QUANTIC

The UK Quantum Technology Hub
in Quantum Enhanced Imaging

10 YEARS *OF* **QUANTIC**

FOREWORD

It's been 10 years since we sat trying to impress upon the EPSRC interviewing committee just how committed we were to ensuring the success of the UK's investment in quantum technology. After a slight pause, QuantIC was up and running.

Beyond the specific people we've supported, the research they've undertaken, and the tangible real-world impacts that have followed, I believe the most profound contribution of the National Quantum Technology Programme has been something even more transformative. In 2014, quantum science was an esoteric academic interest—our first annual showcase was attended by around 100 academics, mostly discussing ideas amongst themselves. Fast forward 10 years, and the 2023 Showcase attracted over 1,500 participants, the majority from established industry, start-ups, and spin-outs. What was once purely academic has evolved into a thriving industrial-academic ecosystem. The UK has pioneered a new model of turning world-class science into impactful technologies —a model that's now being emulated across the globe.

What once seemed like science fiction—such as the ability to see around corners, build super-resolution cameras, image tissue types, or create an endoscope the width of a human hair—has become a reality. Many of these innovations have already led to new products and services. More broadly, the dialogue between researchers, technologists, engineers, end users, and policymakers has fostered a co-created ecosystem that will continue to drive quantum forward, identifying new use cases and sparking further innovations.

While I admire the groundbreaking research that QuantIC has enabled, and the wide-ranging impacts it has had, what brings me the most joy is the career progression it has supported. Many of our postdoctoral researchers have secured independent fellowships or permanent academic positions around the world. Perhaps most significantly, many have transitioned into the industrial sector, climbing the ranks in established companies or launching their own ventures through spin-outs and start-ups.

None of this would have been possible without the researchers, many of whom were at the start of their now successful careers; the Central team that created an open for business, can-do Hub; and our ever-supportive Strategic Advisory Board and Market Opportunities Panel for providing guidance throughout the years. Thank you to each and every one of you.

Though I still have a few years ahead of me, I am fully aware that the leaders of tomorrow are all around me today. They're taking up the reins and propelling the quantum field forward. The future of quantum research, and its role in shaping mission-driven government, is in capable hands.

Professor Miles Padgett, *Principal Investigator*

INTRODUCTION

For decades, the UK has boasted a strong research base in quantum science. However, translating this great science into market-ready technology and products was considered to be a long way off. 2014 saw a step-change in the UK quantum technology landscape with the creation of the £1b UK National Quantum Technologies Programme (NQTP), a programme set up by UK Government to translate academic work in quantum into new products and services.

Four Quantum Technology Hubs were created to deliver a new era of quantum technologies, to transform economies and help to address society's most pressing challenges; advancing healthcare, providing defence and security capabilities, driving global quantum information and computing and achieving net zero targets and environmental protection.

QuantIC – the UK Technology Hub in Quantum Enhanced Imaging was launched in late 2014, central to the UK beginning to make its mark as frontrunners in the emerging global quantum market.

Over the past decade at QuantIC, we have developed revolutionary imaging systems that shift the way imaging occurs. These developments have been enabled by new technologies, such as single-photon cameras, detectors based on new materials and single-photon sensitivity in the mid-infrared spectral regions.

We've had a successful ten years at QuantIC, and making significant technological breakthroughs, forging project partnerships and co-creating new ideas with industry across the UK has given me a personal sense of pride. We've utilised funding, in particular, our Partnership Resource Fund to support the formation of an active quantum community that has facilitated collaboration among researchers and stakeholders that has led to the spark of novelty, technology progression and economic growth.

There is huge commercial potential for the kind of quantum-enhanced technologies we've been working on. We are proud that QuantIC has supported UK industry to lead the global imaging revolution.

Professor David Cumming, *Director, QuantIC*

10 YEARS *OF* **QUANTIC**

2014 — QuantIC, the Quantum Technology Hub in Quantum Enhanced Imaging, is established as part of the £1b National Quantum Technology Programme

2015 — QuantIC develops strong partnerships with industry, facilitating over 100 company meetings and visits and securing £8m additional funding

2016 — QuantIC receives £640k funding boost from UK Quantum Technologies Innovation fund to strengthen links with industry

2017 — Spinout QLM launched to develop quantum sensing solutions to remotely detect methane leaks. QuantIC supports two further spinout companies, Raycal and Sequestim

2018 — QuantIC hosts the House of Commons Science & Technology Committee. Emerging quantum technologies are listed as one of the UK's key areas of interest

2019 — QuantIC receives £28M for second phase of the programme to continue pioneering quantum technologies and develop new industrial partnerships

2020 — QuantIC research supports the launch of the Horiba Flimera, a fluoresce lifetime imaging camera for the life sciences

2021 — QuantIC's studentship scheme is match funded by industry, totalling £1.63m to support the development of skills in academia and industry

2022 — QuantIC has facilitated a further £65m of industry projects and has supported new quantum companies such as Digistain to improve cancer diagnosis using quantum imaging

2024 — QuantIC celebrates a successful ten years of the Hub, making significant technological breakthroughs and supporting UK industry to lead the global imaging revolution

QUANTIC STAFF (PAST AND PRESENT)

QuantIC Investigators

Stephen Barnett, University of Glasgow
Steve Beaumont, University of Glasgow
Adrian Bowman, University of Glasgow
Gerald Buller, Heriot Watt University
Danial Chitnis, University of Edinburgh
David Cumming, University of Glasgow
Animesh Datta, University of Warwick
Martin Dawson, University of Strathclyde
Daniele Faccio, University of Glasgow
Corin Gawith, University of Southampton
Erdan Gu, University of Strathclyde
Robert Hadfield, University of Glasgow
Giles Hammond, University of Glasgow
Robert Henderson, University of Edinburgh
Stefan Hild, University of Glasgow
John Jeffers, University of Strathclyde
Myungshik Kim, Imperial College London
Jonathan Leach, Heriot-Watt University
Jonathan Matthews, University of Bristol
Martin McCall, Imperial College London
Steve McLaughlin, Heriot-Watt University
Roderick Murray-Smith, University of Glasgow
Rupert Oulton, Imperial College London
Miles Padgett, University of Glasgow
Douglas Paul, University of Glasgow
Chris Philips, Imperial College London
John G Rarity, University of Bristol
Peter G.R Smith, University of Southampton
Michael Strain, University of Strathclyde
Ian Walmsley, University of Oxford
Ian Watson, University of Strathclyde

QuantIC Central Team

Kirsty Annand
Amanda Baird
Joshua Baird
Peter Chua
Zankar Dalal
Sara Diegoli
Michael Fletcher
Claire Kidd
Catherine MacNeil
Kevin McIver
Tanushree Mehta
Louise Mitchell
Christopher Payne-Dwyer

RESEARCH EXCELLENCE

Working within the QuantIC Hub has given our community of researchers a unique opportunity to work closely and collaborate with industry as well as advancing their academic careers.

The foundation of our industrial and user engagement lies in research excellence, as evidenced by over 2000 publications (including journal articles, conference papers, chapters and reviews)., with outputs in prestigious journals such as Science and Nature. Over 220 of these publications were co-authored with an industry partner and over 890 had an international co-author. Sixty of QuantIC's publications are among the world's top 1% most highly cited.

Members of our research community have successfully advanced their careers through the academic journey, gaining Fellowships, Professorships and winning academic recognition, whilst we are delighted that some are carving their careers in industry, taking up positions in businesses such as M Squared Lasers, ST Mircoelectronics and Photon Force.

QuantIC researchers have won prestigious awards throughout the past decade. **Several of these awards are listed below.**

Professor John Rarity elected Fellow of the Royal Society (2015).

Professor David Cumming elected Fellow of the Royal Academy of Engineering (2017) and awarded the Institution of Engineering and Technology's Achievement Medal in Electronics (2023).

Professor Doug Paul awarded EPSRC Established Quantum Technology Fellowship (2015), Royal Academy of Engineering Chair in Emerging Technology (2020) and the Institute of Physics President's Medal (2014).

Professor Miles Padgett appointed Officer of the Order of the British Empire (2020), awarded the Prize for Research into the Science of Light (2015); Royal Society Research Professorship (2021); the IEEE Photonics Society Quantum Electronics Award (2021); the Max Born Award (2017); the European Physical Society prize for quantum electronics and optics, and the Rumford Medal of the Royal Society (2019).

Professor Jonathan Matthews awarded the 2021 Philip Leverhulme Prize for physics.

Dr Ashley Lyons awarded Leverhulme Trust Early Career Fellowship (2021) and a Royal Academy of Engineering Research Fellowship (2021).

Dr Alex Clark awarded Royal Society Fellowship (2017).

Dr Yoann Altmann awarded Royal Academy of Engineering Fellowship (2017).

Dr Simon Peter Mekhail awarded Leverhulme Early Career Fellowship (2023).

Dr Rachael Tobin awarded Royal Academy of Engineering Fellowship (2021).

Professor Daniele Faccio elected to the Royal Society of Edinburgh (2017); elected as Royal Academy Chair in Emerging Technologies (2019); awarded Leverhulme Prize in Physics (2015), and received Cavaliere dell'Ordine della Stella d'Italia (Knight of the Order of the Star of Italy) (2022).

Professor Martin Dawson elected as a Fellow of the Royal Society (2022) and awarded the Aron Kressel Award of the IEEE (2016); The Optical Society's (OSA) Nick Holonyak Jr Award (2021); and the Dennis Gabor Medal from IoP (2016).

Professor Gerald Buller elected Fellow of the Optical Society of America (2017).

Professor Robert Hadfield elected Fellow of the Optical Society of America (2016) and Fellow of the Royal Society of Edinburgh (2019).

Dr Aurora Maccarone awarded Royal Academy of Engineering Fellowship (2020).

Dr Ahkil Kallepalli awarded Leverhulme Trust Fellowship (2023).

Professor Peter Smith elected as Fellow of Optica (2023).

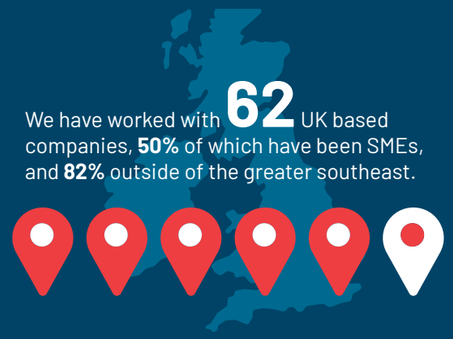
INVESTING IN INNOVATION

Partnership Resource Fund

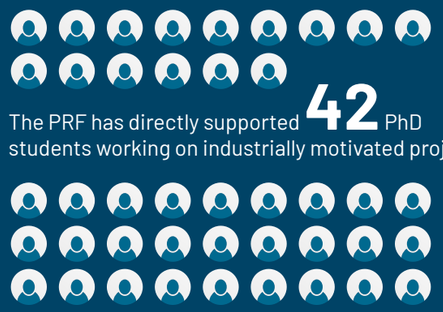
From the inception of the Hub, QuantIC launched an innovation scheme, the Partnership Resource Fund (PRF), to bring academics and industry together to explore the feasibility of new technologies and devote time and effort to the most promising.

In the past five years, the QuantIC £4m PRF has enabled the delivery of 30 projects with 12 companies. It has also facilitated the upskilling of our early career researchers, nurturing a talent pipeline essential for the development and implementation of quantum technology across both academia and industry in the UK and creating an environment encouraging entrepreneurship, innovation and commercialisation.

The PRF has funded **30** industry co created projects over the last 10 years.



We have worked with **62** UK based companies, **50%** of which have been SMEs, and **82%** outside of the greater southeast.



The PRF has directly supported **42** PhD students working on industrially motivated projects.

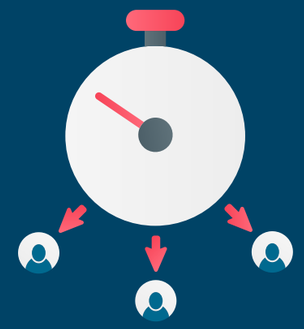
The PRF has enabled **4** training and accelerator programmes with over **130** Quantum Early Career Researchers (ECRs) in attendance.

We have directly supported the formation of **6** spin outs which have won Institute of Physics (IOP) start-up awards, including QLM; a gas monitoring company which uses quantum detectors to identify methane leaks.

We have produced **3** commercially available, multi-award-winning products e.g. FLIMera; an Institute of Physics (IOP) business award winning device for high-speed fluorescence imaging.

We have hosted **15** industrial networking opportunities which brought **133** executives to QuantIC-led events (in Phase 2).

The PRF has supported **372,000** research hours, creating **70+** quantum jobs.



Supporting Spinouts and Startups

Quantum research and technologies are helping the UK position itself as a global leader, turning academic strength in quantum into economic success.

QuantIC supports its researchers on their innovation journeys, developing the pipeline of new technology to revolutionise everyday applications in healthcare, transport, defence and security and climate change.

QuantIC has embraced the challenge of commercialising our quantum imaging research through industrial collaboration, joint ventures or spinouts.

QLM: VISUALISING AND QUANTIFYING METHANE LEAKS

QLM Technology is a start-up company, founded by QuantIC researchers at the University of Bristol, who aim to mitigate greenhouse gas emissions through LiDAR technology.

Reducing methane leaks in the atmosphere is one of the fastest ways to prevent climate change. With a warming effect of nearly 80 times that of carbon dioxide, methane, commonly referred to as natural gas, is the second greatest greenhouse gas contributor to climate change. Invisible to the human eye, methane is detectable using specially designed infrared cameras, where sensors are extremely expensive and have a limited supply.

QLM has developed quantum sensing technology capable of remotely detecting and quantifying minute methane leaks. This work was supported by QuantIC through an EPSRC Impact Acceleration award, and the Quantum Technology Centre (QTEC) at the University of Bristol. QuantIC also supported QLM leading the Innovate UK 'SPLICE' project, involving a consortium of academic and industry partners to accelerate the development of QLM's prototype to create their quantum gas-sensing lidar camera.

A subsequent collaboration agreement with the world's largest oilfield services company, SLB (formerly Schlumberger), enabled QLM to scale manufacturing and become part of SLB's End-to-end Emissions Solutions (SEES) business offering to provide accurate and sensitive measurement for the oil and gas industry.

"The unique QLM LiDAR technology will allow operators to continuously monitor their facilities for methane emissions, and the technology is differentiated in its ability to detect even small emissions; to quantify emission rates accurately; to provide actionable information by locating the emission source precisely; and to fit upstream, midstream, and downstream facilities of all sizes."
Kahina Abdeli-Galinier, Emissions Business Director, Schlumberger.

In 2023, QLM commercially launched its Quantum Gas Lidar and the QLM Cloud, an analytics platform for analysing and managing associated emissions data. The Quantum Gas Lidar is unique in the marketplace, combining leading-edge quantum photonics detection technology, telecom tuneable lasers and robust lidar to achieve detailed images of equipment up to 200m away and any associated methane emissions, with exceptional accuracy.

The company are currently working with Severn Trent Water to deploy the QLM system at multiple sites to quantify their methane emissions and reduce their process emissions.

QLM were awarded Best Breakthrough Company in the South-West at The Spectator 2023 Economic Innovator of the Year awards, and also won recognition as Bloomberg NEF Pioneers 2021 and an Institute of Physics Business Start-Up award 2020.

"From QLM's initial inception at the University of Bristol until the present day, QuantIC has offered tremendous support throughout the lifecycle of our product development and growth as a company. Working with QuantIC and other partners has helped us build our initial research and development into worldwide industrial application."
Andrew Weld, Head of Research & Development, QLM

DIGISTAIN: QUANTUM-ENHANCED BREAST CANCER DIAGNOSIS TECHNOLOGY TO PROVIDE RAPID AND RELIABLE ANSWERS TO PATIENTS AND CONSULTANTS

World-leading research by QuantIC in mid-infrared imaging has led to a start-up company, Digistain, delivering quantum-enhanced analysis to doctors so they can provide the best treatment for breast cancer patients.

Traditional methods of diagnosing cancers involve assessing dyed samples of tissue by eye under a microscope, to diagnose the presence and severity of the disease. These processes are subjective and can take weeks to deliver a result, resulting in increased patient anxiety, and medical uncertainty.

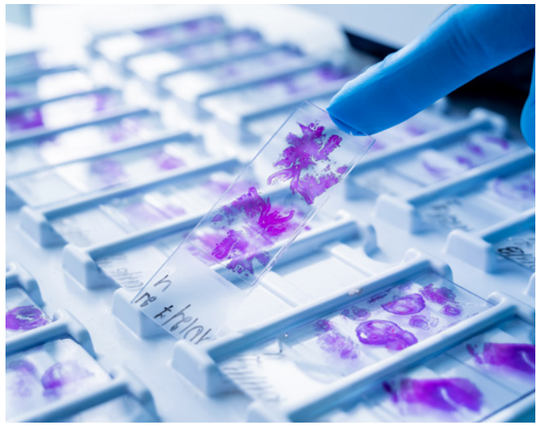
The Digistain diagnostic tool, developed by Professor Chris Phillips and Dr Hemmel Amrania at Imperial College London, analyses samples by measuring signature changes in the mid-infrared light attributed to cancerous cells. When incorporated into a computer program, the severity of the disease can be assessed in moments at a fraction of the cost.

Mid-infrared cameras have long been extremely expensive, and have several limitations due to their inherently noisy, unstable images. Quantum imaging enables infrared information to be transferred onto a visible RGB camera system using non-linear materials, allowing Digistain to produce ultra-high quality mid-infrared images for medical diagnostics.

After a landmark trial with over 800 breast cancer patients, Digistain demonstrated the QuantIC developed tool produced results equivalent to the current gold standards and received Medicines and Healthcare Products Regulatory Agency approval, meaning patients can now get the treatment they need more quickly.

A recent independent health economic study, commissioned by the UK government, concluded that the Digistain technology could save the NHS £287m, with much lower acquisition costs, transport fees and a reduced prescription of chemotherapy.

Most breast cancer biopsy results are currently air freighted to the US for analysis at huge cost to the NHS – and the environment. The study found that Digistain's technology eliminates this need, therefore reducing the NHS carbon footprint by 460 tonnes.



The report concludes that Digistain proves to be an optimal alternative to the currently offered tumour profiling test, as it delivers non-inferior health outcomes while generating cost saving.

Northampton General Hospital is an early adopter of Digistain and sees the technology as a worthy substitute for the current care that leads to improved health outcomes.

"Digistain cuts down wait times for results massively when compared to our current provider who is sending samples to Texas for analysis. The turnaround time with Digistain is much quicker, it is more accurate and cheaper.

"I have worked for the National Health Service for 25 years and it is innovation like this that will open up a new digital pathway and frontier for the NHS – and help future-proof it. It can only be a matter of time before Digistain is adopted across the whole of the NHS."
Sharaz Khan, NHS Head of Pathology at the Northampton General Hospital

Digistain has won a Royal Society Innovation Award and an Institute of Physics Business Start-Up Award for solving treatment delays in breast cancer.

Professor Phillips explains, "We hope Digistain imaging technology will be incorporated into existing hospital labs over the next few years, enabling radically faster breast cancer treatment decision-making for physicians and patients."

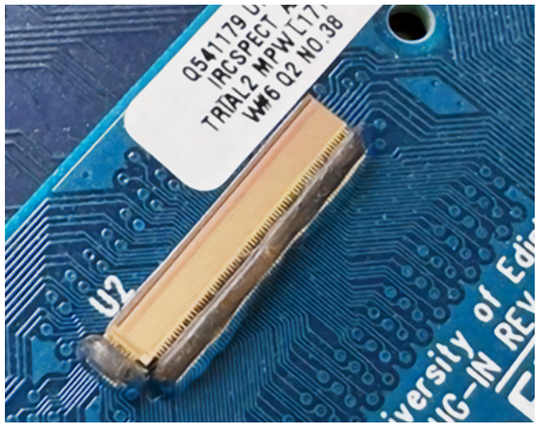
Singular Photonics

SINGULAR PHOTONICS: DEVELOPING NEXT GENERATION SENSITIVE DETECTORS

Singular Photonics, a spin out from the University of Edinburgh, develops next generation single photon detectors, that can detect and time single photons (light quanta) enabling simultaneous capture of depth and temporal dimensions generating next generation 4D images.

Professor Robert Henderson's research group are world leaders in the development of single photon avalanche diodes (SPADs) and secured QuantIC New Ventures funding for support for their innovation and enterprise journey. With subsequent funding from Scottish Enterprise, the University spun-out Singular Photonics in February 2024, led by Chief Executive Shahida Imani. The company offers camera modules based on SPADs, enabling customers to develop imaging systems that can function in extremely low-light environments. These SPAD-based detectors and cameras can be expected to play a major societal role, from medical devices, environmental applications and even adding further dimensions to the phone camera in your pocket.

"Since the company's incorporation, Singular Photonics has accelerated its commercial traction and is currently working with a number of global customers who are integrating Singular cameras into their own product offerings. This is a great milestone for the company at such an early stage."
Shahida Imani, Singular Photonics



The company were shortlisted for the finals of the Converge Challenge 2023, securing it as one of Scotland's most innovative new businesses and were one of the first companies in the UK Silicon Catalyst ChipStart program that was funded by the UK Government as part of its Semiconductor Industrial Strategy.

Industry engagement

One of the core directives of QuantIC was the development of technologies for economic and societal benefit, which we have achieved through partnership between academic and industrial organisations. Collaboration is at the heart of the advancement of quantum technologies, and working in partnership is pivotal in unlocking their full potential across diverse sectors.

HORIBA Scientific

HORIBA SCIENTIFIC: WIDE FIELD FLUORESCENCE IMAGING (FLIM) CAMERA FOR BIOLOGICAL MICROSCOPY

Horiba Scientific has a long history in the field of fluorescence measurement to develop high performance scientific instruments. Working with QuantIC researchers, the company has developed a game-changing technology into a user-friendly camera that delivers video rate fluorescence imaging of molecular processes to improve medical research, disease diagnostics, screening and tissue monitoring.

FLIMera, a new wide-field fluorescence lifetime imaging camera , uses the QuantICAM, a 192 x 128 pixel array developed by researchers at the University of Edinburgh. The product is exceptionally faster than conventional scanning microscopes and enables the study of mobile samples for the life sciences sector.

A world changing technology, the FILMera camera exploits QuantICAM single photon detection and its capability to resolve timing of photon arrival at the pixel level to deliver large amount of data throughput. That combined with advanced data analysis software, developed by Horiba, delivers the only camera on the market capable of video rate fluorescence imaging of molecular processes for medical research, disease diagnostics, screening, optically guided surgery, and tissue monitoring.

Parallel fluorescence data acquisition makes the camera exceptionally faster than conventional scanning microscopes. The result enables real-time video rate FLIM for the study of mobile samples, such as live cells and fluid biopsy for cancer screening.

Horiba Scientific were awarded the Institute of Physics Business Innovation Award in 2019 for the collaborative work with QuantIC in developing the novel FLIMera technology.

"Partnering with QuantIC has made it so much easier for HORIBA to collaborate in diverse projects with leading research groups. Our FLIMera camera heralds new era in accessible, robust, fluorescence lifetime imaging based on the gold standard of single-photon counting."
David McLoskey, Managing Director, HORIBA Jobin Yvon IBH Ltd

THORLABS

RAYCAL: COMMERCIALISATION SUPPORT TO THORLABS

Raycal, a start-up from QuantIC partner, the University of Bristol, provides consulting services for quantum technologies, with a focus on imaging and metrology. The company collaborated with optical equipment company, Thorlabs, to support the commercialisation of a high-performance Photon Source product.

The SPDC product works by using spontaneous parametric down-conversion, to create a pair of energy-time entangled photons, resulting in a bright, high-efficiency heralded single photon source – ideal for optics applications.

"This is an exciting addition to Thorlabs' line up of products for the Quantum Photonics community. The project started when a researcher from the University of Bristol reached out asking if we could expedite the efforts of those working in quantum optics labs by offering a compact, reliable single photon source. Prompted by that need, we engaged in a collaborative effort that led to the development of the SPDC source",
Peter Fendel, Director of Thorlabs' Laser Division

TECHNOLOGY DEVELOPMENT

A significant goal of QuantIC was to accelerate the development of new quantum-based imaging systems and cameras.

Over the timeline of QuantIC, we have created several technology demonstrators to showcase the potential applications of our research and engage industry, investors and the public in order to explore what can be achieved using quantum technologies. Here are a few examples of our demonstrators.

SINGLE FIBRE IMAGER

Researchers at the University of Glasgow have developed a robust imaging system, capable of imaging through an optical fibre, the width of a human hair.

Optical fibres have revolutionised our data-centric world. It is the highway of our internet, television, and communication needs. Light is often used to transfer data, but not an image. Traditionally to send an image inherently through fibres, such as in endoscopes, bundles of many thousands of optical fibres are needed, with one fibre for every pixel in the image. QuantIC's innovation has been to project a video through a single fibre.

Normally, when light shines through a single optical fibre it is scrambled, making the image unrecognisable. To resolve this, the team at the University of Glasgow reverse this process and use carefully shaped light at the input to create a single spot at the output. That spot of light is then rapidly scanned across the scene and captures each pixel of detail for a camera to record. The technology has been demonstrated for a range of wavelengths allowing infrared and visible inspection or non-visible and eye-safe optics.

Imaging through a super-thin fibre has a multitude of benefits. Because these fibres are cheap, robust, flexible, and so small, they offer perfect accessibly to hard-to-reach areas. Potential applications include inspection of critical infrastructure and manufacturing components, from nuclear reactors, wind turbines, to jet and car engines, or supporting doctors and surgeons for medical procedures and diagnostics by using the fibre within a needle or flexible tube.

ENTANGLECAM

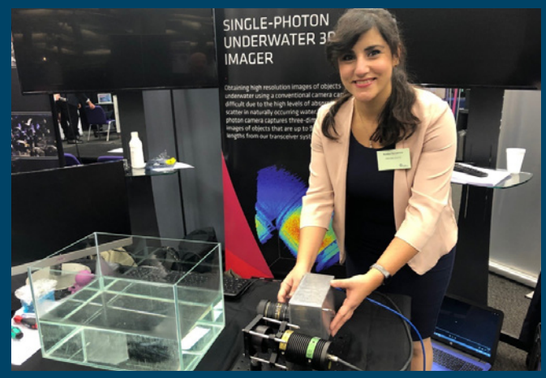
Central to all conventional imaging is the notion that the light illuminating an object is the light detected, but quantum imaging can change this and offer exciting new applications.

QuantIC researchers at Imperial College London and spin-out company, Digistain, have developed EntangleCam to 'see' with undetected light. The team have created pairs of visible and infrared photons using a nonlinear crystal, a cheap and compact quantum solution that can be retrofitted to many existing products.

Quantum entanglement lets the visible photon 'know' where its infrared twin has interacted with the object. End users can reduce their equipment costs by requiring only conventional silicon cameras, whilst at the same time being able to access the rich chemical information available from infrared measurements.

The research continues to develop systems to reach longer infrared wavelengths, and higher efficiency creation of invisible and infrared light with potential applications in cancer detection.

UNDERWATER IMAGING



Optical imaging through water can be quite challenging. Especially once the water becomes turbid, the high degree of back-scattered light saturates the detector and the image can no longer be recognised.

Researchers at Heriot Watt University alongside technology company Sonardyne, are investigating 3D imaging of objects in turbid underwater environments using a single-photon detector array which could revolutionise the clarity of imaging below the surface. This could greatly benefit offshore applications such as site surveys and inspections of windfarms and dams; search, security and defence, including in harbours and rivers; marine science and marine archaeology. Working with industry partners, the team have developed a prototype of a the first of its kind, a fully submerged underwater LiDAR transceiver system based on single-photon detection technologies.

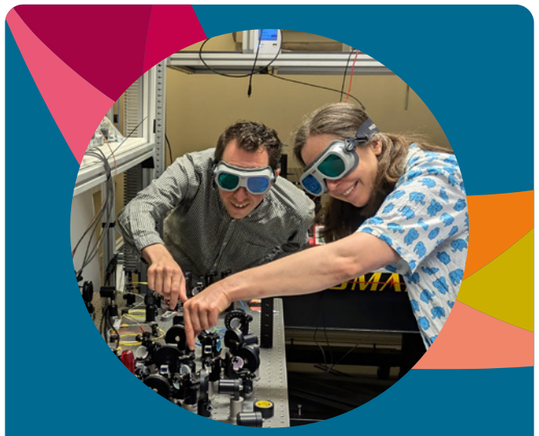
GASSIGHT

Methane is a potent greenhouse gas. Methane leaks can have significant safety risks with undetected leaks contributing to climate change. GasSight, developed by researchers at the University of Glasgow and technology company, M Squared Lasers, allows real-time video images of gas. Although gases are invisible to the naked eye, QuantIC have developed a camera, utitlising single-pixel imaging to create colour-coded images of the gas, providing a highly accurate real-time picture of the scene.

Real-time video imaging of gas has a key advantage over conventional technologies in that it can speed up the time required to locate a gas leak. Watching the gas flow in real-time conveys the direction from which it is dispersing. From this, the source of a leak can be determined. For gas utilities, and many other industrial settings, this technology offers reduced maintenance times for gas pipe infrastructure and improved safety.

QUANTIC PEOPLE CASE STUDIES

Investing in the advancement of our research community has been key to the success of the Hub. QuantIC has supported and developed the careers of researchers at all stages of their research journey, providing funding, skills, training and networking opportunities to allow our people's academic and industrial careers to flourish. Here are the career journeys of just a few of our researchers.



Alex Clark
UNIVERSITY OF BRISTOL

Alex completed his PhD at the University of Bristol and then moved to the University of Sydney where he was awarded an ARC Discovery Early Career Researcher Award to work on integrated photonic quantum frequency conversion. He joined the team at Imperial College London, winning a Marie Sklodowska Curie Fellowship followed by a Royal Society University Research Fellowship. In 2021, he moved back to the University of Bristol as a proleptic Senior Lecturer.

Alex holds an Accelerated Development Fund with QuantIC, where he is exploring, in collaboration with Chromacity Lasers Ltd, the use of seeded and high-gain parametric down-conversion in nonlinear interfererometer systems with applications in greenhouse gas sensing, such as methane and carbon dioxide, the imaging of biological samples for clinical applications and food manufacturing, and the testing of materials and their underlying defects.

"I worked with QuantIC during my time at Imperial College London and then moved to Bristol, and throughout that time have felt part of an incredible quantum imaging community here in the UK.

A real highlight has been taking a nonlinear interferometer outside the laboratory and to events such as the UK Quantum Showcase. Being able to show to the public that QuantIC research is going to have real-world impact has been very gratifying, and it has been very interesting to meet people from diverse backgrounds and tell them about this exciting research field. Of course, this success is also down to working with incredible postdoctoral researchers and PhD students such as Dr Nathan Gemmell and Dr Emma Pearce, and being able to work with them and other QuantIC researchers, has been fun and productive."

Dr Alex Clark, University of Bristol

Alex is excited about the next phase of the National Quantum Technology Programme and will be a work package leader in three upcoming UK Quantum Technology Hubs – the Integrated Quantum Networks (IQN) Hub, where he will lead quantum memory development, the Quantum Imaging, Sensing and Timing (QuSIT) Hub, where he will progress nonlinear interferometry for gas sensing, and the Quantum Enabled Positioning, Navigation and Timing (QE-PNT) Hub, where he will work on miniaturised laser locking systems and quantum-inspired range finding.

Emma Pearce
HUMBOLDT UNIVERSITY

Emma became involved with QuantIC during her PhD at Imperial College London where she went on to become a Research Assistant in Quantum Imaging. Emma was awarded a QuantIC Doctoral Prize award in late 2023 and moved to Glasgow where she developed an off-axis digital holography system with a nonlinear interferometer for infrared imaging with visible photons. Emma is currently a Postdoc Researcher at Humboldt University in Berlin.

Emma uses visible light to look at things in the infrared, using a technique called 'imaging with undetected photons.' Infrared sensing is used all across science: gas detection, plastic recycling, non-destructive industrial monitoring, and diagnostic medicine. The problem is that infrared detectors, especially in the mid-infrared (mid-IR), are much noisier and more expensive than the detectors in the visible range. To get around this, Emma uses entangled photons to look at the object with infrared light but 'pass' the information to visible light which is much easier to detect.

"Moving to Humboldt University was a great opportunity for me to continue this research while gaining new experience, both professionally and personally. I'm excited to be working with Sven Ramelow, who is a leader in the field, so it's been great to find out that our ideas for the technology align and the long-term position enables me to fully explore these ideas."

QuantIC has supported Emma throughout her research career and public engagement activities, giving her the opportunity to showcase her research at the world's largest event of optics and photonics, SPIE Photonics West, and providing a platform to demonstrate her research to industry, investors and members of the quantum community.

"The level of confidence I have in being able to talk about my work is hugely down to the fact that the QuantIC team have put in a lot of faith in me to represent them at events. My involvement with QuantIC was a big turning point for my career. The belief they had in me to deliver these results and present them gave me a huge confidence boost and really opened my eyes to the possibility that I could continue in academia. QuantIC have given me opportunities to accelerate my career through engagement with the wider quantum community, as well as directly supporting me through the QuantIC Doctoral Prize."

Dr Emma Pearce, Humbold University

Matt Edgar
INTEGRATED GRAPHENE

Dr Matt Edgar was a postdoc researcher at the University of Glasgow during QuantIC's conception and was one of the Hub's key science communicators. He left the QuantIC team in 2018 to join one of the UK's most innovative, disruptive technology businesses – M Squared Lasers as a Product Owner and soon became Product Line Manager. In 2022, Matt joined advanced material supplier, Integrated Graphene as Principal Engineer where he is responsible for the company's technology development which allows them to manufacture their unique material at scale whilst maintaining important material performance requirements.

"My research during QuantIC involved building unusual infrared cameras that could see through or reveal invisible gases and developing 3D cameras that could more efficiently map surfaces with millimetre accuracy at long range. These cameras and their impressive

images allowed me to travel the world to showcase events and science festivals and entertain large audiences of scientists, industry leaders, politicians, children and even UK astronaut Tim Peake. I feel very privileged to have had these experiences which helped develop me into an effective communicator and has helped in my career leading large teams of engineers and interacting with important customers."

"

On reflection the research and commercialisation challenges I experienced within Quantic were not so different from the types of day-to-day challenges and commercialisation roadmaps I have experienced during my industry career, so I have felt well prepared for everything that has come my way.

I aspire to continue leveraging my passion for collaborating with teams of engineers to tackle significant challenges with tangible real-world implications. My ultimate aim is to evolve into a pivotal role where I can not only drive innovation but also inspire and guide others towards impactful solutions that shape the future of technology.

Dr Matt Edgar, Integrated Graphene

Lucrezia, a former University of Glasgow PhD student, has founded Lighthearted AI, a start-up which aims to improve the detection of heart conditions and provide a faster, more accurate and affordable system to revolutionise cardiac screening.

During her studies in AI and biomedical technologies, Lucrezia undertook QuantIC co-funded research to develop a contactless, machine-learning assisted method for heart-sound identification as an alternative measure to traditional cardiac examination with a stethoscope and direct contact with a patient. This research has led to the development of a laser camera that can read a person's heartbeat at a distance and pinpoint signs that they might be suffering from cardiovascular illnesses.

The company are working on developing the technology into a market-ready medical device to support primary care and community-based prevention, allowing GPs to screen patients for signs of heart disease in local surgeries, rather than having to be referred to hospitals for expensive tests such as ECGs.

"

We are currently conducting NHS clinical trials to validate our device and work towards regulatory approvals. The benefits of being able to measure patient's heartbeats outside hospital settings are considerable and we want to improve the detection of heart conditions and support the NHS' mission to tackle cardiovascular disease and improve prevention.

Dr Lucrezia Cester, Lighthearted AI

Akhil moved to University of Glasgow in April 2020 after finishing his PhD at Cranfield University to join Professor Miles Padgett's Optics group as a Postdoctoral Research Associate. In April 2024, Akhil took up the post as Chancellor's Fellow within Biomedical Engineering at the University of Strathclyde whilst holding a Leverhulme early career Fellowship.

Akhil's research background has been mixture of working with imaging applications across multiple fields – satellite and airborne remote sensing, laser applications in tissue imaging and imaging through the skin. His current research is a natural progression to applications-based research at the nexus of biophotonics and quantum imaging. Ahkhil's lab is translational and is building capabilities of medical devices using classical and quantum technology.

"An area of real interest to me is in maxillofacial surgery which has long included approaches to correcting damage to the skin in the head and neck region. These damages could be due to accidents or surgical treatments such as tracheotomies, which require surgical removal of tumours from the region. My teams' motivation is to research and develop a low-cost and easy-to-use device capable of quantitatively assessing blood perfusion to completely remove the possibility of flap failures."

As well as providing funding for his research, QuantIC has supported Akhil in showcasing his research to new audiences. "QuantIC has allowed me to achieve my passion for public engagement to inform young people and hard to reach groups about the benefits of quantum and show how optics works in the real world."

"

I'm dedicated to helping my PhD students to become involved in outreach activities to build their development. My own public engagement achievements have been recognised and I have recently been asked to become the Chair for the Education and Training in Optics and Photonics (ETOP) Conference in Glasgow in 2025.

Dr Akhill Kallepalli, University of Strathclyde

Aurora completed her PhD at Heriot Watt University and was introduced to the QuantIC Hub by co-investigator Professor Gerald Buller. During her time with QuantIC, Aurora has been awarded a Royal Academy of Engineering Research Fellow and has been promoted to Assistant Professor.

Aurora's research is focused on underwater quantum imaging and she is working on a new LIDAR system that can image objects in three dimension underwater using a single-photon detector array. The technology has applications in inspecting, monitoring and surveying underwater objects, off-shore engineering, and even archaeology. With several windfarms being built off the shores of Scotland, the technology will become crucial for surveys of the seabed at potential windfarm locations.

Aurora's research team are working on the development of the first prototype of a fully-submerged imaging system based on quantum detection technologies. They are working with industry to reduce the size of the system to make it small enough to fit in an underwater vehicle.

"

Working with QuantIC has given me the opportunity to interact with a wide range of researchers, helping me to build my network and think about my research from different perspectives, which has ultimately helped to progress my academic career. I received an invaluable support from the Hub in advertising my research and achievements, and in obtaining funding. This support has been instrumental in developing my research laboratory and increase my network of collaborators.

Dr Aurora Maccarone, Heriot Watt University

BUILDING A QUANTUM COMMUNITY

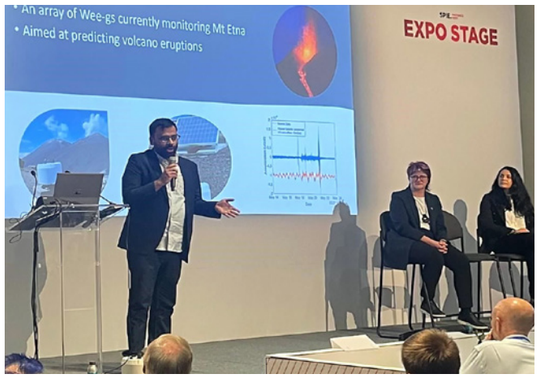
Throughout the duration of the Hub, QuantIC has been dedicated to supporting future UK leaders in quantum by facilitating research, collaboration, skills and training for our community of researchers.

We have supported industry co-invested studentships with a total of 42 quantum PhDs across 22 companies. Many of these students have moved into prime-based companies in the quantum and photonic sector, as well as continuing in research positions.

In 2023, we awarded Doctoral Prizes, where we provided five positions across our institutions to accelerate research and raise the profiles of the candidates.

Cyril Torre, a current PhD student in quantum engineering at the University of Bristol is one of QuantIC's Doctoral Prize students.

"I am very grateful to be awarded doctoral prize funding which has supported my research with Dr Carrie Weidner on sub-shot noise precision enhancement for magnetic field imaging . With the funding from QuantIC, I was able to buy laboratory consumables essential to support the completion of my project. I'm grateful to the QuantIC team for encouraging me to showcase my work to colleagues at scientific meetings and to key quantum sector leaders at the QuantIC's strategic advisory board meeting."



Above: Quantum Leap researchers pitch their ideas to investors at Photonics West
Above right: QuantIC's Doctoral Prize awardees present their research at the Strategic Advisory Board meeting

Accelerating quantum imaging and sensing technologies

Recognising that researchers often lack the knowledge and experience of the commercialisation process when developing new technology, QuantIC created Quantum Leap, an entrepreneurship and innovation training programme to inspire and accelerate the successful commercialisation of quantum technologies.

Working with partners to turn research into new businesses, products and services is one of the main ways researchers can deliver meaningful social, economic and environmental impact.

The programme, delivered by Anchored In, equipped the commercially-interested research delegation with business and innovation skills, enhancing their engagement with industry partners within a supportive training environment.

After a series of bootcamp workshops in late 2023, several researchers were invited to travel to San Francisco for SPIE Photonics West 2024, the world's largest photonics tech conference, to pitch their business ventures to venture capitalists. The group also benefitted from a visit to SRI International at Menlo Park to learn more about entrepreneurial approaches and journeys in the quantum tech landscape.

"It has been a pleasure to watch the confidence and entrepreneurial skills of the participants grow just by working alongside like-minded colleagues. I am very excited to see what the cohort goes on to do, together and individually, in the coming years."
Dr Kirsty Annand, QuantIC Project Manager

Below left: The Quantum Leap cohort visit SRI International, Menlo Park, San Francisco
Below right: QuantIC Scientific Conference, Aviemore, June 2022

Building a quantum community

Creating a supportive, inclusive research culture and community helps nurture researchers and provides a professional support network during their careers. Recognising that bringing people together can lead to future collaboration and invigorated research activity, QuantIC has organised several community conferences to bring the community together for career development workshops, scientific discussions and networking.

The global Covid pandemic halted face-to-face conferences and gatherings for several years, but the Hub organised quarterly online Scientific Meetings to raise morale within the research community and enabled participants to hear about what others in the quantum technology landscape were working on, as part of deeper scientific discussions.

In June 2022, QuantIC brought together the **scientific community for its first-in person conference** after the Covid pandemic in Aviemore for three days of presentations, workshops and social activities. Attendees enjoyed the combination of discussion and learning alongside time to reflect on impact of Covid on research activity.

Below: Festive Scientific Meeting, December 2023
Bottom: QuantICOM, Crieff, June 2024
Below right: Quantum Summer School, August 2023

A festive Scientific meeting in the University of Glasgow's Advanced Research Centre in December 2023 brought an end to QuantIC's online meetings, with researchers keen to resume face-to-face interaction and we were delighted to host colleagues from the universities of Glasgow, Strathclyde, Edinburgh, Durham and Bristol throughout the morning which led to some great discussions during the festive lunch.

Following on from the success of Aviemore, the team organised **QuantICOM,** the QuantIC Community Conference in the picturesque grounds of Crieff Hydro in June 2024. QuantICOM brought researchers and support staff together to celebrate the achievements and successes of the past 10 years of QuantIC. As well as reflecting onthrf previous decade, the community were enthusiastic about discussing the future of the UK quantum ecosystem and the next phase of UK quantum hubs that will support the delivery of the ambitious National Quantum Strategy.

Quantum Summer School

QuantIC, alongside the three other UK quantum hubs, organised an international summer school to train promising early career researchers in quantum technologies in August 2023. The 10-day residential event, held at the University of Birmingham, provided training and networking opportunities for 60 researchers from the UK and Canada. Both countries have identified quantum as a key emerging technology and have invested heavily in this area. The summer school created opportunities for increased research mobility, giving students an international perspective and provided an enhanced talent pipeline for UK academia and industry.

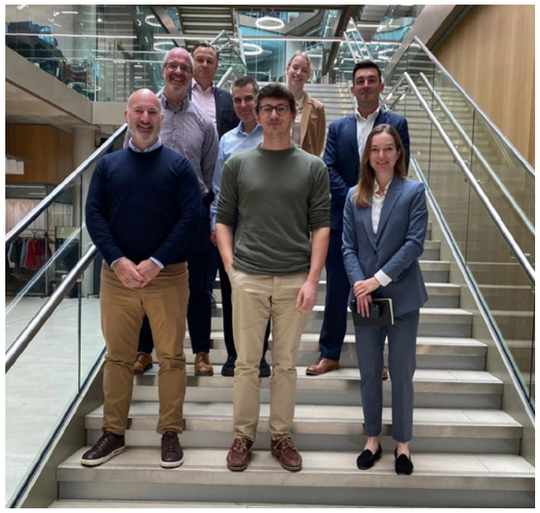
"There is a growing need for more talent in both industry and academia in this field and recruitment is becoming very competitive. A summer school and student exchange scheme has created opportunities for more bilateral research and commercialisation collaborations in the future."
Kathryn Chen, Head of Science, Innovation and Policy, British Consulate-General Toronto, Canada

SHOWCASING OUR RESEARCH

Promoting our research and technology capability to stakeholders throughout the UK and internationally has enabled us to raise the profile of the UK's advancements in quantum imaging and gain valuable insights from industry leaders, policymakers and investors and potential collaborators.

When QuantIC started in 2014, the Hub had attracted 30 industry partners to collaborate with. We are delighted to now actively engage with over 100 companies, an expansion of our user network we're immensely proud of. QuantIC has organised several industrial sandpits throughout its duration, giving industrial partners the opportunity to visit our laboratories, receive hands-on demonstrations of our technology and in-depth discussions with our research base.

As a core part of Scotland's internationally recognised photonics landscape, QuantIC has hosted several international delegations. In May 2023, we welcomed a delegation of several German companies to share best practice in quantum technology transfer. In May 2024, QuantIC was requested to host a Dutch photonics-quantum delegation, organised by the Embassy of the Kingdom of the Netherlands, where we brought together industry partners and key opinion leaders in the quantum sector.



Technology Showcase

The UK Quantum Technologies Showcase, a celebration of the expanding landscape of quantum technology commercialisation and industrial advancement in the UK, is the premier exhibition event in QuantIC's event calendar. The first Showcase event took place in November 2015, attracting 300 industrial and academic attendees in the Royal Society of London. The event has grown from strength to strength, attracting over 1500 people and 70 exhibitors from over 30 countries at the 2023 event in the Business Design Centre, London.

We were delighted to welcome the previous UK Science Minister to our stand for a demonstration of our Single Fibre Image technology, which images through an optical fibre, the width of a human hair.

Left: QuantIC hosts Netherlands Innovation Network
Above: QuantIC team at Quantum Technology Showcase 2023

Left: QuantIC researcher Peter Mekhail demonstrates the single fibre imager technology to previous Science Minister, George Freeman
Bottom left: Parliamentary Quantum Technologies Showcase in November 2023
Below: The EPIC Conference at the University of Glasgow, September 2022
Bottom right: Exhibiting at Laser World of Photonics, Munich, April 2022

Parliamentary Engagement

QuantIC has attended several parliamentary events, the most recent in the Parliamentary Quantum Technologies Showcase in November 2023 at the Palace of Westminster.

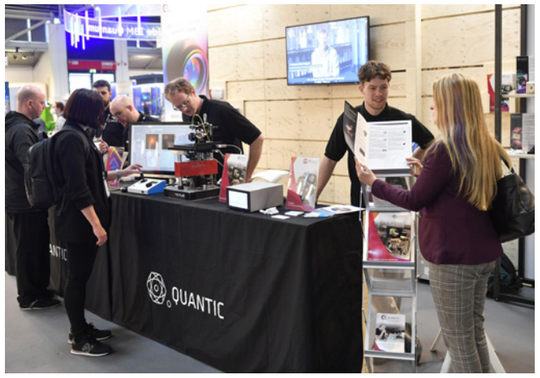
Organised by the Department for Science, Innovation & Technology (DSIT), Carol Monaghan MP and Baroness Neville-Jones, the event introduced MPs and peers to key representatives from the quantum ecosystem across industry, the public sector and academia.

QuantIC was proud to be one of the few select exhibitors to highlight the strength and diversity of the UK sector, showcasing products and tangible commercial applications of quantum technologies and helping to raising awareness of the industry amongst parliamentarians.

International events

In September 2022, QuantIC co-hosted the European Quantum Summit, alongside EPIC at the University of Glasgow's Advanced Research Centre. EPIC, European Photonics Industry Consortium, are one of the world's most prominent industry bodies for cross-collaboration with over 800 members, meaning the event draw in a significant audience of representatives keen to explore more about Quantum technologies.

QuantIC has been a regularly exhibitor at international events such as SPIE Photonics West in San Francisco, the world's largest photonics technical conference, and Laser World of Photonics in Munich, the world's largest optics and photonics trade showcase to exhibit our technological advancements, present our research findings during technical conferences and network with industry and potential investors.



The QuantIC team would like to extend thanks to all researchers, support staff, investors, industry representatives and funders who have supported its achievements throughout the duration of the Hub.

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