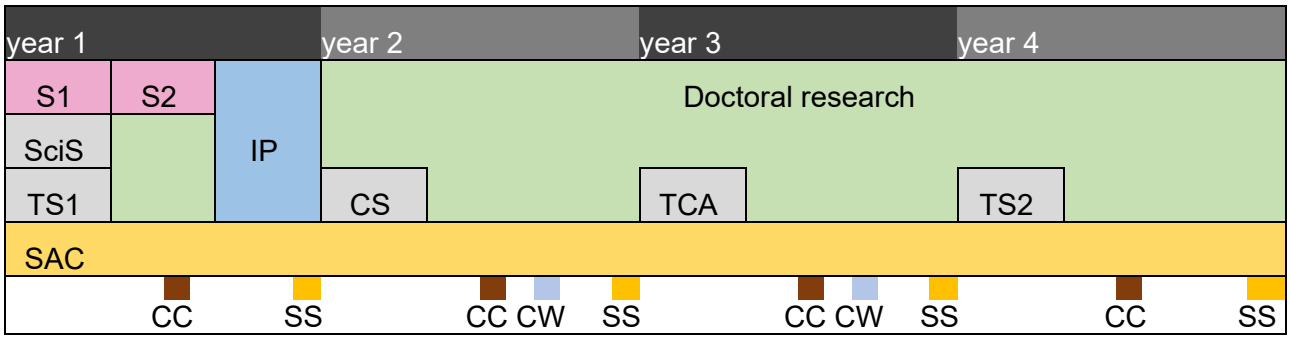
EPSRC Centre for Doctoral Training in Quantum Technology Engineering – 2027

Information for Students

The EPSRC Centre for Doctoral Training in Quantum Technology Engineering (CDT-QTE) has been designed, with industry advice, to match the needs of the expanding quantum technology industry and set you up for a successful and rewarding career in or beyond the quantum technology sector, from academic research to business development. The PhD will take 4 years and combine an exciting research programme with a training programme to equip you with a range of scientific, technical and commercial know-how to support your future career, backed by communications coaching, a 12-week industry placement, and shared challenges to build your peer network and foster cross-fertilization of research ideas.

The PhD has the following structure:



Science 1 & 2 (S1, S2): two Masters-level modules to bolster understanding of the specific area of doctoral research. These modules are assessed.

Scientific Skills (SciS): workshops, exercises and a practical challenge addressing experiment and trial design; control, measurement & simulation; and systematic problem solving.

Technical Skills 1 (TS1): training/practical exercises in common design & fabrication techniques.

Technical Skills 2 (TS2): workshops and exercises covering systems engineering (SE).

Commercial Skills (CS): taught module with exercises, workshops and guest lectures.

Technical & Commercial Awareness (TCA): talks, examples, exercises and discussions covering a range of concepts and considerations likely to be encountered in future careers.

Scientific Awareness & Communication (SAC): a programme-long series of scientific and technical seminars, critical analysis, and training in communication and presentation.

Communications Coaching (CC), Summer School (SS), Challenge Week (CW).

Industry Placement (IP): a 12-week placement with an industrial partner.

Further Details:

About the CDT:	https://qte.ac.uk/
Application procedure:	https://qte.ac.uk/phd-opportunities/
General inquiries:	qte@soton.ac.uk

We look forward to hearing from you.

Tim Freegarde, Marina Carravetta, Peter Horak

PhD projects in Quantum Technology Engineering – 2027

1 - Quantum key distribution with 5G technology integration

Dr Chao Xu

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The objective of this project is to integrate quantum communication into emerging wireless networks, paving the way for a global quantum network in time for 6G.

Continuous-variable QKD (CV-QKD) modulates its information onto the phase or amplitude of the electromagnetic wave. This enables quantum-secured applications such as banking and healthcare to be delivered using off-the-shelf wireless transceivers.

Nonetheless, the current wireless CV-QKD systems face two significant limitations. Firstly, transmission distance is constrained by both atmospheric turbulence and the multipath effect in electromagnetic wave propagation. Secondly, the generation rate of secret key is orders of magnitude lower than the classical communication data rate. To mitigate these challenges, on one hand, 5G-compliant error correction codes will be designed for enhancing CV-QKD's robustness against channel impairments. On the other hand, leveraging the principal waveform of orthogonal frequency division multiplexing (OFDM) in 5G, the secret key rate is expected to increase with the number of OFDM subcarriers, thereby optimizing wireless spectrum access.

This frontier research will address key national strategies: the National Quantum Strategy, the EPSRC Strategic Delivery Plan 2022-2025, the Telecommunications (Security) Act 2021 and National Cyber Strategy 2022, and the Net Zero Strategy.

This project will be supervised by Dr Chao Xu, the first researcher from the University of Southampton to achieve the highest score 100/100 in the EU's Marie Sklodowska-Curie Actions (MSCA) fellowship proposal evaluation.

This project will provide a unique cross-disciplinary training to an aspiring PhD student. The PhD student and supervisors will also intensively collaborate with industrial collaborators. Moreover, the knowledge gleaned by this project will be transferred to students through teaching by the supervisors, which will inspire more Southampton students to quantum research.

3 - Millimetre-wave multiplexed qubit control through on-chip nonreciprocal space-time superconducting frequency multipliers

Dr Sajjad Taravati

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Today's quantum computers need a dedicated microwave source per qubit, a wiring bottleneck limiting scale-up. This project builds an on-chip superconducting device where a single microwave frequency source drives an entire qubit array at distinct frequencies up to the millimetre-wave range, using space-time-modulated Josephson junctions for nonreciprocal multiplexing.

Superconducting quantum processors are limited not just by qubit coherence but by wiring: each qubit typically needs its own microwave control line, and this overhead grows rapidly as processors scale toward hundreds or thousands of qubits. This PhD project addresses that bottleneck by developing a fundamentally new class of on-chip control hardware: a nonreciprocal, space-time-modulated superconducting frequency multiplier that converts a single drive into a full comb of directionally isolated tones spanning up to millimetre-wave frequencies, with each tone addressing a different qubit, removing the need for a dedicated high-frequency source per qubit.

Building on theoretical and simulation work recently published by the supervisory team (IEEE Transactions on Antennas and Propagation), you will take this device from simulation to hardware: developing the circuit and Hamiltonian models, designing and fabricating superconducting thin-film prototypes, and integrating them with a small array of flux-tunable transmon qubits. You will

characterise harmonic-comb generation, nonreciprocal isolation, and the resulting suppression of Purcell decay and qubit-qubit crosstalk at millikelvin temperatures, establishing whether this architecture can genuinely reduce the wiring burden of scalable quantum computing.

The project sits at the interface of quantum engineering, superconducting electronics, and space-time metamaterials. Suited to candidates with a background in quantum science, physics, electromagnetics, electronic engineering, or applied mathematics.

4 - On-chip programmable circulator for scalable superconducting qubit readout

Dr Sajjad Taravati

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Every superconducting quantum computer's readout chain relies on bulky, magnetic ferrite circulators that block noise from reaching qubits, but cannott be miniaturised or scaled. This project designs, fabricates, and tests a reconfigurable, on-chip, magnet-free circulator using space-time-modulated Josephson junctions, programmable in real time for next-generation AI-driven quantum control systems

Reading out a superconducting qubit without destroying its quantum state requires strict nonreciprocity: probe signals must reach the qubit, while reflected or amplifier-generated noise must be blocked from travelling back. Today this is achieved with ferrite-based circulators, bulky, magnetic, fixed-response components that cannot be integrated and dominate the physical footprint and cost of the readout wiring as qubit counts scale toward hundreds or thousands. This PhD project addresses that bottleneck by developing a fundamentally new class of on-chip hardware: a nonreciprocal circulator based on space-time-modulated superconducting Josephson junctions, using their nonlinearity to break time-reversal symmetry without any magnetic material. Because the modulation is electronically controlled, the circulator's isolation, bandwidth, and routing can be reconfigured and programmed in real time, a key advantage over static ferrite devices, and a natural fit for next-generation quantum control systems that adapt readout and calibration on the fly.

You will develop theoretical and circuit models of space-time-modulated Josephson circuits for on-chip, programmable circulation; design and simulate candidate circulator architectures optimised for compatibility with standard qubit readout chains; and fabricate prototype devices, characterising isolation, noise performance, reconfigurability, and readout fidelity through cryogenic microwave measurements benchmarked against conventional ferrite circulators.

This research targets a bottleneck recognised across the quantum computing community as a key barrier to scaling qubit readout, offering a compact, magnet-free, and programmable route to denser, AI-compatible quantum processors. You will gain expertise in superconducting circuit design, nonreciprocal electromagnetics, nanofabrication, and cryogenic microwave engineering, within a vibrant research team with strong industrial and academic collaborations.

6 - Large-area metasurface optics for quantum technology

Prof Otto Muskens, Dr Kai Sun

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Metaoptics, the application of metasurface concepts in optical elements, can help make quantum devices smaller, more efficient, and easier to integrate into practical systems. This PhD project will advance the science and technology of metaoptics for quantum imaging and cold atom trapping, making use of state-of-the art cleanroom nanofabrication.

Metaoptics are ultra-thin, lightweight optical components that derive their optical function from nanostructured surfaces with precise sub-wavelength arrangement. They can replace bulky lenses and mirrors while precisely controlling light, polarisation, aberrations, and wavefronts. Their

properties are seeing increasing interest in applications such as smartphones, sensors and telecommunications.

The scope of this PhD research is to advance the science and technology of metaoptics for use in next-generation quantum systems. The project will explore the design of metasurfaces through both commercial and custom-built (e.g., deep learning) software. Experimentally, we will fabricate metasurface optics using advanced full-wafer fabrication tools such as Southampton's deep-UV lithography (the only such system available in the UK's academic research community) and our new 200 kV electron beam lithography system (the only such system currently installed in UK and Europe).

During the PhD research the student will receive training and will develop strong expertise in fabrication of devices using one of the leading research cleanroom facilities in the UK. The project will link to existing collaborations with groups at Imperial and Bristol through the Quantum Sensing Imaging & Timing (QuSIT) Hub and cold atom experiments at Durham, and we will develop new academic and industrial collaborations during the activity.

7 - Electrochemically engineered chiral tellurium nanowires for spin-orbit quantum devices

Prof Iris Nandhakumar, Dr Yoshishige Tsuchiya

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This PhD project will use electrochemical deposition to grow chiral tellurium nanowires with controllable handedness, verified by circular dichroism, Raman spectroscopy and electron diffraction. Wires will be fabricated into devices for cryogenic magnetotransport studies probing spin-orbit coupling, quantum dots and Coulomb blockade, paving the way towards chirality-selected spin qubits.

Semiconductor spin qubits are a leading platform for scalable quantum computing, and a new paradigm is emerging in which the handedness of the host lattice, not just its composition, determines qubit properties. Tellurium is an archetypical example: Its atoms form helical chains that produce unusually strong spin-orbit coupling and gate-tunable charge-to-spin conversion. This allows spins confined in gate-defined quantum dots to be manipulated with electric fields alone, a route to fast, compact qubit control. Tellurium nanowires have already shown phase-coherent, quasi-ballistic transport and gate-defined quantum dots. However, tellurium crystallises in two mirror-image forms, as-grown material usually mixes both, and the spin-orbit response reverses with handedness. This is a fundamental barrier to reproducible qubits.

This project will realise enantiopure tellurium nanowires with controllable handedness as a materials platform for chiral spin qubits. Low-temperature electrochemical deposition at Southampton gives direct control over diameter, orientation, defect density and surface chemistry. Using it, we will develop templated and template-free growth routes and bias deposition towards a single handedness using chiral additives and chirally modified electrodes. Handedness will be verified by circular dichroism, Raman spectroscopy and convergent-beam electron diffraction. Wires will then be fabricated into devices in the Southampton Nanofabrication Centre and measured at cryogenic temperatures. These measurements will probe phase coherence, Coulomb blockade, g-factor anisotropy and spin-orbit energy scales, the quantities that define qubit operation, and establish how chirality governs electrical spin control.

8 - Quantum frequency conversion for hybrid quantum networks

Dr Patrick Ledingham

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Future quantum networks will need to connect technologies operating at very different wavelengths. This experimental PhD will develop high-bandwidth quantum frequency converters using four-wave

mixing in warm rubidium vapour, translating photons from visible single-photon sources and telecom channels to the near-infrared for direct interfacing with atomic quantum memories.

Future quantum networks will need to connect diverse technologies for generating, transmitting and storing quantum information. A major challenge is that these components often operate at very different optical wavelengths: single-photon sources may emit in the visible, communication channels favour telecom wavelengths, while atomic quantum memories operate at specific near-infrared transitions.

To overcome this challenge, this experimental PhD will develop high-bandwidth quantum frequency conversion devices using four-wave mixing in warm rubidium vapour. You will build and investigate two complementary interfaces: converting visible photons (630nm) from hexagonal boron nitride (hBN) single-photon sources and telecom photons (1529nm) from quantum communication channels to the near-infrared (795nm) for interfacing with atomic quantum memories. These interfaces will provide a route to connecting otherwise incompatible quantum technologies within future heterogeneous quantum networks.

As a PhD candidate, you will gain hands-on experience building atomic physics experiments and laser systems, investigating nonlinear light-matter interactions, and characterising conversion efficiency, bandwidth and noise. You will progress from continuous-wave spectroscopy to nanosecond optical pulses and ultimately quantum frequency conversion at the single-photon level.

The project forms part of the international AL FreSQO collaboration, bringing opportunities to work with researchers developing hBN single-photon sources, atomic quantum memories and free-space quantum communication links. You will gain extensive experience in experimental quantum optics, nonlinear optics, atomic physics, lasers, high-speed optical control and single-photon detection. You will have flexibility to follow your particular research interests, with opportunities to engage with collaborators and industrial partners in the UK and abroad.

9 - Integrated quantum buffers for photonic quantum computing

Dr Patrick Ledingham, Dr Alberto Politi

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Photonic quantum computers require the ability to temporarily store photons while measurements and feed-forward operations are performed. This experimental PhD will develop integrated quantum buffers by combining rare-earth-ion-doped crystals with silicon nitride photonic circuits, replacing bulky optical-fibre delays with compact devices suitable for scalable photonic quantum processors.

Integrated photonics is a promising platform for large-scale quantum computing, enabling photon sources, optical circuits and detectors to be realised on a single chip. However, photons cannot simply be stopped while a quantum processor decides what to do next. Current systems route photons off-chip through hundreds of metres of optical fibre to provide the delays needed for measurement and feed-forward. As processors scale, these bulky fibre buffers present a major obstacle to fully integrated photonic quantum computers.

To overcome this challenge, this experimental PhD will develop compact quantum buffers by integrating rare-earth-ion-doped crystals with silicon nitride (SiN) photonic circuits. You will investigate thulium-doped yttrium aluminium garnet (TmYAG), using its exceptional optical coherence and controllable absorption to temporarily store GHz-bandwidth photons. The aim is to realise microsecond-scale delays within a millimetre-scale integrated device, replacing hundreds of metres of optical fibre.

As a PhD candidate, you will gain hands-on experience in cryogenic quantum optics, rare-earth-ion spectroscopy, integrated photonics and single-photon experiments. You will develop atomic frequency comb quantum buffers, characterise their efficiency and coherence, and ultimately

interface the devices with integrated single-photon sources. The project also provides opportunities to explore electrically controlled, on-demand photon retrieval.

You will work within a multidisciplinary team spanning quantum memories and integrated photonics, with access to Southampton's quantum optics laboratories and nanofabrication facilities. The project has strong links with the UK quantum industry, including ORCA Computing and Duality Quantum Photonics, providing opportunities to understand how these technologies could be translated into future photonic quantum processors

10 - Counterdiabatic shortcuts for quantum linear system solvers

Dr Stefano Cipolla

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What if a quantum algorithm could take a shortcut to the true answer? This PhD will test whether practical counterdiabatic controls can accelerate adiabatic quantum linear-system solvers within realistic noise and hardware limits. It will deliver theory, open software and rigorous benchmarks showing when these shortcuts offer genuine computational benefit.

Solving linear systems underpins simulation, optimisation, control and data analysis. Quantum linear-system algorithms prepare a state proportional to the solution and can benefit applications needing selected properties. Adiabatic solvers are attractive but can become slow when spectral gaps are small or matrices poorly conditioned. Counterdiabatic driving — a shortcut to adiabaticity —could suppress unwanted transitions. Exact controls may be nonlocal and costlier than the evolution they replace.

This PhD will investigate whether implementable counterdiabatic controls can reduce coherent circuit depth or improve robustness once their full construction, compilation and simulation costs are counted. The student will derive regularised local, variational, nested-commutator or Krylov approximations to the adiabatic gauge potential and establish error and resource bounds where feasible. Tests will determine how performance depends on condition number, sparsity, precision, matrix structure, noise and hardware connectivity.

The main focus is early fault-tolerant computation; small hardware demonstrations will provide validation, not advantage claims. Structured matrices from differential equations, networks and optimisation will be tested against unassisted and discrete-adiabatic quantum solvers and appropriate classical methods. Metrics will include solution-state fidelity, observable error, circuit depth, two-qubit gates, state preparation and readout.

Expected outputs are new control constructions, open software, reproducible benchmarks and a map of useful, break-even and unfavourable regimes. The project suits candidates from physics, mathematics, computer science or engineering who enjoy quantum theory, numerical linear algebra and careful computational experiments.

10 - Integrated photonic chips for neutral atom quantum computers

Dr Peter Horak

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Join our dynamic research team to develop the photonic technology needed to scale neutral-atom quantum computers. In this PhD, you will design integrated photonic chips that generate, shape and steer the laser beams used to control arrays of individual atoms, combining cutting-edge photonics, quantum technology and computational modelling.

Neutral atoms trapped in optical tweezers are a promising platform for quantum computing, but scaling these systems to much larger numbers of atoms for more powerful quantum computers presents a major technological challenge: each atom must be precisely trapped, controlled and manipulated using laser light. Today, this relies largely on complex free-space optical systems involving lenses, mirrors and spatial light modulators, which become increasingly difficult to align and scale.

In this project, you will explore a different approach: putting the optical system onto a photonic chip. Instead of routing light through bulky free-space optics, integrated waveguides will deliver light to where it is needed, while structures such as Bragg gratings will shape and direct beams from the chip towards the atoms trapped in vacuum above its surface.

You will develop new photonic device concepts and use theoretical and numerical modelling to investigate capabilities including:

- generating large arrays of optical tweezers;
- optimising beam shape and polarisation for simultaneous control of many atoms;
- integrated switching of optical beams; and
- dynamic beam steering for addressing individual atoms.

If you are excited by photonics, quantum technologies and computational modelling, this project could be for you. You will work in a collaborative research environment and will have the opportunity to interact with experimental researchers at the University of Southampton and the QCi3 National Quantum Technology Hub (https://qci3.org/), connecting your computational designs with the challenges of real quantum-computing hardware.

12 - Hybrid quantum–classical stochastic optimisation for future energy systems under uncertainty

Dr Hongyu Zhang

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Can quantum computers help make better energy decisions when the future is uncertain? This project will develop hybrid quantum–classical algorithms that use limited quantum hardware strategically within large-scale stochastic optimisation. Applications will address renewable uncertainty, storage and infrastructure planning, connecting quantum computing with real-world challenges in the net-zero energy transition.

Planning future energy systems requires decisions about generation, storage and infrastructure years before future demand, weather and renewable generation are known. Stochastic optimisation provides a rigorous framework for such decisions, but realistic models can contain thousands of uncertain scenarios and millions of variables, creating major computational challenges.

This PhD will investigate whether quantum computing can help overcome these barriers. Rather than attempting to place an entire energy system model on a quantum computer, the project will develop hybrid quantum–classical algorithms that use scarce quantum resources selectively for computationally challenging components of large-scale stochastic optimisation.

Research will explore how quantum optimisation and sampling methods can be embedded within classical decomposition frameworks. Potential directions include quantum solution of scenario subproblems, combinatorial planning decisions, scenario generation or selection, and coordination between long-term investment and short-term operational decisions. Variational quantum algorithms, quantum annealing and emerging quantum optimisation approaches will be investigated alongside state-of-the-art classical methods.

The algorithms will be tested on real-world energy applications involving uncertain renewable generation, long-duration storage, infrastructure investment and system resilience. A central objective will be to establish when quantum resources provide computational value, what limitations current hardware imposes, and how algorithms should evolve as quantum hardware improves.

The student will join Southampton’s interdisciplinary quantum technology environment and receive specialist quantum training through the EPSRC Centre for Doctoral Training in Quantum Technology Engineering, including an industry placement and opportunities for extended research visits.

13 - Variational quantum computing beyond the near term

Prof Thomas Blumensath, Dr Richard Boardman

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This PhD project investigates improving the robustness of variational quantum algorithms on noisy quantum computers. Using simulated quantum systems, it explores error-correction-inspired approaches and learned redundancy within hybrid classical-quantum frameworks. The research can be theoretical or computational, aiming to enable larger, more reliable quantum computations despite hardware noise and decoherence.

By utilizing quantum entanglement and parallelism, quantum computers are, in theory, able to quickly solve many problems that cannot be efficiently solved on traditional computers. However, in the near term, system noise and decoherence significantly limit their utility as they limit the number of operations that can be performed before system noise destroys computational results.

To overcome these limitations, variational quantum algorithms have been proposed, which have some inherent robustness to noise. These hybrid classical-quantum methods utilize the advantages of noisy near-term quantum computers whilst using well established classical optimization methods to adapt a small number of quantum operations.

Beyond these current developments, a key mid-term goal in quantum computation is the push for ever larger quantum computers that will allow the use of many more computational steps. The hope is that in addition to hardware improvements, noise robustness can be achieved utilizing error correction methods. In this project

Your work will explore the development of methods using simulated quantum computers that incorporate error correction ideas and in particular the use of learned redundancy within the variational computational framework. The goal is to increase the robustness of these methods to noise and to thus allow for the use of more complex computational structures.

This is a field where there is significant scope that allows you to develop and follow your own interests and to pursuit different directions, whether these are theoretical (by looking at the mathematical properties of the methods) or computational (by experimentally exploring the practical performance of methods).

14 - Cryogenic memristors for quantum-computing control electronics

Dr Firman Simanjuntak

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Quantum computers are limited by the quantum-classical interface, where power-hungry control electronics struggle to scale with growing qubit numbers. This project explores cryogenic memristors as ultra-low-power adaptive calibration elements that can learn and compensate for qubit drift, enabling more stable, scalable, and energy-efficient quantum computing systems and future architectures.

As qubit numbers increase, the control, calibration and readout electronics required to operate them consume significant power and generate substantial wiring complexity. A major challenge is qubit drift, where device characteristics change over time and require continuous recalibration. This project will investigate cryogenic memristors as ultra-low-power adaptive calibration and memory elements for future quantum-computing control systems.

The research aims to understand how memristors behave at cryogenic temperatures and determine whether their memory, non-linearity and learning capabilities can be exploited to compensate for qubit drift automatically. The outcomes will include new cryogenic memristor materials, device models, adaptive calibration circuits and proof-of-concept neuromorphic control architectures for scalable quantum technologies.

Year 1: You will develop and optimise new thin-film materials for cryogenic operation, working closely with engineers from Von Ardenne GmbH through collaboration with the MEMNICS Laboratory (www.memnics.com). This will give you experience in advanced thin-film deposition, materials engineering and industrial device development.

Year 2: You will fabricate and characterise cryogenic memristor chips, investigating switching behaviour, retention, endurance, multilevel operation and stability at low temperatures. Experimental protocols for electrical testing under cryogenic conditions will be established. Device physics models and cryogenic behavioural models will also be created.

Year 3: You will design, build and experimentally evaluate adaptive calibration circuits and neuromorphic control architectures using cryogenic memristors. Demonstrator systems will be developed to assess their ability to compensate for qubit drift and reduce power consumption for future quantum-computing.

The project offers multidisciplinary training spanning nanofabrication, thin-film materials, cryogenic electronics, neuromorphic engineering and quantum technologies.

15 - Photoswitches as light driven molecular qubits for quantum computing

Dr George Williams, Dr Karl Michael Ziems

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Controlling molecular spin states remotely (i.e. with light) is key to enabling next generation quantum sensing and computing technologies. This project will focus on the synthesis and characterisation of novel photoswitches that will enable control over either radical persistence or dynamic spin state interactions.

Molecular photoswitches undergo reversible structural changes in response to light and are the cornerstone of many stimuli responsive materials. Whilst they have found a range of applications in biomedical and material fields, their use in controlling spin-states is more limited [1]. The properties of organic photoswitches can be altered through judicious synthetic alterations, enabling access to tuneable half-lives, activation wavelengths, distances between positions and photostationary states. Achieving such precise control over properties make all organic spin state photoswitches ideal candidates for the development of novel technologies including quantum sensing and as qubits for quantum computers. This strategy also circumvents the issues of conventional spin state switches, which are often based on toxic metal complexes, enabling the development of more environmentally benign technologies.

This project will use chemistry recently developed in the Williams group to synthesise novel photoswitches with tuneable properties which enable the control over the spin state using low energy (long wavelength) light. In doing so, the candidate will gain expertise in:

- Organic synthesis
- Photophysical characterisation
- Quantum chemical calculations
- Advanced NMR techniques

The project will be jointly supervised by Dr George Williams and Dr Karl Michael Ziems, who will support the experimental and theoretical aspects respectively. The ideal candidate will have a good grounding in organic synthesis, and a willingness to learn computational and spectroscopic techniques as they apply to the project.

Please contact Dr Williams at G.T.Williams@soton.ac.uk if you have any questions.

[1] DOI: 10.1002/anie.202512691

16 - Random point sources for quantum measurement and sensing

Dr Daniel Clark

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Quantum measurements often produce sparse, noisy observations from underlying sources or fields. This project develops mathematical methods for quantum measurement and sensing using random point sources, point processes and random measures, asking what source information can be recovered from realistic measurements and how noise and limited resolution affect that recovery.

Quantum measurements often provide indirect observations of an underlying source or field. Photon detections, interferometric measurements and spatial intensity data may be sparse, noisy and resolution limited, making recovery of the underlying physical structure an inverse problem.

This project will develop mathematical methods for quantum measurement and sensing based on random point sources, point processes and random measures. It will investigate how source configurations and their statistical properties are transformed by measurement, which features remain identifiable, and how uncertainty, correlations and non-Gaussian structure appear in observable data. Particular attention will be given to ambiguity, resolution, detector noise and restricted observation, leading to quantitative limits on source recovery, estimation and discrimination.

The project will use examples from quantum optics and quantum sensing, including photon counting, imaging and interferometric measurement, while remaining primarily mathematical and computational. It builds on Clark's Random Point Sources: A Mathematical Theory of Point-Source Recovery (Springer, 2026), together with Field Theory for Point Processes (Birkhäuser) and Information and Inference for Point Processes (Springer).

The intended outcome is a rigorous theory of inverse problems for stochastic point sources under quantum measurement, with potential applications to quantum sensing, imaging, photodetection and measurement design.

17 - Algorithm development for molecular simulations on quantum computers

Dr Karl Michael Ziems

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Help shape the future of molecular and materials simulations with quantum computers! Develop innovative quantum algorithms, explore their applications, and test your ideas on real quantum hardware. Join an international research environment where your interests shape your project, combining quantum computing, chemistry, physics, and mathematics to tackle challenging scientific problems.

Quantum computing promises to transform how we simulate molecules and materials, potentially enabling breakthroughs in chemistry, physics, and beyond. Realising this potential requires fundamentally new algorithms that exploit quantum phenomena such as superposition and entanglement. This creates exciting opportunities for creative, high-impact research at the intersection of quantum computing, computational chemistry, physics, and applied mathematics.

You will join a dynamic and collaborative research group of eight scientists working across the entire spectrum of quantum algorithms, from near-term, to early fault-tolerant to fully fault-tolerant. Our research spans novel algorithm design, quantum error mitigation, benchmarking, resource estimation, and applications on real quantum hardware. We maintain active collaborations with leading academic groups, quantum start-ups, and industry worldwide.

Your research direction will be shaped by your interests and expertise. Possible projects range from fundamental algorithm development to practical implementations and demonstrations on quantum computers, with a focus on advancing molecular and materials simulations. You will have opportunities to explore new approaches to modelling electronic structure, quantum dynamics, and material properties, addressing scientific challenges that are difficult for classical computers. You will work closely with experienced researchers and your supervisor, combining mathematical theory, classical and quantum programming, numerical simulations, and quantum hardware experiments.

We welcome applicants from diverse scientific backgrounds. Essential strengths include programming experience (preferably Python), solid mathematical foundations, and an interest in developing computational methods. Experience in quantum chemistry, second quantisation, quantum dynamics, or quantum information is advantageous.

A research stay in Denmark is possible through collaboration with the Danish quantum initiative HQC2.

18 - Quantum Gas Sensing with Hollow-Core Fibres

Dr Ian Davidson, Dr Thomas Kelly, Prof. Natalie Wheeler, Dr Patrick Ledingham

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This project will combine hollow-core optical fibres, single-photon detection, and non-classical light to create new, faster and more sensitive gas sensors. These sensors will be capable of detecting pollution, greenhouse gas emissions, hazardous leaks and industrial gases, enabling cleaner air, safer infrastructure, smarter manufacturing and progress towards net-zero.

Gases by their nature are hard to detect, especially at low concentrations, making approaches that can achieve this (especially rapidly) vital for many applications. This is especially true for biomedical, gas safety, environmental sensing, and many industrial processes where detecting gases in part-per-million (or lower) range is highly important.

In this project you will develop quantum-enhanced gas-sensing techniques that can achieve this and hence transform how we monitor the atmosphere, detect illness, and build safer, cleaner, and more efficient industrial processes. Key to this is combining hollow-core optical fibres (HCFs), a revolutionary technology which guides light in air rather than glass, with quantum technology to investigate:

- The use of superconducting single-photon detectors to further enhance the speed and sensitivity of HCF-enhanced Raman gas sensing, and enable distributed measurement,
- The generation and use of quantum light, i.e. entangled, correlated and squeezed light sources, at selected wavelengths to improve HCF-enhanced mid-IR absorption spectroscopy,
- The potential use of gas-filled HCFs to generate entangled photons for mid-IR gas sensing

Your project will see you join the Optoelectronics Research Centre, home to >150 researchers and a diverse PhD community, and collaborate with this highly experienced team to build these new sensors. Through this you will gaining skills in:

- Quantum engineering and technology,
- Experimental and instrument design,
- System integration, and
- Problem solving

So, if you have a background in STEM, an interest in optics, and a desire to develop new sensors capable of positively impacting on our society, then this is the project for you!

19 - Advanced signalling and detection in quantum communications

Prof Lie-Liang Yang, Prof Mohammed El-Hajjar

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This four-year PhD project optimises quantum communication systems by countering uncertainties in quantum states and channels. It focuses on designing resilient quantum constellations via maximising minimum trace distance and Holevo-x information and developing advanced detectors for optical channels. The programme includes a 3-month industry placement, targeting publication in top-tier journals.

In quantum communication systems, uncertainties exist within both quantum states and quantum channels. Consequently, the achievable performance of these systems relies on two critical factors: the design and optimisation of a quantum constellation to maximise classical information signalling, and the design of a quantum detector (measurement) to counter channel-induced uncertainties.

This project focuses on the design and optimisation of quantum constellations and detectors for quantum communication systems. Specifically, signalling constellations will be designed and optimised by maximising the minimum trace distance and the uniform Holevo-x information. Quantum detectors will be developed in the context of quantum optical channels, addressing both low-rate and high-rate communication scenarios.

The project expects to generate high-impact research outcomes, including efficient quantum signalling schemes for conveying classical information and practical quantum detection techniques for quantum optical communication systems. The findings are expected to yield at least two top-journal research papers and one or more conference papers.

This project is a four-year doctoral programme that includes one year of structured training and a 3-month industry placement. The ideal candidate will possess a strong mathematical background - particularly in linear algebra and probability theory - a keen interest in classical and quantum mechanics, and a solid foundation in classical communication engineering.

20 - Super-resolution imaging and metrology with quantum light detectors

Dr Giorgio Adamo, Prof Kevin Macdonald

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Super-resolution imaging and metrology now routinely break the classical optical diffraction limit. Leveraging recent advances in subwavelength control of light, metamaterials, information theory and artificial intelligence, this project will investigate the use of quantum light and quantum detectors in scenarios where classical light and its detection fail.

Optical imaging and metrology become increasingly difficult at the nanoscale, where objects, their dimensions, shapes, positions and displacements, are much smaller than the wavelength of light. Despite recent remarkable advances in label-free deep-subwavelength imaging and metrology, there are scenarios where classical methods do not perform satisfactorily or cannot be applied, and the use of non-classical light and single-photon detectors and detector arrays is necessary.

In this project you will explore the use of single-photon detectors and detector arrays, in conjunction with non-classical light, to push the boundaries of deep-subwavelength label-free imaging and metrology. This might allow, for example, to sample the diffraction pattern of nanoscale objects interacting with single photons, to identify photon correlations within the scattered light patterns, or to infer three-dimensional information of an object from temporal correlations between entangled photons interacting with it. You will do it through a blend of experimental activities, theoretical analysis and numerical modelling.

You will join the ORC, a world-leading photonics research organization, and collaborate closely with students, researchers and academic experts. You will be encouraged to take initiative, develop and test your own ideas. You will engage in collaborations, research meetings and present your work at major international conferences. Your research is expected to generate several papers in leading academic journals and contribute to shaping the future of this exciting field.

You will gain transferable skills in experimental photonics, computational electromagnetic modelling, nanofabrication, machine learning, and electron and optical microscopy, preparing you for opportunities in academia and industry.

21 - Trapping thousands of atoms with a single metasurface chip

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Quantum computers using individual atoms could solve problems beyond today's machines, but controlling thousands of atoms requires complex optical equipment. This project will create a chip-based optical metasurface that forms many tiny atom traps, making atom quantum computers more stable, easier to build and potentially more scalable.

Could a single chip help scale neutral-atom quantum computers from hundreds to thousands of atoms? Today's optical-tweezer systems rely on bulky, lossy and alignment-sensitive free-space optics, creating a major barrier to practical scale-up. In this PhD, you will design, fabricate and test a power-efficient dielectric metasurface that creates a thousand-atom-class trapping array on one compact chip. Your goal will be to deliver validated inverse-design tools, fabrication protocols and benchmark data, culminating in the ambitious demonstration of ≥1,000 simultaneously trapped atoms and potentially the UK's first metasurface-based atom-trapping platform.

You will work across adaptive optics, nanophotonics, semiconductor nanofabrication and atomic physics, using Southampton's specialist cleanroom and optical-characterisation facilities alongside the National Quantum Computing Centre (NQCC) neutral-atom quantum-computing platforms. Placements of up to three months at NQCC will give you hands-on experience of system integration, atom loading and performance benchmarking, as well as exposure to a national quantum-computing research environment. You will receive interdisciplinary training in inverse design, data analysis, responsible innovation and research translation, while developing skills valued across academia, photonics and the quantum industry. This project offers the opportunity to tackle challenges in scalable quantum hardware and contribute directly to compact, modular neutral-atom processors and the UK quantum-technology ecosystem.

23 - Wideband all-fibre polarisation-entangled photon pair sources for enhanced versatility in quantum optical experiments and quantum information processing

Dr Morten Ibsen

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Quantum sources that produce entangled photon pairs are crucial components in many quantum applications. This project will develop fibre-based entangled photon sources based on poled silica fibre technology where entangled photon pairs are directly generated in an optical fibre thereby enabling the construction of low-cost, versatile sources for quantum applications.

Quantum sources providing broadband biphotons entangled in both polarisation and time-energy degrees of freedom are a rich quantum resource that finds several applications in quantum communication, quantum sensing, and quantum metrology. Creating such a source while maintaining reliability and high entanglement quality over a broad spectral range is a challenge that conventionally requires various compensation steps to maintain high fidelity. The key to generate broadband polarisation-entangled biphotons via type-II spontaneous parametric down conversion (SPDC), without compensation, is to use nonlinear materials with sufficiently low group birefringence such that the biphoton bandwidth becomes dispersion-limited. Most nonlinear crystals or waveguides cannot meet this condition, but the condition is easily met in optical fibre-based systems. These systems have the added advantage of not requiring precise alignment or the use of bulky free-space optics and, additionally, are directly compatible with telecom fibre network infrastructure. Because of the amorphous nature of glass, optical fibres do not intrinsically possess any second-order nonlinearity (SON) required to generate the polarisation-entangled photons. However, it is possible to create an effective SON by exposing the fibres to a strong electric field, a process known as poling.

This project will develop all-fibre polarisation-entangled photon pair sources based on optical fibres and periodically poled silica fibre (PPSF) technology. During the project you will be involved with the design of optical fibres suitable for the poling process, the fabrication and optimisation of the PPSF devices for maximum efficiency, the characterisation and testing of the devices, and their deployment in different quantum applications.

26 - Lanthanide coordination complexes as single-photon emitters for quantum photonics

Dr Richard Knighton, Dr Patrick Ledingham

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This PhD project involves coordination chemistry to design new brightly luminescent lanthanide (rare-earth) complexes, with a focus on near-infrared emitters. By using molecular synthetic inorganic chemistry, we will apply these compounds as single-photon emitters and test their ability to be used in quantum photonics, such as quantum memories.

The ability to generate single photons on-demand is a crucial aspect of quantum photonics, with applications in memories, computing, and cryptography. Unlike other candidates such as quantum dots and organic dyes, using lanthanide complexes offers the unique opportunity to produce single-photon emitters which can be tailored at the single-ion level using molecular coordination chemistry. This project will utilise synthetic organic and inorganic chemistry to develop new ultra-efficient emitters to be integrated into novel devices, with a focus on near-infrared emitting ions (e.g., Yb, Nd,

Er) which offer excellent potential for combination with mature telecoms technology such fibre optics or silicon nitride waveguides. You will integrate these new complexes onto waveguide materials and test the single-photon emitting properties - via g(2) values) - investigating both their spatial and temporal coherence properties.

The successful candidate will acquire proficiency in synthetic organic, coordination chemistry, photoluminescence spectroscopy, and X-ray crystallography. The researcher will have full access to a suite of techniques via state-of-the-art facilities including NMR spectroscopy, IR, HPLC and Mass-Spectrometry, in addition to world-leading X-ray diffraction facilities.

The candidate will also participate in group-meetings, school seminars and represent the group at national/international conferences. The University of Southampton will give professional training via the Quantum Technologies DTP programme and transferable skills through the PGR Development Hub which provides a suite of training courses and support services which promotes well-being and employability.

28 - Reconfigurable quantum photonic chips for quantum computing and networks

Dr Tanmoy Mukhopadhyay, Dr Susmita Naskar

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What if quantum chips could change how individual photons travel and interfere? This project explores reconfigurable photonic circuits using mechanically responsive architectures to precisely control quantum light. The aim is to develop adaptable, low-loss devices that could open new possibilities for quantum computing, quantum information processing and secure communication networks.

Quantum computers and future quantum networks depend on controlling individual photons with exceptional precision. However, achieving low optical losses, accurate tuning and independent control of multiple components within integrated photonic circuits remains a major challenge.

This PhD project will investigate how to make quantum photonic chips dynamically reconfigurable, allowing their optical properties to be programmed for quantum operations. The research will explore electrostatically actuated mechanical metamaterial architectures to control nanoscale gaps between waveguides or between waveguides and nearby dielectric elements. Changing these gaps alters evanescent coupling or the effective refractive index, enabling switching, phase tuning and programmable single-photon interference.

A particular focus will be on developing mechanical architectures that independently control multiple photonic components while minimising unwanted interactions and maintaining quantum optical performance. Compared with thermo-optic phase shifters, electrostatic tuning could reduce standby power and thermal crosstalk, particularly for circuits requiring occasional reconfiguration rather than ultrafast modulation. Architected compliant mechanisms may improve displacement control and mechanical isolation, while bistable structures could retain selected switching states without sustained actuation.

The ultimate ambition is to establish new concepts for compact, low-loss and energy-efficient quantum photonic chips that could contribute to quantum computers, quantum communication networks and integrated quantum information processing.

The project offers an opportunity at the intersection of quantum photonics, device engineering and mechanical metamaterials. Students will benefit from Southampton's interdisciplinary quantum research environment.

30 - Integrated photonic ultra-high-Q ring resonators

Prof James Gates, Prof Chris Holmes

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Integrated ring resonators are a key component in photonics and will be an enabling technology in several areas, including the stabilisation of atom-trap clocks, rotation sensors and narrow-linewidth lasers. With our partner (California Institute of Technology, Caltech), you will develop ultra-high-Q ring resonators for rotation sensing and timing.

We are seeking a PhD student to join our interdisciplinary, friendly team of students, postdocs, and senior researchers developing quantum technology systems.

In partnership with the California Institute of Technology (Caltech), you will develop ultra-high-Q ring resonators for Quantum Technology. These integrated resonators are a key component in photonics and will enable several areas, including the stabilisation of atom trap clocks, rotation sensors, and narrow-linewidth lasers. We will also work with other UK and international collaborators and PhD students to develop and demonstrate these applications.

In this project, you will design, fabricate, and test these ring resonator systems. A key aspect of the project will be glass deposition using the university's state-of-the-art cleanroom facilities. You will also work with researchers at Caltech (with the opportunity for visits, if desired) to develop and test the fabricated devices. If you are interested in a PhD, want to do computer modelling, and have the required skills, we can also adjust the project accordingly.

If you are interested in photonics, microfabrication, and quantum technologies, you would be a strong fit for this project. You will benefit from our world-leading expertise in these fields and enjoy working in our group's highly supportive environment in Southampton, while collaborating with partner groups across the UK National Quantum Technology Programme.

Find out more about our department and research group:

https://www.southampton.ac.uk/research/institutes-centres/optical-engineering-quantum-photonics-group

31 - Manufacture of photonic and quantum technologies via ultra-precision diamond machining

Prof James Gates, Dr Paul Gow

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This project will develop the core components of superconducting, photonic and atom/ion trap quantum systems using ultra-precision diamond machining. The project will work with leaders in the field (academia and industry) to create vacuum systems with integrated photonics and electrical functionality.

Quantum Technologies present new challenges for manufacturing engineering. Southampton has been developing ultra-precision machining systems to scale up the manufacture of superconducting, photonic, and atom/ion trap quantum systems. These components are central to quantum sensing and quantum computing systems. You will work with leaders in the field (academia and industry) to create vacuum systems with integrated photonics.

In this project, you will design, fabricate, and test atom and ion trap systems while working with experimentalists to demonstrate quantum sensing and computing. If you are interested in a PhD focused on computer modelling and have the required skills, we can also adjust the project to suit this. Areas include:

- Development of atom and ion trap cells using diamond milling systems. You will create miniature vacuum cells from silicon, silica (glass) and sapphire. These will contain optical windows, integrated mirrors and electrical and vacuum feedthroughs.
- Fabrication of integrated optical waveguides and large-area tilted Bragg gratings to couple light out of integrated waveguides to form free-space beams for micro-atom traps.
- Development of freeform micro-optics (lenses, mirrors, resonators, etc.) enabling the creation of more compact (SWaP-C) and more efficient quantum photonic systems.

If you are interested in quantum technologies, photonics, and microfabrication, you would be a strong fit for this project. You will benefit from our world-leading expertise in these fields and enjoy working in a friendly, highly supportive environment in our Southampton group and collaborating with partner groups within the UK National Quantum Technology Programme.

Our research group:

https://www.southampton.ac.uk/research/institutes-centres/optical-engineering-quantum-photonics-group

32 - Multilayer metasurfaces for compact quantum imaging

Dr Xu Fang, Dr Peter Horak

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This project will develop compact quantum imaging sensors using multilayer metasurfaces and entanglement-enabled holography. Building on successful bilayer nanofabrication, you will design, fabricate and test devices for imaging under strong noise and distortion. No previous cleanroom experience is required; Southampton's Quantum Technology Engineering CDT provides training alongside support from supervisors.

This project will develop compact quantum imaging sensors that use entanglement-enabled holography to recover information from photon-pair correlations. The goal is imaging under strong background noise and optical phase distortion. Potential applications include machine vision and optical inspection of components under challenging illumination conditions. Our long-term ambition is to reduce both system size and cost tenfold.

Metasurfaces are planar nanostructures that shape light. By stacking layers with complementary functions, we aim to replace bulky optical assemblies with compact modules for beam shaping, splitting and polarisation analysis. With recent funding support from the Royal Society, EPSRC and the Leverhulme Trust, our team has successfully demonstrated bilayer nanofabrication. You will build on this foundation to develop multilayer devices, with substantial hands-on cleanroom work supported by structured training. No previous nanofabrication experience is required.

You will take your own device designs from simulation through fabrication to testing in a quantum imaging experiment. Electromagnetic and quantum photonic modelling will guide the designs. Early photon-pair measurements will inform device development. You will investigate how layer alignment, optical loss and fabrication tolerances affect imaging performance, and benchmark resilience to background noise and phase distortion against conventional approaches.

Supervised by Dr Xu Fang and Dr Peter Horak, you will develop expertise in quantum device engineering. Southampton's EPSRC CDT in Quantum Technology Engineering provides technical and commercial training, an industry placement and opportunities to learn alongside a cohort working across quantum technologies.

33 - Fault-tolerant quantum algorithms for rapid aerospace design and topology optimisation

Dr Jie Yuan, Prof David Toal

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Could quantum computers let engineers explore far more designs, far faster? This PhD will develop algorithms for future error-corrected quantum computers to accelerate topology optimisation and engineering design, and rigorously test where they can outperform today's supercomputers, helping create lighter, more efficient aircraft and engines for a net-zero future.

Aircraft and jet engines must be as light and strong as possible, but finding the best design is computationally expensive. Topology optimisation, which decides where material should go, requires solving a huge finite-element system for every candidate design, so even supercomputers can explore only a fraction of the possibilities. Fault-tolerant quantum computers could transform this, but no one yet knows whether their theoretical speedups survive in real engineering problems.

This PhD will answer that question. You will develop fault-tolerant quantum algorithms for rapid engineering design, combining quantum linear solvers (such as the Quantum Singular Value Transformation), efficient block encodings of finite-element models, quantum search and amplitude estimation into one end-to-end optimisation loop. You will implement them in PennyLane, test them by emulation on GPU and high-performance computing resources, and estimate the logical qubits, gate counts and runtime needed at industrial scale, benchmarking against the best classical solvers.

The outcomes will be new quantum algorithms for structural design, realistic resource estimates for aerospace components, and clear evidence of where quantum advantage is, and is not, achievable.

This matters because faster, better design means lighter, more fuel-efficient aircraft, and because industry, including Rolls-Royce, is investing heavily in quantum computing for engineering.

You will join the Computational Engineering and Design Group, supervised by experts in structural dynamics, robust design and aerospace design optimisation with extensive industry experience.

35 - Quantum-classical hybrid algorithms for risk-aware autonomous maritime navigation

Dr Huanhuan Li, Dr Hongyu Zhang, Dr Qin Zhou

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How can quantum computing help autonomous ships navigate safely in busy waters? This project will investigate quantum-classical algorithms for route planning and collision avoidance, combining quantum optimisation with maritime traffic data and risk assessment. Students will explore new computational methods and assess their potential against established classical approaches.

Autonomous ships must make safe navigation decisions while accounting for surrounding traffic, uncertain vessel movements and navigational constraints. As traffic situations become more complex, identifying safe and efficient routes can involve difficult optimisation problems.

This PhD project will investigate quantum-classical hybrid algorithms for risk-aware maritime route planning and collision avoidance. It will focus on the Quantum Approximate Optimisation Algorithm (QAOA) and examine how quantum optimisation methods can be adapted to navigation problems with multiple constraints.

The research will develop quantum-compatible problem formulations, including Quadratic Unconstrained Binary Optimisation (QUBO) models, and investigate approaches to quantum circuit design, constraint handling and hybrid optimisation. Automatic Identification System (AIS) data and vessel trajectory prediction will be used to estimate collision risks and account for uncertainty in surrounding traffic.

The proposed methods will be tested using representative maritime traffic scenarios and compared with established classical optimisation techniques. The work will examine solution quality, computational cost, scalability and the effects of quantum hardware noise. A key aim is to understand where quantum-classical methods may be useful and where classical approaches remain more practical.

The project offers an opportunity to work across quantum computing, maritime artificial intelligence and autonomous systems. The student will gain experience in quantum algorithm development, optimisation, maritime data analysis and computational modelling.

38 - Designing molecular crystals for quantum sensing of pressure and temperature

Prof Graeme Day

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Could we design molecular crystals that detect small changes in pressure and temperature? You will use computer simulations to explore how a crystal's packing shapes the signal from a molecular spin. Learning from known materials, the project will develop a computational framework for discovery of new crystals for quantum sensing.

Can we predict which molecular crystals will make sensitive quantum sensors for pressure and temperature? Dilute guest molecules embedded in a host crystal can act as spin probes. Light prepares their spin states, and changes in fluorescence reveal their microwave resonances. Pressure and temperature can shift those resonances, while the host packing influences how sharp and easy to read they are. Previous studies have demonstrated pressure and temperature sensing and compared the same guest's temperature response across several hosts [1–3].

In this project, you will benchmark computational methods for predicting guest incorporation, site preferences and spin properties against published data. You will combine crystal structure prediction and mixed-crystal modelling with electronic structure calculations to predict resonance shifts under compression and broadening from differences between guest sites. Lattice dynamics calculations

will help separate the effects of thermal expansion and vibrations on the spin signal and identify motions that contribute to spin relaxation.

Based on these benchmarks, you will develop a computational framework for discovering new guest–host molecular crystal sensors. Computational studies on known and predicted crystals will establish design rules for choosing both the guest and the crystal line host.

Through the project, you will gain experience in high-performance computing, materials modelling and structure prediction, and quantum spin dynamics.

[1] https://doi.org/10.1038/s41467-025-65508-2

[2] https://doi.org/10.1126/sciadv.aeb5422

[3] https://doi.org/10.1021/j100132a008

40 - Data-driven geometry of quantum states for quantum computing

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Fault-tolerant quantum computing requires classical adaptive methods to chaperone quantum processes. While NISQ devices used optimisation to find circuits to solve domain-specific objectives, fault tolerance requires costly physical and computational resources for logical operations. This project will take a machine learning-driven geometric approach to generate resource-optimised quantum circuits.

Quantum circuits with gates parametrised by angles tuned by optimisation methods have become the go-to method for finding applications of near-term, NISQ computing. Bottlenecks in the setting of these parameters have also emerged as characteristic features that are linked to the exponential size of Hilbert space, the same source of a promise of quantum advantage over classical computational methods. With early fault-tolerant devices becoming available, applying variational and other circuits come with a further set of challenges: gate operations are to be executed across multiple physical qubits chaperoned by adequate error detection and correction steps using classical computing methods. To achieve universal quantum computing this will require the incorporation of expensive operations such as magic state distillation. Optimisation choices in quantum computing applications will not only have to translate the requirements of the problem (whether it is in physics or logistics) into cost functions, computational constraints from expensive quantum technological ingredients (such as T-gate count) will also have a play a significant role.

In this proposal we will develop machine learning-based methods to describe the intrinsic geometry of quantum states for which variational quantum circuits provide coordinates. Constraints will be formulated as least path problems in the geometry of quantum states thus characterised. We will evaluate and optimise over the resource requirements for fault-tolerant implementations of task-specific circuits in this geometric reformulation. While the project will address benchmark problems drawn from many-body physics or chemistry, the focus will be on developing new methods for future quantum technologies.

41 - Strain-engineered nanodiamond quantum sensors

Dr Marcus Newton, Dr Makars Šiškins

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This project will develop multifunctional quantum sensors based on nitrogen-vacancy centres in diamond nanocrystals, capable of simultaneously detecting magnetic fields and mechanical pressure. Combining optically detected magnetic resonance with three-dimensional X-ray strain imaging, it will investigate how crystalline strain influences quantum spin properties and explore new approaches to high-sensitivity measurements.

Nitrogen-vacancy (NV) centres in diamond enable optical readout of quantum spin states at room temperature [1], while their sensitivity to magnetic fields, pressure, temperature, and lattice distortions makes them promising candidates for nanoscale sensing applications. However, internal crystalline strain can broaden spin resonances and degrade sensitivity, limiting measurement

accuracy and reproducibility [2]. Understanding these effects is therefore essential for developing practical NV-based quantum devices for variety of applications, ranging from NV-diamond scanning nano-magnetometry to navigation.

You will develop an optically detected magnetic resonance (ODMR) spectroscopy approach to characterise and utilise individual nanocrystals, measuring their magnetic response, resonance linewidths, and spin coherence. These measurements will be correlated with three-dimensional strain tensors obtained using Bragg coherent X-ray diffraction imaging (BCDI) [3], establishing a direct relationship between internal crystalline structure and spin-based sensing performance. The project will thus establish a method for using structural information to predict the ODMR response of individual nanodiamonds to external mechanical stress.

Using controlled mechanical loading and calibrated magnetic fields, you will develop methods to distinguish the contributions of intrinsic crystalline strain, externally applied pressure, and magnetic fields to the ODMR response [4]. The project goal is to demonstrate simultaneous pressure and magnetic field detection, and thus establish a new class of structurally calibrated, multifunctional quantum sensors with improved accuracy and reproducibility.

[1] Doherty et al., Physics Reports 528, 1-45 (2013).

[2] Sahnawaz Alam et al., Physical Review Applied 22, 024055 (2024).

[3] Hruszkewycz et al., APL Materials 5, 026105 (2017).

[4] Shelton et al., Review of Scientific Instruments 95, 083901 (2024).