantum photonic technologies with the promise of high density integration, mature fabrication processing, and compatibility with microelectronics. However, highspeed modulation of quantum states in standard silicon photonic fabrication has been limited. With no natural electrooptic non-linearity, many silicon quantum photonic experiments instead utilise slow thermo-optic phase modulators (TOPM) for high-fidelity state preparation. Carrier injection or carrier depletion modulators (CDM) offer high-speed operation, but incur phase dependent loss and saturation, which are detrimental in quantum applications where state preparation has stringent requirements. Here we show an approach to overcome the limitations of saturation and phase dependent loss of high-speed carrier depletion modulators in standard silicon photonic fabrication.We describe a combination of slow, but ideal, thermooptic phase modulators alongside fast, but non-ideal, carrier depletion modulators utilised for QKD state preparation at GHz speeds. We then use this technique to demonstrate three implementations of high-speed low-error QKD.

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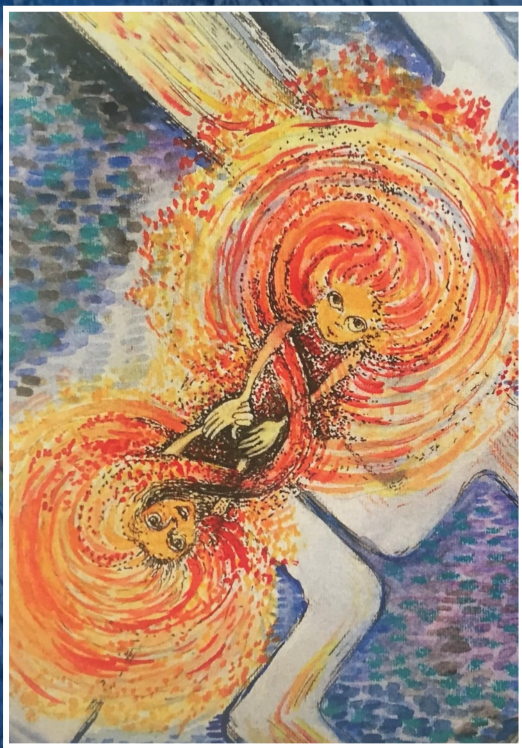
QET Labs has created a platform where quantum 'talks' in many inter-disciplinary dialects. We want this website to be a wholesome cocktail of insights. There will be videos, podcasts, paintings and texts.

Neils Bohr said that 'We are a part of that nature that we seek to understand.' Therefore it is both needed, and very timely, to build our understanding of how our world is perceived, as well as impacted, by quantum concepts, technologies and engineering.

This is why we invited quantum researchers, investors in quantum research, artists, historians, children and the wider public, to build a mutual understanding and ask the right questions. We invite you to join, comment or contribute in any way you seem fit and join us as the conversation unfolds.



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