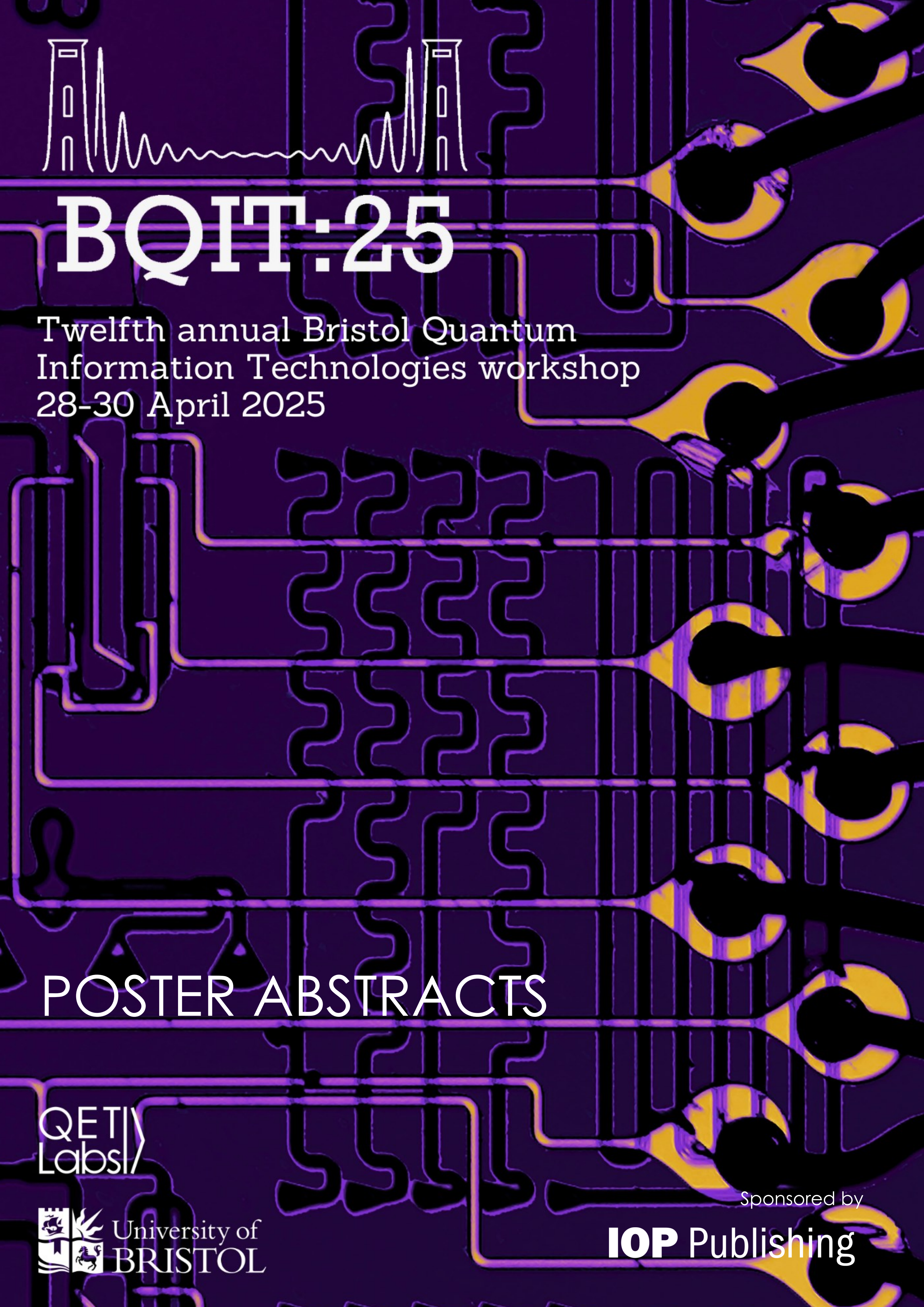

BQIT:25

Twelfth annual Bristol Quantum Information Technologies workshop
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POSTER ABSTRACTS

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CONTENTS

1. Eesa Ali

University of Bristol

Two photon spectroscopy for ladder transitions in Rubidium

Atomic quantum memories which allow for on demand photon storage are important for quantum repeater protocols. In particular, ladder schemes which utilize higher lying excited states in Rb exhibit ultra-low noise operation and the flexible to store and convert photons between near IR wavelengths (780nm) to telecoms wavelengths (1529nm). These experiments require robust, narrow linewidth lasers locked to atomic transitions. Two photon spectroscopy of 1529nm and 780nm lasers can produce a Double Resonance Optical Pumping (DROP) or polarisation spectroscopy signal which can be used to lock the 1529nm laser. We are investigating this two photon spectroscopy over a full range of frequency detuning for both lasers under different power and polarization configurations to construct 2D spectroscopy plots. The experiments and simulations I have performed are across the hyperfine manifold of the 5P3/2 to 4D5/2 energy levels. This gives us a wide range of applicability to explore locking lasers at different frequencies to explore quantum memory protocols across a range of hyperfine states.

2. Yolan Ankaine

University of Bristol

Shaken Lattice Interferometry with Ultracold Atoms

Global Navigation Satellite Systems (GNSS) are vital for sectors such as aerospace, defence, maritime, and public transport, where precise position, velocity, and timing information are essential. However, GNSS disruptions can cause receiver vulnerabilities and environmental challenges. High-precision sensors, namely atom-based interferometers, leverage quantum interference to achieve enhanced accuracy in detecting acceleration and rotation signals, enabling navigation in GPS-denied environments such as underwater. Unlike conventional light-based methods, atom interferometry offers higher sensitivity to applied forces without requiring long trajectories and allows real-time measurements. However, current techniques face limitations, including transmission losses in nano-fabricated gratings, poor resolution, and deadtime issues. Shaken Lattice Interferometry (SLI) presents an alternative approach to traditional atom interferometry by utilizing ultracold trapped atoms within a phase-modulated optical lattice. Previous work demonstrated the theoretical feasibility of this technique in a 1D optical lattice. Our research extends this work to a full 3D lattice system, providing three spatial degrees of freedom by which the atoms can be interrogated. By measuring along the three axes simultaneously, we can construct a multi-axis sensor. Previous simulations of the SLI sequence indicate that the device achieves a sensitivity on the order of 10^−11 g for interrogation times of 1 s and atom numbers of 10^6 . The sensitivity of such devices scale with the square of the interrogation time (i.e., T^2), consistent with theoretical predictions. In addition to the ability to measure the magnitude and direction of the applied signal, the SLI system can be fine-tuned to specific signals by optimizing the shaking protocols – distinguishing SLI from standard atom interferometry techniques. These findings demonstrate the potential of 3D shaken lattice interferometry as a viable and highly effective approach for quantum-enhanced inertial sensing applications.

3. Hugh Barrett

University of Bristol

Oversights in Characterising Heralded Single Photon Sources

The development of ideal sources is a fundamental challenge for the practical implementation of quantum integrated photonic technologies. Here we analyse the state-of-the-art in heralded single photon sources; pointing out inconsistencies in the how key parameters, such as brightness and heralding efficiency, are characterised in the literature. Furthermore, we note several experimental considerations which affect these parameters that are often disregarded. These issues present a barrier to fair comparison between different photon sources, making it unclear which type of source would be best suited for a given application. We suggest considerations that could be made in future works to facilitate fair comparison.

4. Granthick Barua

University of Bristol

Compact organic crystal growth for molecular single photon sources

An ideal single photon source is greatly sought after in a variety of quantum technologies, but this has not yet been realised. There has been numerous work in this field such as quantum dots and diamond-NV centres but each has their own faults. To create an ideal single-photon source in practice, the issues of the photons being indistinguishable from each other and being emitted at a controlled, consistent rate must be addressed.

A single-photon source that has been researched and shown potential is dibenzoterrylene (DBT) molecules within a crystalline anthracene matrix. There have been multiple methods explored to grow doped anthracene crystals but many of these do not allow for easy control of the concentration of DBT molecules, which is a necessity for our application. Improving upon a previous design that attempted to solve the same problem, we describe a compact, table-top vapour deposition chamber that produces DBT-doped anthracene crystals of optical quality, with good control over the DBT concentration.

5. Fedor Benimetskiy

University of Sheffield

All-optical few-photon phase shift in open-access polariton microcavities

We demonstrate significant progress in achieving strong all-optical cross-phase modulation (XPM) using tunable open semiconductor microcavities containing a single InGaAs quantum well. Our system leverages the strong exciton-polariton nonlinearity, resulting in phase shifts as high as 160 mrad per polariton, even at single-photon average intensities. Compared to previous demonstrations the phase shift in a polariton system based on semiconductor micropillar structures, represents an enhancement of more than 50 times in per-polariton efficiency, and the absolute phase shift of up to 550 mrad under higher-power excitation conditions. The open microcavity system facilitates precise tunability and potential for scalability of polariton systems, paving the way for integration into quantum optical information processing platforms. Our results highlight the substantial potential of exciton-polariton systems as a basis for scalable, nonlinear photonic devices critical for future quantum computing, communication, and quantum optical technologies.

6. Deepak Bhardwaj

University of Bristol

Generation of Highly Sensitive GKP States in Cold Atoms.

Ultracold atoms in deep optical lattices can be controlled robustly using time-varying optical potentials. It provides us a testbed for quantum sensing, quantum simulations, and quantum computations. By knowing the initial state, one can generate any desired state via phase modulation. One of the examples are highly sensitive GKP (Gottesman, Kitaev, Preskill) states, which use the redundancy of a larger harmonic oscillator Hilbert space to encode lower-dimensional information. Ideal GKP states require infinite energies, but approximate GKP states have been demonstrated in a number of platforms, although an atom-based demonstration is still lacking. Recently, we have theoretically simulated quantum optimal controls to generate these exotic states deterministically with 10 dB squeezing via phase modulation of the deep lattice potentials. We are now building an experimental system to generate these GKP states. We have achieved magneto-optical trapping of Rb atoms and are working on achieving BEC and optical lattices. Our experiment will enable us to demonstrate GKP states with efficient control. The desired GKP states, with greater than 99% fidelity, can feasibly be generated in our planned experimental setup.

7. Withdrawn

8. Martin Bielak

Palacký University Olomouc

Real-time polarization sensing through a few-mode fiber at a single-photon level

The polarization of light conveys crucial information about a specimen's optical properties and spatial organization. However, accurate polarization measurement of dynamic specimens requires high-speed single-shot sensing, which remains a significant challenge under low light conditions. We present a real-time polarization measurement technique with single-photon-level sensitivity, offering complete polarization state information. Our sensor, free of moving components, uses a few-mode fiber with fiber array sampling. Calibrated by a deep neural network, it achieves unprecedented accuracy across all polarization states, including partially polarized light. We validate the method by visualizing the temporal dynamics of the liquid-crystal polarization transition and revealing a biological specimen's polarization structure. This approach provides a reliable real-time single-shot polarization sensing solution in low-light environments.

9. Georgia Booton

University of Bath

Towards high-speed low-loss all-optical switching in rubidium vapour

High bandwidth low-loss optical switching is a key challenge in quantum optics. Commercially available optical switches often compromise between speed and insertion loss, limiting their utility in quantum technologies. However, optically controlled phase modulation in warm atomic vapour offers a promising alternative. These criteria are crucial for implementing single photon multiplexing and loop memory schemes towards scalable photonic quantum computation.

We present a cavity-based system that enables all-optical switching of a signal field with minimal loss by leveraging strong two-photon absorption in warm rubidium vapor. Using a three-level atomic ladder configuration in rubidium vapour, the signal field experiences a phase shift conditioned on a counter-propagating control field. The phase shift modifies the cavity resonance, enabling re-routing of photons between transmitted and reflected ports. Confining the interaction within a resonant ring cavity enhances the phase accumulation, leading to a greater switching efficiency. We demonstrate full pi-phase shifts with a switching speed that approaches the fundamental limit of the cavity ring-down time. Our results demonstrate a promising pathway toward high-speed, low-loss optical switching, offering a scalable solution for advancing photonic quantum technologies.

10. Russell Brooks

Heriot Watt

Quantum-private distributed sensing

Quantum networks allow connected quantum devices to perform advanced communication tasks such as multi-user secure communication, distributed sensing and computing. Recently, there has been interest in coupling quantum cryptography and quantum metrology to realise so-called quantum-private network sensing, which introduces a new framework of security, privacy and sensitivity conditions. One such scheme is called private parameter estimation (PPE).

The goal of PPE is for a group of users to perform distributed quantum sensing without revealing the local sensor values, for which the GHZ state is well-suited. To achieve this, the users request a number of copies of the resource state over a quantum network and perform a verification on a subset of the copies to guarantee they are sharing a GHZ state. In this work, we follow the protocol that makes use of stabiliser generator measurements to lower-bound the fidelity of the state, establishing the security and privacy when performing the quantum sensing task, i.e., parameter estimation, using the remaining copy of the states

11. Tom Bryce

University of Bristol

Calming Nuclear Spins in Quantum Dots for Quantum Memory Applications

Semiconductor quantum dots (QDs) embedded in photonic devices are highly attractive light sources with applications in a range of quantum photonic technologies. A primary area of interest is in storing information in single electron spins within quantum dots and then transferring the information efficiently to photons. Using semiconductor QDs embedded within DBR micropillar devices, we can combine the high extraction efficiencies of micropillar photonics with the long underlying coherence times of electrons, which are on the order of microseconds. This guarantees the transfer of quantum information between electron spins and photons. This technology will lead to applications in scalable and efficient quantum memory technologies for quantum communications, and quantum simulations using photonic and spin cluster states and distributed entanglement of spin states. However, a limitation of these technologies are the random nuclear spins within the quantum dot whose destructive effective fields negatively impact electron spin coherence. This poster discusses the development of nuclear spin calming techniques such as Dynamic Nuclear Polarisation (DNP) and Nuclear Frequency Focusing (NFF) which aim to make the long electron coherence times more accessible and lengthen them, as well as this project's ongoing search for candidate QD-micropillar devices for this research.

12. Paul Burdekin

Imperial College London

Enhancing quantum memories through light-matter interference

Optical quantum memories are a crucial component of future quantum technologies, providing a means to distribute entanglement across large networks as well as synchronise local probabilistic operations for quantum computing. Practical implementation demands near-unity efficiency, high fidelity, GHz bandwidth, and sufficiently long lifetimes but simultaneously achieving all these requirements remains a significant challenge.

We propose and experimentally demonstrate a novel method to improve existing quantum memory protocols, using interference between matter-based coherence and optical coherence, in a scheme analogous to an optical Mach-Zehnder interferometer. After a first memory storage attempt, any leaked optical field is looped back to the front of the memory for a second storage attempt, where the remaining optical coherence interferes with the stored matter-based coherence. Through tuning this interference, a storage efficiency of 50% can be increased to 100%. By also applying this scheme to the retrieval process, total efficiency can be enhanced from 25% to 100%. We experimentally demonstrate this effect, achieving a three-fold efficiency enhancement to 34%, together with numerical simulations showing our schemes potential to improve several different memory protocols and architectures to near unity. This approach represents a significant step toward overcoming key limitations in quantum memory performance.

13. Amaya Calvo Sánchez

Imperial College London

Towards mechanical Gottesman-Kitaev-Preskill states via quantum measurement

Gottesman-Kitaev-Preskill (GKP) codes allow for the encoding and error correction of qubits in continuous variable systems, addressing issues with scalability by reducing the number of oscillators needed for a protected logical state. Although the original proposal noted radiation pressure as a potential interaction for preparing encoded states, an optomechanical framework for GKP states has yet to be explored due to the low coupling rates available in state-of-the-art systems. Utilizing pulsed optomechanics, we theoretically develop a state preparation and error correction protocol for mechanical GKP states with more attainable experimental parameters, by enhancing the nonlinearities of the radiation pressure interaction through a geometric phase. The use of the geometric phase is extended to propose how it can, in addition, be harnessed in the implementation of CZ and CNOT gates in order to achieve a universal set of operations. Our framework opens a new avenue for such an encoding in mechanical degrees of freedom and offers new routes for applications such as quantum-enhanced sensing.

14. Dhritiman Chakraborty

University of Bristol

Shaken Lattice Interferometry with Enhanced Device Sensitivity using Time Reversal

Shaken Lattice Interferometry (SLI) has been demonstrated as a highly reliable method for developing quantum inertial sensors by both theoretical and experimental means. Here, ultracold atoms are trapped in an optical lattice, which is then phase-modulated, or shaken, to give desired atomic momentum states. SLI uses these shaking functions to split, propagate, and recombine atomic matter waves, analogous to light in Michaelson's interferometer, to give extremely sensitive and robust inertial sensors.
In this work, we simulate shaking functions optimized using a genetic algorithm that complete the interferometer sequence. We make use of shaking functions with a time reversed component to simplify the sequence and give repeatable, rapid and sensitive simulated devices which surpass previously established sensitivity results. We demonstrate that device sensitivity scaling greater than the square of interrogation time T is readily possible. Lastly, we show that shaking function fidelities play a significant role in final device performance allowing sensitivity scalings of T^3 and beyond.

15. Shushmi Chowdhury

University of Strathclyde

New Benchmarks of single qubit control errors on different quantum hardware

Our study builds on previous research examining magnetic domain walls in an Ising chain with antiparallel boundary spins [1]. Initially expected to behave as particles in a box under quantum setting due to a transverse field or distribute evenly across all sites in the classical limit, surprising results were observed. The domain walls formed a U-shaped distribution, an outcome attributed to classical random fields that emerged despite zeroing local random fields and neutralising qubit couplings. [1] introduced a metric to find single qubit errors on quantum annealers, detailed further in the benchmarking review[2]. This metric operates assuming that dissipative effects dominate, allowing the system to settle into a thermal equilibrium where quantum effects are negligible. A numerical fit against the distribution obtained for thermal distributions at varying noise levels is applied to calculate the error in β (defined as the inverse of temperature). We applied this metric to the new D-Wave Pegasus device along with other analogue devices to draw meaningful comparisons. With the introduction of D-Wave's fast anneal feature, we aim to explore regimes where anneal times are shorter than coherence times, thus highlighting coherent quantum effects. By extending this analysis to the newer Pegasus graph in D-Wave, we aim to observe if any quantum effects prevail and subsequently prepare a comparative analysis with other analogue quantum devices.

1) Chancellor, N., Crowley, P.J.D., Durić, T. et al. Error measurements for a quantum annealer using the one-dimensional Ising model with twisted boundaries. npj Quantum Inf 8, 73 (2022). https://doi.org/10.1038/s41534-022-00580-w
2) Lall, Deep & Agarwal, Abhishek & Zhang, Weixi & Lindoy, Lachlan & Lindström, Tobias & Webster, Stephanie & Hall, Simon & Chancellor, Nicholas & Wallden, Petros & Garcia-Patron, Raul & Kashefi, Elham & Kendon, Viv & Pritchard, Jonathan & Rossi, Alessandro & Datta, Animesh & Kapourniotis, Theodoros & Georgopoulos, Konstantinos & Rungger, Ivan. (2025). A Review and Collection of Metrics and Benchmarks for Quantum Computers: definitions, methodologies and software. 10.48550/arXiv.2502.06717.

16. Rachel Clark

University of Bristol

Precision enhancement in microscopy imaging using a bright Kerr-squeezed state

For absorption imaging, optical noise can be a key limiting factor. Photon counting experiments using correlated photon pair sources can achieve sub-shot noise imaging but are not scalable to high brightness. Here, we use bright Kerr-squeezed light for precision-enhanced absorption microscopy for optical power of ~200 μW. Squeezing is generated by propagating a coherent beam within a non-linear interferometer which incorporates a photonic crystal fibre that mediates the Kerr-effect for self-phase modulation. Subsequently, the squeezed probe is modulated in time between two optical paths to translate a static-loss measurement to a higher frequency bandwidth where the laser and detectors are shot noise limited. The probe passes through a sample held between two lenses in a confocal configuration and the induced loss is estimated by measuring the power at the frequency sideband. As the noise reduction from squeezing increases, the measurement variance decreases, leading to precision enhancement in the sample absorption estimate. Using a custom-built detector with shot noise clearance of 4 dB, we demonstrate a measurement variance that reaches the quantum noise limit, corresponding to the smallest variance achievable for a similar probe power of a shot-noise limited light source.

17. Marcus Clark

University of Bristol

Coexistence of Entanglement with Classical Channels over Hollow Core Fibre in a Quantum Network

We experimentally demonstrated for the first time, a 4-user quantum network with the coexistence of three entanglement-based quantum channels with carrier-grade classical optical channels over 11.5 km Hollow Core Nested Antiresonant Nodeless fiber (HC-NANF). A coexistence transmission of 800 Gbps is achieved by transmitting four classical channels simultaneously with three quantum channels all operating in the C-band with a separation of 1.6 nm. We established Quantum Key Distribution (QKD) in the four-node full-mesh quantum network with visibility of ≥ 80% of all the links. The Secret Key Rate (SKR) for all the links in the network are preserved with a satisfied level of quantum bit error rates, given that quantum channels encoded in polarisation degree of freedom coexist with four classical channels at a high aggregated coexistence power of –3 dBm and over 55 hours of experimental time.

18. Tamanna Dasanjh

University of Bristol

Logic-inspired explainable quantum machine learning

Classical machine learning has been incredibly successful in many ways, but it also comes with its own challenges. Classical deep learning, for example, has struggled with the problem of interpretability, which is the ability to understand, in a way that resembles human reasoning, why a machine learning model produced a given output. One approach to addressing this issue in classical machine learning is the integration of logic-based methods with neural networks, a framework known as NeuroSymbolic AI. On the other hand, quantum machine learning seeks to harness quantum mechanics to improve upon classical machine learning. In our work, we draw inspiration from NeuroSymbolic AI, and the idea of fuzzy logic (a continuous relaxation of truth values of statements to be between 0 and 1), to inspire a quantum machine learning algorithm. We make use of the fact that quantum superposition of a qubit state naturally lends itself to encoding fuzzy logic values via the probability of the qubit being in the |1> state. Specifically, we use a popular paradigm of quantum machine learning, known as the variational quantum algorithm, and study its effectiveness for the problem of finding optimal logic circuits. We aim to evaluate the capacity of these circuits to train on fuzzy logic datasets and, in particular, to investigate strategies for selecting good parameterised gate sets and designing their arrangements to build logic-inspired variational quantum circuits.

19. Jasper De Witte

Ghent University - IMEC

Reliable integration of quantum dot emitters on SiN via micro-transfer printing

State-of-the-art single photon sources are currently realized using In(Ga)As quantum dots embedded in GaAs waveguides. While these sources exhibit excellent performance in terms of coherence and indistinguishability of the emitted photons, the platform suffers from significant propagation losses, which limit scalability to large-scale integrated quantum photonic circuits. In this work, we demonstrate their reliable heterogeneous integration onto a low-loss SiN platform. The integration achieves high yield fabrication using a commercially available micro-transfer printing tool. This versatile approach allows for the first time to consider a heterogeneous platform that includes multiple components integrated on a single SiN interposer. This directly adresses the significant coupling losses linked with previous hybrid approaches in a more modular system comprised of multiple photonic integrated circuits. This achievement opens up new avenues for advanced spectroscopic experiments, quantum nonlinearities and spin physics, all built upon a low-loss SiN platform.

20. Edward Deacon

University of Bristol

An Integrated Source of Single-mode Squeezing

Squeezed states are an essential resource in continuous-variable (CV) quantum optics such as for CV quantum computing architectures [1], quantum metrology [2], and Gaussian boson sampling [3]. Presented here is an integrated photonic source optimised for the generation of single-mode squeezing that is both spectrally pure and low in noise. The design is based on the concept of linearly uncoupled nonlinearly coupled (LUNC) ring resonators introduced in [4] which enables the suppression of parasitic four -wave mixing (FWM) processes which otherwise introduce loss and noise onto the single-mode squeezed vacuum (SMSV) state generated via dual-pump spontaneous FWM [5]. Two pulsed pump lasers are used to create SMSV via DP-SFWM on a silicon-on-insulator photonic chip. We employ reconfigurable Mach-Zehnder interferometers to control and optimise couplings to the LUNC rings to minimise spectral correlations in the generated SMSV and correspondingly obtain a high spectral purity in excess of 97% measured via stimulated emission tomography. The suppression of parasitic single-pump (SP) spontaneous FWM is demonstrated via photon counting measurements where pairs of degenerate and non-degenerate photons arising from the DP and SP processes are measured simultaneously. We observe almost total extinction of the SP processes with over 15dB of attenuation in the generation rate.

[1] Aghaee Rad, H., et al. Scaling and networking a modular photonic quantum computer. Nature 638, 912–919 (2025).
[2] Tse, Maggie, et al. Quantum-enhanced advanced LIGO detectors in the era of gravitational-wave astronomy. Physical Review Letters 123.23 (2019): 231107.
[3] Madsen, L.S., et al. Quantum computational advantage with a programmable photonic processor. Nature 606, 75–81 (2022).
[4] Menotti, M., et al. Nonlinear coupling of linearly uncoupled resonators. Physical Review Letters 122.1 (2019): 013904.
[5] Sabattoli, F. A., et al. "Suppression of parasitic nonlinear processes in spontaneous four-wave mixing with linearly uncoupled resonators." Physical Review Letters 127.3 (2021): 033901.

21. Withdrawn

22. Martin Dostál

Palacký University Olomouc

Experimental investigation of heralded Gaussification of phase-randomized coherent states of light

Probabilistic heralded Gaussification of quantum states of light is an important ingredient of protocols for distillation of continuous variable entanglement and squeezing. An elementary step of heralded Gaussification protocol consists of interference of two copies of the state at a balanced beam splitter, followed by conditioning on outcome of a suitable Gaussian quantum measurement on one output mode. When iterated, the protocol either converges to a Gaussian state, or diverges. Here we report on experimental investigation of the convergence properties of iterative heralded Gaussification. We experimentally implement two iterations of the protocol, which requires simultaneous processing of four copies of the input state. We utilize the phase-randomized coherent states as the input states, which greatly facilitates the experiment, because these states can be generated deterministically and their mean photon number can easily be tuned. We comprehensively characterize the input and partially Gaussified states by balanced homodyne detection and quantum state tomography. Our experimental results are in good agreement with theoretical predictions and they provide new insights into the convergence properties of heralded quantum Gaussification.

23. Anežka Dostálová

Palacký University Olomouc

Sensing and imaging with single organic molecules with photon-number-resolved detection and deep learning

Single fluorescent molecules offer vast potential for quantum sensing and biomedical imaging. However, the implementations of sensors based on these molecules are predominantly limited to cryogenic temperatures, thereby significantly reducing their applicability. Imaging applications typically rely on long frame sequences with stochastically blinking fluorophores. We present the utilization of statistical properties of fluorescent light emitted by single molecules and their clusters to address both challenges. Our approach is based on a fluorescence microscope setup in combination with deep learning. Samples contain various concentrations of terrylene molecules embedded in a host matrix. We exploit photon-number-resolving detection for full statistics characterization of the emission. We compared the photon statistics of the emission from a single molecule and a larger cluster and evaluated various criteria of nonclassicality for both cases. Furthermore, we developed a calibration-free neural network capable of super-resolving image reconstruction from a single intensity frame and without requiring prior knowledge about the specific optical setup. We are working towards further enhancement of the resolution and sensing abilities leveraging the full photon statistics information. The room temperature operation and novel statistical readout methods pave the way for a broad range of new applications, including minimally invasive and in-vivo sensing.

24. Asem Elarabi

National Physical Laboratory

Low Temperature SOLR Calibration for Precise S-Parameter Measurements of Quantum Microwave Devices

Accurate RF measurements at low temperatures are crucial for characterising superconducting quantum devices. Achieving precision requires compensating for losses and phase shifts introduced by cables, amplifiers, attenuators, and connectors within cryogenic setups. We address this by shifting the calibration reference plane from the VNA at room temperature to millikelvin temperatures near the Device Under Test (DUT).

We embed SHORT, OPEN, LINE, and Reciprocal THRU (SOLR) calibration standards directly at millikelvin temperatures, matching conditions of the DUT. Implemented within a 300 mK dilution refrigerator, this method enables precise in-operando characterisation of critical quantum devices, such as Josephson Traveling Wave Parametric Amplifiers (JTWPAs). SOLR calibration is compact, versatile, and simpler to implement than traditional methods like Thru-Reflect-Line (TRL), effectively overcoming challenges such as thermal contraction at cryogenic temperatures.

25. Imogen Forbes

University of Bristol

Path-Transverse Electric Mode Hyperentanglement on an Integrated Photonic Chip

Hyperentanglement, or the simultaneous entanglement of qubits across multiple degrees of freedom (DOFs), increases the dimensionality of the Hilbert space whilst maintaining particle number. We present a photonic integrated circuit to generate and verify a hyperentangled state between the path and transverse-electric mode DOFs. Components on the chip are designed to facilitate the propagation of both TE0 and TE1 modes of light, including high-visibility multi-mode interferometers, crossers and mode converters.

We generate a range of entangled states, including a GHZ-type state and the hyperentangled state. We bound the fidelity of the GHZ-type state using an entanglement witness, with $F > 82.6\%$. The hyperentangled state is verified using tomography measurements, culminating in a fidelity, to date, of $F = 88 \pm 3\%$ when tracing out on path, and of $F = 94 \pm 2\%$ when tracing out on mode.

We discuss the applications of this hyperentangled state, focusing on entanglement distillation. By encoding our information across multiple DOFs and distilling down to a single DOF using a deterministic CNOT, we can increase the fidelity of our state in the presence of errors. At the time of submission, this work is the first fully on-chip demonstration of hyperentangled state generation and verification.

26. Stephanie Foulds

University of Strathclyde

Discrete-time Quantum Walks simulated with Rydberg-mediated gates

We present 4-, 8- and 16-node discrete-time quantum walks (DTQW) on a ring simulated with gate sequences. We model the expected fidelities that would be achieved on current neutral atom hardware and compare with other implementations. 3- and 4-qubit operations are native to Rydberg-mediated gates and therefore this work highlights the suitability of this hardware for such protocols. Further, we explore an extension to 'lazy' quantum walks with the addition of a rest state, towards fluid dynamic simulation.

27. Stefan Frick

University of Innsbruck

An Algorithm for Sub-Coherence-Length Domain Engineering with arbitrary Resolution

Domain engineering is the art of selection a series of domains inside a non-linear crystal, where adjacent domains have opposing polings. This series is designed in a particular way to craft the spectral properties of photon pairs generated in (a)periodically poled crystals. Annealing algorithms were so far the most commonly used method to produce poling structures yielding factorizable joint spectral amplitudes, and therefore pure herald single photon sources. Deterministic algorithms have recently emerged which dramatically reduced the computational effort to find optimal polings. When applied to domain widths far below the coherence length of the phase-matching process, these algorithms produce record spectral purities.

Here we present a new algorithm of similar kind but working on variable domain widths. The algorithm presented here is sensitive to critical manufacturing parameters, such as minimum feature sizes and resolution and can deterministically produce optimal poling structures down to numeric precision. While for large and small coherence lengths the resulting structure's performance is practically identically to that of previous algorithms, we find improved performance for moderate coherence lengths on the order of the manufacturing process' minimum feature size. The algorithm presented here maintains better performance across a wider range of coherence lengths without parameter tuning.

28. John Hadden

Cardiff University

Laser-written waveguide-integrated coherent spins in diamond

Nitrogen vacancy (NVs) in diamond are excellent candidates for Quantum Technologies. The NV is susceptible to changes in the local environment's temperature, strain, electric and magnetic field. Moreover, optical detected magnetic resonance is an efficient tool to initialize, manipulate and read out the NV's quantum state at room temperature. These outstanding properties have established NVs as robust, high-sensitivity and high-resolution sensors. However, its challenging to fabricate high coherence NVs in photonic structures - a crucial requirement for enhanced quantum sensing applications. Recently, femtosecond laser-writing emerged for creation of photonic waveguides integrated with quantum emitters in diamond. In this work, we investigate single waveguide-integrated NVs (WGINVs) in type-IIa chemical vapor deposition diamond and ensemble WGINVs in type-Ib high-pressure-high-temperature diamond. We probe the NV's spin coherence properties. We show single WGINVs in type-IIa diamond with spin coherence properties (T2 ~ 0.5 ms) comparable to native NVs. Additionally, in type-Ib diamond, we demonstrate creation of ensemble WGINVs with up to 900 times intensity enhancement resulting in a sub 26 nT · Hz−1/2 photon-shot-noise-limited DC magnetic field sensitivity. Thus, femtosecond laser-writing provides a cost-effective way to create photonic-integrated quantum sensing devices based on economical type-Ib diamond.

29. Sam Harding

University of Bristol

Towards Trapping and Transport of BEC 87Rb using Photonic Integrated Circuits

The scalability of photonic integrated circuits (PICs) has transformed quantum technologies, but their full potential remains untapped in cold atom applications. Miniaturising atomic systems could unlock real-world viability for advanced positioning, navigation, and timing applications. My project aims to connect these technologies by developing a chip-scale platform for trapping, manipulating, and interrogating Bose-Einstein condensate (BEC) Rb atoms using Silicon Nitride PICs.

Cold atoms are trapped on-chip via grating magneto-optical trapping and cooled to a BEC using magnetic wire evaporative cooling, building on prior work in chip-scale trapping. The BEC is then transported above the waveguide using evanescent fields from red- and blue-detuned light, which provide tunable attractive and repulsive forces. Higher-order waveguide modes and standing waves enable full spatial confinement. This platform would allow for BEC interrogation via laser locking for atomic clocks as well as shaken lattice interferometry for accelerometry - paving the way for compact, high-precision quantum sensors.

30. Meagan Hough

University of Bristol

Introducing the Four-Level Off-Resonant Absorption (FLORA) protocol for warm vapour atomic quantum memories

Atomic memories are strong candidates for quantum repeaters, which are essential for large scale quantum networks as they extend the range of entanglement distribution. To ensure scalability, these memories must be compact and have a low operational overhead. Due to the complex cooling systems required for ultra-low temperature operation, many state-of-the-art memory platforms suffer from substantial spatial and operational overheads. Here, we will introduce the Four-Level Off-Resonant Absorption (FLORA) protocol for warm rubidium vapour memories, which includes transitions in both the telecom C- and O-bands. FLORA enables the complete cancellation of k-vector mismatch between the signal and control fields. This cancellation eliminates Doppler dephasing, the primary limitation in room-temperature memory operation, without requiring cryogenics. Our preliminary simulation results demonstrate that higher temperature memories such as FLORA have the potential to drive substantial advancements in the scalability of quantum memory technologies.

31. Shiang-Yu Huang

University of Stuttgart

Topology-Optimized Integrated Photonics for Quantum Experiments

Integrated photonics opens a new window for photonic quantum technologies and facilitates a variety of relevant applications. In the meantime, designing photonic integrated components via topology optimization demonstrates a potential for high-density integration and makes further miniaturization of photonic integrated circuits possible. However, despite the steady progress in various topology-optimized on-chip components, their capability for quantum experiments is not yet fully investigated.
Here, we inversely design (i) a fiber-to-chip vertical coupler using topology optimization and (ii) perform two-photon experiments with a topology-optimized interferometer. The simulated coupling efficiency of the topology-optimized coupler is −0.37 dB when incorporating a bottom reflector and its footprint is 14 μm × 14 μm. The designed topology-optimized 2 × 2 beam splitter has a size of 4.5 μm × 3 μm. We perform the on-chip Hong-Ou-Mandel (HOM) interference with the topology-optimized beam splitter and yield the visibility of 88.7%. From our simulation and experimental results, both topology-optimized components have great potential for building up high-density photonic integrated circuits for applications of quantum technologies.

32. Andrew Hutcheson

National Physical Laboratory

Design and performance of a mK Scanning Probe Microscope for Imaging Two-Level System Defects in Live Superconducting Quantum Circuits

Parasitic two-level system (TLS) defects inside quantum circuit materials are widely known to cause loss and decoherence. Directly observing their impact on quantum circuits, traditional methods rely on applying global electric or strain fields to the whole device, tuning TLS frequencies into resonance with the measurement circuit.
Here we present the design and performance of a scanning gate microscope (SGM) operating at mK temperatures inside a cryogen-free dilution refrigerator. The SGM is compatible with the in-situ operation of superconducting quantum circuits, necessitating low vibration levels and a highly coherent environment. Our SGM can spatially locate individual defects with sub-micron precision and tune their frequency until resonant with a live readout circuit as well as determine TLS dipole orientation. Improving this technique to gain additional insight into different (and potentially new) types of defects present in devices face further challenges.
We discuss challenges and mitigation methods such as mechanical cryocooler vibration where at 1.4Hz, vibrations in probe-circuit displacement of 15nm distort applied electric fields reducing imaging resolution. Another significant challenge is maintaining the highly coherent environment whilst scanning required for the measurement circuit. We show thermal management techniques that are implemented to isolate this heating, maintaining a sample temperature of 300mK.

33. Vaibhav Jain

University Of Bristol

Post-Processing and Key Management for Secure Entanglement-Based QKD Networks

The Smart Internet Lab at the University of Bristol is a leading research centre in Information and Communications Technology (ICT), focused on integrating quantum technologies into future communications networks. The lab is developing next-generation optical network solutions to enhance data security, particularly with the use of Quantum Key Distribution (QKD) to safeguard communications against the emerging threats posed by quantum computing.
To support this, a use case for end-to-end encryption and decryption of sensitive data was developed, where the critical data to be exchanged securely was material design simulations conducted by NCC (National Composites Centre) on ORCA's quantum computers/simulators. The system employs entanglement-based QKD to generate secure keys starting with the distribution of entangled photons from a common entanglement source and measurement using in-house developed measurement modules. For the secure and efficient exchange of these keys, post-processing and Key Management System (KMS) are essential. Raw data from the measurement modules, such as timestamps, requires further processing to correct errors, amplify security, and convert it into usable keys. To address this, a post-processing module was developed, which ensures the integrity and security of the raw keys. Furthermore, a Key Management Layer, compliant with ETSI GS-014 standards, was built to manage and securely distribute the keys. Finally, the integration with MACSec-enabled FPGA-based encryptors and decryptors ensures the seamless end-to-end encryption and decryption of critical data, completing the secure data transmission.
This work provides a foundation for scaling up to multi-user quantum networks, supporting the development of quantum-safe communication systems and applications in metropolitan quantum networks and quantum data centres.

34. John Jeffers

University of Strathclyde

Retrodictive state estimation from informationally incomplete measurements

We outline an approach to state estimation based on multi-shot quantum retrodiction. The approach is illustrated by via examples of state estimation with non-informationally complete measurements, so the state cannot normally be identified perfectly in a single shot. As examples we examine three systems: Using a two-component projective measurement to discriminate between three and four equiprobable qubit states that are symmetrically distributed in a plane of the Bloch sphere. We show that it is possible to estimate the state with high fidelity, provided that the correct measurement is used. Estimation of single mode photonic states, where we show that it can be advantageous to lower the efficiency of your detector deliberately. Optical implementations of three qubit states, where we discriminate between the polarization states of, in turn, single photons and coherent states. Here the total mean photon number that is detected is the relevant parameter that needs to be maximised, whatever the number of shots of the experiment.

Quantum retrodiction provides a simple, powerful framework for analysing quantum state estimation problems.

35. Callum Jones

University of Bristol

Optical fuse for protection against high power laser attacks in chip-based QKD devices

Quantum key distribution (QKD) systems must be protected against side-channel attacks to prevent hacking attempts. One class of attacks uses high power lasers, i.e. Trojan horse or detector blinding attacks [1, 2]. Chip-based QKD devices could use the optical damage thresholds of grating couplers to provide in-built protection against high power laser attacks. By knowing the damage threshold, we can add sufficient optical isolation to prevent information leakage from the device.

We present an investigation of optical damage thresholds on 2D grating couplers. This is done using a chip coupling setup with a 10W CW laser at 1550nm. Previous studies have reported optical damage for 1D gratings and edge couplers [3], but 2D grating couplers are required for chip-based QKD user modules using polarisation encoding. We have also designed chip-based QKD user modules which will be used to test security against Trojan horse and laser damage attacks, based on these initial studies of optical damage.

This work is highly relevant to the assurance of future QKD systems; optical damage of chip components can be used as a physical security measure on top of which other side-channel countermeasures are built [4].

[1] Nitin Jain, et al. New J. Phys. 16, 123030 (2014)
[2] Vadim Makarov, et al. Phys. Rev. A 94, 030302 (2016)
[3] Friederike Jöhlinger, PhD Thesis, University of Bristol (2023)
[4] Friederike Jöhlinger, et al. arXiv:2408.16835 (2024)

36. Matt Jones

University of Bristol

On-the-fly reconfigurable integrated circuits for quantum photonics

Fast optical switches are essential for large-scale quantum photonics, with applications in QKD and as a key component in the development of feed-forward. Here, we demonstrate an integrated fast optical switch combined with a waveguide loopback for on-chip light rerouting. Utilising a compact, GHz-speed electro-optic modulator with precise synchronisation of RF electronics and pulsed light, we achieve real-time reconfiguration of photon paths whilst maintaining a photon on-chip. This enables repeated access to different regions of a chip, facilitating more compact circuit designs and reducing resource requirements. We illustrate this by analysing a reduced-footprint scheme for implementing arbitrary unitary operations. The same structure can be used to generate high-dimensional time-bin encoded qudits. By tailoring modulator drive signals to compensate for optical losses, we achieve arbitrary control over the splitting of an optical pulse across three time bins. With reduced modulator loss, this setup could enable the rerouting of a photon an arbitrary number of times, increasing the degree of time-bin encoding without requiring additional components.

37. Filip Juran

Palacký University Olomouc

From Micro to Macro-World: Device-Agnostic Single-Emitter Super-Resolution Imaging using Deep Learning

Any optical imaging system, from microscopes to telescopes, is subjected to diffraction owing to its finite aperture. For objects consisting of many single emitters, such as molecules, quantum dots, or stars, the blurring effect of diffraction can significantly impair our knowledge of the number of present emitters. Deep learning techniques showed great potential in overcoming this problem. However, these methods remain device-specific, and explicit knowledge of the imaging system and its parameters is required. We propose a novel device-agnostic approach to deep learning which surpasses these limitations. In this work, we demonstrate the „plug-and-play“ nature of the device-agnostic approach on an unprecedented scale. From galaxy observations through a laboratory imaging system to dense molecule microscopy, our approach uses no information about the imaging system while achieving better accuracy than state-of-the-art methods.

38. Shruti Kalkar

University of Bristol

Software Architecture for the SPOQC Mission – A QKD CubeSat

The unparalleled security offered by Quantum Communication (QC) is guaranteed by the No-Cloning Theorem, which makes it impossible to create perfect copies of unknown quantum states and, consequently, prevents the use of amplifiers. Over long distances, the exponential loss in optical fibres far exceeds the roughly quadratic loss experienced in satellite-based free-space optical links, making satellites a more viable option for global-scale quantum networks.

At the University of Bristol, we are developing a compact, dual-wavelength, decoy-state and BB84 protocol-based transmitter payload for deployment in the UK’s National Quantum Technology Programme’s 12U CubeSat—SPOQC, along with a mobile optical ground station.

This work contributes to these efforts by designing a software architecture for an FPGA-based System-on-Chip (SoC), the ZYNQ-7000 system, which integrates programmable logic with an ARM processor to enable efficient hardware-software co-design. To provide ease for software development, networking capabilities, and security, it is crucial to use an operating system on the FPGA board. For this purpose, Linux boot files are built and configured using PetaLinux tools to run on the FPGA board. Also, every operation performed by the Quantum Source (QS) in space generates relevant data like housekeeping logs, post-processing logs, and UTC logs, etc, which must be sent to the ground infrastructure on request. To achieve this, mission control software has been developed in C++, based on the TCP/IP protocol, to run on the satellite’s On-Board Computer (OBC) and establish communication with the ground for file transfer. This also enables the ground team to exercise operational control over the QS through relevant commands sent from the ground. Additionally, managing system components like optical fibres requires application software to control their activation efficiently. The software must minimise overhead for time-critical tasks while ensuring safety against corruption, as well as optimise memory and I/O operations. To accommodate this, the application is developed as a device driver and loaded as a module within the Linux kernel. Furthermore, a dedicated QKD service is being developed to enable closed-loop temperature stabilisation, pulse shape control, and synchronisation, ensuring stable and efficient quantum key distribution operations.

Together, this software framework provides complete control over the QKD transceiver, ultimately enhancing the feasibility of space-based quantum communication.

39. Sunghwa Kang

Agency for Defense Development

Single-shot detection limits of quantum illumination with multipartite qubits

This study extends the quantum illumination protocol from two-mode qubit states to three-mode qubit states, considering three configurations: (i) three signal modes, (ii) two signal modes and one idler, and (iii) one signal mode and two idlers. Various three-qubit states, including GHZ, W, bipartite entangled, and product states, are analyzed under a white noise environment. The detection error probabilities for each configuration are evaluated, revealing that entanglement between signal and idler qubits enhances detection performance, while entanglement among signal qubits degrades it. The optimal probe state is found to be a bipartite entangled state rather than a maximally entangled state. Additionally, the ranking of detection error probabilities is consistently verified by quantum mutual information. The study also explores whether this trend persists in multipartite qudit states.

40. Sanjay Kapoor

University of Warsaw

Electro-optic frequency shift of single photons from a quantum dot

Quantum dots (QDs) are a promising source of single photons for future photonic quantum networks. However, their emission wavelength depends on their size and immediate surroundings in the solid-state environment. We demonstrate an electro-optic frequency shift of single photons emitted from a quantum dot (QD) using a serrodyne phase modulation technique. By applying a sawtooth waveform to an electro-optic phase modulator (EOPM), we achieve a deterministic spectral shift of up to 3.5 GHz (0.01 nm) while preserving the purity and indistinguishability of the photons. This method offers a scalable and efficient approach for tuning QD emission wavelengths without relying on nonlinear processes or probabilistic frequency conversion. Electro-optic frequency shifting is promising for applications in quantum communication, quantum key distribution, and integrating remote QD sources into large-scale quantum networks.

41. Wridhdhisom Karar

University of Glasgow

Fast measurement and characterization of Novel Niobium Trilayer Superconducting Qubits

Major challenges with Aluminum based junctions are oxide barrier instability and structural and chemical inhomogeneities leading to noise, reduced coherence, and high device variability during scaling. Thermal instability during fabrication greatly complexes the oxide barrier chemistry, and two-level system (TLS) defects are a significant source of energy loss making qubits more prone to errors.

We present a novel junction fabrication process based on Niobium based trilayer junctions process that leverages existing subtractive etch techniques with additional improvements to limit junction variation across a wide range of sizes. This offers superior control over the growth and stoichiometry of the enclosed Aluminum Oxide layer, which improves interlayer roughness, reducing TLS coupling and junctional oxide variations. Using these Nb trilayers we have fabricated and observed tunable flux transmons at 9.1 GHz and resonators from 4-8.5 GHz with internal Quality factors exceeding 10^6. This work focusses on measurement and depiction of the junctional transport characteristics, Nb based resonator spectroscopy, Nb trilayer based flux tunable transmon spectra and time domain measurements of qubits based on these improved Nb junctions.

The qubits feature an improved and protected AlOx tunnel barrier, reducing variability across sizes and junction growth parameters enabling production of consistent qubits properties over multiple fabrication iterations.

42. Shreya Kumar

University of Stuttgart

Multiphoton interference and entanglement using beam splitters

Quantum interference and entanglement of photons are crucial for photonic quantum technologies. The extent of interference of photons depends on their overlap, typically measured via the visibility of two-photon Hong-Ou-Mandel (HOM) interference. However, when using imperfect photon sources, visibility decreases, and for two photons, one cannot discern whether this results from distinguishability or mixedness. We experimentally study three-photon interference in pure and mixed state preparations, showing different scattering statistics in the two cases, despite identical pairwise HOM visibility.

In a second experiment, we investigate the role of symmetry in photon interference. While all photonic states follow bosonic permutation symmetry, different symmetries emerge when probing specific degrees of freedom. We explore the scattering of entangled Bell states with different symmetries in the presence of a single photon, observing bosonic, fermionic, and anyonic statistics.

Entangled states serve as an important resource in quantum computation and communication. We demonstrate a simple and versatile scheme to generate different genuine tripartite entangled states using a single setup. By sending three photons through a three-port splitter and varying their internal states, we generate post-selected W, G, and GHZ states, achieving fidelities up to (87.3±1.1)%, confirming genuine tripartite entanglement.

43. Emilien Lavie

University of Bristol

Post-selected distilled teleportation

In quantum communications, the teleportation protocol is a fundamental subroutine that allows the transfer of arbitrary information without a direct transmission; using instead fixed preshared entangled pairs and classical communication. The main benefit is an increased robustness to loss since entangled pairs can be generated repeatedly until success without destroying the actual information we wish to transmit, which is teleported only once a suitable entangled pair has been generated.

Entanglement distillation is another important subroutine used to reduce the noise and increase the quality of entangled pairs starting from several pairs of a lesser quality.

In its original formulation by Benett et al. (PRL76 722, 1996), the procedure effectively acts as a filter to concentrate the good pairs and dump the others.

It is also possible to perform a similar procedure using higher dimension systems to concentrate the entanglement initially present in a high-dimension Bell pair into a qubit Bell pair with less noise.

However in this case, because there is only one pair to perform the concentration filter and recover the distilled pair, this procedure has to be postselected, and typically the type of operations that one can perform on post-selected states is limited.

Here, we describe a scheme proving that it is possible to teleport an arbitrary state into the post-selected Bell pair resulting from the post-selected distillation of a higher-dimension Bell pair.

The potential benefit of this operation is both a higher robustness to loss thanks to the teleportation bit, and to noise from the distillation bit.

44. Zhaojin Liu

University of Bristol

Chip-Scale Construction of Multiple Quantum Dots with Active Control for Indistinguishable Single -Photon Emission

Photons are ideal quantum information carriers due to their high speed, low noise, and low decoherence properties. To enable deterministic photon-based quantum information processing, a reliable single quantum emitter is essential [1]. Among the various single-photon sources, III-V semiconductor quantum dots (QDs) stand out as the fastest candidates, capable of generating photons at GHz rates [2]. Various research has been performed on quantum dots by incorporating the source into photonic cavities [3], it is also worthwhile to integrate the dots into photonic integrated circuits (PIC) [4] to guide and control the photon emission for quantum application purpose. However, it is challenging but very crucial to get the multiple quantum dots with the indistinguishable photon emission, particularly when aiming to achieve multiple identical quantum dots on a single chip. This work is going to investigate a scalable method for integrating quantum dots into PICs on the same chip, leveraging the advanced fabrication capabilities of the University of Bristol cleanroom [5]. The approach consists of the chip design, device fabrication as well as the optical characterisation. The chip design includes the process of optimisation of photonic structures suitable for photon emission at around 940nm wavelength, and how to layout the chip for efficient use of chip space as well as balancing the fabrication tolerance. Active electro-optic control is explored to achieve frequency locking, ensuring spectral indistinguishability of the emitted photons from different emitters. By combining these elements, the proposed approach aims to advance the development of on-chip quantum light sources for scalable quantum photonic technologies. Furthermore, the methodology is directly transferable to site-controlled quantum dots and can be adapted for quantum dots emitting at telecommunication wavelengths, broadening its applicability in quantum communication and networking.

[1] Huber, D. et al. "Highly indistinguishable and strongly entangled photons from symmetric GaAs quantum dots." Nat Commun 8 (2017).
[2] Liu, F., Brash, A.J., O'Hara, J. et al. "High Purcell factor generation of indistinguishable on-chip single photons". Nature Nanotech 13, 835–840 (2018).
[3] Dlaka, D. et al. "Design principles for > 90 % efficiency and > 99 % indistinguishability broadband quantum dot cavities" New J. Phys. 26 (2024).
[4] Uppu, R., Eriksen, H.T., Thyrrestrup, H. et al. "On-chip deterministic operation of quantum dots in dual-mode waveguides for a plug-and-play single-photon source". Nat Commun 11, 3782 (2020).
[5] Jiang, P and Balram, K.C, "Suspended gallium arsenide platform for building large scale photonic integrated circuits: passive devices," Opt. Express 28, 12262-12271 (2020).

45. Withdrawn

46. Innes Maxwell

University of Twente

Quantum-Inspired Algorithm for Sampler-Encoded Graph Isomorphism

The graph isomorphism problem has proven to be fertile ground for research throughout the history of computing, recently as potential means with which to realize quantum advantage, due to its NP-Intermediate complexity. The problem asks if a pair of discrete graphs can be made completely equivalent by only re-labeling their vertices, and its efficient solution would have applications in fields including image matching an cheminformatics. In this work, we approach the problem through the lens of near-term photonic quantum computing, yet through this construction arrive at a classical algorithm inspired by the properties of our quantum device of interest. We make use of an existing method to encode a graph's adjacency matrix in a Gaussian boson sampler and resulting sufficient condition for the graph isomorphism problem from Bràdler et. al. [1]. Given the inability to efficiently test for this condition, we introduce a similar graph invariant based on the statistical properties of these encoded-graph distributions. We define a necessary condition based on these properties, which can be tested for efficiently at low order with the algorithm introduced in this work. The algorithmic process, as well as its complexity, limitations, and relation to similar methods in the literature, are discussed.

47. Will McCutcheon

Heriot-Watt University

Programming High-dimensional time-bin measurements inside a multimode fiber

Here we present a novel approach to realizing high-dimensional, programmable, generalized measurements for photonic time-bins by utilizing the natural spatial mode dispersion that occurs inside a commercial multimode fiber. We first fully characterize the multi-spectral transmission matrix (MSTM) of a 40m step-index MMF. Here, a swept laser source and a digital micromirror device (DMD) prepares probe states and off-axis holography is used to measure the MMFs output complex field at each wavelength, forming the MSTM. A Fourier transform yields the time-resolved transmission matrix (TRTM) from which we can find tau-modes - these are a set of spatial modes which exhibit a fixed time-delay upon exiting the MMF. Knowledge of the tau-modes, supplemented with an output spatial light modulator, single mode fiber collection and single-photon detection, we are able to implement generalized high-dimensional projective measurements of time-bins. We perform prepare and measure scheme with a 1550nm pulsed laser and phase-locked Franson interferometer, allowing us to prepare a 2 dimensional time-bin states with arbitrary delays and phases. These measurements allow to perform quantum measurement tomography on the high-dimenional time-bin measurements.

48. James McDougall

University of Bristol

Improving Mode Matching Between Quantum Dot Micropillars and Single Mode Fibres

A deterministic, plug and play single photon source is a key missing component from the quantum technology supply chain. Quantum dots (QDs) in micropillars are one of the brightest options available and have achieved extraction efficiencies of 74% (Unsleber, Sebastian, et al. Optics express 24.8 (2016): pp8539-8546). A large source of loss is the bulk optics used to couple light into and out of the quantum dot device. A microlens can reshape the quantum dot micropillar's emission profile to optimise coupling with a single-mode fibre, enabling a compact and efficient single-photon source. Using a new design for a broadband quantum dot micropillar with >90% single photon extraction efficiency out of the top (D Dlaka et al 2024 New J. Phys. 26 093022), our simulations show that integrating an optimised microlens on top of the pillar can boost end-to-end device efficiency from below 20% to over 90%. I will be using a two-photon polymerisation tool to experimentally realise this lens on pillar design. Successful implementation would represent a key breakthrough for an efficient, bright, and high-quality single photon source needed for quantum communication and computation.

49. Nathan Moses

University of Bristol

Optimising heralding efficiency and brightness of a micro-ring resonator by tuning coupling regime

Due to properties such as high confinement of light, small form factor and non-linearity, Silicon-on-insulator (SOI) based integrated photonics has proven to be an effective platform for realizing photonic quantum technologies such as computing, communications and sensing. An important resource of these technologies is the single photon source and the ability to efficiently generate pairs of high quality photons is of high interest, particularly for applications such as Quantum Key Distribution (QKD) and quantum networking where the quality impacts security and performance. Harnessing the Spontaneous Four Wave Mixing (SFWM) process, micro-ring resonator photonic structures can behave as photon-pair sources. This work investigates how the brightness and heralding efficiency of a micro-ring resonator across multiple wavelength entangled pairs can be optimised by tuning the coupling of light into the resonator. Brightness and heralding efficiency of a source has large impact on throughput and determines the secret-key rate (SKR) of a QKD system or entanglement rate of a quantum network. It is experimentally demonstrated that operating within an over coupled regime provides the optimum brightness and heralding efficiency. Illustrating how the simple design choice of engineering the coupling strength can make ring resonators preferable sources for quantum communication applications.

50. Leah Murphy

University of Bath

Continuously tunable frequency conversion in photonic crystal fiber pumped near degeneracy

We report a frequency converter capable of continuously tunable conversion of InAs Quantum Dot (QD) wavelengths to the telecommunications C-band, as well as between wavelengths within the InAs QD emission band. Our frequency converter is a photonic crystal fibre with a germanium-doped core which features group velocity matching between InAs QD wavelengths and the telecoms C-band. This condition allows a near-degenerate Bragg Scattering-Four Wave Mixing (BS-FWM) interaction to be sustained over long sections of fibre with high tunability. We demonstrate both small and large frequency shifts experimentally by performing BS-FWM using classical pump and signal sources, where the sources required for our two conversion schemes are commercially available C-band lasers with a single amplifier, and TiSapph lasers (Fig. 1(c)). We achieve up to 79% internal conversion efficiency for the small frequency shifts, constrained by the available pump power. We also cascade the frequency conversion in the near-degenerate pumping regime to generate a frequency comb spanning several nanometers around the signal wavelength using two near-degenerate pumps in the C-band with a signal that is well separated from the pumps. Achieving this scheme in fibre marks a major step towards the full fibre integration of quantum networks.

51. Michael Neville

University of Bristol

Insertion sites of Dibenzoterrylene in Anthracene Crystals

Dibenzoterrylene (DBT) is a polycyclic-aromatic hydrocarbon that demonstrates stable, fast, and narrow single-photon emission from the coherent zero-phonon line (ZPL) when hosted in anthracene (AC) and cooled to cryogenic temperatures (< 4K). DBT in AC emits single photons with a wavelength distribution spanning 780-796nm. This overlaps with the D1/D2 rubidium transitions (780.214 & 794.98nm), enabling compatibility with atomic-based quantum technologies.

Currently, DBT emission is observed from two distributions, attributed to two crystallographic sites. The `main-site' spans 780-786nm, centred at 784nm. Lower energy emission is observed from the `red' site; a less frequently populated site that spans of 792-796nm, centred at 794nm.

In this work, we present the observation of a third distribution of DBT molecules. The `blue-site' demonstrates emission between 775-780nm. This distribution overlaps with the D2 transition suggesting it may also be compatible with rubidium-based technologies.

Additionally, we report that our fabrication method leads to higher population of the `red-site'. We attribute this to the relative speed and low temperature conditions of the fabrication process. This increases the probability of finding an emitter with a ZPL close to the D1 transition.

We present properties of the different insertion sites, details of the fabrication method and assess their compatibility with rubidium technologies.

52. Oliver Page

Ruprecht-Karls-Universität Heidelberg

Scalable High-Fidelity Photon Detection Using a 20-Channel Spatially-Multiplexed SNSPD Array

Accurate photon number state resolution is critical for photonic quantum computing architectures to ensure high-fidelity computational outputs [1]. To address this challenge, we have developed a spatially-multiplexed array of waveguide-integrated superconducting-nanowire single-photon detectors (SNSPDs). Waveguide-integrated SNSPDs represent state-of-the-art detector technology, offering operation with low jitter (<30ps), high-count rate (10Mcps), and high photon detection efficiency (>90%), especially in the near-infrared range [2]. Leveraging advances in reliable nanofabrication, we have fabricated SNSPDs using NbN thin films on compact, low-loss photonic SiN circuitry.

Our prototype is a 20-channel quasi-photon-number-resolving (PNR) detector chip based on a spatially-multiplexed array of eight SNSPDs [3]. This system employs low-loss optical beam splitters to minimize photon pile-up and enables reliable detection of up to three photons.

We are actively developing a 100-channel version with intrinsic PNR capabilities to enable higher photon counts and reduce readout complexity [4]. This 20-channel chip represents a significant advancement in scalable, high-performance quantum information processing, paving the way for next-generation quantum computing and communication systems.

[1] Slussarenko et al., "Photonic quantum information processing: A concise review", Appl. Phys. Rev. 6, 041303 (2019)

[2] Ferrari et. al., "Waveguide-integrated superconducting nanowire single-photon detectors", Nanophotonics 7, 11, 1725 (2018)

[3] Page et al., "Progress in the realization of multi-channels waveguide-integrated photon number resolving detectors", Proc. SPIE 13025, Advanced Photon Counting Techniques XVIII, 1302505 (2024)

[4] Cahall et al., "Multi-photon detection using a conventional superconducting nanowire single-photon detector", Optica, 4, 12 (2017)

53. Love Pettersson

University of Copenhagen

Long-distance quantum communication using concatenated ring graph codes

To realize long-distance quantum communication, it is crucial to design quantum repeater architectures that can deal with transmission losses and operational errors. Code concatenation of photonic graph codes is a promising way to achieve this; however, existing concatenated codes that can correct both transmission losses and operational errors are extremely hardware-demanding. We propose a one-way quantum repeater architecture based on concatenated ring graph codes and linear optical Bell-state measurements. We construct a scheme to generate the concatenated ring graph codes using quantum emitters, where the number of matter qubits scales linearly with concatenation depth. Furthermore, we devise a measurement strategy at each repeater station with a simple experimental setup where photons are measured in the order that they are created and show that entanglement swapping is fault-tolerant to both transmission losses and operational errors. This allows for long-distance quantum communication (> 10.000 km) at a kHZ rate, even in the presence of high single-qubit error rates.

54. Withdrawn

55. Beth Puzio

University of Bristol

On-Chip Generation and Verification of Photonics Continuous Variable Entanglement for Distributed Quantum Sensing

Thanks to advances in nanofabrication technology, integrated photonics is proving to be a key platform for efficiently scaling up quantum photonic systems. One such application that can benefit from these technological advances is distributed quantum sensing (DQS) protocols, in which a linear function of distributed parameters can be estimated with a precision beyond what can be achieved using separable states by employing entangled probe states.

Here we present experimental progress towards estimating linear functions of four spatially distributed phase shifts with entanglement enhanced precision, in a continuous variable distributed quantum sensing (CVDQS) protocol on a silicon photonic integrated chip (PIC). The PIC features an array of four integrated homodyne detectors for on-chip parameter estimation and state measurement, and we demonstrate entanglement verification over two modes in preparation for expanding to four modes. Using squeezed light enables entanglement to be generated deterministically using linear optics, where even with loss on each mode, the entanglement still provides an advantage in the sensing scheme, as well as exhibiting sub shot noise phase sensitivity. This scheme explores the potential for scaling up such sensing protocols by exploiting the inherent scalability of integrated photonics, where previous DQS protocols have only been demonstrated in bulk optics.

56. Mikhael J Rasiah

Imperial College London

Rephased-ORCA Quantum Memory

Quantum memories are vital in scaling future quantum technologies: they can aid the distribution of entanglement for quantum communication protocols and synchronise local probabilistic operations in quantum computation. It is desirable for the memory to store high-bandwidth telecom signals for long lifetimes and have low noise upon signal retrieval. The ORCA memory is a promising candidate. It can store a 1GHz telecom C-band signal as a matter-based coherence with low noise upon retrieval. However, Doppler dephasing limits the lifetime to 1ns. We propose a novel modification to undo Doppler dephasing. The introduction of rephasing pulses reverse the effects of Doppler dephasing and rephases the coherence. We experimentally demonstrated this and observed a 25-fold increase in lifetime without an increase in noise. The rephasing pulses also allowed storage of multiple time-bin modes, which we can use to encode a time-bin qubit. This encoding is more robust to noise over long optical fiber links than other encoding types. Preliminary results demonstrated storage and retrieval of these qubits. Our scheme is a crucial advancement in overcoming limitations in quantum memory performance.

57. Toby Rawlings

University of Sheffield

Resonance Fluorescence as a Highly Sensitive Probe of Spectral Diffusion in Nanowire Quantum Dots

Semiconductor quantum dots (QDs) have emerged as the leading platform for the development of quantum light sources. However, due to their solid-state nature, they experience environmental interactions which cause dephasing. One such interaction is charge noise, which results from the probabilistic occupation of nearby charge traps and leads to spectral diffusion. Efficient and accurate characterisation of these noise processes is necessary to optimise device performance for the needs of quantum technologies. Also essential to the performance of QD light sources is resonance fluorescence (RF) – an operating scheme where the excitation laser energy is in resonance with an s-shell exciton state. RF has been extensively performed in epitaxial QDs but remains challenging in nanowire QDs due to scattering from the sub-diffraction limit nanowire tip.

Here, we present RF of nanowire QDs with an excellent signal to background ratio. We then apply this method to perform a detailed study of spectral diffusion resulting from charge noise. By performing second -order measurements on the fluorescence, we resolve noise dynamics with a far greater time-resolution than comparable first-order methods. Furthermore, the nature of resonant excitation provides a spectral sensitivity superior to that of second-order methods using spectral filtering. The second-order correlation function is fitted with a model that accounts for the coherent dynamics of RF – antibunching and Rabi oscillations – with the product of N exponential terms to account for multiple-timescale bunching due to spectral diffusion. This allows us to study the timescales involved down to nanosecond resolution. Finally, the addition of weak above-bandgap excitation has been demonstrated to reduce spectral diffusion and modify the noise spectrum.

58. Tom Reinacher

University of Bristol

Integrated Brillouin optomechanics for microwave to optical photon conversion

To network quantum information processors based on superconducting qubit technologies, we require efficient microwave to optical photon conversion with high-fidelity. Piezo-optomechanical approaches leverage phononic and photonic degrees of freedom to bridge the five orders of magnitude gap between microwave and telecom wavelengths of light. By developing devices which can support co-propagating optical and mechanical modes, the fields of cavity and Brillouin optomechanics are tied together, leveraging strong optomechanical interactions in racetrack cavities and spiral waveguides to efficiently convert microwave photons to microwave phonons which phase-modulate a pump field to up-convert circulating photons to the telecom band. Moreover, we propose a release-free device architecture that is mechanically robust, simplifies nanofabrication, and enables continuous operation instead of requiring a pulsed mode.

59. Phila Rembold

Atominstitut, TU Vienna

State-Agnostic Approach to Certifying Electron-Photon Entanglement in Electron Microscopy

Transmission electron microscopes (TEMs) enable atomic-scale imaging and characterisation, driving advances across fields from materials science to biology. Quantum correlations, specifically entanglement, may provide a basis for novel hybrid sensing techniques to make TEMs compatible with sensitive samples prone to radiation damage. We present a protocol to certify entanglement between electrons and photons naturally arising from certain coherent cathodoluminescence processes. Using mutually unbiased bases in position and momentum, our method allows robust, state-agnostic entanglement verification and provides a lower bound on the entanglement of formation, enabling quantitative comparisons across platforms. Simulations under experiment-inspired conditions and preliminary experimental data highlight the feasibility of implementing this approach in modern TEM systems with optical specimen access. Our work integrates photonic quantum information techniques with electron microscopy. It establishes a foundation for entanglement-based imaging at the atomic scale, offering a potential pathway to reduce radiation exposure.

60. Hannah Seabrook

University of Bristol

Surpassing the loss-noise robustness trade-off in quantum key distribution

Quantum key distribution (QKD) offers a theoretically secure method to share secret keys, yet practical implementations face challenges due to noise and loss over long-distance channels. Traditional QKD protocols require extensive noise compensation, hindering their industrial scalability and lowering the achievable key rates. Alternative protocols encode logical qubits in noise-resilient states, but at the cost of using many physical qubits, increasing susceptibility to loss and limiting transmission distance. In this work, we introduce a logical qubit encoding that uses antisymmetric Bell-states in the continuous photonic degrees of freedom, frequency and time. By leveraging the continuous space, we overcome this noise-loss robustness trade-off by minimising the number of photons per logical qubit, whilst optimising the encoding resilience over noise fluctuations. We analyse the security of our encoding and demonstrate its robustness compared to existing state-of-the-art protocols. This approach provides a path towards scalable, efficient QKD implementations under realistic noise conditions.

61. Joe Smith

University of Sheffield

Multi-site NV quantum sensing with silicon photonics

Nitrogen-vacancy centres (NVs) are solid-state optically-addressable spins that make exceptional quantum sensors. Working at room-temperature with high biocompatibility, NVs in nanodiamonds facilitate atomic-scale tracking and real-time monitoring within living systems.

Conventionally, these systems either work by addressing stochastically-positioned defects with a complex bulk-optic microscope or using a single scanning probe, limited in scalability and the ability to capture spatial and temporal information simultaneously.

To address these challenges, we introduce a microchip where a deterministically-positioned NV sensor array is interfaced with parallel silicon waveguide channels. In this proof-of-principle demonstration, we show that four NVs can be readout simultaneously and independently from the microchip into four

efficiently edge-coupled fibres. Notably, coupling the signal into single-mode waveguides provides significant enhancement compared to coupling directly to a fibre mode.
The uniformly positioned sensors allow structured multi-site sensing. Operating as a magnetic field sensor, we perform parallel optically-detected magnetic resonance under varying magnetic fields, reporting a linear dependent Zeeman splitting with field strength across the four sites.
Beyond these results, we introduce our follow-on microchip: a 64-pixel array. Combining a two-dimensional array with interleaved spin readout will provide a unique window on processes within biochemical structures, using technology readily adoptable by non-specialist practitioners.

62. Ruaridh Smith

Fraunhofer UK

Telecom-band polarisation-entangled photons using Type-0 PPLN waveguides

Waveguide-based spontaneous parametric downconversion (SPDC) offers a route to high efficiency generation of entangled-photon pairs with applications in many quantum technologies, such as quantum key distribution (QKD) systems. We present results on an SPDC source based on a novel periodically poled lithium niobate (PPLN) waveguide fabrication process that offers high power handling and a high-rate of polarisation-entangled photon pairs. A 780 nm pump source of photons entered a sagnac interferometer design, orientated for Type-0 SPDC in a PPLN waveguide. Signal and idler SPDC photons are separated from the pump via a dichroic mirror before a beamsplitter separates the photons into two paths. The photons are then coupled to single-mode fibres and a high-rate of photon pairs was detected on superconducting nanowire detectors. Polarisation optics are used to measure a CHSH entanglement parameter of 2.64. This source demonstrates a promising integrated photonic platform for photon pair generation.

63. Matthew Stafford

Riverlane

Local Clustering Decoder: a fast and adaptive hardware decoder for the surface code

To avoid prohibitive overheads in performing fault-tolerant quantum computation, the decoding problem needs to be solved accurately and at speeds sufficient for fast feedback. Existing decoding systems fail to satisfy both of these requirements, meaning they either slow down the quantum computer or reduce the number of operations that can be performed before the quantum information is corrupted. We introduce the Local Clustering Decoder as a solution that simultaneously achieves the accuracy and speed requirements of a real-time decoding system. Our decoder is implemented on FPGAs and exploits hardware parallelism to keep pace with the fastest qubit types. Further, it comprises an adaptivity engine that allows the decoder to update itself in real-time in response to control signals, such as heralded leakage events. Under a realistic circuit-level noise model where leakage is a dominant error source, our decoder enables one million error-free quantum operations with 4x fewer physical qubits when compared to standard non-adaptive decoding. This is achieved whilst decoding in under 1 μs per round with modest FPGA resources, demonstrating that highaccuracy real-time decoding is possible, and reducing the qubit counts required for large-scale faulttolerant quantum computation.

64. Molly Thomas

University of Bristol

Interfacing NV-centres with integrated photonics

Nitrogen-vacancy (NV) centres in diamond are optically-addressable atom-like structures with long-lived spin coherence, making them a promising component to include in quantum networks.
Integrated photonics enables complex systems to be contained in small packages with significantly greater stability than fibre or bulk-optic set-ups, unlocking scalability in photonic technologies. Integrated photonics also allows for resonant structures to be fabricated around emitters to enhance emission into particular modes, improving the indistinguishability of sources.
Interfacing NV centres with integrated photonics will help the realisation of technologies such as deterministic single photon sources and on-chip quantum memories. Here we present work towards this, using silicon-nitride (SiN) integrated photonic devices from commercially available foundry processes.

65. Cyril Torre

University of Bristol

Microscopic magnetic field imaging with hot atoms

In the recent years, atomic sensors have demonstrated superior performance in magnetic field sensing compared to other technologies. While atomic vapour cells have been integrated into compact systems, such as bioimaging, the spatial resolution remains limited by the size of the sensors. Here, we propose

combining single pixel imaging (SPI) technique with an atomic vapour cell to achieve microscopic-scale imaging for magnetic field sensing. SPI technique involves projecting pattern of light onto a sample while monitoring the intensity. The magnetic field is then estimated using the Faraday effect, where an incident linear polarised beam rotates in the presence of a magnetic field as the probe beam propagates through the atomic vapour cell.
We experimentally demonstrate magnetic fields imaging with a microscopic resolution of 50µm. The sample consists of three magnets arranged in a Halbach array placed on the top of the vapour cell filled with Rubidium 87 atoms. A vertical gradient induced by the sample is then measured. We believe that this technique could be implemented with quantum light, decreasing the noise of the probe and increasing the precision and sensitivity of the magnetic field imaging, while a microscopic spatial resolution in achieved through SPI techniques.

66. Rebecca Walters
University of Bath

Rubidium filled hollow-core fibres for use in integrated quantum technologies

We aim to engineer a platform for interactions between light and matter by filling purpose-made hollow-core optical fibres with rubidium (Rb) vapour. As waveguides, hollow-core fibres can provide a long interaction length between the atomic vapour loaded inside the core of the fibre and the light that is guided by the fibre. They are also a promising route to miniaturising atom-based quantum technologies. They allow for better coupling loss and integration with optical fibre networks than is currently feasible with vapour cells. We highlight some of the potential applications for our Rb filled fibre, such as a fibre-based quantum memory and fibre-based sensing of weak electromagnetic fields. We will also discuss the considerations to be made while designing hollow core fibres for the purpose of filling them with alkali vapours. These considerations include the ease and speed of filling the fibre core with Rb vapour, the adsorption of the Rb atoms to the silica walls of the fibre, as well as the guidance properties of the fibre, e.g ensuring that it guides wavelengths of light that couple to the desired transitions of the encapsulated Rb vapour.

67. Andrew Wright
Newcastle University

Unconditionally Secure Threshold Signature Schemes Using Quantum Networks

Digital signature schemes are synonymous with internet security. These are widely used cryptographic primitives that help in processing secure and fair transactions. The security of the current classical schemes relies on computational assumptions. With the advent of quantum computing, it has become apparent that the security of these schemes is threatened. As a result, the National Institute for Standards and Technology (NIST) is recommending for the development and standardisation of post-quantum secure cryptographic schemes with the aim of replacing as many of the insecure schemes as possible. To that effect, our research is to expand into the area of unconditionally secure threshold digital signature schemes and experimentally demonstrate their feasibility on quantum networks. Of particular interest is how much additional strain the network is placed under when considering the extra communication requirements imposed by a threshold scheme over a non-threshold counterpart.

68. Shicheng Zhang
Imperial College London

Frequency domain super-resolution using Raman quantum memory

The quest for higher resolution is a longstanding challenge in optical metrology but is always constrained by resolution limits. For instance, spatial imaging is fundamentally restricted by the diffraction limit imposed by the Rayleigh criterion. Yet, quantum estimation theory has shown that this limit can be surpassed by measuring the light field onto carefully chosen mode bases, thereby enabling the discrimination of arbitrarily small separations between two Gaussian-shape light sources [1]. Here, we build upon this concept to achieve super-resolution of closely spaced spectral lines in the frequency domain. By employing the temporal-mode selectivity of a photonic Raman quantum memory [2], we experimentally achieve super-resolution, surpassing classical limits to resolve separations smaller than the spectral linewidth. This enhanced ability to resolve closely spaced spectral features paves the way for super-resolving spectroscopy and time-frequency quantum optical metrology.

[1] M. Tsang, R. Nair, and X.-M. Lu. Quantum theory of superresolution for two incoherent optical point sources. Phys. Rev. X, 6:031033, Aug 2016.
[2] J. Nunn, I. A. Walmsley, M. G. Raymer, K. Surmacz, F. C. Waldermann, Z. Wang, and D. Jaksch. Mapping broadband single-photon wave packets into an atomic memory. Phys. Rev. A, 75:011401, Jan 2007.

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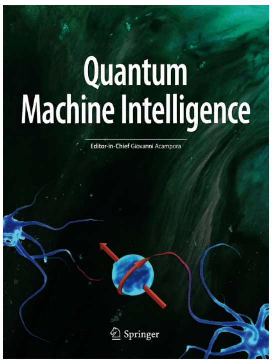

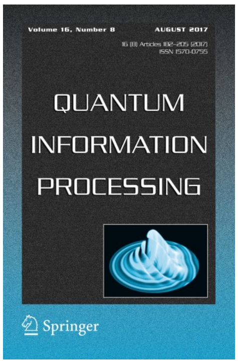

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