NPL

Department for Business, Energy & Industrial Strategy

University of Strathclyde

University of Surrey

PostGraduate Institute for measurement science

A Year in the PGI

2022 Edition

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A Year in the PGI

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A few words on the PGI

Richard Burguete
PGI Director

The past year has been quite a journey for us and our students as they transitioned into a post-pandemic world of blended physical and digital engagement. It is reassuring to see that the quality of the research has not been impacted and still delivers critical measurement solutions to diverse global challenges.

In this publication, we selected a few highlights that showcase the breath of activities delivered by the PGI, in collaboration with industry and academia. We would like to extend out thanks to all the people that support our work, and especially our strategic partners, the University of Surrey and the University of Strathclyde.

I am therefore, with the whole PGI team, especially proud to be able to play a part in the journey that our postgraduate researchers are on, by helping to communicate their work, particularly as they move forward to establish careers within and beyond NPL.

- Transitioning talent
- Pioneering through quantum computing
- Innovation in healthcare and well-being
- Advancing measurement science
- Responding to immediate crises
- Creating a global footprint
- Working with industry
- Engineering the future
- Creative development of new materials

Transitioning talent

An interview with Dr Ben Webster

PGI Alumni and Doctoral Student Development Officer (Kings College London)

The PGI alumni community is growing and making a significant impact across many sectors. The destinations of these students are not only noteworthy but are also diverse, ranging from postdoctoral research positions to patent attorneys and one CEO at a Quantum Technology start-up. Over 45% of our graduates now work in industry and hold a variety of different types of roles, with many having achieved significant promotions in their company. A considerable number of students have been successful in securing roles at NPL after completing their PhD, where they continue to be great advocates for the PGI. There are 9% of students applying their skills to other sectors including scientific charities and government departments.

"I can say with confidence that all of the skills and experiences that I gained during my time as a PhD, including through those 'extra-curricular' activities, have prepared me well for my post-PhD career. This all proved massively valuable when it came to applying for jobs. I had skills to show-off that I wouldn't have developed if I didn't do things outside of my PhD. It also gave me so many more examples to draw on during interviews, which I'm sure gave me an advantage over other candidates. "

Ben Webster
on the impact of enhancing his skills during his PhD.

What was your PhD about?

My PhD project involved developing methods for chemically separating medically promising radioactive isotopes from impurities produced. I focused on one of the lanthanide elements, terbium (Tb), for which there are four radioactive isotopes (149Tb, 152Tb, 155Tb and 161Tb) which show promise in either medical imaging, therapy, or both. It is this 'theranostic' potential of these terbium isotopes which has been the cause of increasing excitement and interest over the past decade. During my PhD, I developed semi-automated chemical separation methods which resulted in high-purity terbium isotope samples. I used solid-phase extraction chromatography and mass spectrometric (inductively coupled plasma mass-spectrometry, ICP-MS) techniques throughout the method development stages. My methods were used to process terbium isotopes produced at CERN and at other labs across Europe. The subsequent chemically purified samples were used for a world-first primary standardisation of 155Tb, a more accurate 155Tb half-life measurement, medical imaging studies and radiolabelling studies (check out my ResearchGate profile if you want to see some of the work I contributed to). I was fortunate to collaborate with scientists within the Nuclear Metrology group at NPL and many other researchers from across Europe through the MEDICIS Collaboration and PRISMAP.

What did you do during your PhD to enhance your skills and plan for the next step?

I naturally developed many research skills throughout my PhD including laboratory skills, project management skills, and publishing and communication skills. I was very fortunate to be able to present my research at conferences and research meetings which, although very daunting at times, was a fantastic way of developing my presentation and networking skills. More generally, I saw my confidence as a researcher and as a professional grow massively as a result of being involved in these conferences. I also volunteered with the Postgraduate Institute (PGI) as a Student Ambassador, where I developed my science communication and graphic design skills by putting together the quarterly newsletter and other non-research publications. I also helped to organise a couple of conferences, which was a great way to develop my project management skills within a smaller project (small relatively compared to my PhD project anyway).

Did you know what you wanted to do when you finished your research? What did you do since and is your current role reflective of this?

No, if I'm honest, I didn't think or plan that far into the future. I enjoyed doing research, but I wasn't certain if I wanted a long-term career in research. One thing I realised as I neared the end of my PhD was that the skills I developed during it are very valuable and transferrable, and if I decided to not stay in research, I will just have to learn how to apply those skills in a new setting or profession.

I worked with the PGI at NPL for a period as I finished writing up (not for the faint hearted!) and for a while after I submitted my thesis. I managed some funding competitions, the PGI's Student Ambassador Group, the PGI's Mentoring Programme, and supported the PGI's communications and training activities – it was a deep dive into research and researcher development. I have since moved to King's College London, where I am in a similar role in their Centre for Doctoral Studies, but with a greater focus on training and development.

I definitely didn't see myself working in a role like this when I started my PhD, but I used my PhD journey as an opportunity to discover what I did and didn't enjoy in my work and, for now, that has led me here (and I'm enjoying it!). I have since started my journey in 'Researcher Development'. That means I help researchers, particularly postgraduate researchers, to develop and excel during and beyond their doctorate.

What would be your top message for future PGI partners thinking about doing joint projects?

NPL is a fantastic place to do research. There are world leading experts, a wealth of experience, knowledge and techniques, and that's without mentioning their wider research networks. The importance of good measurement should not be underestimated and, if that's what a project needs, then the PGI is the best place for it.

Pioneering through quantum computing

We are entering a period of historic universal change. The catalyst of this change will be advances in areas such as artificial intelligence, digital pathology, super-fast intelligent communication networks, synthetic biology, distributed ledger technology, robotics, internet of things, additive manufacturing and autonomous systems. Secure, traceable and authenticated digital approaches and embedding measurement into our digital infrastructure is the key to meet the digital challenge. By 2025, the global quantum computing market will be worth $949 million.

Efficient semiconductor quantum light sources

Rachel Clark - Cardiff University

Recently, standardised efficiency measurements have been introduced into research on solar cells by the prestigious Nature publishing group, enforcing a "checklist" that must be reported before claiming an efficiency in any publication. This project will identify the key measurements required to report efficiency of single photon sources, independent of material, wavelength and measurement system, which may be reproduced in separate laboratories. The aim is to develop novel light sources and determine their efficiency, with a view to creating a "checklist" for this measurement.

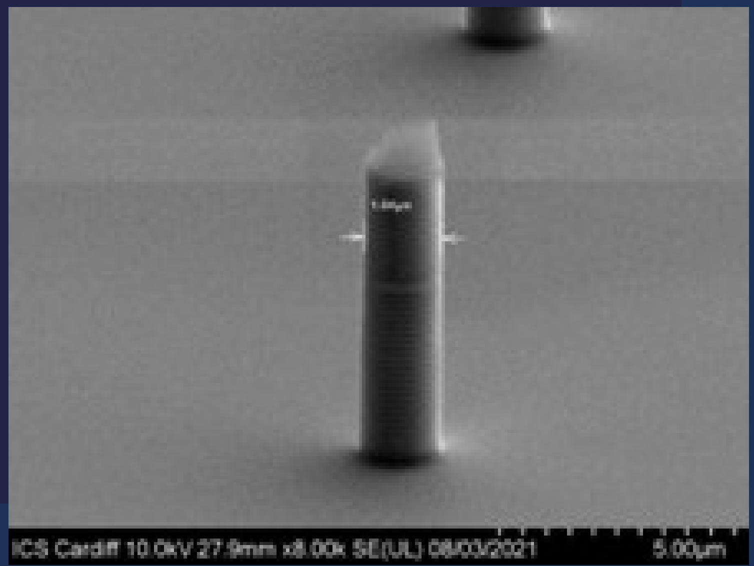
This PhD, a collaboration between the National Physical Laboratory and Cardiff University, is investigating quantum light sources and detectors, in particular fabricating bright and efficient micropillar quantum dot sources.

Semiconductors supply a physics-rich environment to host various quantum light sources applicable for quantum information processing. These light sources have the capacity to generate non-classical photon streams that demonstrate antibunching photon statistics, high-fidelity entanglement and strong indistinguishability. Furthermore, the generation of efficient and fast quantised states of light is imperative for many aspects of quantum technology, including computing, cryptography, sensing and imaging. Quantum light sources are important for future quantum-communication protocols, such as quantum teleportation.

"This work is motivated by the need for a well-established metrological standard for novel quantum light sources."

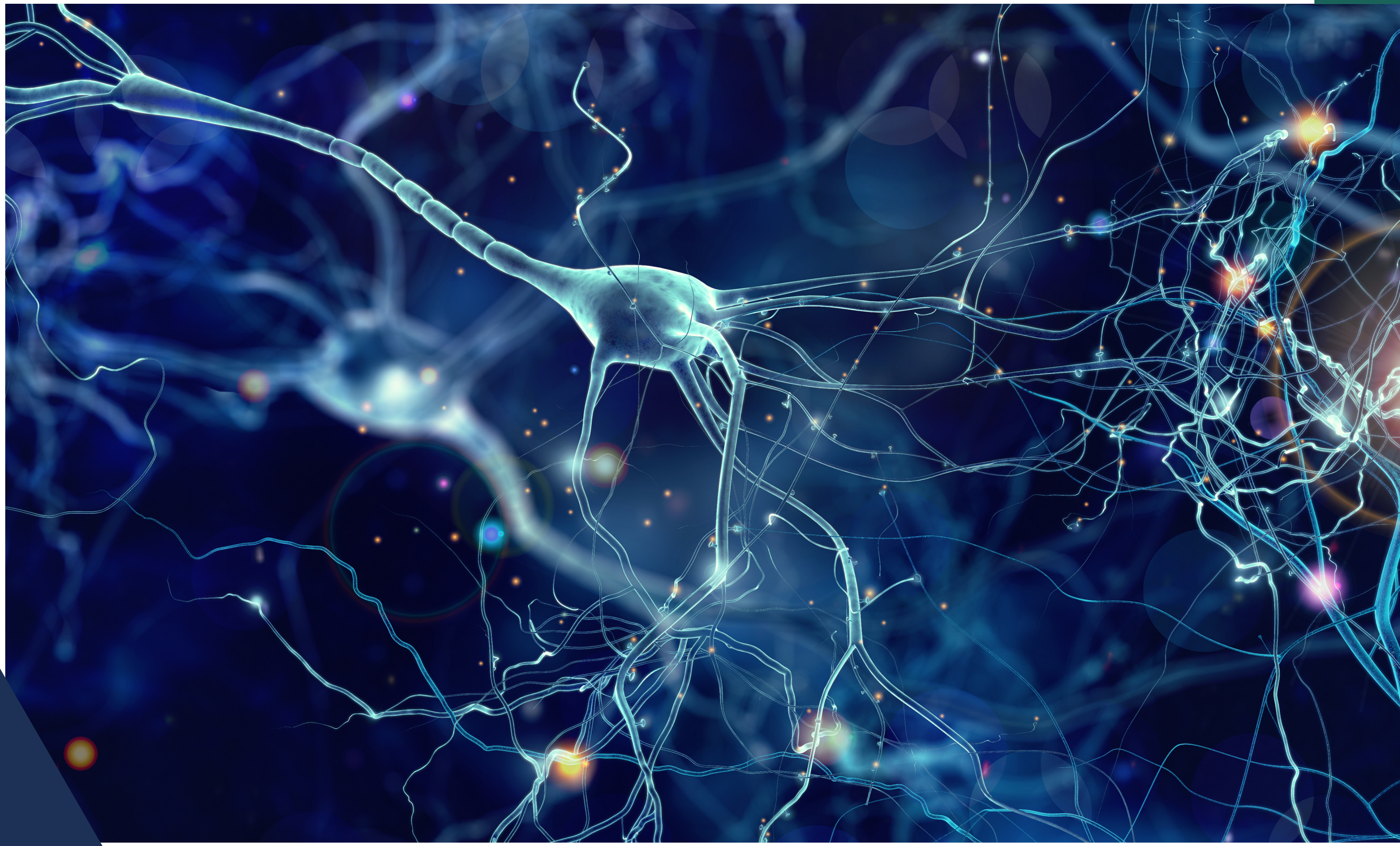
Rachel Clark
on the motivation for her research.

This image (right), courtesy of Rachel Clark, shows a micropillar with embedded quantum dots that Rachel has fabricated in the cleanroom of the Institute for Compound Semiconductors at Cardiff University.



Innovation in healthcare and well-being

The life sciences and healthcare landscape is transforming. Demographics, quality of life, environmental and economic shifts are all contributing to this change. As the global population is growing and aging, new areas of medical need are emerging. The COVID-19 pandemic has also shown us all that the world needs to be better prepared to respond to global health emergencies, regardless of geography or socioeconomic position. Advanced measurement science infrastructure and capability is essential to address these challenges and realise the opportunities they provide.



Towards the magnetic control of target cells

Anna Munro - University of Manchester

Many animals use the Earth's geomagnetic field to navigate long distance migrations, using information such as the strength and polarity of the field to inform them of where they are. For many years, there has been debate over how these animals are able to do this, with multiple theories being suggested. The current widely accepted theory is that a blue-light sensitive protein called Cryptochrome is responsible for this 'sixth sense', via a mechanism called the Radical Pair Mechanism. This theory describes a blue light dependent mechanism, where exposure to a magnetic field will push the system to form more of an active product, leading to downstream biological effects.

Delivered through a collaboration between the National Physical Laboratory and the University of Manchester, the PhD is using the fruit fly, Drosophila melanogaster, to investigate the cellular signalling which occurs to mediate these effects.

Although Cryptochrome is without doubt a part of this system, data has arisen in the last decade to suggest that this isn't the whole story and the widely accepted hypothesis needs updating. We have shown that the last 52 amino acids appear to be responsible for signalling magnetic field effects, while an associated light sensitive cofactor may in fact act as a 'magnetosensor'.

Understanding the fundamental and widely debated question of magnetosensitivity will help answer the longstanding question of how animals can detect magnetic fields. However, there are also potential impacts of this work on human health, and even the potential to harness magnetosensitivity to develop new laboratory tools, such as those to control cellular activity.

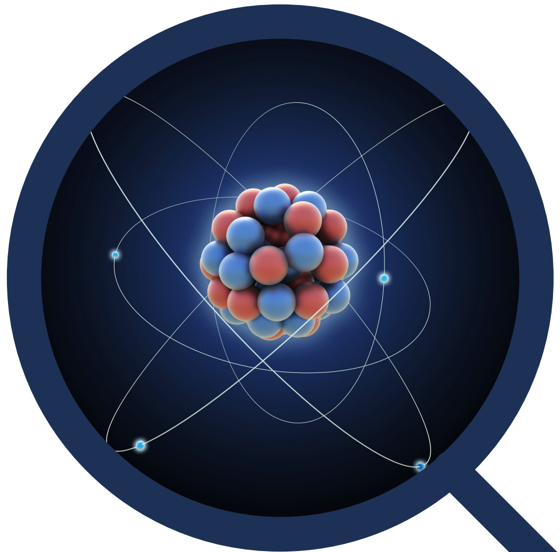
Image: Anna Munro

This image (right), courtesy of Anna Munro, shows a DmCRY structure.

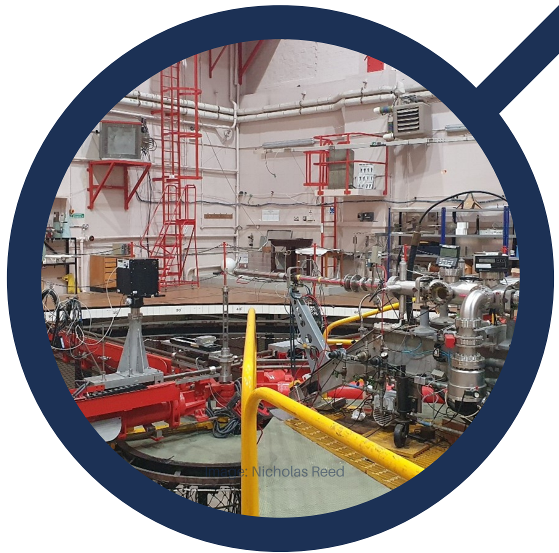
Image: Anna Munro

Advancing measurement science

Measurement solutions are critical to business and government, accelerating research and innovation, improving quality of life and enabling trade. Measurement science is always evolving and improving its methods. **One of the next big steps forward is for superior digital measurement to become the norm in an effort to improve measurement accuracy and minimise human error.**



This image (right), courtesy of Nicholas Reed, shows the dosimeter technology being developed through Nicholas' PhD research.



"By combining this detector technology with modern machine learning techniques to analyse the signals, this device could become a new reference instrument for neutron and gamma dosimetry, allowing a more accurate assessment of radiological safety than the current state-of-the-art."

Nicholas Reed outlining the potential future of his project

Development of a novel approach for the direct measurement of effective dose in neutron and gamma fields

Nicholas Reed – Imperial College London

Understanding and accurately measuring radiation dose is critical to protect the health of workers in modern nuclear facilities, with radiological protection standards characterised by risk to health. Thus safeguarding the modern workplace typically requires using dose quantities such as ambient dose equivalent, defined as the dose in a human tissue average. However, this does not take into account the fact the different doses to organs results in varying risks to health. Therefore, the gold standard for protection is effective dose: the weighted sum of the dose per organ weighted by the risk to health from a dose to that organ.

Measuring effective dose directly is not currently possible for the state of-the-art dosimeters due to the difference in complexity between the human body and any practical detector. Therefore, effective dose calculations rely on simulated energy-dependent conversion coefficients for radiation incident from different directions in order to convert from radiation fluence to an effective dose. As most state-of-the-art dosimeters cannot measure both energy and direction of incident radiation, modern dosimetry instead relies on ambient dose measurements being a conservative estimate of risk in comparison with effective dose. If effective dose could be accurately measured, workers could potentially work safely for longer times in these environments with confidence.

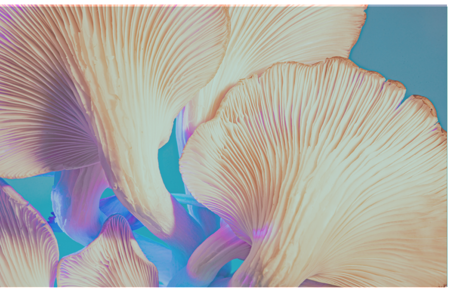
This PhD, a collaboration between the National Physical Laboratory and Imperial College London, is developing a novel dosimeter that is sensitive to both energy and direction of gammas and neutrons in order to improve dose measurements for radiological protection measurements. This dosimeter is comprised of a 3D array of polyvinyl toluene (PVT) scintillator cells with LiF:ZnS(Ag) scintillator screens attached to each cell. Neutrons are thermalised in the PVT before capturing on the scintillator screens, whilst photons are detected through Compton scattering in the PVT, and the distribution of counts encodes the energy and direction of the incident field.

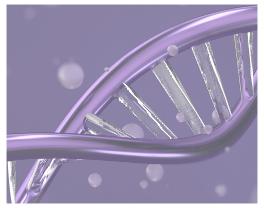
The dosimeter, while not as complex as the human body and unable to provide exact measurement of effective dose, can provide a coarse measurement based on a directional decomposition of the radiation field, an improvement on relying solely on ambient dose.

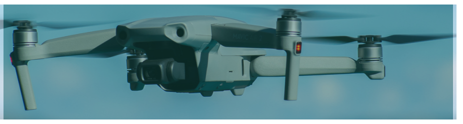
TACKLING GLOBAL CHALLENGES

Our 'Year in the PGI' highlights celebrating PGI and PGI student achievements in 2022

61%
of PGI students graduate into NPL or industrial roles
(with 36% in research or academic roles)







"Rapidly changing healthcare models require novel technologies that enable flexible, cost-effective manufacture of medicines to meet patient demands."
Peter Hou
University of Strathclyde

Winner of both the CMAC 2022 Researcher Award and the 2022 Stephen Young Entrepreneur Award for Outstanding Business Idea Research Paper

33
UK Universities have collaborated with the PGI

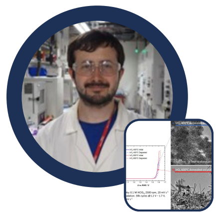
34%
of student projects partnered with industry

Transitioning talent
An interview with Dr Ben Webster

Efficient semiconductor quantum light sources
Rachel Clark | Cardiff University

Towards the magnetic control of target cells
Anna Munro | University of Manchester

Development of a novel approach for the direct measurement of effective dose in neutron and gamma fields
Nicholas Reed | Imperial College London



Improving stability of iridium-oxide anodes for hydrogen production
James Murawski | Imperial College London

Noise-resilient quantum algorithms and software for quantum computers
Alessandra Lignarolo | University of Strathclyde

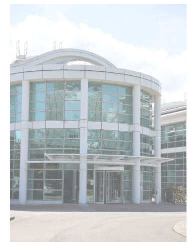
Quality and safety assessment of advanced batteries
Charlie Kirchner-Burles | University of London

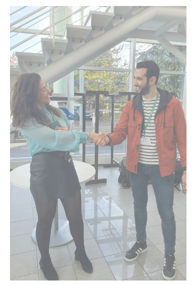
Modelling and performance optimisation of micro-Doppler effects in millimetre wave vehicular applications for 5G and beyond communications
Khalid Al Mallak | Bristol University

2D materials moving a step closer to support emerging technologies
Dimitrios Sagkovits | UCL

"The PGI is shaping collaborative research and providing a portal for PhD engagement that is inclusive, sustainable and agile to partners across the globe."

Dr Peter Thompson
Chief Executive Officer at the National Physical Laboratory (NPL)





361
PGI students attended

18
Training events during 2022

PostGraduate Institute
for measurement science

Improving stability of iridium-oxide anodes for hydrogen production

James Murawski
- Imperial College London

Polymer electrolyte membrane water electrolysers (PEMWE) represent many advantages over conventional alkaline electrolysers. These include the ability to operate at high current density as well as being able to cope better with intermittent use that would accompany the use of renewable energy sources such as wind and solar power. To improve the commercial viability of PEM electrolysers improvements to stack lifetime are required. One of the principles ways this could be achieved is to increase the stability of the catalysts used.

This PhD is a collaboration between the National Physical Laboratory, Imperial College London and Johnson Matthey, looking at improving the understanding of oxygen evolution reaction (OER) catalysts stability and dissolution mechanism. It builds on methods used for standardised short term accelerated stress testing in aqueous acidic media, that can better benchmark stability of OER catalysts for PEMWE applications. It also looks at the limitations of these techniques and how they can be mitigated.

The outcome of this project should enable better development and testing of new electrochemical catalysts that suffer less from metal dissolution when in operation at high potentials, such as those required for electrochemical water splitting for hydrogen fuel generation.

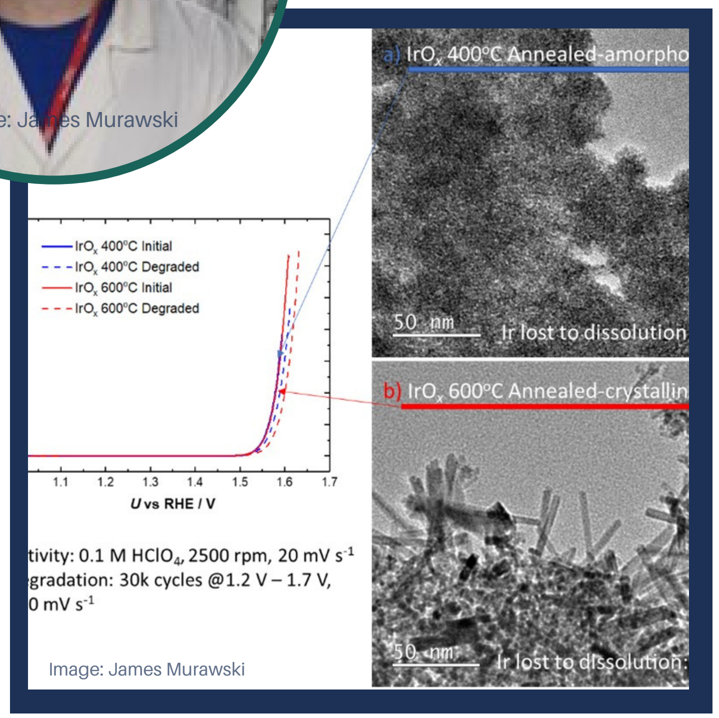
"Maintaining both catalyst stability and performance while reducing precious metal loading is key to the large scale implementation of electrolyser technologies."

James Murawski reflecting on his research.

Responding to immediate crises

The need to decarbonise our economy whilst monitoring and adapting to climate change is driving huge transformation in all sectors. Managing the sometimes conflicting needs of society and our environment is a complex challenge. It demands a whole system approach supported by a global effort, with decision making that needs to be anchored in trustworthy science and data. Measurement science is critical to identifying and quantifying this environmental impact as well as making energy generation and transport more efficient, safe and affordable.

This image (right), courtesy of James Murawski, shows the performance change of two different IrOx nanoparticle catalysts during accelerated stress tests for screening catalyst lifetime. The purpose of this is to assess the suitability of the test for stability screening



Creating a global footprint

Universities and businesses across the world are making the most of the research and innovation opportunities by forming global partnerships and fostering relationships with other institutions. **The PGI is embedding measurement solutions in PhD projects for real world problems as well as creating global partnerships that focus on interdisciplinary R&D solutions.**

"These algorithms [from my research] could help to study relevant aspects (e.g. ground and excited states) of molecules and have a strong impact in the field of quantum chemistry."

Alessandra Lignarolo discussing the impact of her research

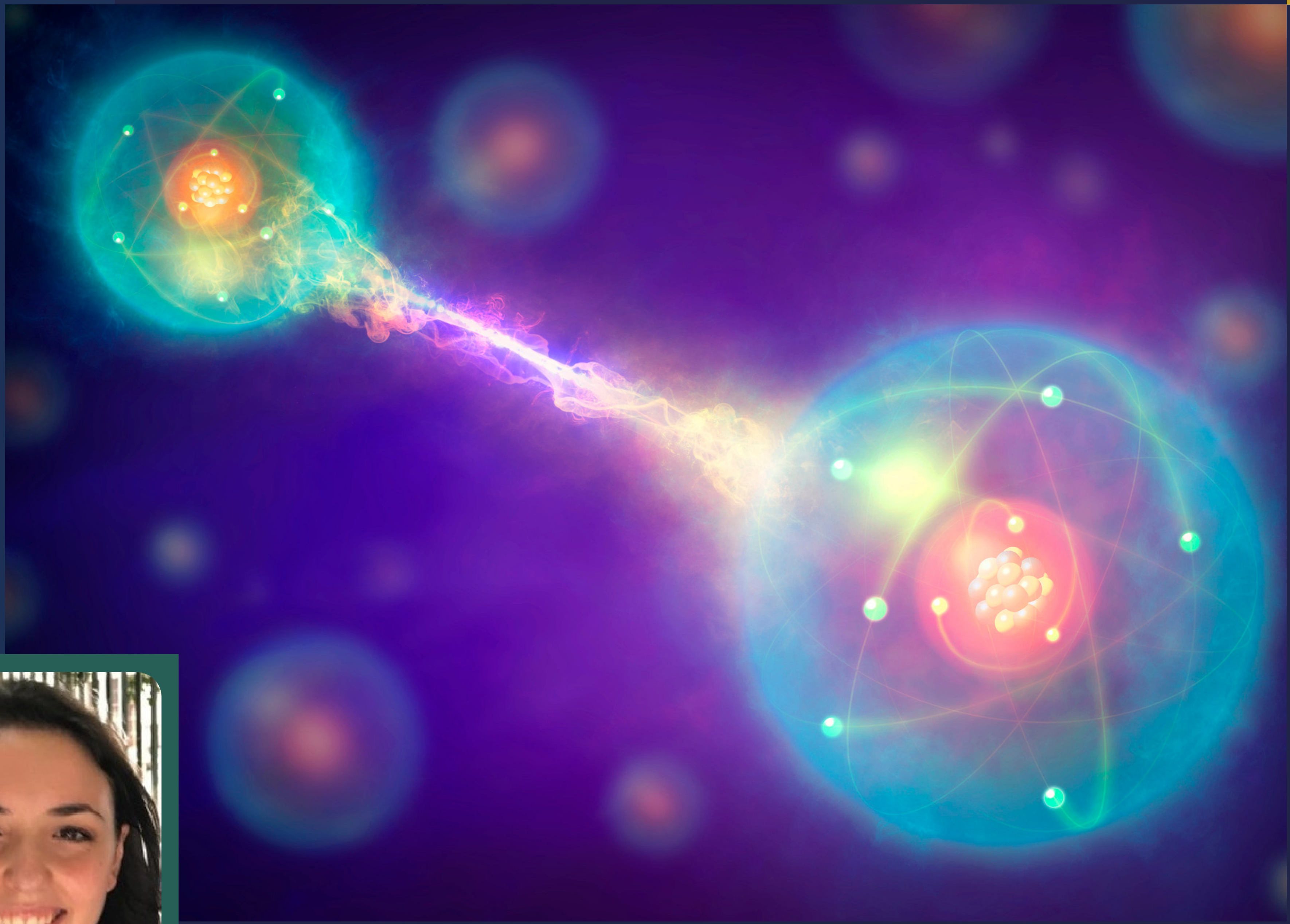


Image: Alessandra Lignarolo

Noise-resilient quantum algorithms and software for quantum computers

Alessandra Lignarolo - University of Strathclyde

Quantum computers are now a reality and have immense potential to solve problems of relevance for wide ranges of industrial applications. However, the results are inherently probabilistic and therefore have associated uncertainty and errors. Since quantum computers will allow us to simulate systems not accessible on conventional computers, it is infeasible to verify these errors by simulations on conventional computers. This PhD project is a partnership between National Physical Laboratory, Quantinuum and Strathclyde University and is focusing on quantum algorithms for quantum chemistry.

Since recent advances in the near-term quantum computer open a new route for materials and chemistry simulations, in this project we investigate the impact of quantum computing mainly for quantum chemistry. This is done by developing quantum algorithms and implementing different methods that, applied on Hamiltonians, allowing us to derive important properties of these latter ones.

Working with industry

Industry needs support from science and technology communities to meet the challenges of the fourth industrial revolution and the advancing digital transformation. Without this, there is a risk that the UK falls behind on the international stage, fails to meet climate change targets, and businesses struggle to survive. **Good measurement creates certainty in the quality and safety of new and existing products and processes, and boosts productivity by reducing waste, increasing efficiency and enabling confidence.**

Quality and safety assessment of advanced batteries

Charlie Kirchner-Burles - University College London

In recent years numerous high-profile failures of Li-ion batteries have been reported, contributing to wider concerns about the safety of high energy density cells. Therefore, it is important to work on a method to advance the safety of high energy.

This PhD is a collaboration between the National Physical Laboratory and University College London and is adapting a new method for battery failure characterisation using high speed radiography and tomography. The plan is for these to be further developed to include correlative thermal, calorimetric and acoustic spectroscopy allowing us to better understand thermal runaway processes and providing a more robust method for cell qualification.

The scientific objectives of the project are represented in demonstrating high speed X-ray imaging for a range of failure scenarios (mechanical, electrical, thermal abuse), which can be interpreted through complementary modelling, undertaking correlative measurements, such as acoustic and thermal analysis and extending investigations to next generation cells, including Li-S and Na-ion. It also supports the translation of synchrotron capabilities to the laboratory to enable routine quality control metrology and contributing to new international standards for cell qualification and safety.

"Investigating techniques that aim to assess the safety of advanced batteries has been an amazing experience. Research into correlative thermal, calorimetric and acoustic spectroscopy could help advance battery management systems to better predict and mitigate cell failures while providing insights into the mechanisms behind thermal runaway and of the devices that prevent it."

Charlie Kirchner-Burles reflecting on his research.

Modelling and performance optimisation of micro-Doppler effects in millimetre wave vehicular applications for 5G and beyond communications

Khalid Al Mallak - Bristol University

Millimetre waves (mm-waves) communications are currently hot research topics aiming to evolve the capabilities of cellular communications. Congressed radio spectrum and band fragmentation for cellular, WiFi and broadcast services beyond 6 GHz has resulted in poor receiver sensitivities and in some case adjacent channel blocking. To facilitate a realistic performance assessment of emerging 5G systems, it is necessary to develop propagation channel models at mm-waves for indoor and outdoor environments that reflect the true behaviour of the radio channel considering the effects of realistic antenna arrangements.

This project, a collaboration between the National Physical Laboratory and Bristol University, is investigating the characterisation of millimetre wave frequencies in vehicular applications, including modelling different vehicular channels in different environments, which reflect realistic vehicle-to-vehicle or vehicle-to-infrastructure scenarios. The models are supported by methodologies designed by performing outdoor and indoor measurements, these were also optimised by considering different parameters such as the base station height, antenna's beamwidth, and polarisation, as well as the types of road surface (asphalt or concrete).

These parameters were used to investigate the effects of vibrations that occurred due to suspension variation when a vehicle moves on an uneven road. The vibrations cause antenna's depointing; consequently, they induce Doppler and micro-Doppler power spectrum due to the changes in the composite phase and amplitudes of the antenna's radiation pattern. The phase changes are the main reason for generating micro-Doppler shifts and for being investigated by conducting reflectivity measurements of different metal reflectors acting as targets in a controlled environment.

These images (left, below), courtesy of Khalid Al Mallak, shows in situ measurements from his research.

Engineering the future

Advanced manufacturing is transforming industry and productivity. Ensuring that material formulation and manufacturing technologies meet the standards and specifications that businesses demand and can be traced, is vital to control manufacturing processes and assure the quality of products. **Good measurements are critical to productivity, acceleration of product to market and innovation.**

"My research impacts the design of new '5G and beyond' modems as well as any application of millimetre waves where the channel is time-varying. It can also, potentially impact the implementation of millimetre waves in the industrial Internet of things due to the requirements for ultra-reliable low latency communication."

Khalid Al Mallak on the impact of his research

2D materials moving a step closer to support emerging technologies

Dimitrios Sagkovits - University College London

Recent advancements in material science have allowed us to push technological applications to their extreme fundamental limits. Two dimensional (2D) materials with thickness of just one atom, like a sheet of atoms arranged on a plane, were discovered about 15 years ago and have become a major research field. Since then, a very large number of 2D materials has been discovered. Importantly, a few years ago, layered materials that preserve their magnetic properties down to the single layer limit have been added to the list of 2D materials.

This project aims to investigate the properties of magnetic 2D materials, by fabricating electrical devices that consist of different layers of 2D materials stacked on top of each other, much like LEGO™ blocks. The resulting devices, called van der Waals heterostructures, are essentially artificial materials, and their properties can be tuned by combining different materials or even by twisting the angle of each respective layer.

Understanding the properties of 2D materials is the first step in order to eventually integrate them in industrial production lines, which is the ultimate big picture scope. This could potentially have a major impact for the semiconductor chip industry, where 2D materials are a natural extension of the traditional silicon based electronics, which is already reaching its limit in terms of scaling down and is looking for alternatives in the never-ending pursuit of Moore's law verification.

Right now, the exotic and tunable properties of 2D materials are a suitable playground for understanding the fundamental properties and phenomena underlying these novel technologies, but in the future, they could become the foundation on which real-life applications are built on.

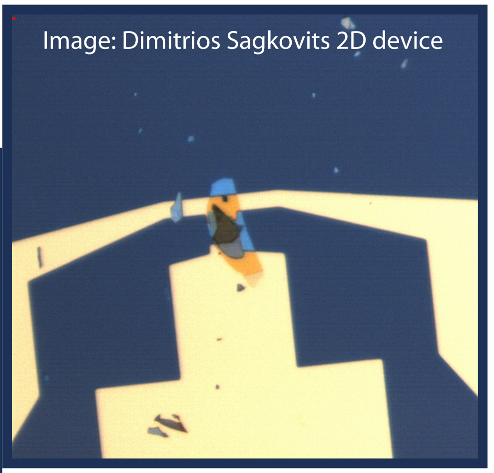


Image: Dimitrios Sagkovits 2D device

Image: Dimitrios Sagkovits

Creative development of new materials

Materials that can endure the harshest conditions are needed to allow us to dig at the bottom of the ocean and to transport the fuels of tomorrow. Learning to manufacture these materials at scale and incorporating safety and sustainability into their design and innovation is as important as their discovery and development. This effort is essential to unlocking innovation across all major industrial sectors and could not be achieved without measurement science.

"My project is funded as part of the Centre for Doctoral Training in Advanced Characterisation of Materials and embedded in NPL's excellence in metrology. It has enabled me to develop new methods of making such devices, in order to measure their properties both in the direct current and high frequency regimes, making it easier to bring novel ideas one step closer to becoming a viable solution for emerging technologies."

Dimitrios Sagkovits on the novelty of his research