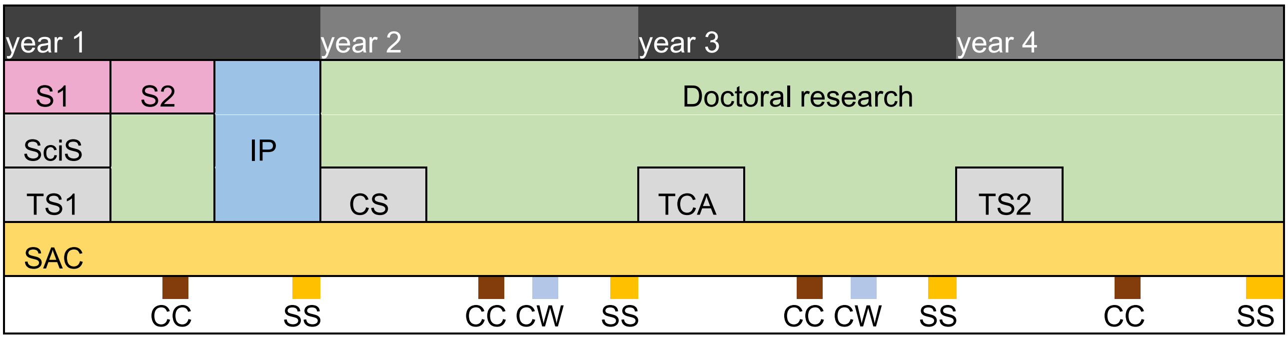
EPSRC Centre for Doctoral Training in Quantum Technology Engineering – 2026

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

2 - Spatiotemporal superconducting metasurfaces for next generation quantum technologies

Dr Sajjad Taravati

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Design and pioneer groundbreaking space-time-modulated superconducting metasurfaces to overcome critical quantum computing limitations. This experimental-theoretical PhD will develop dynamic metasurfaces that enable all-to-all qubit connectivity, significantly enhance coherence, and suppress decoherence in next-generation quantum processors, working at the frontier of quantum technologies, quantum computing and electromagnetic engineering.

Quantum computing promises to revolutionize technology but faces critical challenges in qubit connectivity, decoherence, and scalability. Conventional quantum architectures suffer from limited nearest-neighbour interactions and vulnerability to environmental noise, which restricts their computational potential. This groundbreaking PhD project will address these limitations by pioneering the development of space-time-varying superconducting metasurfaces—a transformative approach to quantum processor design.

You will research, design, and experimentally validate innovative Josephson-based metasurfaces that enable polychromatic qubit coupling and nonreciprocal quantum state transmission. Unlike traditional static systems, these dynamic metasurfaces will facilitate frequency-selective interactions across qubit arrays, effectively transforming limited connectivity into all-to-all qubit interactions while simultaneously suppressing crosstalk and decoherence. This research will leverage advanced electromagnetic simulation tools (CST Studio Suite, COMSOL Multiphysics), theoretical modelling of wave-matter interactions in active quantum systems, and experimental characterization using cryogenic measurement techniques.

The project offers a unique opportunity to work at the intersection of quantum physics, advanced electromagnetics, and nanofabrication technology. You will gain expertise in superconducting circuit design, cryogenic measurement techniques, and quantum system characterization while contributing to foundational knowledge for future quantum technologies (6G and beyond). This research has direct applications in enhancing quantum processing efficiency, enabling fault-tolerant quantum computation, and developing programmable quantum environments.

You will join a vibrant research team with strong industrial and academic collaborations, including potential partnerships with leading quantum technology hubs. The project emphasizes both theoretical innovation and practical implementation, with access to state-of-the-art nanofabrication facilities and quantum characterization laboratories.

3 - Space-time quantum metasurfaces for fault-tolerant, scalable quantum computing

Dr Sajjad Taravati

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This PhD project studies a new hardware paradigm for quantum computing, will theoretically design and experimentally realise a space-time quantum metasurface, a network of dynamically coupled, time-varying qubits. This architecture aims to enable real-time error mitigation and unlock scalable, fault-tolerant quantum processing through emergent collective phenomena.

The greatest obstacles to practical quantum computing are qubit errors and the daunting hardware complexity of scaling millions of qubits. This project proposes a radical solution: the space-time quantum metasurface. This novel architecture integrates a 2D array of superconducting qubits with local tuning elements, creating a surface where both spatial and temporal dimensions are actively engineered. By applying precise spatio-temporal modulations, we can generate a protected, high-dimensional Hilbert space where quantum information is encoded in the collective states of the surface, inherently resilient to local noise and errors.

Your research will address the core challenge of scalability and error correction by:

Developing theoretical models for the dynamics of large-scale coupled qubit arrays under spatio-temporal driving, predicting novel error-suppressing phases.

Designing and simulating the metasurface unit cell, combining a qubit with integrated control elements to enable local parameter modulation.

Fabricating prototype devices using our state-of-the-art nanolithography facilities and performing cryogenic microwave experiments to characterise collective dynamics, coherence, and real-time error mitigation capabilities.

This research is critical as it could fundamentally bypass the need for massive redundant qubit overhead, providing a more direct path to scalable fault-tolerant quantum processors. You will gain unparalleled expertise in quantum theory, advanced nanofabrication, and cryogenic microwave engineering, working within a vibrant team with strong industrial and academic collaborations in quantum technologies.

4 - Sparse variational quantum machine learning

Prof Thomas Blumensath, Dr Xiaohao Cai

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Variational quantum algorithms (VQAs) are hybrid classical-quantum machine learning methods designed to optimally utilize current quantum hardware, which remains limited by noise, limiting the number of computational operations. This project will adapt methods from sparse optimization to adapt the order and choice of the fundamental computations in VQAs.

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 the limitations, variational quantum algorithms have been proposed. These hybrid classical-quantum methods utilize the advantages of noisy quantum computers whilst using well established classical optimization methods to adapt a small number of quantum operations.

Unfortunately, if we restrict optimization to a small, fixed number of computational steps, the resulting quantum computation will remain fundamentally limited, significantly restricting the problems that can effectively be solved. To overcome this fundamental limitation of variational methods in quantum computation, you will explore and study a range of approaches to optimize the choice and order of the computational steps within the variational framework. Inspired by sparse optimization methods, you will extend the framework to the variational quantum machine learning algorithm.

Your work will explore the developed methods using simulated quantum computers to test the new methods on a range of applications from the quantum computing literature and contrast these to current state-of-the-art approaches.

This is a field with 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).

5 - Design and synthesis of photoresponsive organic spin-state switches

Dr George Williams, Dr Karl Michael Ziems

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Project no longer available.

6 - 2D Materials as quantum sensors

Dr Makars Šiškins

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Project no longer available.

7 - Quantum-enabled memristors for neural interface engineering

Prof Liudi Jiang, Dr Ruomeng Huang

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Shape the future of neuro-controlled medical devices using quantum memristors as artificial synapses. Gain hands-on experience in micro/nano-fabrication, quantum state characterisation, neuromorphic circuits, and biohybrid interfaces, developing the critical neuromorphic interfaces that transform healthcare technologies to think, learn, and move like natural human body.

Quantum-effect-driven memristors have emerged as a promising frontier in nanoscale device engineering, attracting significant interest across biomimetic and neuromorphic systems. Their distinctive quantum conductance behaviour arises from the formation and rupture of atomic-scale conductive filaments, producing quantized conductance states that emulate adaptive learning and sensory feedback processes found in biological neural networks. Harnessing these quantum phenomena could enable biohybrid neural interfaces for adaptive motor control and neurorehabilitation, offering a new pathway toward quantum-enabled healthcare solutions for individuals with impaired neurological functions caused by e.g. stroke or spinal cord injuries, ultimately facilitating intuitive limb control and restoring mobility.

Building on our recent progress in memristor-based neuromorphic research, this project aims to design, fabricate, and characterize quantum memristors as artificial synaptic devices. The focus will be on developing new memristive materials and device architectures that enable stable, controllable, and reproducible quantum conductance phenomena. Through engineering of device geometry, filament dynamics, and electrode interfaces, the project seeks to achieve modulation of quantum states for low-power, learning-capable operation. Experimental work will include micro/nanofabrication, quantum transport characterization, and synaptic plasticity emulation to demonstrate how engineered quantum effects can support adaptive neuromorphic behaviour.

Supervision will be provided by experts in quantum device engineering, memristive systems, and assistive neurotechnology. The successful candidate will gain interdisciplinary expertise spanning quantum materials, nanoscale device physics, neuromorphic engineering, and bioelectronic systems, preparing them to lead future advancements in quantum-enabled healthcare and human–machine integration.

8 - Reconfigurable origami phononic metamaterials for on-chip quantum acoustics

Dr Tanmoy Mukhopadhyay, Dr Susmita Naskar

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How about building programmable acoustic highways on a chip! Using origami-inspired phononic lattices, we will switch topological edge paths to route phonons between quantum devices with low loss and high isolation. The project includes multi-scale computational modelling and MEMS fabrication, leading to scalable quantum sensing, multiplexed readout, and adaptive routing.

Quantum technologies need reliable ways to move information on a chip without adding noise or loss. This project tackles that challenge by creating reconfigurable pathways for microscale elastic waves (phonons). We will use origami-inspired metamaterials whose fold state changes stiffness and bandgaps, so protected edge channels can be switched on or off to route signals between devices. The goal is low insertion loss, high isolation, and stable operation from room temperature to cryogenic conditions.

You will begin with multi-scale modelling to link fold kinematics to elastic properties and band structure. Using semi-analytical spectral elements and Bloch analysis, you will design lattices that support switchable topological transport. You will then fabricate MEMS prototypes in low-loss materials such as silicon nitride or aluminium nitride, add interdigitated transducers for excitation, and characterise performance with RF network analysis and laser Doppler vibrometry. Later stages integrate the routers with quantum acoustic elements, for example, surface acoustic wave cavities or spin defect platforms.

The outcome is a high-impact programmable acoustic component for modular quantum systems that enables scalable sensing, multiplexed readout, and adaptive routing, along with an open computational toolkit for further design and optimization.

Training covers elastic wave physics, nanofabrication, cryogenic measurement, and data-driven optimisation. You will have access to world-class facilities such as cleanrooms, RF labs, vibrometry, and cryostats, and work across mechanics, electronics, and quantum device groups. There are opportunities to engage with our established industry partners and collaborators in RF components, quantum networking, and cryogenic metrology.

10 - Quantum computing and optimisation for large-scale energy system planning under uncertainty

Dr Hongyu Zhang

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This project explores how quantum computing can transform energy system planning for a net-zero Europe. By integrating quantum and classical optimisation methods, it will address uncertainty in renewable generation and develop scalable algorithms for large-scale stochastic models, advancing both optimisation theory and practical tools for the energy transition.

Achieving a net-zero European energy system by 2050 requires effective long-term planning that accounts for uncertainty in renewable generation. Stochastic optimisation is widely used to support such planning under uncertainty, but these models often become computationally intractable as system complexity grows.

The rapid development of Noisy Intermediate-Scale Quantum (NISQ) devices offers new opportunities to develop quantum-based algorithms capable of tackling these large-scale challenges. However, significant gaps remain in understanding how quantum computing can be applied to real-world stochastic optimisation problems.

This project aims to: (1) harness the inherent uncertainty of quantum computing—arising from superposition, entanglement, and probabilistic measurement outcomes—for stochastic optimisation; (2) integrate Variational Quantum Algorithms (VQAs), such as the Quantum Approximate Optimisation Algorithm (QAOA), with classical decomposition algorithms to create a hybrid quantum–classical solution framework; and (3) apply these techniques to large-scale energy system planning models, benchmarking their performance against state-of-the-art classical solvers to assess potential quantum advantages.

By leveraging advances in both quantum computing and classical optimisation, the project will contribute to the development of hybrid quantum–classical paradigms for energy system modelling, supporting Europe's transition to a sustainable, low-carbon energy future.

The successful candidate will collaborate with experts in quantum computing, stochastic and computational optimisation, and energy systems. Opportunities include a research stay and an industry placement.

11 - Embodied quantum information flow for collective intelligence in robotic swarms

Dr Mohammad Soorati

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You will explore how principles of quantum information flow and probabilistic entanglement can enhance coordination, adaptability, and resilience in multi-robot systems. The project bridges quantum technologies and embodied swarm intelligence, aiming to create a new class of collective robotic systems that think and act beyond classical limits.

As part of this project, you will investigate how physical principles of quantum information transfer can be embedded into swarm robotic systems to achieve new forms of distributed intelligence. Unlike existing "quantum-inspired" algorithms that mimic quantum computation mathematically, this work explores how quantum communication, sensing, and probabilistic entanglement can underpin real swarm interactions in the physical world. The project will design a hybrid architecture combining classical control loops with a quantum-inspired information layer, implemented in simulation and on a testbed in indoor (small wheeled or dog-like legged robots) and outdoor environments (UAVs). By simulating partial entanglement using probabilistic coupling and adaptive communication channels, we will study how information correlation affects resilience, adaptability, and task completion in complex environments. Expected outcomes include (1) a theoretical framework for embodied quantum information flow in multi-robot systems, (2) an experimental demonstration of swarming behaviour (e.g., aggregation or flocking) emerging from probabilistic coupling, and (3) design principles for integrating quantum-inspired reasoning into physically deployed robots. This work moves beyond metaphor, proposing a new computational-physical synthesis of quantum and swarm intelligence that could inform future hybrid quantum-robotic systems. We expect you to have a strong background in mathematics and high proficiency in at least one programming language. Experience or prior knowledge in quantum technology is an advantage.

Relevant Papers:

[1] https://doi.org/10.1098/rsta.2024.0139
[2] https://doi.org/10.1016/j.robot.2023.104362
[3] https://doi.org/10.36227/techrxiv.24563293.v1

13 - Continuous-variable 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 quantum key distribution (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 project will be supervised by Dr Chao Xu, who is 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.

14 - Shadow tomography for in-context quantum machine learning

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The project brings ideas from the observation of "in-context learning" in large language models into quantum computing. The aim is to design transformer-inspired quantum circuit architectures that brings in-context choice of families of measurement operators for shadow tomography. This contributes to hybrid NISQ quantum-classical algorithms.

In quantum computing, encoding and extracting information from a quantum state that undergoes unitary evolution has been the principal bottleneck in demonstrating quantum advantage. The introduction of shadow tomography - randomised measurements to compute expectation values of observables to create a quantum channel to be inverted by a classical machine learning method - has provided evidence for the potential for sample-efficient data driven methods in hybrid quantum-classical near-term noisy intermediate-scale quantum (NISQ) algorithms. In parallel developments in classical machine learning, the widespread adoption of large language models (LLMs) has showcased the capacity of chatbots to adapt their outputs upon exposure to prompts of input-output pair patterns without having to alter the weights of the trained model, a phenomenon dubbed "in-context learning". This project aims to architect parameterised quantum circuits that take inspiration from attention-based transformers. The goal of this project would be to use such provide in-context guidance for actively choosing specific observable measurement families - local or entangled - for shadow tomography in machine learning applications.

15 - Symmetry-based control of quantum dynamics: from quantum sensing to magnetic resonance imaging

Prof Malcolm Levitt, Dr Christian Bengs, Dr Giuseppe Pileio

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Quantum spin systems may be controlled by the experimentalist using sequences of magnetic fields. In this project, you will design control fields for spin systems using recently developed symmetry theorems. The project involves a combination of theory, numerical simulation, and experiments performed locally and through international collaborations.

Quantum spin systems, such as those involved in quantum computing, quantum sensing or magnetic resonance imaging may be controlled by the experimentalist using sequences of external control fields. In this project, you will design control fields for spin systems by leveraging recently developed symmetry rules to generate robust Floquet-engineered dynamics. The resulting symmetry-based control protocols will be studied by theory and numerical simulations and applied to practical use cases such as nanoscale magnetometry with nitrogen-vacancy diamond sensors or imaging of materials across multiple length scales using magnetic resonance techniques.

This PhD project provides practical training in advanced quantum control methods, such as dynamic decoupling and composite pulse design, widely applied in several quantum devices and technologies. Together with strong international collaborators, we will explore techniques at the forefront of quantum technology development, such as nanoscale quantum sensing, complemented by local expertise in Electron Paramagnetic Resonance, Nuclear Magnetic Resonance, and Magnetic Resonance Imaging.

16 - High resolution sensing and computing for extreme conditions

Dr Bahareh Zaghari

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Aviation is entering a transformative era defined by emerging propulsion technologies, intelligence, and innovations such as quantum technologies. If you are driven to create high-resolution sensing technologies that enable smarter, data-informed decision-making in aviation, this project offers an opportunity to contribute to the next generation of intelligent aerospace systems.

Developing lightweight sensing capabilities for aerospace applications is a critical step toward achieving precise perception, navigation, and environmental awareness in next-generation flight systems. However, these sensors are inherently limited by signal-to-noise ratio (SNR) constraints, which are exacerbated by the miniaturisation and low-power requirements of airborne platforms. The proposed research aims to investigate how emerging quantum sensing and quantum-inspired signal processing techniques can overcome such limitations, enabling aircraft with significantly enhanced detection capabilities under constrained operating conditions.

Fundamental understanding of MEMS design principles, printing technologies, and their interaction with physical domains such as acoustics, vibration, and thermal fluctuations is required. Through access to our state-of-the-art MEMS printing facility, the project will enable the fabrication and characterisation of customised microscale sensor architectures. This interdisciplinary approach will enable the exploration of how nanoscale quantum phenomena can be engineered within microscale sensor platforms, advancing both the theoretical and practical foundations of quantum-enhanced sensing for aerospace systems.

17 - Integrating quantum and classical sensors for long-duration inertial navigation

Prof Blair Thornton, Prof Tim Freegarde

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Navigational drift is a major bottleneck for systems operating in GPS-denied underwater, space, and subterranean environments. This project advances navigation in such conditions by fusing fast, drift-prone classical inertial sensors with stable quantum measurements. You will develop fusion algorithms, explore sensor configurations, and validate performance through simulation and hardware-in-the-loop testing.

Classical inertial navigation systems (INS) combine gyroscopes and accelerometers to track position and orientation. However, errors such as gyro drift and accelerometer bias accumulate over time, degrading navigation performance. Quantum gyroscopes and accelerometers offer highly stable, low-drift measurements, but typically operate at slower update rates. Combining them with fast classical sensors could enable robust, long-duration navigation in GPS/GNSS-denied environments.

This project aims to develop algorithms and software for hybrid quantum–classical INS, correcting both gyro- and accelerometer-induced errors to produce reliable, low-drift navigation solutions. You will focus on sensor fusion and state estimation, integrating a single-axis quantum sensor with classical 3-axis MEMS or optical-based inertial sensors. You will investigate how the relative configuration (e.g. axis orientation) between slow, stable quantum measurements and high-rate classical data impacts navigational performance. The project will also explore multi-axis quantum setups to evaluate their potential for further constraining navigational drift. Research will include simulation, hardware-in-the-loop testing, and validation using real-world quantum and classical sensor data, with a particular focus on marine applications.

You will gain expertise in hybrid navigation, sensor fusion, and real-time state estimation, developing the ability to translate raw multi-sensor data into practical navigation outputs. The project will provide a strong foundation for future multi-axis quantum INS development and deepen your understanding of the trade-offs between quantum and classical sensors. You will work with industry advisors throughout the project, gaining insight into real-world challenges and priorities, building a professional network, and developing skills aligned with the needs of autonomous navigation technologies.

18 - On-chip quantum cryptography using two-dimensional materials

Dr Yasir Noori, Prof Frederic Gardes

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The objective of this PhD project is to develop an on-chip entangled photon source that can be integrated within a quantum cryptography system to enable ultimate security of digital communication based on the laws of quantum physics.

Existing techniques to encrypt data in our Internet networks are vulnerable to being easily broken by emerging quantum computers. IBM has recently released a 1000-qubit quantum computer and the challenge of finding alternative techniques to encrypt our data is becoming ever more urgent. Fortunately, quantum cryptography is a suitable solution to overcome this challenge.

However, quantum cryptography requires unique lasers that emit entangled photon pairs one at a time. In this PhD project, you will use two-dimensional (2D) materials as light sources for entangled photons for quantum cryptography applications. You will have hands-on experience in fabricating on-chip photonic structures in a cleanroom environment to improve the emission of entangled photons and engineer integrated waveguides to manipulate the polarisation of these photons, store them in memory devices and sense them at the receiver end.

During your PhD, you will design, simulate, fabricate and test various on-chip photonic structures to develop single photon sources. You will work within the Sustainable Electronic Technologies Group, a vibrant group of Academics, Research Fellows and PhD students at the School of Electronics and Computer Science. Your research will involve accessing a large set of experimental facilities that are hosted by the group, equipping you with expertise and skills for performing research and development within academic and industrial settings.

Your background is expected to be in Physics, Electronic Engineering, Chemistry, Materials Science or a related discipline.

19 - Algorithm development for molecular simulations on quantum computers

Dr Karl Michael Ziems

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Dive into the fascinating world of quantum computing by developing new algorithms for molecular simulations and running your algorithms on actual quantum hardware. Your interest and background shapes the project with a focus on quantum chemistry inspired method development, algorithms enabling ultrafast dynamics, or quantum error mitigation schemes.

Quantum computing is poised to be the next big emerging technology with the potential to fundamentally change our capabilities to model materials and thus impact discoveries in chemistry, physics, and biology. The necessity to completely re-think our algorithm design and adapt to new architecture operating around superposition and entanglement makes it a high-impact, interdisciplinary, and exciting field of study. Material simulation on quantum computers is not just a hot academic topic but is also addressed by start-ups, traditional industry, and policymakers, with a growing demand for talent from academia.

This project aims to develop quantum algorithms enabling molecular simulations on quantum computers. You will derive new methods, develop classic and quantum computing code together with senior researchers and your PI, simulate experiments and finally run your newly developed algorithms on actual quantum hardware. Depending on your background and interests, various project pathways can be explored, including electronic structure theory [1,2,3], quantum or semi-classical dynamics [4,5,6], efficient quantum simulations [7], (early) fault-tolerant algorithms based on time evolution, or quantum error mitigation schemes [1].

Candidates with a wide range of scientific backgrounds will be considered. Most important qualifications are coding experience (preferably python), solid mathematics for science background, and previous exposure to any kind of algorithm development/implementation. Optional experiences include method/algorithm development in 2nd quantization, quantum chemistry, quantum dynamics, or quantum information/computing.

An optional stay in Denmark is possible via collaboration with the Danish quantum project HQC2.

[1] doi.org/10.1039/D4SC05839A
[2] doi.org/10.1021/acs.jctc.3c01402
[3] doi.org/10.1021/acs.jctc.5c00893
[4] doi.org/10.1038/s41566-024-01436-9
[5] doi.org/10.3389/fchem.2022.942633
[6] doi.org/10.1088/1361-6455/acc4fa
[7] doi.org/10.1063/5.0278717

20 - Electrically driven quantum light sources from two-dimensional materials

Dr Soumya Sarkar, Dr Makars Šiškins

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This PhD project will develop reliable and cost-effective on-chip quantum light sources from foundry-compatible 2D materials. Using advanced nanofabrication and spectroscopy, the research will control strain, spin injection, and twist angles to create electrically driven, high-purity entangled single-photon emitter arrays that are crucial for photonic quantum information processing technologies.

Quantum entangled networks of single photons are key to photonic quantum information processing (QIP) technologies [1]. Developing reliable single-photon emitters (SPEs) in scalable materials is therefore important for on-chip quantum photonics. This PhD project aims to create cost-effective, reproducible arrays of SPEs based on atomically thin two-dimensional (2D) materials.

Layered 2D materials exhibit robust single-photon emission, yet electrically generating entangled photons coupled to spin-polarised carriers remains a major hurdle [2]. Building on our recent advances in fabricating ultraclean 2D materials and metal contacts for spin injection [3], and controlled defect engineering [4], the project will investigate how surface adsorbates, strain, and interlayer twist angle influence electroluminescence from SPEs. The long-term technological goal is to find cost- and energy-effective methods to produce and control quantum emitters on chip.

The student will fabricate optoelectronic devices in the Southampton Nanofabrication Centre, one of UK's leading university cleanrooms, and will characterise and assess device performance within the Sustainable Electronic Technologies and Quantum, Light and Matter research groups. Research visits to the National Physical Laboratory and the University of Cambridge for spectroscopic characterisation will be encouraged.

We welcome applications from students with backgrounds in microelectronics, materials science, solid-state physics, or electrical engineering. We strongly encourage applications from underrepresented groups and those seeking a supportive and collaborative research environment.

[1] Nature Reviews Materials 3.5 (2018): 38. https://www.nature.com/articles/s41578-018-0008-9
[2] arXiv:2509.08259 (2025). https://www.arxiv.org/abs/2509.08259
[3] Nature Electronics (2024). https://www.nature.com/articles/s41928-024-01330-w
[4] Nano Letters 24.1 (2023): 43-50. https://pubs.acs.org/doi/abs/10.1021/acs.nanolett.3c03113

21 - Engineering perfect superconducting qubits

Dr Dikai Guan, Dr Bruce Ou

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Superconducting qubits power today's quantum computers, yet their fragile performance is limited by tiny material flaws. This project engineers the atomic-scale microstructure of Josephson junctions—optimising grain orientation, stress, and interfaces—for longer-lived, reproducible qubits. Students will combine advanced thin-film growth, microscopy, and cryogenic testing to engineer "perfect" quantum hardware.

Superconducting qubits underpin today's most advanced quantum computers, yet their performance is limited by materials imperfections at the heart of their nonlinear element — the Josephson junction (JJ). Presently, most transmon qubits use Al/AlOx/Al junctions fabricated by double-angle shadow evaporation [https://www.nature.com/articles/s41598-023-31003-1]. While effective at the nanoscale, this approach faces critical challenges of qubit lifetime, inhomogeneous broadening from fabrication and precise interface control at the nanoscale.

The UK National Quantum Strategy highlights materials and fabrication science as critical to achieving reproducible, manufacturable qubits. There is an urgent need to bring a materials-engineering approach — grain orientation, stress relaxation, micro-texture, interface bonding — to the superconducting JJ stack.

This project aims to systematically engineer and optimise the multilayer materials microstructure of Josephson junctions for superconducting qubits, achieving low lifetime variation, controlled texture, reproducible critical current, and compatibility with scalable manufacturing processes.

Research objectives include:

I. Thin Film Nanostructure Control: Study Al, Nb, and NbN thin films: deposition rate, substrate temperature, and post-deposition annealing to tune grain size, orientation, nanoscale texture, and residual stress.

II. Barrier and Interface Engineering: Compare native thermal AlOx vs plasma vs Atomic Layer Deposition (ALD) Al_2O_3 and explore epitaxial oxide barriers; characterise interfacial bonding, stoichiometry, and roughness.

III. Device-Level Validation: Fabricate test JJ arrays, resonators, and transmons; correlate qubit metrics (T_1, T_2, Ic spread) with measured microstructure and interface chemistry.

IV. Design Rules and Process Map: Build deposition–microstructure–performance correlations to guide reproducible, scalable JJ fabrication.

22 - Quantum-enhanced mid-IR spectroscopy for high-precision sensing

Prof Senthil Murugan Ganapathy, Dr Katrina Morgan, Prof Liudi Jiang

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This project aims to revolutionise diagnostics with a quantum-enhanced mid-IR sensing platform for quick, easy and non-invasive detection of pollutants and disease markers. By integrating advanced materials, it will enable ultra-sensitive, real-time environmental and health monitoring, offering a powerful tool for early disease detection and improved pollutant tracking.

Imagine a world where detecting pollutants or diagnosing diseases is as simple as a quick, non-invasive test. This project aims to make that vision a reality by developing a quantum-enhanced mid-IR sensing platform with the power to transform environmental monitoring and biomedical diagnostics. The technology will allow for the real-time detection of low-concentration pollutants, such as volatile organic compounds (VOCs), and enable rapid, precise screening for disease biomarkers, like cancer, at ultra-low levels.

To achieve this, we will integrate Photonic Integrated Circuits (PICs) with Transition Metal Dichalcogenides (TMDCs) and advanced metasurfaces. Known for their tunable optical properties, TMDCs will boost light-matter interactions, while metasurfaces amplify specific resonances to increase mid-IR detection sensitivity. These quantum sensors, leveraging phenomena like coherence and superposition, will detect subtle thermal changes from mid-IR absorption. This innovative approach promises ultra-sensitive, compact, and scalable molecular fingerprinting solutions, setting new standards for environmental and health diagnostics.

Additionally, this project will be highly multidisciplinary, and the student will be strongly supported by a supervisory team with expertise across three Schools: Optoelectronics Research Centre, Electronics and Computer Science, and Engineering.

23 - Resource-efficient quantum simulation of chemistry with quantum computers

Prof Dimitrios Angelakis

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This project involves the development of resource-efficient quantum algorithms for molecular simulation and their implementation in quantum hardware in the cloud or directly with experimental collaborators. Beyond the basic science, applications of the quantum solutions developed in transformative technologies like clean energy catalysts and advanced batteries will also be sought.

One of the frontiers of quantum computing is to create cutting-edge algorithms to simulate molecular behaviour in quantum computers.

The research direction is to be customized to the participant's background, with potential specializations in:

- Designing efficient quantum algorithmic ansatze for variational quantum algorithms for simulating molecular and material systems in ground and excited states.
- Preparing for the logical qubit and fault tolerant era, improving circuit efficiency, runtimes, and error correction schemes.
- Developing software toolkits and middleware for a wide range of quantum computing applications, including device emulators.

The research will involve both analytical ‘pen and paper’ studies as well as numerical simulations; it is also expected to use prototype cloud quantum computers or work with experimental collaborators to implement the solutions developed in quantum hardware.

This is your opportunity to translate quantum physics into tangible solutions for the world's most pressing challenges. We are seeking curious minds with a foundation in the physical, engineering or chemical sciences, complemented by strong mathematical and programming intuition. Earlier exposure to quantum computing algorithm or programming courses will be a plus. By joining this pursuit, you will be directly shaping the tools that will make quantum computing a transformative force for industry and society.

The project will include funded visits to collaborating groups in Singapore and Greece, as well as leading theoretical and experimental teams in the US, Asia and the EU.

Computing Electronic Correlation Energies using Linear Depth Quantum Circuits Summary at https://www.quantumlah.org/about/highlight/2024-03-algorithm-quantum-chemistry

24 - Qubit efficient quantum optimization and applications to industrial problems

Prof Dimitrios Angelakis

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The main challenge in the adoption of quantum computing is the gap between algorithmic requirements and current quantum hardware. In this project, you will codevelop novel qubit efficient quantum approaches and techniques that can be used to solve optimization problems and apply them to logistics, pharma, transport, or manufacturing industries.

The research will have both fundamental and applied science components. The former concerns the development, and benchmarking of the algorithms developed in classical emulators, cloud quantum computers or directly in collaboration with collaborating experimental teams; the latter will focus on translating the findings into quantum software applications

Combinatorial binary optimization problems are known to be hard for classical computers. Quantum solutions based on quantum digital, annealing or variational algorithms promise to solve such problems faster and more efficiently. However, the requirements in the number of physical qubits needed to implement these algorithms are still beyond the reach of any near-term quantum processors.

Here you will be working on novel, physics inspired quantum algorithms, allowing for much larger problems to be tackled with near term quantum processors. These will be applied to a range of industrial use cases from optimizing of shipping routes, to financial optimization, aviation and energy management.

We are seeking curious minds with a solid foundation in the physical, engineering or mathematical sciences. Previous exposure to quantum algorithm or programming courses will be a plus but not necessary.

The project will include funded visits to collaborating groups in the Centre for Quantum Technologies Singapore, Greece, as well as leading theoretical and experimental teams in the US, Asia and the EU.

- Qubit efficient quantum algorithms for the vehicle routing problem on quantum computers of the NISQ era, Summary at https://www.quantumlah.org/about/highlight/2024-06-vehicle-routing-efficient-qubits
- Exponential Qubit Reduction in Optimization for Financial Transaction Settlement.

Summary at https://www.cqt.sg/highlight/2024-10-algorithm-financial-transactions-qubits/

25 - Quantum computing for computational fluid dynamics and applications

Prof Dimitrios Angelakis

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This project explores the emerging field of Quantum Computational Fluid Dynamics (QCFD), combining quantum computing and CFD to simulate nonlinear systems such as turbulence and shockwaves. You will be working and implementing quantum variational algorithms in quantum computers that bridge fundamental physics with quantum algorithmic innovation for next-generation fluid simulation.

The coming decade promises a transformative intersection between quantum computing and computational fluid dynamics (CFD). CFD allows the understanding of phenomena like turbulence and pattern formation with numerous applications in aerodynamics, climate modelling, battery design and many other areas.

Quantum computational fluid dynamics (QCFD) is a novel area that leverages quantum superposition, entanglement, and variational optimization to establish a quantum-native framework for simulating fluid dynamics, rethinking how nonlinear evolution can be expressed, approximated, and stabilized within quantum architectures.

This project will investigate how quantum variational methods can be used to simulate classical and quantum nonlinear systems, bridging fundamental physics with quantum algorithmic innovation in the field of CFD. The research will involve both analytical 'pen and paper' studies as well as numerical simulations; it is also expected that prototype cloud quantum computers will be used for testing of the algorithms.

Strong candidates from physics, applied mathematics, engineering, or computer science are encouraged to apply. Prior experience in CFD, quantum computing, and/or PDE simulations will be a plus. A background in quantum mechanics, CFD or numerical modelling will be valuable.

The project will include funded visits to collaborating groups in Greece, Germany, Austria and Singapore, as well as leading theoretical and experimental teams in the US and Asia

- Efficient estimation and sequential optimization of cost functions in variational quantum algorithms. Research summary https://www.cqt.sg/highlight/2025-07-quantum-simulation-fluid-dynamics/
- QCFD in Ion Quantum Computers https://www.aqt.eu/solution/simulating-turbulent-flow-aerospace-prepares-for-quantum-computing/

27 - Nitrogen-vacancy centres as nuclear polarization injectors for spin-based quantum sensing

Dr Christian Bengs, Prof Malcolm Levitt

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Spin-based quantum sensing converts tiny quantum signals into detectable responses by aligning microscopic spins, for example in diamond nitrogen-vacancy centres. Can this alignment be exploited to amplify responses in other systems? This project addresses that question—theoretically and experimentally—via novel transfer protocols utilising periodic control fields and Floquet-engineering methods.

Optically active colour centres, such as diamond nitrogen-vacancy (NV) centres, have emerged as promising quantum devices for quantum computation and quantum sensing applications, as well as efficient sources of spin hyperpolarization. While control via external fields is common to many quantum platforms, NV diamonds are uniquely flexible in that their operational mode can be dynamically reconfigured through optical and magnetic control, or any combination of these.

In this project, you will develop novel nuclear hyperpolarization protocols (Dynamic Nuclear Polarization, DNP) exploiting the capabilities of NV diamond centres as versatile polarization injectors, with practical applications in spin-based quantum sensing. Unlike typical DNP techniques that require strong external magnetic fields, optical spin injection with NV centres operates effectively without them. Moreover, the periodic control fields (Floquet protocols) used for DNP can be readily adapted to facilitate quantum sensing operations.

The project will encompass engineering, experimental, and theoretical components, tailored to the candidate's interests. You will gain valuable experience and expertise in optical and radio-frequency quantum control strategies, such as Floquet-engineering and Dynamic Decoupling, common to a large variety of quantum technologies.

Candidates from diverse scientific backgrounds are encouraged to apply. A problem-solving orientation and the ability to work independently are valued. Solid mathematical skills, experience in optics or techniques related to magnetic resonance, and a background in quantum physics would be advantageous.

Some Background:

- https://doi.org/10.1038/s41467-022-32907-8
- https://arxiv.org/abs/2410.09028
- https://doi.org/10.1063/5.0252743

28 - Quantum communications enabled by hollow core optical fibres

Prof Radan Slavik, Prof Francesco Poletti

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Optical fibres can transport telecom signals over long distances. However, qubits or other quantum states such as multiple-entangled-photos are often generated at wavelengths where current optical fibres are unsuitable. There is an emerging class of new optical fibres pioneered in Southampton that could revolutionize transport of quantum signals and states.

Hollow-core fibres are an emerging class of optical fibres where light is guided in a hole surrounded by a special glass structure. This allows light guidance through a core that has lower refractive index than the surrounding material, enabling the core to be formed by empty space. This is not possible in traditional fibres that guide light based on total internal reflection.

Recently, design and manufacturing of hollow-core fibres reached such levels of maturity that they can transport light with lower attenuation than standard optical fibres, including at wavelengths where many quantum sources (e.g., quantum dots) and low-cost detectors (Silicon Avalanche Photodetectors) operate. This enables many designs of quantum memories and repeaters capable of transporting quantum signals over large (e.g. inter-country or inter-continental) distances.

In this project we will exploit hollow-core optical fibres that can guide quantum signals at wavelengths where quantum sources and detectors operate (700-1000 nm) simultaneously with classical telecom signals that typically exploit longer wavelengths (1530-1610 nm), representing a 'universal' (supporting quantum, classical, or both) transmission medium.

The Optoelectronics Research Centre (ORC) at the University of Southampton is the world-leader in the design and manufacturing of these novel fibres (led by Prof. F. Poletti, a co-supervisor of this project). We will work with leading quantum physics and technology groups, e.g., at the University of Vienna, to demonstrate a range of new approaches enabled by these novel hollow-core fibres.

The project is also supported by Microsoft Azure which acquired the ORC spin off that manufactures hollow-core fibres.

29 - Quantum levitated mechanics for GPS-denied autonomous underwater vehicle navigation

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Project no longer available.

30 - Advanced lasers for quantum enhanced microscopy

Dr Lin Xu, Prof Sumeet Mahajan

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This PhD project aims to develop advanced entangled photon sources for quantum enhanced microscopy, enabling high-resolution, label-free, deep-tissue imaging. By combining mid-infrared probing with near-infrared detection, the project leverages quantum physics to overcome limitations of classical microscopy in biomedical research.

Quantum enhanced microscopy offers improved resolution, sensitivity, and speed compared to classical optical imaging, making it a promising tool for biomedical applications. This project aims to develop advanced entangled photon sources to support this emerging imaging method.

Optical microscopy is widely used in biological research for visualizing tissues in their natural state. However, most current systems rely on visible or near-infrared light, which limits their ability to image deeply or without labels. In contrast, the mid-infrared spectrum contains distinct molecular vibrational and rotational signatures that can be used as a natural contrast mechanism, enabling label-free imaging. This is particularly useful for observing living tissues without altering them. A major limitation of mid-infrared imaging, however, is the lack of efficient detectors.

Quantum enhanced microscopy can address this challenge. It uses pairs of entangled photons at different wavelengths: one in the mid-infrared to probe the sample, and the other in the near-infrared to carry the image information. Only the near-infrared photon is detected, taking advantage of existing high-performance detectors, while still capturing the benefits of mid-infrared imaging. This approach enables deeper tissue penetration and molecular-specific contrast without the need for direct detection of mid-infrared light.

The project will focus on developing laser systems capable of generating these entangled photons efficiently for practical use in microscopy.

31 - Quantum optimal control for long-lived NMR methods

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NMR on Long-Lived States (LLS) and Long-Lived Coherences (LLC) offers an approach for extending the lifetime for entangled nuclear spin states. A new theoretical model will be developed, with the aim to predict and optimise experimental lifetimes, aided by quantum optimal control methods.

CH2 and CF2 moieties, frequently occurring in simple organic molecules and amino acids, contain spin-½ pairs that can often form entangled states. LLS are spin singlet states; LLC are a special class of zero-quantum coherences, superpositions of singlet and triplet states. These can exhibit longer lifetimes than the individual spin ½ nuclei even by an order of magnitude, and can also be created on spin chains, under favourable conditions.

The prediction of their lifetimes is complex and often unreliable, using analytical models. This project will address it via a comprehensive representation of the molecular system, its relaxation pathways and dynamics, with numerical calculation in the Liouville space. This new model will be the basis for quantum optimal control (QOC) calculations, to design novel experiments for more efficient excitation of these entangled states, and to improve their experimental “spin memory”. Longer spin memory is crucial for many applications: (i) the creation of more complex correlated states involving other nuclei, (ii) for detecting even minute variations of the spin environment at atomic level, and (iii) for quantum computing via nuclear spins, as qubits. The project will produce a “toolbox” with new theory and new QOC-NMR methods for the exploitation of LLS/LLC in a variety of systems.

International collaborators will provide specialised samples, complementary expertise, and access to facilities, for hyperpolarization and high field NMR applications on alpha-synuclein, a well-studied intrinsically disordered protein.

The project is well suited for candidates with a good theoretical background and coding skills.

32 - Quantum optimal control for symmetry-based NMR sequences

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Symmetry is a powerful tool for selection of NMR interaction and creation of correlated spin states. Many exquisite experiments are based on analytical calculation via average Hamiltonian or Floquet theory. A step change in efficiency and robustness may be obtained by combining Hamiltonian symmetry, periodicity and quantum optimal control.

Symmetry-based sequences have long been used in NMR, especially on solid materials undergoing magic-angle spinning (MAS NMR), for the control of the average Hamiltonian and the selection of which spin interaction should be recoupled. These, in turn, can be used to create multi-spin correlated states, provide filtering of specific parameters and answer structural questions about the materials being investigated. Similar approaches have more recently been demonstrated to be useful also for liquid state NMR. Methods have often a moderate tolerance to experimental imperfections and mis-set of parameters and experimental conditions, and the full analytical approach struggles to be useful when the first order Hamiltonian does not provide a faithful description of the system.

This work will aim to use full numerical calculations, as well as guiding symmetry and periodicity principles, for the development of quantum optimal control (QOC) symmetry-inspired sequences. The utilization of symmetry and periodicity will guide the QOC optimization, with an expectation of massive time reduction, and the possibility to tackle more demanding spin systems or nuclei with spin larger than 1/2. Attention will be also on pattern recognition on the new QOC methods, which may potentially lead to the discovery of possibly new classes of symmetry-based sequences, with a semi-analytical description of their operation. Possible industrial sponsorship is under consideration.

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

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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, sensing, and 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.

36 - MEMS/NEMS-integrated ultralow stand-by power quantum circuits

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Novel Micro/Nano-Electro-Mechanical Systems (MEMS/NEMS) switches will be developed to significantly reduce overall power consumption of integrated quantum circuits. The MEMS/NEMS switches will be optimised for low temperature operation and will be integrated with existing quantum circuits to evaluate the energy efficiency of the systems.

This project aims to develop RF/DC MEMS/NEMS switches to work as power gating devices for quantum circuits at low temperatures. MEMS/NEMS switches are known to have considerable advantages over conventional semiconductor switches like Field-Effect-Transistors (FETs) as power gating devices thanks to their ultralow current at the off-state due to mechanical separation. The design of the MEMS/NEMS switches will be optimised for their operation at low temperatures, and the devices will be prototyped by using cleanroom facilities in Southampton.

The project also includes the study of contact materials suitable for low temperature operation of MEMS/NEMS switches. The optimised MEMS/NEMS switches will be integrated into existing quantum circuits such as quantum computers or quantum sensors, and then the improvement of the power consumption for the overall quantum systems will be evaluated.

The supervisory team has strong links with research institutions in Japan and will seek further collaboration opportunities during the project, potentially with industries. Successful development of low temperature MEMS/NEMS switches will make a significant contribution to reduce power consumption of quantum circuits and computers and thus make quantum technology more accessible and environmentally friendly.

38 - Nano-opto-electro-mechanical (NOEM) tunable SiC entangled photon source

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A novel nano-opto-electro-mechanical (NOEM) tunable SiC entangled photon source will be developed for future on-chip quantum photonic circuits technology. Design optimisation, device fabrication and single photon measurements are planned to prove the working principle and tunability of the device.

The aim of this project is to establish a solid technological platform to generate an entangled pair of photons in a controlled manner for future advanced quantum information and communication technology. Opto-Electro-Mechanical interactions are employed to control the timing of single photon emissions and to regulate the level of the entanglement of photons coherently generated from two adjacent photon sources. Silicon carbide is chosen as a platform material for future integrated on-chip reconfigurable quantum information and communication circuits. At the end of the project, a novel tunable entangled photon generator will be demonstrated on a silicon-based substrate. The outcome will make significant contribution not only to inspiring discrete photon generation device research but also to opening up a path to on-chip photon-source-integrated quantum circuit technologies. This is a collaborative project between the University of Southampton and the Institute of Science Tokyo.

39 - Quantum reservoir computing via nano-opto-electro-mechanical (NOEM) coupled quantum oscillators

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A novel Quantum Reservoir Computing hardware using Nano-Opto-Electro-Mechanical (NOEM) coupled quantum oscillators is proposed to demonstrate quantum neural networks where quantum information is used as data in machine learning algorithms. The project could either follow a modelling approach or a device fabrication route.

The aim of the project is to develop a novel platform technology for quantum reservoir computing, a promising approach for quantum neural networks where quantum information can be used as data in machine learning algorithms. We propose Nano-opto-electro-mechanical (NOEM) coupled oscillators as a potential candidate for quantum coupled oscillators and to create models for such systems. Subject to the expertise and interest of a candidate, two approaches are possible. One is to develop mathematical or numerical models of NOEM-based quantum reservoir computing, which is more suitable for Computer Science students. Another approach is to develop NOEM-coupled oscillators that can get into the quantum regime and to demonstrate quantum coupled oscillators experimentally, which is more suitable for Physics or Electronic Engineering students.

40 - Quantum nano-optical metadevices

Dr Giorgio Adamo, Prof Kevin Macdonald

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Controlling nanoscale light−matter interactions will be foundational for advanced quantum nanophotonic devices, including optically/electrically pumped light sources, switches, modulators, and photodetectors. In this project we will engineer coupling of quantum emitters (e.g. quantum dots, atomic defects in 2D materials, Moiré superlattices) to metasurfaces for future monolithic chips with indistinguishable emitters.

Engineering light−matter interactions will be foundational for advanced quantum nanophotonic devices. A motivation that drives this research field is the industry demand for monolithic integration of photonics and optoelectronics to achieve all-optical interconnects, photonic logic gates, and quantum networks.

This next generation photonic systems requires advances that allow, for example, the precise placement of quantum emitters - e.g. quantum dots, atomic defects in 2D materials, Moiré superlattices - into photonic cavities.

During the project you will explore metasurfaces as optical cavities to study phenomena like coupling multiple quantum emitters for indistinguishability or fostering strong or ultrastrong light−matter interactions for tuning nonlinear interactions. You will do it through a blend of experimental activities, theoretical analysis and numerical modelling.

You will join the Optoelectronics Research Centre, 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 have the opportunity to engage in collaborations, research meetings and to 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.

As you progress through the project, you will gain highly transferable skills in cleanroom nanofabrication, photonic and optoelectronic materials, device design, manufacturing and characterisation, numerical simulations. You will also explore new concepts and play an active role in shaping innovative ideas. This experience will prepare you for opportunities in academia and industry.

For further information see: http://www.southampton.ac.uk/study/postgraduate-research/photonics-optoelectronics.

42 - Optimising optical microresonators for quantum technology applications

Dr Peter Horak, Dr William Hughes

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Join our dynamic research team to explore cutting-edge microscale optical resonator designs for quantum technologies. This PhD will combine photonics, quantum physics, and computational modelling to design devices that enhance the interaction between matter and light on the quantum level to unlock new capabilities in quantum computing, communication, and sensing.

Optical microresonators - devices that trap photons between microscopic mirrors - are key to enhancing the interaction between light and quantum emitters, such as atoms, ions, or nonlinear crystals. They are considered a crucial technology for future more efficient and faster quantum interactions. Traditionally, these mirrors have spherical shapes; however, we have recently shown that if the shape of the mirrors is optimised, the trapped photons can create strong interference patterns that lead to a dramatic increase of their localisation in space, vastly beyond what is currently achievable.

In this project, you will develop and perform numerical simulations to take this powerful approach further and investigate its full potential by optimising these novel resonator designs, tailoring the spatial shape of photons for a range of quantum applications such as:

- Trapped ion chains for quantum computing.
- Neutral atom arrays for quantum simulation.
- Entangled photon sources for quantum communication.
- Micro-optomechanical systems for quantum sensing.
- Single-photon wavelength conversion for hybrid quantum networks.

If you are interested in photonics, quantum technology, and computer-based modelling (potentially including machine learning techniques), you would be highly suitable for this project. You will benefit from our world-leading expertise and a collaborative, supportive research environment. You will also have the opportunity to work in close collaboration with experimental groups within the University of Southampton and the QCi3 National Quantum Technology Hub (https://qci3.org/).

43 - Nanoscale quantum optoelectronic platforms for next-generation neuromorphic systems

Prof Dimitra Georgiadou

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This PhD explores quantum dots and perovskite nanocrystals to create nanoscale optoelectronic devices that mimic functionalities of the biological eye. You will design and integrate quantum-enhanced photonic systems for energy-efficient, high-speed neuromorphic computing and sensing, advancing sustainable and intelligent quantum technologies.

This PhD project focuses on designing and fabricating of high-performance nanoscale systems using quantum dots and perovskite nanocrystals as active optoelectronic materials.

You will investigate light–matter interactions at the nanoscale, implement nanopatterning and thin-film deposition techniques, and develop integrated photonic architectures for in-memory computing and brain-inspired device functionalities. The work will involve optoelectronic device fabrication and characterisation, characterisation of excitonic and charge transport properties, and integration with photonic sources to realise high-speed, energy-efficient optoelectronic neural networks.

You will join the multi-disciplinary Flexible Nanoelectronics Lab (www.flexiblenanoelectronics.com), work at the world-class labs of the Optoelectronics Research Centre and will have the opportunity to build connections with UK and European research partners by being affiliated also with the UK Multidisciplinary Centre for Neuromorphic Computing (https://www.uk-neuromorphic-centre.net/). Additionally, you will be encouraged to attend major conferences, sharing your work and networking with leading experts.

The project provides hands-on training in quantum materials deposition in films, device nanofabrication, optoelectronic device engineering, and photonic system integration, with access to advanced cleanroom facilities and state-of-the-art optical characterisation tools. Successful candidates will gain interdisciplinary skills spanning materials science, nanotechnology, photonics, and neuromorphic computing, positioning them for careers at the forefront of quantum-enabled technologies and AI hardware.

44 - 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 for the scalable manufacture of superconducting, photonic and atom/ion trap quantum systems. These components are the kernel of 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 looking to do computer modelling and have the required skills, the project can also be adjusted for 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 micro-fabrication, you would be highly suitable for this project. You will benefit from our world-leading expertise in these fields and enjoy working in a 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

45 - Nonlinear photonics for quantum technologies

Prof Corin Gawith, Prof James Gates

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Nonlinear parametric photonics creates an interface between light and the atoms/ions and detectors used in quantum systems. This project combines novel fabrication approaches for nonlinear waveguides with established commercial materials to expand their operation into the ultra-violet and mid-infrared wavelength regions for use in practical quantum systems.

In this project you will have the opportunity to design, fabricate and test parametric devices and integrate these into larger quantum systems through collaboration with our interdisciplinary team of students, postdocs, senior researchers, and industrial partners. If you are looking to do computer modelling and have the required skills, the project can also be adjusted for this. Areas of research include:

- Development of blue/UV-generating parametric waveguides for the control of atom and ion trap systems. These will convert blue and UV light from infrared laser sources.
- Investigating nonlinear waveguides for single/paired photon generation, including the use of coupled cavities to enhance efficiency. Applying this to develop prototype systems that can be used in photonic quantum computing.
- Developing up-conversion devices to enable single photon imaging in the mid-infrared for environmental monitoring and life-science imaging.

Each area involves design, fabrication, metrology, and optical testing, and work with our partners to apply these devices to quantum systems. This project aligns closely with our research in the EPSRC Quantum Technology Hub for Sensing, Imaging and Timing (QuSIT).

If you are interested in quantum technologies, photonics, nonlinear optics, or micro-fabrication you would be highly suitable for this project. Our team offers a supportive environment for training and research, world-leading facilities and expertise, and extensive opportunities to collaborate with our industrial partners and academic researchers across the UK National Quantum Technology Programme.

Find out more about our Optical Engineering and Quantum Photonics research group at: https://www.southampton.ac.uk/research/institutes-centres/optical-engineering-quantum-photonics-group

46 - Low-loss photonics for quantum networks

Prof James Gates, Prof Corin Gawith

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In the world of Quantum Technology every photon is precious. This project will create new ultra-low-loss optical components that will lead to advanced quantum memories, switchable delays, and the creation of large, entangled quantum states.

We welcome applications for a PhD student to join our interdisciplinary team of students, postdocs, and senior researchers developing systems for quantum technologies.

Join us to develop core components for interfacing quantum computers and networks using Southampton's state-of-the-art fabrication facilities. Unlike optical telecoms, where amplifiers compensate losses, in the world of Quantum Technology, every photon is precious. This project will create new ultra-low-loss optical components, including quantum memories and switchable delay lines, with the goal of reducing system-wide losses and allowing us to create large, entangled quantum states.

This project will develop various technical approaches, including an all-optical fibre-based system and integrated atomic vapour devices. You will have the opportunity to design, fabricate, and test these photonic systems and to work with experimentalists to validate their use in larger quantum systems. If you are interested in a PhD looking to do computer modelling and have the required skills, the project can also be adjusted for this.

If you are interested in quantum technologies, photonics, nonlinear optics, or micro-fabrication you would be highly suitable for this project. Our team offers a supportive environment for training and research, world-leading facilities and expertise, and extensive opportunities to collaborate with our industrial partners and academic researchers across the UK National Quantum Technology Programme.

Find out more about our Optical Engineering and Quantum Photonics research group at: https://www.southampton.ac.uk/research/institutes-centres/optical-engineering-quantum-photonics-group

49 - Quantum reservoir computing for photonic and quantum materials modelling

Prof Marian Florescu

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Quantum physics and artificial intelligence are converging to redefine how light–matter systems are explored and engineered. This project will develop Quantum Reservoir Computing as a new theoretical and computational framework, exploiting the dynamics of quantum systems to achieve efficient learning, prediction, and inverse design of photonic and quantum materials.

The research will advance Quantum Reservoir Computing (QRC) as a powerful computational paradigm for modelling and designing complex quantum and photonic systems. Rather than relying on data-intensive or brute-force numerical methods, QRC uses the intrinsic dynamics of quantum systems, including coherence, memory, and nonlinearity, as natural resources for information processing and learning.

The project will focus on rigorous theoretical modelling and large-scale numerical simulations that reveal how quantum dynamics can perform tasks analogous to neural networks.

- The first stage will establish physically interpretable algorithms capable of capturing strongly correlated and open quantum systems.
- The second stage will explore quantum neuromorphic architectures in silicon, using computational models of superconducting, photonic, and hybrid reservoirs to identify routes to energy-efficient learning.
- The final stage will apply these frameworks to the inverse design of photonic and quantum structures, demonstrating how QRC can accelerate discovery and optimisation entirely within a computational setting.

You will be based at the Optoelectronics Research Centre, a world-leading photonics institute with over 90 laboratories and around 200 researchers working across all areas of optics and photonics. Within this project you will have opportunities to develop advanced skills in high-performance computing, numerical simulation, machine learning, and quantum theory, with access to large HPC/GPU clusters.

53 - Excitons in hybrid semiconductor quantum dots for tunable emitters

Dr Silvia Motti

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Perovskite quantum dots show great potential for tunable light emitters. They are also promising candidates for single-photon emitters, which are key building blocks for quantum communication networks. This project will study the fundamental photophysics behind photon emission of perovskite semiconductor nanoparticles and develop new platforms for quantum technologies.

Perovskite nanocrystals can be fabricated in colloidal suspensions and offer a wide range of colour tunability with high radiative efficiency, making them excellent candidates for light emission applications. Nanoparticles present quantum confinement and provide another degree of tunability. In addition to classical light emitters, these nanocrystals act as quantum dots and present promising potential for single-photon emitters, which are key building blocks for quantum communications. Perovskite quantum dots offer high radiative efficiency, defect tolerance, high purity at room temperature, and low-cost fabrication. Furthermore, mixed crystal compositions allow us to tune the emission wavelengths to match specific transitions of quantum memories and other components. Further development is required to improve stability, minimise blinking, and understand and optimise the factors that regulate single photon purity and indistinguishability. The chemical composition, shape anisotropy, and the choice of capping ligands must be optimised to improve efficiency, stability, radiative rates, and quantum coherence.

This project will study perovskite nanoparticles with different compositions, aiming to tune their emission properties, and will investigate the exciton fine structure and the impact of vibrational properties on stability and light emission dynamics, aiming to optimise their application as quantum emitters. The project will involve material processing and fabrication, construction and alignment of optical setups, laser spectroscopy, and integration of quantum dots into functional devices.

54 - Quantum technologies for early detection of dementia

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Explore the frontier of quantum technologies for healthcare! Investigate how quantum technologies can transform MRI based dementia research, laying foundations for novel diagnostics. Work at the intersection of quantum engineering, neuroscience, and clinical analysis, and lead an interdisciplinary project with the potential to shape future dementia care and beyond.

Quantum technologies offer fundamentally new ways to represent and process information, enabling algorithms that may surpass classical capabilities in high-dimensional tasks such as dementia MRI analysis. This novel project investigates variational quantum circuits, quantum enhanced feature maps, and hybrid quantum/classical architectures to capture subtle neuroanatomical correlations. Leveraging entanglement, interference, and non-classical feature interactions, the research explores algorithmic and approaches in quantum machine learning and their applicability to real-world medical imaging for early detection of dementia. By improving classification of dementia related changes in MRI, this work could lead to more accurate prognostic tools, earlier intervention strategies, and enhanced monitoring of disease progression, ultimately supporting better patient outcomes and informing clinical decision-making.

The PhD will design and implement cutting-edge quantum algorithms integrated with classical CNN feature extractors. Key research components include developing quantum kernels for high-dimensional embeddings, optimising variational quantum circuits, evaluating performance under realistic noise, and benchmarking against classical models. Simulations will be performed using University of Southampton HPC resources and existing software frameworks, with select circuits deployed on real quantum devices. The project will systematically analyse scalability, robustness, and hybrid architecture performance, providing insights into novel quantum algorithmic strategies for medical image processing.

The project benefits from a rich internal MRI dataset covering healthy, at-risk, and clinical dementia cohorts, supplemented by open-source datasets for validation. The interdisciplinary supervisory team provides combines expertise in quantum engineering, algorithm development, and MRI-based dementia research.

57 - Quantum technologies for GNSS-denied navigation: a quantum inertial navigation sensor simulator

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Quantum sensors may permit long-range navigation when satellite systems cannot be used. This project will develop a quantum inertial sensor simulator, built around experimentally validated computational models, to provide real-time simulated data from actual motions, so that navigation engineers can explore quantum integration ahead of real quantum device availability.

Underground and under water, navigation satellite signals cannot reach you; above ground, they can be interrupted and spoofed. Inertial navigation, the main alternative for vehicle guidance, is range-limited by accelerometer and gyroscope instability. Quantum sensors using atom matterwave interferometry promise much higher performance and, even though they are currently only prototypes, future users are keen to explore their integration into navigation systems.

This project will produce a stand-alone device that simulates a variety of future quantum inertial sensor platforms, so that navigation engineers can explore their navigational use and performance, and in turn steer the future development of quantum sensors themselves. Containing conventional sensors and a high-performance processor, and building upon our experimentally validated computational models, it will output real-time simulated responses to actual motions over standard navigation system interfaces, while recording data from a range of environmental sensors. Where current quantum prototypes are typically limited to single axis, discontinuous measurements, the simulator will mimic continuous 3-axis acceleration and rotation sensing and be configurable to simulate different sensor schemes.

The project will combine quantum physics simulations, hardware selection and implementation, packaging and interfacing. You will address a range of quantum sensor configurations and establish the practical requirements of a field-testable system. A major challenge will be the computational performance required for real-time optimization, so you will investigate efficient simulation techniques including analytical, Monte-Carlo and machine learning methods and parallel processing. Finally, you will test and validate the simulator in real and simulated field environments, including alongside existing quantum sensor prototypes.

58 – AI-designed metasurfaces for quantum light manipulation

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Quantum computers and communication networks require precise control over individual particles of light (photons). However, the "lenses" needed to do this are incredibly complex to design. This PhD project uses Artificial Intelligence to "invent" new, ultra-thin surfaces—called metasurfaces—to steer and shape quantum light in ways previously thought impossible.

Quantum optical systems require sources of single photons, entangled photons, and other forms of non-classical light, along with advanced detection techniques. The quantum states might rely on various light properties such as polarization, direction, and orbital angular momentum. Metasurfaces hold immense promise for manipulating these states.

Metasurfaces have extraordinary abilities to control light in both classical and quantum domains. These metasurfaces serve as an ideal and distinctive foundation for creating optical components with a range of characteristics previously beyond reach. Metasurfaces have the potential to replace bulky optical components and provide functionalities beyond conventional optics based on their flexibility, compactness, and versatility.

This PhD project will focus on using AI to design quantum metasurfaces for the manipulation of complex interactions between quantum light for quantum computing and communications. In this project, the AI-designed metasurfaces will be manufactured using the semiconductor fabrication processes in the largest academic cleanroom in the UK. Finally, the metasurfaces will be implemented in a quantum system.

The project is highly flexible and interdisciplinary.

What you will do:

- AI-design, and prototype passive and active metasurface components.
- Conduct research that aims to use metasurfaces for manipulating quantum states of light.
- Collaborate with a team of world-class researchers and engineers.
- Present your findings in leading journals and at international conferences.

Who we are looking for:

- Candidates with a strong background in physics, photonics and/or engineering.
- Individuals who are innovative and have a passion for research.
- Excellent problem-solving skills and the ability to work independently.

59 - Towards the miniaturisation of quantum gravimeters and gradiometers

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This project explores novel methods to measure the local gravitational field and its gradient using phononic excitations in a Bose–Einstein condensate (BEC). The student will develop theoretical models for next-generation gravity sensors that exploit phononic mode mixing and particle creation to enhance measurement sensitivity.

We previously introduced a scheme to measure gravitational acceleration using two differently oriented BECs (or cavities) on length scales of approximately 200 μm. The measurement relies on differences in the fundamental frequencies of phononic modes arising from the deformation of the trapping potential (or cavity length) under gravity. Such a device can be miniaturised without loss of precision, enabling access to gravitational field strengths beyond the Newtonian regime. The aim of this PhD project is to extend this framework beyond phase-based measurements by enabling a full Bogoliubov transformation of the phononic quantum states. This is expected to lead to a significant increase in measurement precision and open new avenues for quantum-enhanced gravimetry and gradiometry. The theoretical models developed will be used to interpret and guide experiments on BECs in collaboration with the experimental group of Professor Christopher Foot at the University of Oxford. The student will gain expertise in quantum metrology and sensing, working at the interface of quantum theory and experimental quantum technologies. The student will be based within a vibrant theoretical physics group at the University of Southampton, with opportunities for collaboration with experimental teams, participation in seminars, and specialised training in mathematical physics and quantum theory.

Entry Requirements

Essential:

- A strong undergraduate or master’s degree in theoretical physics, mathematics, or a closely related field.
- Solid knowledge of quantum theory.
- Demonstrated ability in mathematical and theoretical reasoning and problem-solving.

Desirable:

- Familiarity with quantum information, quantum metrology, or related areas.
- Interest in connecting theoretical models with experimental tests.

60 - Quantum levitated nanodiamond gyroscope

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Levitated nanomechanical systems promise compact, high-sensitivity gyroscopes but are currently limited by incomplete rotational readout, particularly for fast-spinning particles. This project exploits NV centre spins in levitated nanodiamonds for quantum orientation sensing, while developing

Purcell-enhanced readout schemes to boost NV fluorescence and improve overall gyroscope sensitivity.

Levitated nanomechanical systems offer a compelling platform for next-generation gyroscopes, combining extreme mechanical isolation with the ability to reach exceptionally high rotational frequencies. These systems promise compact, high-sensitivity rotation sensors that operate at room temperature and provide a scalable, low-power alternative to bulky cold-atom-based inertial sensors. However, their performance is currently limited by incomplete and noisy rotational readout, particularly in the regime of fast-spinning particles where conventional optical methods provide little orientation information.

This project focuses on levitated rotating nanodiamonds hosting nitrogen-vacancy (NV) centre spins as a hybrid quantum sensor for gyroscopic applications. The internal spin degree of freedom of the NV centre provides an intrinsic, orientation-sensitive probe of the nanodiamond's rotation, enabling quantum detection of particle orientation beyond what is accessible with purely optical techniques. A central challenge, however, is the efficiency and speed of NV spin-state readout, which directly determines the detection noise and bandwidth of the gyroscope.

To address this, the project will develop new strategies for enhancing NV-based readout using Purcell enhancement. By coupling NV fluorescence to resonant structures compatible with optical levitation, the fluorescence photon collection efficiency can be significantly increased. This enhanced light–matter interaction enables faster and higher-fidelity spin readout, reducing photon shot noise and improving sensitivity to rotational motion.

This project aims to establish levitated nanodiamond gyroscopes as a powerful and practical platform for precision rotation sensing, capable of detecting both slow drifts and rapid rotational dynamics in a compact, room-temperature device.