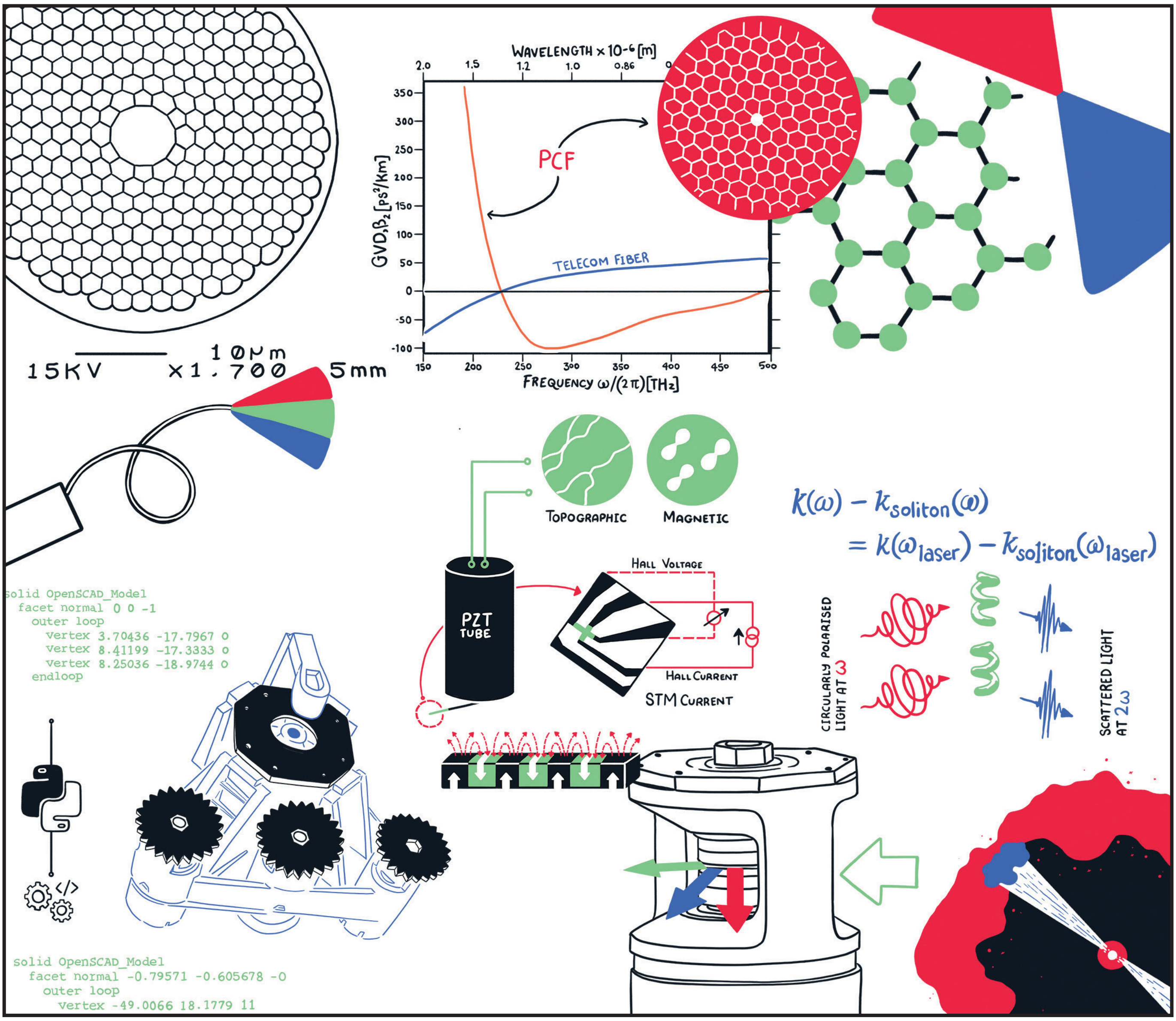
# PHYSICS at BATH

## Department of Physics **End of Year Report** 2023




Cover art by Rae Goddard at paraphrase.studio

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# Another year of transformation

The year 2023 saw the continuation of our transformation. Over 550 m$^2$ of our lab space has been reorganised, with nanoscience labs built in 5 West and with detailed plans established for the photonics and more nanoscience labs, in 8 West. Discoveries await! The new mechanical workshop has also been built and it is already supporting the exciting projects of our students and researchers alike. We have started implementing a novel structure for our degrees and I am very grateful to all who have contributed time and efforts to 'Curriculum Transformation'. The organisation of the Astrophysics group was clarified. Following our away day, we have formulated the cultural values we wish reflected in our environment and activities: *collegiality*, *achievements* and *learning*. Based on these values, we have started to develop a distinctive visual identity with a number of unique murals, featuring our research and educational missions. Some of our "great days for science" are covered in this report. There have been more and many more are yet to come!

**Prof Ventsislav Valev**
Head of Department

# Today is a great day for science!

## Our Vision for Physics in Bath **update**

(Sentences in green have become reality, those in blue are being worked on).

The year is 2029, the national Research Excellence Framework results are just in and we have hit all our targets. For outputs, impact and environment, we are in the top 10 UK physics departments. Our grant income has steadily increased over the years. An ever-larger proportion of our research income now comes from sources other than the Research Councils. We consistently score very high in student satisfaction surveys and we comfortably recruit strong undergraduate students to meet our targets. We are committed to delivering exceptional courses. We are recognised as a leading department of physics education and research, capable of coordinating large initiatives, such as centres for doctoral training. Our reach is global. We lead numerous partnerships with nearby universities within the South West. Our leaders are focussed on strategy, implementation and above all, on delivering results.

### Building upon our culture is the priority

To meet our strategic growth targets, we have increased our productivity by creating a vibrant community. All staff feel valued, with clear roles and career paths. Our staff enjoy each other's company. We have a (re)generator room – our staff often have energizing discussions there to generate great ideas. It is also a place to drink coffee, relax and revitalise. Our staff have the opportunity to have lunch together and many of them do. When they have a problem or need support, there is always someone they can talk to. We collectively celebrate our successes and our events are inclusive. All staff feel empowered to bring their distinctive contributions to develop and deliver the vision. Diversity brings different perspectives and viewpoints that help us to increase our impact and reach. Our community includes the undergraduate and postgraduate students and there are Department events dedicated to each learning stage. We have created a community record – a department yearly report that staff can bring home at the end of the calendar year. There, one can read about our activities, our research and teaching successes, our new department members, etc. The report also goes to our extended community, including partners and alumni of the department. A library of all previous reports is available in our meeting room.

## Research funding is diversified

Over recent years, our funding has diversified. The majority of our research income is now from sources other than the Research Councils, such as: business and industry, Innovate UK, the Royal Society, the Leverhulme Trust, West of England Combined Authority, the Wellcome Trust, the Royal Academy of Engineering, the British Embassies, Research England, Bath and North East Somerset Council, DSTL, DASA, etc. We regularly exchange visiting postdoctoral researchers and PhD students with partners abroad. Our increased research power softens the vagaries of Government research funding. Within our grant portfolio, our academics are leading large research programs. Growing resilience to failure has been the key. We support each other in overcoming rejections and we take failure as scientists – it is data! It is never personal. Our increased research power means that rejections have a short-term effect on morale and grant applications are swiftly redeveloped into new proposals.

## Our environment is refurbished

From the west car park, the physics building is immediately recognisable and inviting. We are now working in a completely refreshed environment and we are all together, in the same building. Once inside, there is an immediate impression that this is a place of learning. The corridors and meeting room walls are lined up with items that celebrate our successes: prizes, prominent research papers, cover arts and prototypes are all present. Display items also demonstrate the career possibilities that Physics offers (we have a section on the wall with alumni photographs), as well as spin-out successes and prominent collaborative work. Office doors are personalized with laser cut doorplates that highlight our achievements. The meeting room is a place of inspiration. Visitors are impressed with the attention to detail and want to work in a place like our building.

## Our labs are inspiring and world-leading

Inspiration takes different forms. Walking into some of our labs feels like being on a glamorous science fiction movie set (with lasers, robots, space vacuum, quantum computers). Others are places of contemplation – this is where the first hollow core fibre was made, the first Hall probe microscope built, etc. Our safety measures and signage tell everyone that our labs are special places and that we care for people. The labs host unique and cutting edge equipment operated by scores of students, postdoctoral researchers, and expert technical staff. Our researchers also have access to world-leading shared facilities (including observational satellites and high performance computing machines). In the words of Nicolaas Bloembergen (Physics Nobel 1981): "When you use new technology, new things are bound to happen." Following this recipe for scientific discoveries, our unique equipment and our access to world-leading facilities routinely produce high-impact research results.

## We create impressive narratives

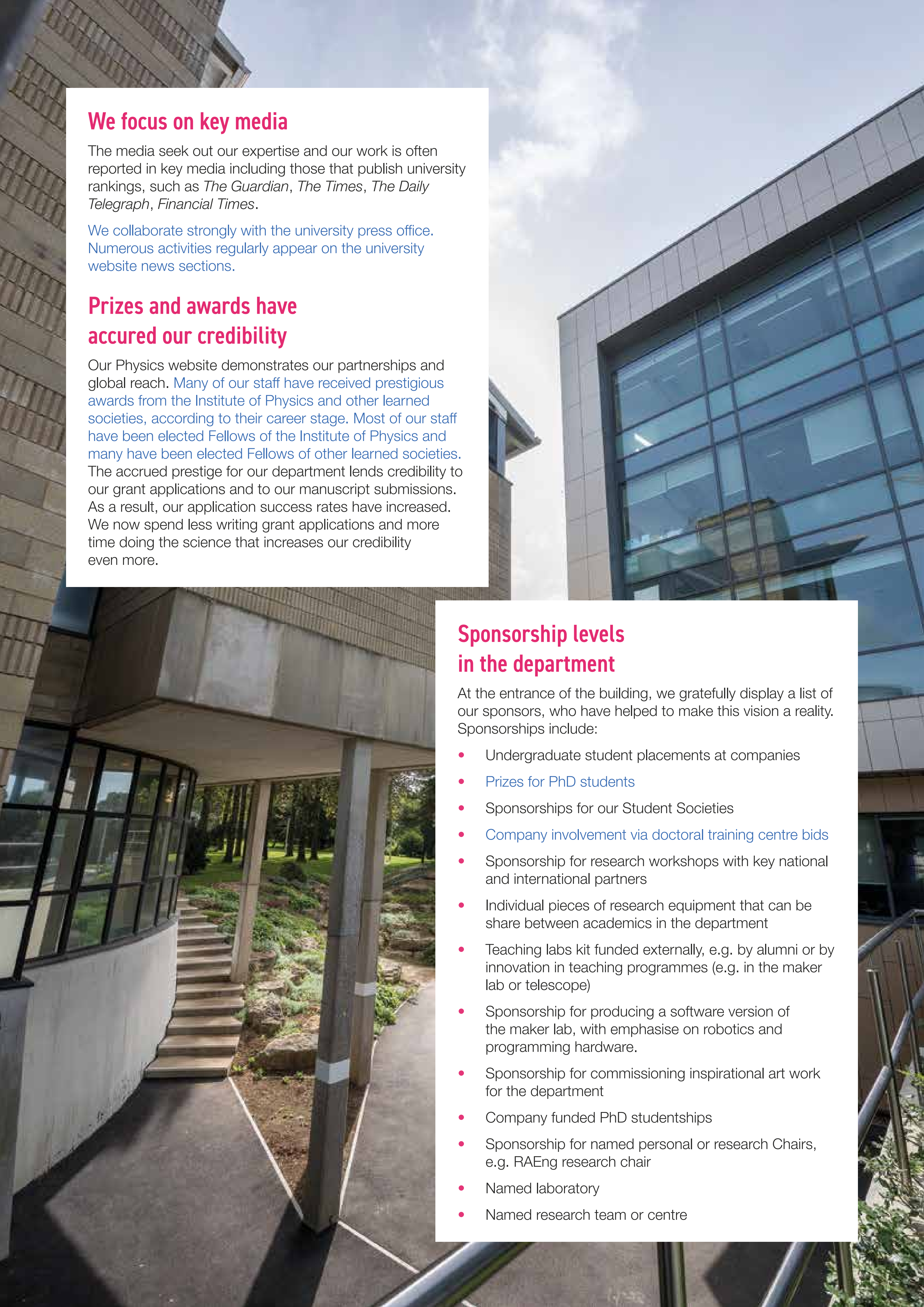
For most of our exciting research, there are outreach activities, with narratives and props to explain the science to visitors. A public engagement professional is in charge of lab tours and of organising meetings with academics (both theorists and experimentalists). Some of our visitors have been fund managers, industry partners, editors, higher management, and we regularly host visits from our alumni. Many are very impressed and the visits have changed the perceptions of key partners. As a result, our academics are much more confident about submitting ambitious grant applications and manuscripts. Consequently, our success rates have increased.

## Our leadership is shared and empowering

Leadership and management are distributed throughout the department through effective delegation processes. A senior department manager ensures that our administrative processes run smoothly. A Deputy Head of Department complements the Head of Department's expertise. The Head of Department draws expertise from training, feedback, mentorship, experience. The Head of Department focusses on strategy and on meeting the key performance indicator targets for the department. Throughout the department, delegation improves our staff's leadership and management skills. The process benefits their research teams and their teaching. It also prepares them for taking on larger responsibilities within the department. Our staff look forward to their Career Conversations, which are recognised as useful to achieve their career goals. Teamwork and volunteering within the Department are a valued integral part of the career conversations and promotion processes. Department meetings tell stories of colleagues who are leading initiatives of strategic importance for our community.

## We concentrate on guided learning

In our undergraduate programmes, our focus is on the effective guidance of learning. This shows in our student satisfaction survey results. We are committed to delivering exceptional courses. We have star teachers and teaching awards reflect that fact. Our teaching labs are inviting playgrounds where even parents visiting on open days want to start a physics degree. We have attracted a large number of overseas students. All researchers are enthusiastically participating in the learning process. Our learning spaces are stimulating environments. Our courses are continuously refreshed and remain fit for the future. All the overheads of preparing new courses and new assessments has freed time for research. At the end of each year, we offer student prizes to our best students to reward their efforts, to build their confidence and to strengthen their CVs as they launch their professional lives. The number of our PhD students has increased. Our PhD students benefit from visits to internationally leading research institutions abroad and, in turn, we host PhD student visits from these institutions.



## We focus on key media

The media seek out our expertise and our work is often reported in key media including those that publish university rankings, such as *The Guardian*, *The Times*, *The Daily Telegraph*, *Financial Times*.

We collaborate strongly with the university press office. Numerous activities regularly appear on the university website news sections.

## Prizes and awards have accured our credibility

Our Physics website demonstrates our partnerships and global reach. Many of our staff have received prestigious awards from the Institute of Physics and other learned societies, according to their career stage. Most of our staff have been elected Fellows of the Institute of Physics and many have been elected Fellows of other learned societies. The accrued prestige for our department lends credibility to our grant applications and to our manuscript submissions. As a result, our application success rates have increased. We now spend less writing grant applications and more time doing the science that increases our credibility even more.

## Sponsorship levels in the department

At the entrance of the building, we gratefully display a list of our sponsors, who have helped to make this vision a reality. Sponsorships include:

- Undergraduate student placements at companies
- Prizes for PhD students
- Sponsorships for our Student Societies
- Company involvement via doctoral training centre bids
- Sponsorship for research workshops with key national and international partners
- Individual pieces of research equipment that can be share between academics in the department
- Teaching labs kit funded externally, e.g. by alumni or by innovation in teaching programmes (e.g. in the maker lab or telescope)
- Sponsorship for producing a software version of the maker lab, with emphasise on robotics and programming hardware.
- Sponsorship for commissioning inspirational art work for the department
- Company funded PhD studentships
- Sponsorship for named personal or research Chairs, e.g. RAEng research chair
- Named laboratory
- Named research team or centre

# Highlights of 2023

## Staff: Hellos and Goodbyes

In 2023 we said goodbye to Dr Kunjalata Majhi, Dr Jack Binysh, Dr Julieta Arancio, Dr Jun Toshikawa, Dr Stephen Hamer, Dr Stavros Drakopoulos, Ahsan Jafri, Dr Menglong Li, Dr Euan Allen, Dr Josh Nunn, Dr Anton Souslov and Dr Steve Andrews.

We've also welcomed Ruidong Ji, Dr Petros Androvitsaneas, Dr Dipti Chauhan, Dr Soraya Caixeiro, Dr Hoyeon Choi, Dr Joseph Wilcox, Dr Sayan Kundu and Dr Paramita Pal.

## Prizes

- Prof Valev was awarded the Thomas Young Medal 2023, from the Institute of Physics.
- Dr Allen was awarded the Clifford Paterson Medal 2023, from the Institute of Physics.
- Prof Wuyts was named Hiroko Sherwin Chair in Extragalactic Astronomy.
- Dr Van Eerten was honoured with IOP Publishing Top Cited Paper Award
- Best Team in Support of Student Learning Award was awarded to The Bath Physics Observatory team (Dr Sloan, Dr Scowcroft, Dr Davies and Dr Mathlin). It recognises exceptional or innovative teamwork in the delivery of learning and teaching.
- Dr Laughton was awarded a Curriculum Transformation Award for institutional leadership of this highly ambitious and demanding programme
- First place poster prize was awarded to a PhD student, Pieter Keenan, at the Microscience Microscopy Congress (MMC) organised by the Royal Microscopy Society.
- Charlotte Avery won the Excellence in Research PhD Prize.
- Prof Valev was elected Fellow of SPIE for achievements in nonlinear & chiroptical nanomaterials, plasmonic and nano-photonics.

## Research Grants and Fellowship

- Dr Rusimova was awarded a new Investigator grant by the EPSRC. She also received a research grant from the Royal Society.
- Prof Skryabin received a Short Industry Fellowship from the Royal Society for collaboration with the National Physical Laboratory (NPL) and the University of Helsinki. He was also awarded EPSRC grant to develop power efficient microresonator frequency combs.
- Dr Tsang and Dr Dale were awarded research grants from the Royal Society.
- Dr Zeidler was awarded a 3-year Mercator Fellowship.
- Drs Ilie and Takashina were successful with three project proposals submitted to Diamond Light Source in the area of 2D materials, resulting in three separate rounds of beam time.
- Dr Van Eerten was awarded a grant by the Royal Society to establish a collaboration with astronomers from Nanjing University, covering multiple visits and hosting of visitors over a two-year period. Bath and Nanjing astronomers will work on bespoke models for extraordinary cases of gamma-ray bursts, cosmic explosions when black holes are formed.

## Research Visits

- Dr Tsang received Visiting Professorship at Toulouse Earth and Space Sciences Graduate School.
- Prof Wuyts & Junkai Zhang visited National Astronomical Observatories of China in Beijing over the summer, which has been facilitated through the Royal Society International Exchange.
- Dr Gorbach, Dr Rusimova, Prof Wolverson, and Mr Kiernan visited Photonics Material Laboratory of Prof Hu in Massachusetts Institute of Technology, which has been facilitated through the Royal Society International Exchange.
- Prof Valev spent one month at the Sapienza University of Rome, as a Visiting Professor.

## Spin off companies

Dr Ilie filed a new patent application with her spinout company Transdermal Diagnostics Ltd. which is developing a proprietary non-invasive technology for glucose monitoring. Also, the original patent underpinning the company's core technology has been very recently granted also in the EU (to add to the already granted status in the USA and Japan). Further, Transdermal Diagnostics secured a range of ancillary governmental-funded business grants to support additional aspects of the core project.

## Conferences

- Dr Mucha-Kruczynski co-organized the Annual Meeting of the IoP Theory of Condensed Matter Group in Warwick.
- Prof Wadsworth co-organised the AFRL/EOARD Optical Fibre workshop in July.
- Dr Blondel, who sits on Scientific Committee for the UACE2023, helped co-organise Underwater Acoustics Conference & Exhibition series 2023.
- Dr Rusimova, Dr Schady and Prof Bending, on behalf of the Department of Physics Research and Knowledge Exchange Committee, organised third Eureka conference in June.
- Prof Bending also organised an International Workshop on Superconductivity and Magnetism in Two Dimensional Films and Heterostructures in the summer. Prof Walker co-organized the DeModeP23 (Characterisation and modeling of devices) symposium as a part of the MATSUS23 Materials for Sustainable Development conference in Valencia.
- Prof Wolverson co-organised TMD-UK at Sheffield in July as part of the Semiconductors UK conference.

# Outreach

Dr Tsang gave talks with the Bath Astronomers group as well as an undergraduate Pub Lecture. Dr Rusimova led 9 outreach workshops to children from schools in the broader Bath area, covering in total 225 children in years 5&6. She has also participated in remote outreach talks at two secondary schools in Bulgaria, and, together with Prof Valev, was featured in a light installation as part of the LUNAR Festival of Lights in Sofia as a way of celebrating the successes of British-Bulgarian connection and inspiring more people to get involved with and pursue studies in STEM. Dr Blondel collaborated with "We The Curious" in Bristol on the "What does music sound like in space?" film project. Prof Walker, together with Prof Cameron from the Department of Chemistry, participated in "A bright future for solar energy" podcast on the future of solar power, featuring interviews by the internationally renowned journalist Roland Pease. Dr Laughton, Dr Scowcroft and 12 final year Communicating Physics students collaborated with the Wiltshire Music Centre to run My Science Fair Project Competition 2023. Dr Van Eerten authored the article "Brightest cosmic explosion of all time: how we may have solved the mystery of its puzzling persistence" in The Conversation UK. Prof Walker showed how Artificial Intelligence AI and mathematical modelling could light the way for solar cells of the future. Dr Narduzzo and Dr Gorbach showcased the Sound Crystal built in collaboration with an artist, Rob Olins, at The Green Man Festival. Together with the Department of Chemistry and the Department of Life Sciences, the Department of Physics held a "Science in the Spotlight: 2023 Nobel Prizes talks" event in November.

# Congratulations!

## to all PhDs who have received their award in 2023:

Dr Zhiwei Fan

Dr Alize Vaihiria Gaumet

Dr Rita Mendes Da Silva

Dr Guillermo Jimenez Arranz

Dr Danila Puzyrev

Dr Charlotte Parry

Dr Alexander William Allen Murphy

Dr Leah Murphy

Dr Will Luckin

Dr Joseph Knapper

Dr Bethan Easeman

Tom Weaver (MPhil)

Dr Aimee Nevill

Dr Ross Challinor

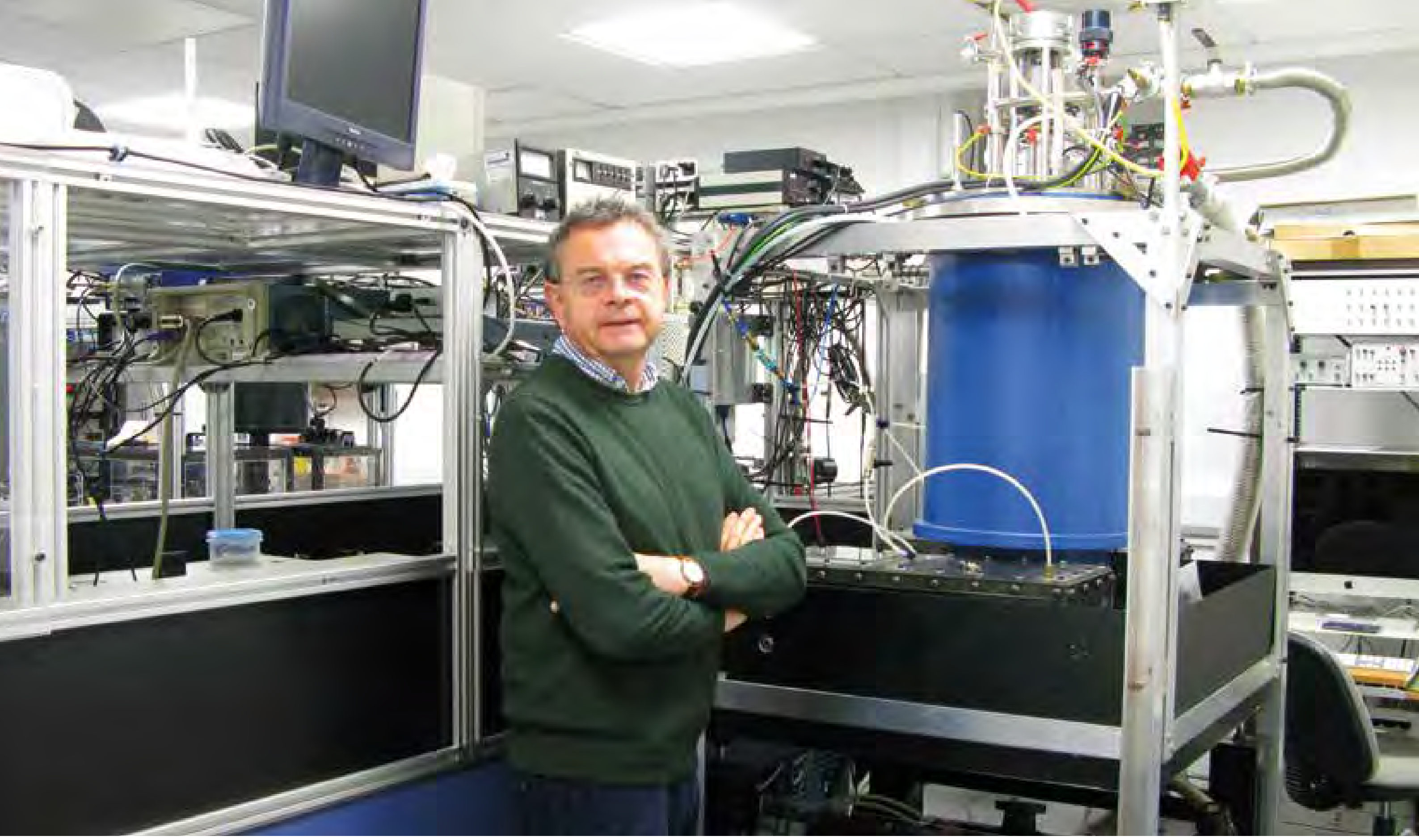
Dr Guido Baardink

Dr Duncan Neill

Dr Ed (Qingxin) Meng

Dr Junkai Zhang

Dr Robin Jones



# A few words from...
# Steve Andrews

## How did you decide to become a physicist?

Physics was my first choice as a degree subject because I loved that you can work so many things out yourself if you understand the physical principles and that it connects strongly with the world around us. It wasn't until I was half way into my PhD and I had started to produce original research that I knew for sure that I wanted to become a physicist.

## What kept you going?

Variety, challenges and rewards. I have always enjoyed learning about new areas of science and have been able to work in a range of different fields including phase transitions, semi-conductor devices, ultrafast science, functional materials and terahertz technology. This variety and the challenges of moving into new areas together with the satisfaction of getting experiments revealing new science to work has maintained my engagement. I have also enjoyed the varied teaching roles and courses that I have been involved with which present different challenges and rewards.

## Can you tell about something that you look back on as a high point or moment of pride, or a moment when you felt that you were making a difference?

I think one of my proudest moments was when, as a PhD student, I managed to develop a novel spectroscopic instrument, making much of the apparatus myself, and successfully used it to try out my own ideas for experiments whilst my supervisor was in the USA on sabbatical. Another is when as a post-doc I discovered and explained a weak diffuse x-ray scattering feature in crystalline materials that gives information about the structure of surfaces and interfaces. In Bath, a high point was getting to perform the first time resolved terahertz experiments in the UK using microfabricated antennae and ultrafast photoswitches made in the department's first cleanroom in 3W. This work led to a raft of successful studies of materials and several consultancies and technology transfer with Toshiba Europe and Teraview.

The most recent high point has been success in optimising the generation of intense and ultrabroadband THz pulses generated in laser excited gaseous plasmas and applying them to perform nonlinear spectroscopy on materials. I also look back at some of my interactions with undergraduate students where, as a personal tutor, placement tutor or director of studies, I have been able to make a difference when supporting individuals to achieve goals or surmount problems.

## Can you tell about a time when you learned something really important for your work or career?

I am not sure how to interpret this question but there were 3 significant decision points in my career after I had committed to being a physicist. The first was when I decided to explore working in an industrial research lab because I didn't want to commit to an academic career without first seeing what else was put there. It was quite an exciting time to be in industry and I learned a lot of science and engineering that has since been useful but most importantly I learned that I enjoyed hands-on science more than management, which I was being pushed towards. That is the main reason I made the decision to move back to academia and ended up in Bath. A third important decision came when I became convinced that ultrafast and terahertz science were both going to be significant future growth areas and that is why I moved into these fields after joining Bath back in 1994.

## Can you tell us about a colleague who's had a major impact on your work/career?

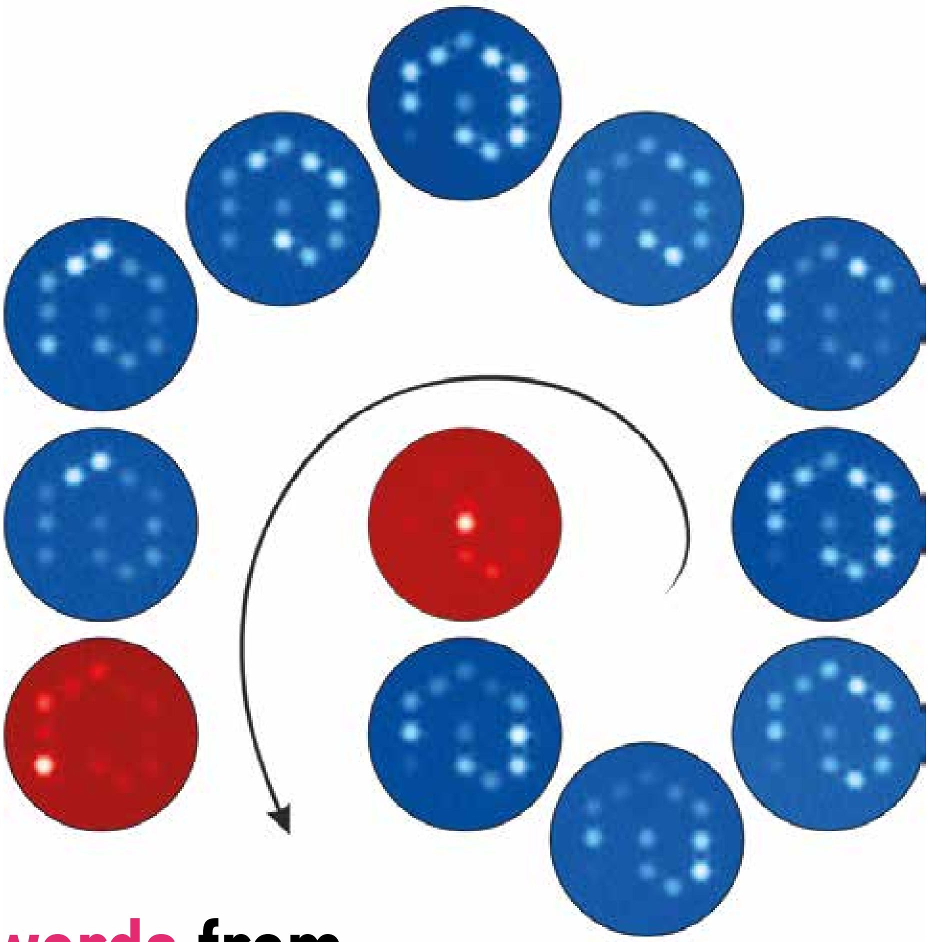
Several people that I have worked with have had a significant impact on my career. Richard Harley, my PhD supervisor in Oxford gave me confidence in and an appetite for difficult experiments and building my own instruments if they either didn't exist, or were unaffordable or not good enough if they did. He has also been my role model for my hands-on approach to PhD supervision. Roger Cowley, my postdoc supervisor in Edinburgh and who I greatly admired as a scientist, made me believe in myself as a scientist and encouraged me to embark on an academic career. Peter Huggard, my first postdoc greatly helped make my first Bath research programme, a success and I am pleased that he has gone on to a very successful scientific career. Stefan Maier, who was in Bath for a time and has moved on to a succession of great things, persuaded me to take an interest in metamaterials and plasmonics and was a great collaborator in this area. I am grateful to Simon Bending without whose efforts to raise the finance needed to start building the nanofab facilities and his subsequent management of it I would not have been able to pursue many of my research projects in Bath. Finally I have picked up a lot of practical skills from a host of technical support staff over the years and these unsung colleagues have made a real difference t what I have been able to achieve.

## Can you tell us about a time when you helped a colleague with their work/career?

Whilst in Bath I have supervised quite a few PhD students and postdocs and large part of that role has been to teach and help them on a daily basis. I am pleased that most are in scientific careers have and trust that aren't are in lucrative ones. I have also tried to help improve the research and teaching infrastructure that supports many colleagues in physics. In particular I am thinking of the work that I have put in t helping develop and expand the years 1 and 3 teaching lab provision and my contribution to the design and equipping of the nanofab facility.

## Is there any other story about your work with us that you think our colleagues and students might find interesting?

Over the last few years I have got interested creating what might be called affordable and sustainable biosensing instruments for developing economies. This is something that I am continuing in retirement and builds on preliminary student projects. An example is the rapid, non-invasive measurement of plant water content to aid in the conservation of irrigation water and breeding of drought resistant plant strains. Another is the real time measurement of carbon dioxide in exhaled breath during anaesthesia which is often life saving but not widely used in many developing counties for reasons of cost and sustainability. The latter project was inspired by a medical friend interested in third world medicine.



# A few words from...
# Anton Souslov

## How did you decide to become a physicist?

I remember wanting to be a physicist since I was little. It was a subject in which I did well in school. My father is a physicist, and although we now work in very different fields of research, when I was little, he would often tell me about the world around me and explain how things work. I think those conversations inspired a lot of curiosity early on.

## What kept you going?

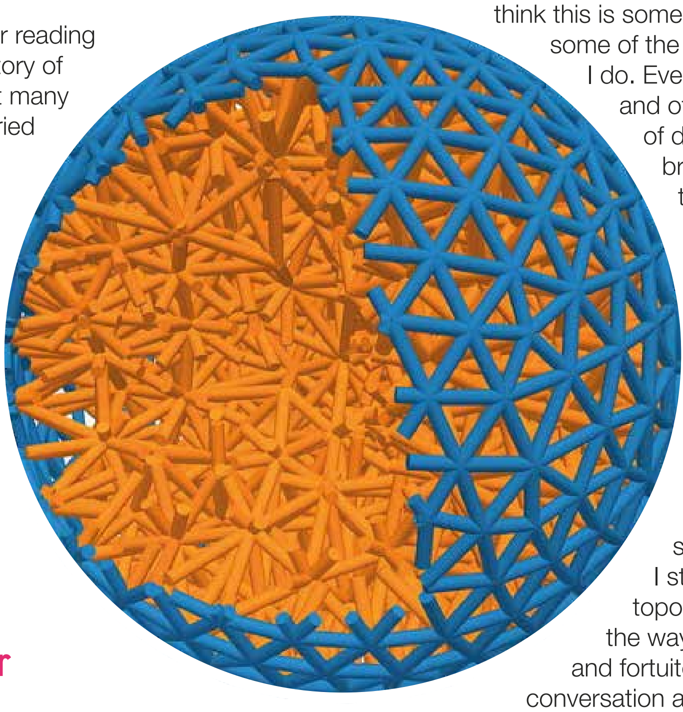
In part, it was just the need to choose a subject to study at university and to choose a career path. However, I think it was often the people around me who inspired me to take new directions in what I did, and who helped me persevere when the way forward was not so easy.

## Can you tell about something that you look back on as a high point or moment of pride, or a moment when you felt that you were making a difference?

I remember vividly when I was first asked for a reference letter for a colleague that I worked with. Although now it seems like an everyday part of the job, back then the idea that someone wanted my opinion on a hiring decision seemed so improbable and so important. When my colleague was hired, it felt like I made a big difference – although in retrospect, I realise that it was the colleague's achievement, and not at all mine!

## Can you tell about a time when you learned something really important for your work or career?

Books can inspire – I remember reading The Idea Factory about the history of Bell Labs. I already knew about many of the research discoveries carried out there, from the transistor to information theory, before reading the book. However, the way these discoveries were not coincidental, but rather emanating from a well-conceived idea of scientific innovation, was inspiring in thinking about how to do good research and how to manage a research group.



## Can you tell us about a colleague who's had a major impact on your work/career

There are so many! Of course, I find my research advisors – PhD advisor Prof Tom Lubensky, and postdoctoral advisors Prof Paul Goldbart and Prof Vincenzo Vitelli – to have been hugely influential in my development as a physicist. Of course, they taught me the subject of soft matter physics, but even more importantly, they taught me how to do research and the many different approaches one can take to tackle state-of-the-art research questions. I am lucky that I stayed in touch with all of them.

## Can you tell us about a time when you helped a colleague with their work/career?

I already mentioned writing reference letters, and I still think this is some of the most influential (and some of the most enjoyable) work that I do. Even more so, seeing students and other researchers feel the joy of discovering physics, especially brand new physics uncovered through our research collaborations (and sharing their enthusiasm) – I find these to be some of the most rewarding parts of my job. Is there any other story about your work with us that you think our colleagues and students might find interesting?

I think one of the most significant research projects I started at Bath is about topological fibre optics. However, the way it started was coincidental and fortuitous. It started with a conversation around the staircase in 3 West, when Josh Nunn, Pete Mosley, and I just ran into each other and were chatting about various ideas around our research – eventually talking about Josh and Pete's work on fibre, my work on topology, and how we should try to do something together. I think Bath has a wonderful culture of casual conversations with colleagues, which is so important. These conversations can lead to new ideas and inspire brand new directions of research.

# The optical fibre that keeps data safe even after being twisted or bent

**by Vittoria D'Alessio**

Physicists have created an optical fibre that uses the maths concept of topology to remain robust, thereby guaranteeing the high-speed transfer of information.

Optical fibres are the backbone of our modern information networks. From long-range communication over the internet to high-speed information transfer within data centres and stock exchanges, optical fibre remains critical in our globalised world.

Fibre networks are not, however, structurally perfect, and information transfer can be compromised when things go wrong. To address this problem, physicists at the University of Bath have developed a new kind of fibre designed to enhance the robustness of networks. This robustness could prove to be especially important in the coming age of quantum networks.

The team has fabricated optical fibres (the flexible glass channels through which information is sent) that can protect light (the medium through which data is transmitted) using the mathematics of topology. Best of all, these modified fibres are easily scalable, meaning the structure of each fibre can be preserved over thousands of kilometres.

The Bath study is published in the latest issue of *Science Advances*.

## Protecting light against disorder

At its simplest, optical fibre – which typically has a diameter of 125 µm (similar to a thick strand of hair) – comprises a core of solid glass surrounded by cladding. Light travels through the core, where it bounces along as though reflecting off a mirror.

However, the pathway taken by an optical fibre as it crisscrosses the landscape is rarely straight and undisturbed: turns, loops, and bends are the norm. Distortions in the fibre can cause information to degrade as it moves between sender and receiver.

“The challenge was to build a network that takes robustness into account,” said Physics PhD student Nathan Roberts, who led the research.

“Whenever you fabricate a fibre-optic cable, small variations in the physical structure of the fibre are inevitably present. When deployed in a network, the fibre can also get twisted and bent. One way to counter these variations and defects is to ensure the fibre design process includes a real focus on robustness. This is where we found the ideas of topology useful.”

To design this new fibre, the Bath team used topology, which is the mathematical study of quantities that remain unchanged despite continuous distortions to the geometry. Its principles are already applied to many areas of physics research. By connecting physical phenomena to unchanging numbers, the destructive effects of a disordered environment can be avoided.

The fibre designed by the Bath team deploys topological ideas by including several light-guiding cores in a fibre, linked together in a spiral. Light can hop between these cores but becomes trapped within the edge thanks to the topological design. These edge states are protected against disorder in the structure.

Bath physicist Dr Anton Souslov, who co-authored the study as theory lead, said: “Using our fibre, light is less influenced by environmental disorder than it would be in an equivalent system lacking topological design.

“By adopting optical fibres with topological design, researchers will have the tools to pre-empt and forestall signal-degrading effects by building inherently robust photonic systems.”

## Theory meets practical expertise

Bath physicist Dr Peter Mosley, who co-authored the study as experimental lead, said: “Previously, scientists have applied the complex mathematics of topology to light, but here at the University of Bath we have lots of experience physically making optical fibres, so we put the mathematics together with our expertise to create topological fibre.”

The team, which also includes PhD student Guido Baardink and Dr Josh Nunn from the Department of Physics, are now looking for industry partners to develop their concept further.

“We are really keen to help people build robust communication networks and we’re ready for the next phase of this work,” said Dr Souslov.

Mr Roberts added: “We have shown that you can make kilometres of topological fibre wound around a spool. We envision a quantum internet where information will be transmitted robustly across continents using topological principles.”

He pointed out that this research has implications that go beyond communications networks. He said: “Fibre development is not only a technological challenge, but also an exciting scientific field in its own right.

“Understanding how to engineer optical fibre has led to light sources from bright ‘supercontinuum’ that spans the entire visible spectrum right down to quantum light sources that produce individual photons – single particles of light.”

## The future is quantum

Quantum networks are widely expected to play an important technological role in years to come. Quantum technologies have the capacity to store and process information in more powerful ways than ‘classical’ computers can today, as well as sending messages securely across global networks without any chance of eavesdropping.

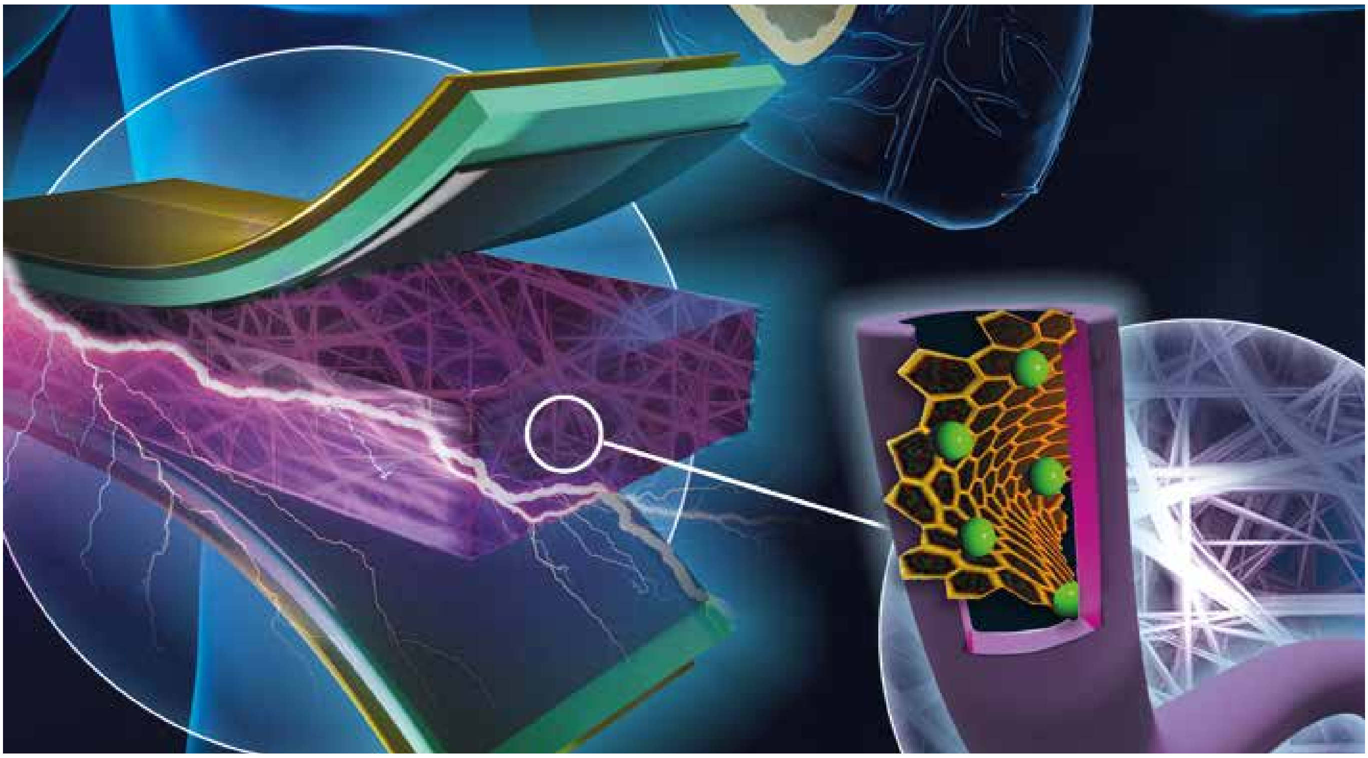
But the quantum states of light that transmit information are easily impacted by their environment and finding a way to protect them is a major challenge. This work may be a step towards maintaining quantum information in fibre optics using topological design.

*This work acknowledges funding from the Engineering and Physical Sciences Research Council (EPSRC) (EP/T000961/1, EP/T001062/1), the Royal Society (RGS/R2/202135), and the Air Force Office of Scientific Research (FA8655-22-1-7028).*

**Scan QR** to read the research paper

# Are piezoelectrics good for generating electricity? Perhaps, but we must decide how to evaluate them

**by Vittoria D'Alessio**



An artistic impression of electricity generation in a piezoelectric energy harvester made from piezoelectric nano-fibers.
Credit: Katharina Maisenbacher, Max Planck Institute for Polymer Research

A 'best practice' protocol for researchers developing piezoelectric materials has been developed by scientists – a first in this cutting-edge field of technology.

The protocol was developed by an international team led by physicists at University of Bath in response to findings that experimental reports lack consistency. The researchers made the shocking discovery that nine out of 10 scientific papers miss experimental information that is crucial to ensure the reproducibility of the reported work. They discuss the urgent need for a standardised piezoelectricity research protocol in the journal *Nano Energy*.

Dr Morteza Hassanpour Amiri at the Max Planck Institute for Polymer Research, Germany and first author of the study, said: "Research into piezoelectricity has accelerated in recent years, and for good reason: piezoelectric materials generate electricity when you exert pressure or mechanical vibrations, or when you tap on or distort them. Add a circuit and this electricity can be stored and then used."

## High energy-harvesting efficiency

Because of the huge potential of the piezoelectrics, over the past 20 years a steady stream of new materials and composites have been developed and tested for their energy harvesting potential, with many claiming high efficiencies.

But the researchers, led by Professor Kamal Asadi from the Department of Physics, suggest these findings – sometimes published in high-calibre journals – often do not include details of key experimental parameters. These details are essential to ensure reproducibility when other research teams set out to independently evaluate or further improve the featured materials.

Explaining, Professor Asadi said: "Reproducibility of experimental research findings may not be the key to the success of a research, but it is the key to ruling out unreliable findings from being accepted as fact. The enthusiasm to develop a champion material that shows impressive performance should be accompanied with enough supporting data."

For the study, the Bath researchers assessed 80 randomly selected research papers published over the past two decades on piezoelectric energy harvesting devices. For nearly 90% of these papers, essential experimental parameters – needed to evaluate materials and devices – were missing, thus rendering the experiments hard, and sometimes impossible, to reproduce.

## The importance of reproducibility

Expanding, Professor Asadi said: "There are three important reasons why reproducibility is important: We are scientists and should strive to be as accurate as possible; we have limited resources, so by reporting all the necessary parameters that guarantee reproducibility, we are helping our peers to build up on our findings and advance the field; by being transparent, we also build trust with the public, and with science funding organisations and policy-makers, and provide a better guidance for future 'big' decisions that can affect us all."

Professor Asadi, who is a leading expert in piezoelectricity, says this lack of data is hampering progress in the field, as researchers can't turn to the literature to identify materials with the best harvesting potential, and then further develop these promising materials.

## New protocol

The new Bath protocol suggests a standardised data collection and reporting. Professor Chris Bowen from the Department of Mechanical Engineering and Institute for Sustainability at Bath, who was also involved in this study, said: "We have basically created guidelines that would be helpful to researchers in their field of piezoelectricity."

Professor Asadi is hopeful that electronic devices powered by piezoelectricity will be on the market within the next 10 years.

"That's why it's important to have a standardised protocol for reporting research data for a quantitative evaluation of energy harvesting materials and devices. Doing so enables scientists to make real progress building on each other's experiments and working towards a common goal: making piezoelectricity a reality for anyone hoping to charge their devices more sustainably and without reliance on a traditional power source."

He added: "The field of piezoelectric energy harvesting is a really exciting field, it has lots of potential and great scientists are working on it, but it's still fledgling, and so to make sure we advance as well and as quickly as possible, ensuring experiments are reproducible is going to be crucial, so I hope our suggested protocol is adopted by the community at large."

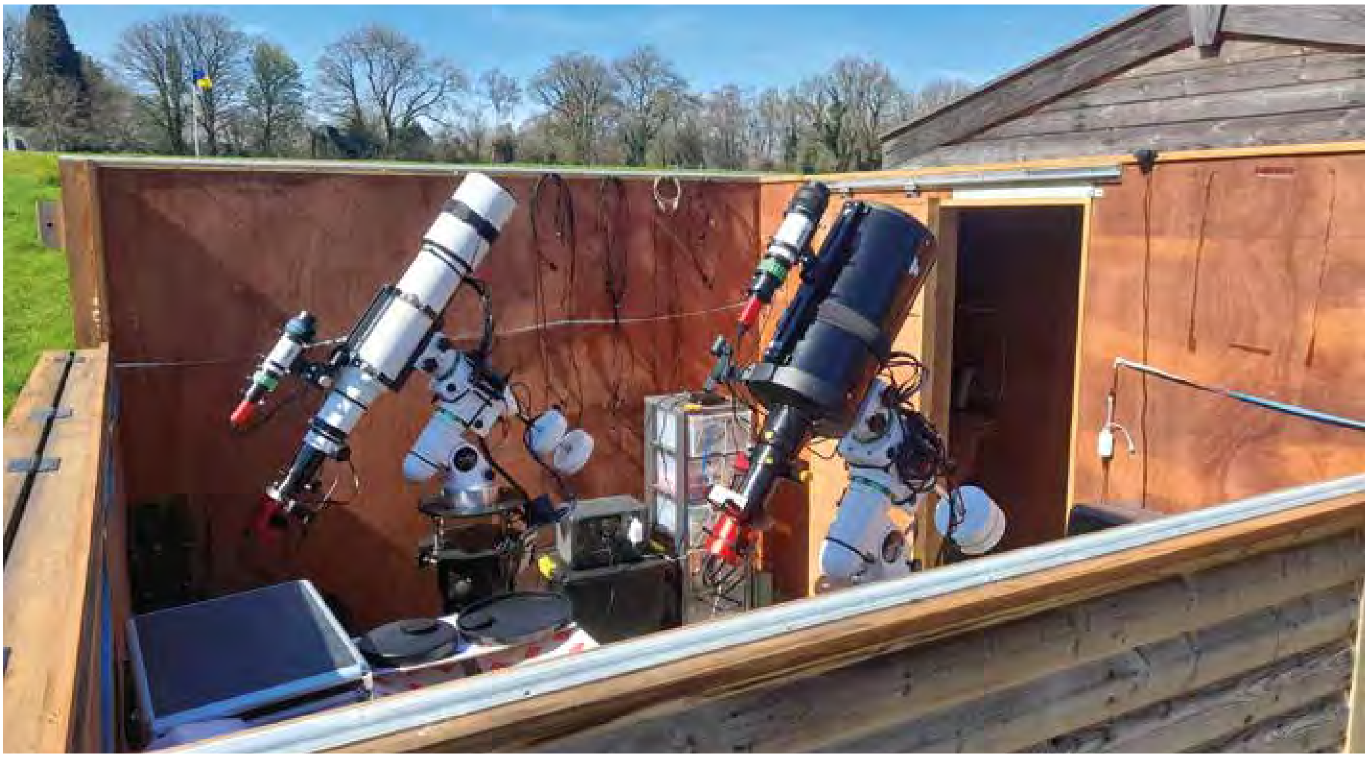
The new protocol is described in the paper "Piezoelectric energy harvesters: A critical assessment and a standardized reporting of power-producing vibrational harvesters".

*The University of Bath Physics undergraduates involved in this study were Rose Fatscher and Rebecca Taylor. The work was part of the PhD thesis of Dr Morteza Hassanpour Amiri and undertaken in collaboration with Professor Paulo Rocha, from University of Coimbra, Portugal.*

**Scan QR** to read the research paper

# From textbook to telescope: Campus observatory adds shine to astrophysics

**by Vittoria D'Alessio**



A low-cost observatory has been set up at the University of Bath to give university students a game-changing experimental tool to study events in space.

A low-cost, high-value observatory with a passing resemblance to a garden shed has been set up in the grounds of the University of Bath. The observatory is proving to be a game-changing experimental tool for undergraduates studying events in space, say lecturers at the university.

The timber cabin – located on the university campus and designed to give astrophysics students hands-on experience observing objects in the night-sky – was built and equipped for under £35,000, thanks in part to a generous donation from Bath alumni.

Academics involved in the construction project are now urging all universities offering courses in astrophysics to consider investing in a similar structure, as a way to bring the subject to life for students who would otherwise learn about stars and deep space almost entirely from lectures and textbooks.

The Bath facility – which is described in a paper published in the journal Physics Education – sports a roll-off roof, two high-quality, computer-controlled telescopes and solar panels, and can accommodate two people at a time. Students use their time in the observatory to gather data that ties into specific science projects or modules on their courses.

The four authors of the Bath Physics Observatory (BPO) paper, all academics in the Department of Physics at Bath who lecture on astrophysics, are coordinator Dr Peter Sloan, science lead Dr Vicky Scowcroft, technical lead Dr Steve Davies and public engagement lead Dr Gary Mathlin.

Dr Sloan said: "We now have over 125 students enrolled on astrophysics programmes, what was missing was the facility – an observatory – to perform hands-on observational astrophysics.

"For some of our students, there's a disconnect between what they learn in lecture theatres and what is happening above them in the sky. The observatory gives them a chance to see where their data – star-light – comes from. They still do hard science with the data they capture in the observatory, but a project becomes a lot more real and exciting when calculations come directly from what is observed and photographed through a telescope."

Before construction of the observatory, students gathered data in a lot less comfort. "We'd set up a collapsible camping table for students to make their observational measurements. By the time they'd finished their night's work, they had ice on their jackets," said Dr Scowcroft.

An important objective in providing an observatory was to make star-gazing less elitist. Explaining, Dr Scowcroft said: "Some of our students have grown up with expensive telescopes in their homes, so they have an obvious advantage when they get to university. We want to make the experience of observing the stars democratic and accessible to all."

Dr Davies added: "We have shown that with the advent of moderate-cost, high-quality, 'back-garden' astronomy, and standard computers powerful enough to produce original research, it's possible to build a small observatory capable of actual astrophysical research for a modest budget."

Dr Mathlin said: "Around 35 universities in the UK have their own observatories but many others don't – we'd highly encourage all places that teach astrophysics to set one up."

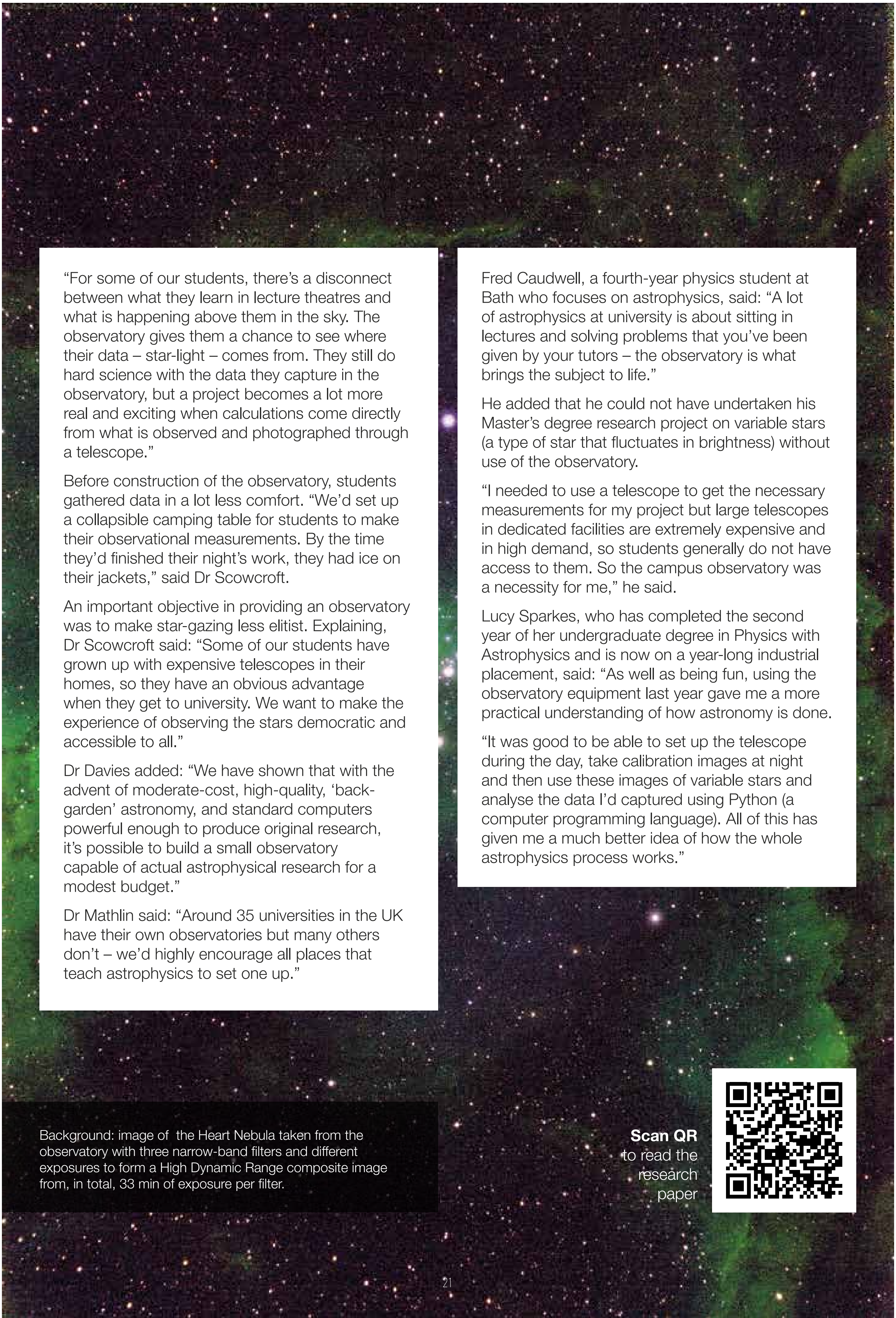
Fred Caudwell, a fourth-year physics student at Bath who focuses on astrophysics, said: "A lot of astrophysics at university is about sitting in lectures and solving problems that you've been given by your tutors – the observatory is what brings the subject to life."

He added that he could not have undertaken his Master's degree research project on variable stars (a type of star that fluctuates in brightness) without use of the observatory.

"I needed to use a telescope to get the necessary measurements for my project but large telescopes in dedicated facilities are extremely expensive and in high demand, so students generally do not have access to them. So the campus observatory was a necessity for me," he said.

Lucy Sparkes, who has completed the second year of her undergraduate degree in Physics with Astrophysics and is now on a year-long industrial placement, said: "As well as being fun, using the observatory equipment last year gave me a more practical understanding of how astronomy is done.

"It was good to be able to set up the telescope during the day, take calibration images at night and then use these images of variable stars and analyse the data I'd captured using Python (a computer programming language). All of this has given me a much better idea of how the whole astrophysics process works."



Background: image of the Heart Nebula taken from the observatory with three narrow-band filters and different exposures to form a High Dynamic Range composite image from, in total, 33 min of exposure per filter.

**Scan QR** to read the research paper

# Limiting loss in leaky fibres

**by Vittoria D'Alessio**

**Scan QR** to read the paper

A theoretical understanding of what makes some hollow-core optical fibres more efficient than others will inspire the design of new low-loss fibres.

Immense progress has been made in recent years to increase the efficiency of optical fibres through the design of cables that allow data to be transmitted both faster and at broader bandwidths. The greatest improvements have been made in the area of hollow-core fibres – a type of fibre that is notoriously 'leaky' yet also essential for many applications.

Now, for the first time, scientists have figured out why some air-filled fibre designs work so much more efficiently than others.

The puzzle has been solved by recent PhD graduate Dr Leah Murphy and Emeritus Professor David Bird from the Centre for Photonics and Photonic Materials at the University of Bath.

The researchers' theoretical and computational analysis gives a clear explanation for a phenomenon that other physicists have observed in practice: that a hollow-centred optical fibre incorporating glass filaments into its design causes ultra-low loss of light as it travels from source to destination.

Dr Murphy said: "The work is exciting because it adds a new perspective to a 20-year-long conversation about how antiresonant, hollow-core fibres guide light. I'm really optimistic that this will encourage researchers to try out interesting new hollow-core fibre designs where light loss is kept ultra-low."

## The communication revolution

Optical fibres have transformed communications in recent years, playing a vital role in enabling the enormous growth of fast data transmission. Specially designed fibres have also become key in the fields of imaging, lasers and sensing (as seen, for instance, in pressure and temperature sensors used in harsh environments).

The best fibres have some astounding properties – for example, a pulse of light can travel over 50km along a standard silica glass fibre and still retain more than 10% of its original intensity (an equivalent would be the ability to see through 50km of water).

But the fact that light is guided through a solid material means current fibres have some drawbacks. Silica glass becomes opaque when the light it is attempting to transmit falls within the mid-infrared and ultraviolet ends of the electromagnetic spectrum. This means applications that need light at these wavelengths (such as spectrometry and instruments used by astrophysicists) cannot use standard fibres.

In addition, high-intensity light pulses are distorted in standard fibres and they can even destroy the fibre itself.

Researchers have been working hard to find solutions to these drawbacks, putting their efforts into developing optical fibres that guide light through air rather than glass.

This, however, brings its own set of problems: a fundamental property of light is that it doesn't like to be confined in a low-density region like air. Optical fibres that use air rather than glass are intrinsically leaky (the way a hosepipe would be if water could seep through the sides).

The confinement loss (or leakage loss) is a measure of how much light intensity is lost as it moves through the fibres, and a key research goal is to improve the design of the fibre's structure to minimise this loss.

## Hollow cores

The most promising designs involve a central hollow core surrounded and confined by a specially designed cladding. Slotted within the cladding are hollow, ultra thin-walled glass capillaries attached to an outer glass jacket.

Using this set-up, the loss performance of the hollow-core fibre is close to that of a conventional fibre.

An intriguing feature of these hollow-core fibres is that a theoretical understanding of how and why they guide light so well has not kept up with experimental progress.

For around two decades, scientists have had a good physical understanding of how the thin glass capillary walls that face the hollow core (green in the diagram) act to reflect light back into the core and thus prevent leakage. But a theoretical model that includes only this mechanism greatly overestimates the confinement loss, and the question of why real fibres guide light far more effectively than the simple theoretical model would predict has, until now, remained unanswered.

Dr Murphy and Professor Bird describe their model in a paper published this week in the leading journal *Optica*.

The theoretical and computational analysis focuses on the role played by sections of the glass capillary walls (red in the diagram) that face neither the inner core nor the outer wall of the fibre structure.

As well as supporting the core-facing elements of the cladding, the Bath researchers show that these elements play a crucial role in guiding light, by imposing a structure on the wave fields of the propagating light (grey curved lines in the diagram). The authors have named the effect of these structures 'azimuthal confinement'.

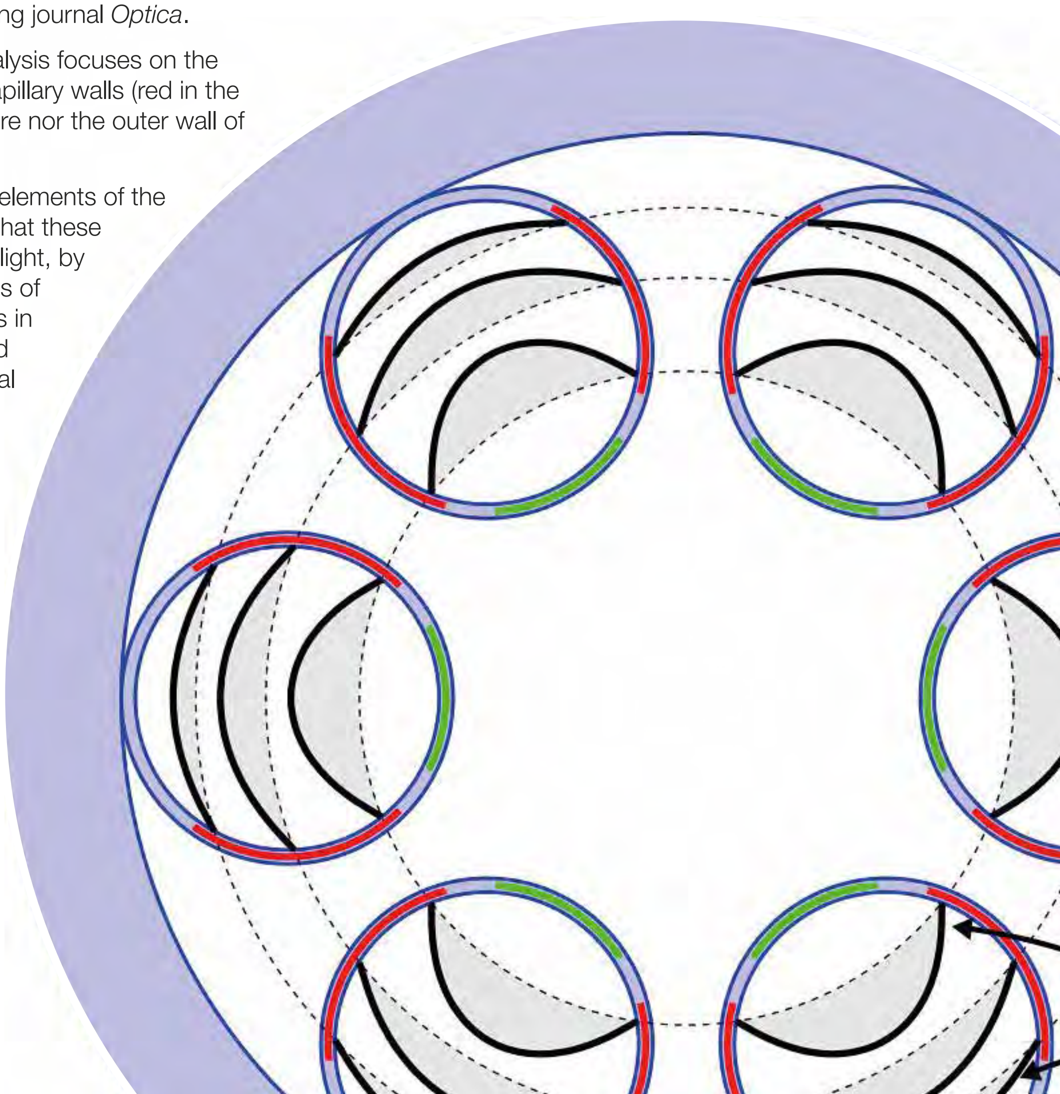
Although the basic idea of how azimuthal confinement works is simple, the concept is shown to be remarkably powerful in explaining the relationship between the geometry of the cladding structure and the confinement loss of the fibre.

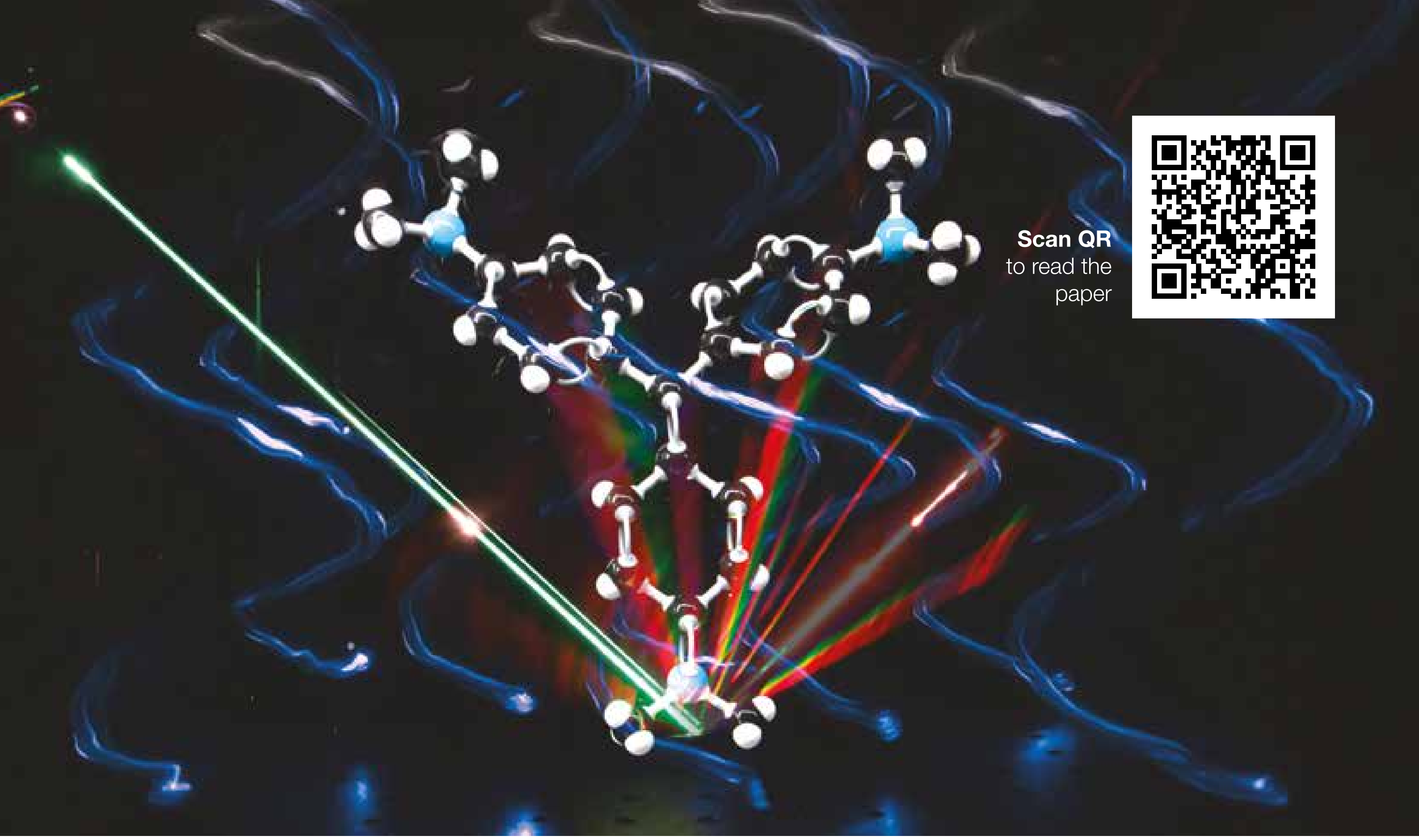
Dr Murphy, first author of the paper, said: "We expect the concept of azimuthal confinement to be important to other researchers who are studying the effect of light leakage from hollow-core fibres, as well as those who are involved in developing and fabricating new designs."

Professor Bird, who led the project, added: "This was a really rewarding project that needed the time and space to think about things in a different way and then work through all the details.

"We started working on the problem in the first lockdown and it has now been keeping me busy through the first year of my retirement. The paper provides a new way for researchers to think about leakage of light in hollow-core fibres, and I'm confident it will lead to new designs being tried out."

*Dr Murphy was funded by the UK Engineering and Physical Sciences Research Council.*






Crystal violet scatters light into a rainbow, revealing the strength of interaction between light and helical nanostructures (artist's impression by photography). Image credit: Ventsislav Valev, Kylian Valev, Eva Valev, Robin Jones

# Can rainbows monitor the environment?

**by Vittoria D'Alessio**

## New nanotechnology may make it easier to identify the chemical composition of impurities and their geometrical shape in samples of air, liquid and live tissue.

Using conventional testing techniques, it can be challenging – sometimes impossible – to detect harmful contaminants such as nano-plastics, air pollutants and microbes in living organisms and natural materials. These contaminants are sometimes found in such tiny quantities that tests are unable to reliably pick them up.

This may soon change, however. Emerging nanotechnology (based on a 'twisted' state of light) promises to make it easier to identify the chemical composition of impurities and their geometrical shape in samples of air, liquid and live tissue. An international team of scientists led by physicists at the University of Bath is contributing towards this technology, which may pave the way to new environmental monitoring methods and advanced medicines.

The emerging chemical-detection technique is based on a light-matter interaction known as the Raman effect. The Raman effect occurs when a material that is illuminated at a certain colour of light scatters and changes the light into a multitude of slightly different colours. It essentially produces a mini-rainbow that is dependent on how atoms within materials vibrate.

Measuring the colours of the Raman rainbow reveals individual atomic bonds because molecular bonds have distinct vibrational patterns. Each bond within a material produces its own unique colour change from that of the illumination. Altogether, the colours in the Raman rainbow serve to detect, analyse and monitor the chemical composition (chemical bonds) of complex molecules, such as those found within mixtures of environmental pollutants.

"The Raman effect serves to detect pesticides, pharmaceuticals, antibiotics, heavy metals, pathogens and bacteria. It's also used for analysing individual atmospheric aerosols that impact human health and the climate," said Dr Robin Jones from the Department of Physics at Bath, who is the first-author of the study.

The study is published in the journal *Advanced Materials*.

## Harmful pollutants

Expanding, co-author Professor Liwu Zhang from the Department of Environmental Science at Fudan University in China said: "Aquatic pollutants, even in trace amounts, can accumulate in living organisms through the biological chain. This poses a threat to human health, animal welfare and wildlife. Generally, it is really hard to know exactly what the chemical composition of complex mixtures are."

Professor Ventsislav Valev from Bath, who led the study, added: "Understanding complex, potentially harmful pollutants in the environment is necessary, so that we can learn how to break them down into harmless components. But it is not all about what atoms they are made of. The way the atoms are arranged matters a lot – it can be decisive for how molecules act, especially within living organisms.

"Our work aims to develop new ways in which the Raman effect can tell us about the way atoms are arranged in space and now we have taken an important technological step using tiny helix shaped antennas made of gold."

The Raman effect is very weak – only 1 out of 1,000,000 photons (light particles) undergo the colour change. In order to enhance it, scientists use miniature antennas fabricated at the nanoscale that channel the incident light into the molecules. Often these antennas are made of precious metals and their design is limited by nanofabrication capabilities.

The team at Bath used the smallest helical antennas ever employed: their length is 700 times smaller than the thickness of a human hair and the width of the antennas is 2,800 times smaller. These antennas were made from gold by scientists in the team of Professor Peer Fischer at the University of Stuttgart in Germany.

"Our measurements show these helical antennas help to get a lot of Raman rainbow photons out of molecules," said Dr Jones. "But more importantly, the helical shape enhances the difference between two types of light that are often used to probe the geometry of molecules. These are known as circularly polarised light.

"Circularly polarised light can be left-handed or right-handed and our helices can, basically, handshake with light. And because we can make the helices twist to the left or to the right, the handshake with light that we devised can be both with left or right 'hands'.

"While such handshakes have been observed before, the key advance here is that we demonstrate for the first time that it is felt by molecules, as it affects their Raman rainbow. This is an important step that will allow us to distinguish efficiently and reliably between left- and right-handed molecules, first in the lab and then in the environment."

## Crystal Violet

In order to demonstrate that the new handshaking between light and antennas could be transmitted to molecules, the researchers made use of molecules – crystal violet – that are unable to 'handshake' with light by themselves. Yet these molecules behaved as if they could perform this function, expressing the 'handshaking' ability of gold nanohelices to which they were attached.

"Another important aspect of our work here is that we worked with two industrial partners," said Professor Valev. "VSPARTICLE produce standard nanomaterials for measuring Raman light. Having common standards is really important for researchers around the world to be able to compare results."

He added: "Our industrial partner Renishaw PLC is a world-leading manufacturer of Raman spectroscopy and microscopy equipment. Such partnerships are essential, so that new technology can move out of the labs and into the real-world, where the environmental challenges are."

Building on this work, the team is now working on developing more advanced forms of Raman technologies.

The research team from the University of Bath included Dr Robin Jones, Dr Kristina Rusimova, Professor Daniel Wolverson and Professor Ventsislav Valev.

# What made the brightest cosmic explosion of all time so exceptional?

by Vittoria D'Alessio

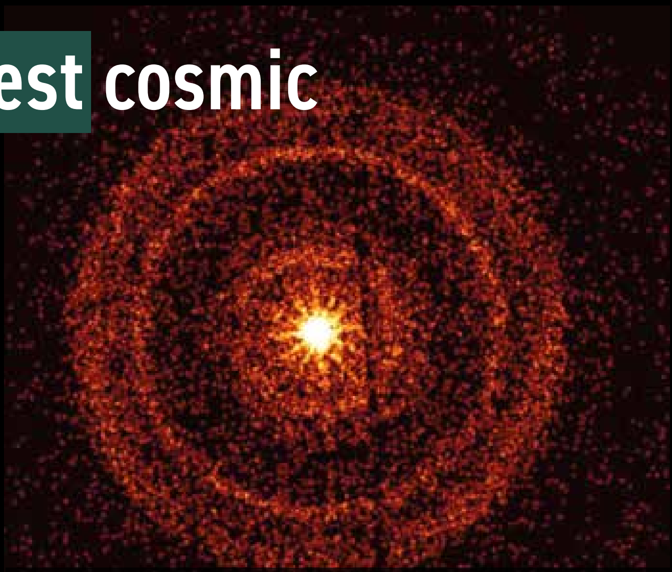


Image: The afterglow of the Brightest of All Time gamma-ray burst, captured by the Neil Gehrels Swift Observatory's X-Ray Telescope. Credit: NASA/Swift/A. Beardmore (University of Leicester)

Last year, telescopes registered the brightest cosmic explosion of all time. Astrophysicists can now explain what made it so dazzling.

Few cosmic explosions have attracted as much attention from space scientists as the one recorded on October 22 last year and aptly named the Brightest of All Time (BOAT). The event, produced by the collapse of a highly massive star and the subsequent birth of a black hole, was witnessed as an immensely bright flash of gamma-rays followed by a slow-fading after-glow of light across frequencies.

Since picking up the BOAT signal simultaneously on their giant telescopes, astrophysicists the world over have been scrambling to account for the brightness of the gamma-ray burst (GRB) and the curiously slow fade of its afterglow.

Now an international team that includes Dr Hendrik van Eerten from the Department of Physics at the University of Bath has formulated an explanation: the initial burst (known as GRB 221009A) was angled directly at Earth and it also dragged along an unusually large amount of stellar material in its wake.

The team's findings are published today in the prestigious journal Science Advances. Dr Brendan O'Connor, a newly graduated doctoral student at the University of Maryland and George Washington University in Washington, DC is the study's lead author.

Dr Van Eerten, who co-led the theoretical analysis of the afterglow, said: "Other researchers working on this puzzle have also come to the conclusion that the jet was pointed directly at us – much like a garden hose angled to spray straight at you – and this definitely goes some way to explain why it was seen so brightly.

But what remained a puzzle was that the edges of the jet could not be seen at all.

"The slow fade of the afterglow is not characteristic of a narrow jet of gas, and knowing this made us suspect there was an additional reason for the intensity of the explosion, and our mathematical models have borne this out.

"Our work clearly shows that the GRB had a unique structure, with observations gradually revealing a narrow jet embedded within a wider gas outflow where an isolated jet would normally be expected."

So what made this GRB wider than normal? The researchers have a theory. As Dr Van Eerten explained: "GRB jets need to go through the collapsing star in which they are formed, and what we think made the difference in this case was the amount of mixing that happened between the stellar material and the jet, such that shock-heated gas kept appearing in our line of sight all the way up to the point that any characteristic jet signature would have been lost in the overall emission from the afterglow."

He added: "Our model helps not just to understand the BOAT, but also previous brightness record holders that had astronomers mystified about their lack of jet signature. These GRBs, like other GRBs, must be directed straight towards us when they happen, as it would be unphysical for that much energy to be expelled in all directions at once.

"An exceptional class of events appears to exist that are both extreme and manage to mask the directed nature of their gas flow. Future study into the magnetic fields that launch the jet and into the massive stars that host them should help reveal why these GRBs are so rare."

Dr O'Connor said: "The exceptionally long GRB 221009A is the brightest GRB ever recorded and its afterglow is smashing all records at all wavelengths. Because this burst is so bright and also nearby (cosmically speaking: it occurred at the minor distance of 2.4 billion light years from Earth), we think this is a once-in-a-thousand-year opportunity to address some of the most fundamental questions regarding these explosions, from the formation of black holes to tests of dark matter models."

**Scan QR** to read the paper

# Using fibre optics to tackle ICU infections

Dr James Stone and his research team are designing specialised optical fibres to help treat lung infections in some of the most vulnerable hospital patients.

Advances in technology have shrunk imaging devices small enough to navigate the human body. Endoscopic optical fibres have become commonplace in medicine, giving clinicians an unprecedented insight into their patients' health.

The state-of-the-art imaging fibres are made up of many thousands of 'cores', bundled together into a single fibre. Each of the cores acts like a pixel, transmitting a part of the image down the fibre to a screen outside the body. These fibres allow clinicians to visualise the smallest areas of the body with microscopic precision. However, they come at a cost. Reaching several thousands of dollars per device, they must also be sterilised between uses. This degrades the fibre limiting its lifespan, while improper sterilisation carries the risk of cross-contamination between patients.

Dr James Stone and his team have been using the Fibre Fabrication Facility to design and test low-cost optical fibres specifically for use within healthcare and medicine. Inspired by the commercially produced technology powering telecommunications, they hope to create high-quality, economically viable disposable imaging devices.

## Getting started

The team began their research by working with clinicians to identify barriers to effective treatment. One of the biggest concerns raised by lung specialists is the danger posed by infection, especially in intensive care units (ICU). In an already weakened state, patients are vulnerable to infection. If they then require mechanical ventilation, their risk of infection rises, and chance of survival drops.

Ventilator-Associated Pneumonia is a catch-all term for lung infections in ventilated patients, and treatment can be harsh. Traditional diagnosis relies on growing bacterial cultures, which can take several days to identify the cause of infection. But when initial clouding on the lungs is picked up by X-rays, patients tend to deteriorate quickly. With no time to lose, clinicians often administer a suite of antibiotics and antifungals, in the hope one of them will begin to take effect.

## Visualising the problem

Dr Stone's research has been exploring the use of a bespoke, low-cost optical fibre-based delivery and imaging endoscope. Using this device, a fibre could be inserted directly into an infected lung and deliver a small amount of fluid into the field of view. This fluid contains a chemical probe that glows in contact with specific bacteria or fungi.

Through a process of elimination and testing different chemical probes to see what lights up, clinicians would be able to rapidly identify infection-causing pathogens and offer more targeted treatments.

Testing their device in ex-vivo human lungs, the team were able to identify the bacteria Staphylococcus aureus within 60 seconds of the fluid being delivered.

## Creating the device

The three-in-one device comprises an imaging fibre and two fluid delivery channels, wrapped together in a polymer coating.

The imaging fibre is made using the low-cost, commercially produced preforms used by the telecommunications industry. These preforms are then drawn out into 8,100 individual cores, that are bundled together into a square formation. The cores are made with differing sizes, and stacked in a unique pattern so that no two of the same size are adjacent.

The resulting images are comparable to those produced by state-of-the-art imaging fibres.

## Taking the next steps

Dr Stone's research team are continuing to work with clinicians at the University of Edinburgh, designing fibres to tackle a range of medical problems. Each fibre is made bespoke and can only be used in devices for patients after thorough testing, starting with safety and feasibility tests.

Once designed and their concept is proven, the next step for these devices is to undergo clinical trials and hopefully commercialisation.

In the meantime, they continue to use the Fibre Fabrication Facility to optimise their fibre designs and create more for use in their research.

# Stack and draw: how plain glass rods turn into the fibre optics of the future

From telecoms to healthcare, fibre optics are an essential tool in photonics research. But how are they made, and what exactly do they do?

Tucked away in the Centre for Photonics and Photonic Materials is an unusual laboratory. In the centre of the room, a metal staircase climbs two stories. It's flanked by two tall machines, each housing a small, cylindrical furnace. These are the drawing towers, and this is the fibre fabrication facility, a hub of activity where the University's optical fibre is crafted.

Optical fibre is a thin, flexible strand made from glass that can carry light signals with very little loss of intensity as it passes through. It's most familiar to us for delivering super-fast broadband to our homes, but our researchers are developing new and exciting ways of using it.

Unlike the solid fibres that carry broadband signals, the fibres crafted in our fabrication facility are predominantly hollow core. This means they're made up of a series of capillaries arranged around a central void and then fused together into a single fibre.

Much like making a stick of rock, the complex fibres are created from larger, preformed glass rods and stretched out into a thin fibre less than a millimetre wide.

## How it works

To begin the process, glass preforms are attached to a chuck at the top of the first drawing tower and lowered at a set rate into the furnace. Reaching around 2000 degrees Celsius, the furnace is hot enough to soften the glass without melting it completely. The first tower is used to create capillaries – thin rods with a hollow centre to them. These capillaries are then slotted into a wider glass tube and arranged in the desired pattern around a central void. The delicate arrangement is fused to create a 'cane'.

Once the cane is made, it passes to the second drawing tower, where it's lowered into another furnace. As the glass at the bottom melts, it falls under gravity, pulling the softened glass above into a fine, hair-like strand. A laser beam measures the width of the strand, and it passes into a chamber where a polymer coating is applied and cured, protecting the glass. As the newly-made optical fibre reaches

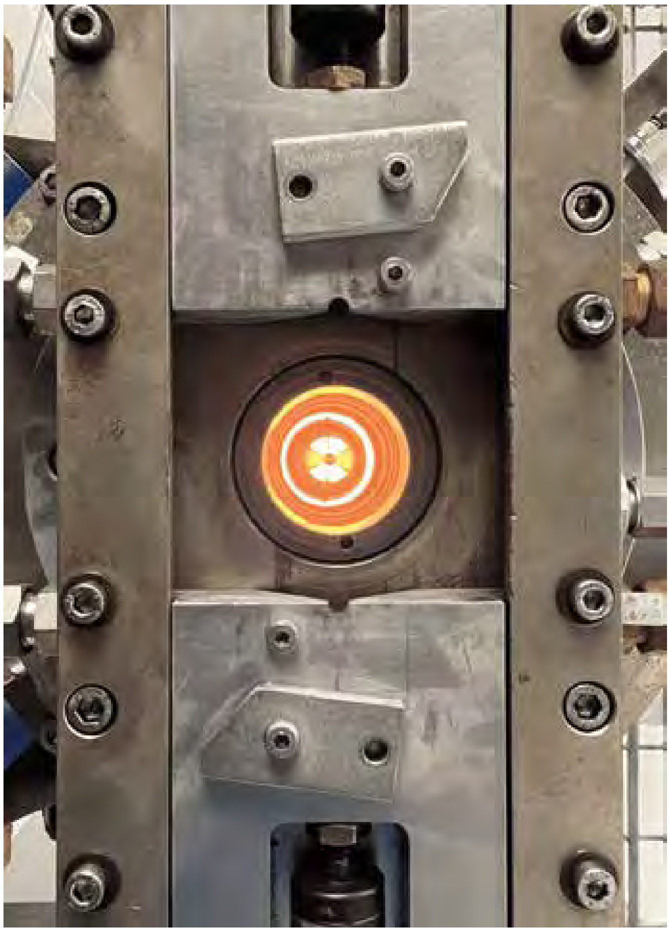


Image: Furnaces in each drawing tower of the fibre fabrication facility heat glass rods to over 2050 degrees Celcius, softening the glass so it can be pulled into a fine strand.

Image: A cross-section of the imaging fibre used in the team's infection-fighting endoscopic device..

the base of the second tower, it winds through a series of pulleys and is collected onto a spool ready for use.

From an initial metre-long preformed glass rod, researchers can create more than 7km of optical fibre to use in their experiments. Having a fabrication facility on site means that not only can researchers make fibre more quickly and cost-effectively than they can buy it, but they can also design and test their own patterns and configurations. This allows them to try things that have never been done before and compete with researchers across the world for inventive new uses.

## Tackling infections in ICU

Dr James Stone and his team also use the facility to make fibres designed for healthcare. Their specialist endoscopes allow clinical teams to access hard-to-reach parts of the body and look at very small areas with microscopic precision.

Working with lung specialists, the team are helping tackle infection in intensive care patients. Already vulnerable to infection, patients' chances of survival drop even further when ventilated. Ventilator-Associated Pneumonia (VAP) is a catch-all term for lung infections in patients on mechanical ventilation, and treatment is harsh. Already weakened patients receive a suite of antifungals and antibiotics in the hope that one will work.

Dr Stone's specialist fibres can deliver a chemical probe directly to infected areas. The probe lights up in the presence of certain bacteria or fungi. Clinicians can then rapidly identify infection-causing pathogens and deliver more targeted treatments.

The team hopes that more efficient treatment can shorten ICU stays, increasing survival rate and saving healthcare providers tens of thousands of pounds.

## Entering the quantum realm

Fibre optics aren't just revolutionising healthcare. Dr Peter Mosley and his research team are using optical fibres to explore how light could help power the supercomputers of the future.

Unlike conventional computers that store information in a series of ones and zeroes, quantum computers harness the laws of quantum mechanics to create new states. Under certain conditions, individual particles of light, or photons, can become entangled, sharing their properties

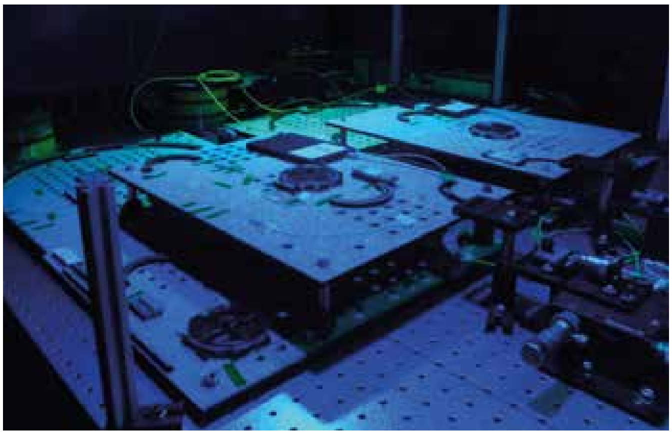


Image: One of the single-photon sources the team use to generate individual particles of light.

with one another. Encoding information onto these linked photons turns them into a 'quantum bit'. The particle can simultaneously represent both a one and a zero, opening a new world of processing power.

Dr Mosley and his team have joined researchers from the University of Oxford, exploring how this information can be shared across long distances using a quantum network. Light scatters and loses intensity as it passes through materials, even specialised optical fibres. Certain wavelengths travel through fibres better than others, with infrared going furthest. The team at Bath are exploring how they can change the colour and wavelength of individual photons so information can be optimised for long-distance sharing.

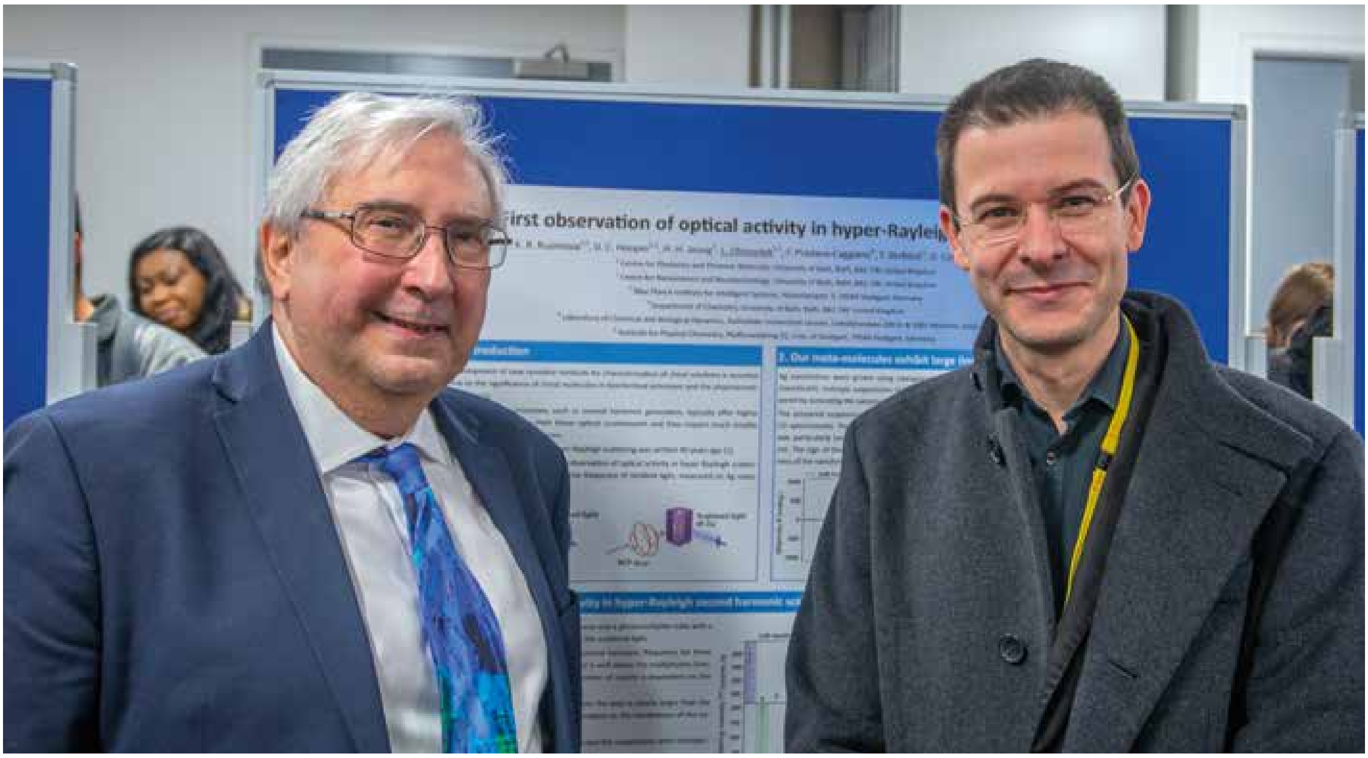
While we're still a long way from seeing this technology in use, its potential power is vast. In the future, quantum computing could help solve logistical problems, encode and decode information, and simulate chemical systems in the drug discovery of tomorrow.

**Find out more**

Not only is our Fibre Fabrication Facility used by researchers in world-leading research projects, but it's also available to external clients. We have expertise spanning design, modelling, fabrication and applications of novel optical fibres, and can provide technical support and consultation to external users.

# Professor Ventsislav Valev awarded the 2023 Institute of Physics Thomas Young Medal

**by Vittoria D'Alessio**



The prize – jointly won with Professor David Andrews from UEA – recognises the discovery of chirality-sensitive optical harmonic scattering.

Professor Ventsislav Valev, head of the Department of Physics at the University of Bath and Professor David Andrews (University of East Anglia) have been jointly awarded 2023 Institute of Physics Thomas Young Medal and Prize for the discovery of chirality-sensitive optical harmonic scattering. This effect was first predicted theoretically in 1979 and was demonstrated experimentally 40 years later.

The Institute of Physics (IOP) is the professional body and learned society for physics, and the leading body for practising physicists, in the UK and Ireland. It awards silver medals for distinguished contributions to the development or reputation of physics across 17 subject areas. The Thomas Young Medal has been attributed since 1941, for contributions to optics, including work related to physics outside the visible region.

Professor Valev, said: “I am delighted and deeply honoured to receive this prestigious award, together with Professor David Andrews. Thomas Young’s work has been an inspiration for me since secondary school.

“Receiving an award in his name is thrilling and it was only possible because of the excellent work of our international team of PhD students, postdoctoral fellows and academics.”

Professor Andrews added: “It is a tremendous honour to be a joint recipient of this award, and a delight to share it with Professor Valev, an outstanding spectroscopist.”

Professor Ian White, Vice-Chancellor at the Univerisity of Bath, said: “This major international award recognises Ventsi’s leadership in optics and illustrates his impact on the research field of nanophotonics. Our department of physics does an excellent work in the areas of photonics and nanoscience and I am very pleased to see it recognised with the Thomas Young Medal.”

Professor Sarah Hainsworth, Pro-Vice-Chancellor (Research & Enterprise) said: “I am delighted to see that Ventsi Valev has been awarded the Thomas Young Medal for his outstanding contributions to Optics and Photonic.

“This demonstrates the significance of his experimental ability to validate the theoretical predication of chirality-sensitive optical harmonic scattering first predicted over 40 years ago. It is a great example of the impact of the University of Bath’s research in physics. Many congratulations Ventsi!”

Professor Valev has been internationally recognised for his ground-breaking contributions to nonlinear (nano) photonics.

In 2019, his team published the first experimental results on the effects predicted by David Andrews in 1979. The work demonstrated that upon illuminating chiral (twisted) nanoparticles with circularly polarised light, at frequency (f), the intensity of light scattered at the second-harmonic frequency (2f) can reveal the direction of twist within the nanoparticles.

This effect is of fundamental scientific importance, as it is the most direct expression of chirality, in nonlinear optics. It could lead to applications ranging from developing new materials to novel drug discovery.

Professor Valev’s work has resulted in over 100 research papers, many appearing in top scientific journals. In 2021, he was elected Fellow of the Institute of Physics and, a year later, Fellow of Optica. In 2022, his team was awarded the 2022 Horizon Prize form the Faraday Division of the Royal Society of Chemistry and, in 2023, he was elected Fellow of SPIE (the international society for optics and photonics).

He has communicated his passion for physics to the general public through interviews (on television, radio and the press), articles, and over 70 visits to primary schools, for which he was awarded the Vice-Chancellor’s Award for Public Engagement with Research in 2018.

**Scan QR**
to learn more about the IOP Thomas Young Medal and Prize

# Research fellow in the Department of Physics awarded Clifford Paterson Medal

## Dr Euan Allan receives the award from the Institute of Physics in recognition of his application of physics in a commercial context.

Dr Euan Allen, a Royal Academy of Engineering Research Fellow in the Department of Physics, has been awarded the 2023 Institute of Physics Clifford Paterson Medal.

The medal, awarded to both Dr Allen and his business partner Dr Alasdair Price, recognises ‘exceptional early-career contributions to the application of physics in an industrial or commercial context’.

Drs Allen and Price are, respectively, the Chief Technology Officer and Chief Executive Officer of Siloton Limited, a company using the latest advancements in integrated photonics to improve the global population’s health.

One in four over-60s experiences age-related macular degeneration, the leading cause of sight loss in the developed world. Treatment must be rapid and precise, but the technology required is currently only available in clinics, limiting availability and leading to poorer patient outcomes.

The pair received the medal for developing and commercialising a world-leading remote monitoring system, that brings together next-generation diagnostic imaging with Siloton’s own cloud-based algorithms.

Dr Euan Allen said: “We are very happy to be recognised by the Institute of Physics and would like to give a big thank you to all the engineers, suppliers, and partners that we have worked with over the past 18 months to make this possible.”

The Clifford Paterson Medal is named after Sir Clifford Paterson, an English scientist and electrical engineer who rose to become director of the General Electric Company.

He was also deeply involved in creating a national framework for science and engineering and served as president of the Institute of Physics from 1937 to 1939.

The IOP awards celebrate physicists at every stage of their career; from those just starting out through to physicists at the peak of their careers, and those with a distinguished career behind them.

They also recognise and celebrate companies which are successful in the application of physics and innovation, as well as employers who demonstrate their commitment and contribution to scientific and engineering apprenticeship schemes.

Professor Ventsislav Valev, Head of the Department of Physics said of the award: “I am delighted that Euan has been awarded the Clifford Paterson Medal from the Institute of Physics. His work is well-deserving of this and many more honours. Congratulations Euan!”

Dr Euan Allan (lop), a research fellow in the Department of Physics, and his business partner, Dr Alasdair Price (bottom), are the winners of the 2023 Institute of Physics Clifford Paterson Medal.

# University of Bath hosts international Physics conference

The Department of Physics played host to the 2023 international workshop on superconductivity and magnetism in two-dimensional films and heterostructures.

The meeting, which took place from 30 August–1 September 2023 in the East Building, was organised within the framework of the European COST Action Superqumap. This brought together leading researchers from across Europe to collaboratively explore radical new approaches to superconducting-based quantum devices. These could, for example, form the building blocks of new generations of quantum computers.

The workshop focussed on the recent advances in materials design achieved by splitting off atomically thin layers from two-dimensional crystals. These layers are then stacked back together, building 'designer' heterostructures that don't normally exist in nature.

This method allows researchers to combine, for example, superconducting layers that exhibit zero electrical resistance with magnetic layers and their associated strong magnetic fields. The resulting devices can then operate using entirely new physical principles.

## A highly interdisciplinary arena

The workshop provided a highly interdisciplinary arena for around 55 scientists from 19 different European countries, including experts in materials synthesis, device fabrication, measurement, and theory. The delegates were a mixture of senior and early career researchers, as well as many PhD students who gave short format talks in a dedicated Young Researcher Session. Alongside speaker sessions, a PhD student poster session and a guided walking tour of Bath provided opportunities for lively discussions and the exchange of ideas.

Several companies also set up exhibition stands in the East Building for the duration of the meeting. These included Quantum Design and Cryogenic Limited, who generously sponsored the PhD student poster prizes.


Among the winners were Lukas Nulens from the Katholieke Universiteit Leuven, who won 1st prize; Celia Gonzalez Sanchez from the Universidad Autónoma de Madrid, who won 2nd prize; and Junyi Zhao from the University of Cambridge, who won 3rd prize.

Professor Simon Bending from the Department of Physics who led the organising team, said: "The workshop provided a unique opportunity to bring together leading experts in low dimensional superconductivity and magnetism from across the whole of Europe to exchange ideas and pioneer new developments in the field of solid-state quantum devices.

While much of this research is still at an early stage, it nevertheless has very strong potential for contributing to future hardware for quantum computation and other quantum technology applications."

# Department of Physics holds Eureka research conference for the third time

The conference celebrated recent scientific achievements in the areas of Photonics, Astrophysics, Nanoscience and Theory.

Researchers from the Department of Physics held their third Eureka conference on 14 June 2023, showcasing Physics research from Universities in the South West in the areas of Photonics, Astrophysics, Nanoscience and Theory. The conference was organised by Dr Kristina Rusimova, Dr Patricia Schady and Professor Simon Bending, on behalf of the Department of Physics Research and Knowledge Exchange Committee (DRKEC).

During the one-day event, academics from Bath and Physics Departments at other Universities (Exeter, Southampton, Bristol, and Cardiff), summarised their latest academic successes, including an impressive number of research grants, prestigious fellowships and scientific prizes. There were over 100 attendees from all five universities, and lively discussions and exchange of ideas were promoted during the day with the lunch, numerous coffee breaks, 17 exhibition stands, a poster session, and a reception to conclude the event. The conference was attended by a number of guests from industry, including Amplitude Laser, Solid State Supplies and Horiba who presented their companies with lightning talks.

The Bath Knowledge Exchange Team were available throughout the day to answer questions about setting up a collaboration between industry and academia. In addition, the optics society, Optica, facilitated a meeting between the Student Chapters across the five attending Universities.

Professor Ian White, Vice-Chancellor and President of the University of Bath said: “I pay great tribute to the organisers of Eureka 2023 for this excellent conference which brings together so many in the Physics community from across the South West and indeed beyond. The strong engagement of industry highlights that the high-quality research being carried out is having strong commercial impact. The Department of Physics deserves much credit for their leadership in this matter.”

Dean of Science, Professor Duncan Craig said: “I was delighted to see the Physics community coming together for the third Eureka conference. The talks this year were outstanding and it was good to see other universities joining and contributing to the event. Its pleasing to see colleagues with passion for their research coming together and collaborating in this way. I would like to thank the organisers Dr Kristina Rusimova, Dr Patricia Schady and Professor Simon Bending, for facilitating the event and am looking forward to the next one already".

The programme of the conference consisted of five oral sessions, poster presentations and an industry trade show. Prof Ian White, Vice-Chancellor of the University of Bath gave the opening scientific talk, followed by a talk from Prof Ventsi Valev, Head of the Department of Physics at Bath, and focused research talks from Dr Patricia Schady and Prof Tim Birks from Bath on the most luminous explosions in the Universe and optical fibres beyond telecommunications.

The overview talk for Exeter was given by Prof Euan Hendry, Director of Research of the Physics Department at Exeter, followed by scientific talks by Prof Saverio Russo and Prof Stefan Kraus on science and applications of 2D materials and astronomical instrumentation for high-angular resolution imaging.

The first afternoon session focused on Physics research at the University of Southampton with an overview talk from Prof David Smith, Deputy Head of School for Research at Southampton School of Physics and Astronomy, followed by a scientific presentation from Dr Philip Wiseman on time-domain astronomy. This was followed by a session on Physics research at Cardiff University, with Dr Cosimo Inserra, Deputy Director of Research at Cardiff School of Physics and Astronomy, giving the overview talk, and Dr Sam Shutts and Prof Kate Dooley presenting their research on compound semi-conductors for photonics and gravitational waves and quantum interferometry, respectively. The final session focused on Physics Research at the University of Bristol. Prof Ruth Oulton, Director of Research for the Bristol School of Physics, gave the overview talk, followed by scientific presentations from Dr Sotiria Fotopoulou and Dr Stacy Moore on big data astronomy and high-speed atomic force microscopy for materials science.

At the end of the poster session, the Department awarded several prizes: – Three Best Poster Awards were also announced, for Dr Charlie Patrickson, Exeter (1st place), Will Smith, Bath (2nd place) and Dr Kerrianne Harrington, Bath (3rd place). – The Best Poster by a PhD student, which was sponsored by the University of Bath Faculty of Science, was awarded to James Capers, Exeter. – The Best Nanoscience poster, which was sponsored by the Royal Society of Chemistry journal Nanoscale Advances, was awarded to John Kerr, Bath. – The jury for the best poster awards consisted of Prof Ruth Oulton (University of Bristol), Prof Euan Hendy (University of Exeter), Dr Cosimo Inserra (Cardiff University), Prof David Smith (University of Southampton), and Prof Ventsi Valev (University of Bath).

The organisers are especially grateful to Dr Charlotte Parry, John Kerr and Nathan Roberts for their help, which allowed the event to run smoothly.

The conference was sponsored by 14 industrial companies, including Amplitude, Horiba, Solid State Supplies, Toptica and Teledyne Princeton Instruments.

This was the first Eureka event to have included external Universities, and we hope to continue nurturing ideas and promoting collaboration amongst the Universities of the South-West in many future Eureka events to come.

# Bath signs new Memorandum of Understanding with the University of Michigan-Ann Arbor

## The University of Bath is proud to announce a new agreement with the University of Michigan-Ann Arbor.

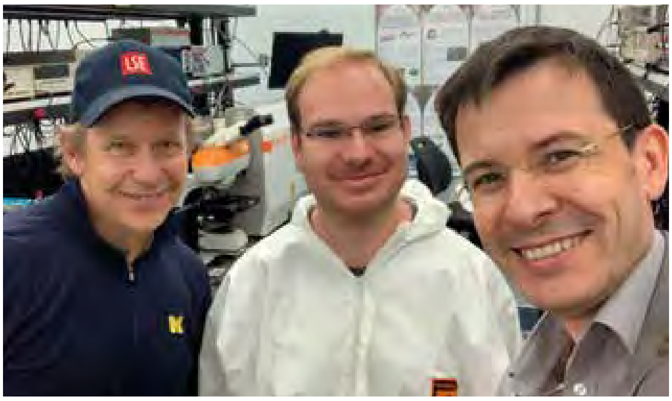
The agreement, between the Department of Physics, University of Bath and the Department of Chemical Engineering, University of Michigan, builds upon established links between the research groups of Professor Ventsislav Valev and Professor Nicholas Kotov.

The work of the two research groups is complimentary: allowing for innovative materials developed at Michigan to be tested by Professor Valev's research group at Bath. The collaboration has already led to a joint paper being published in Nature Photonics last year, and the hope is that this agreement will enable the mobility of PhD students between the groups and lead to more co-authored papers in the future.

The University of Michigan is ranked in the top 50 of the QS World University Rankings 2023 and is a leading research university in the United States. A key part of Michigan's mission is to create collaborative solutions. Another is promoting an inclusive and innovative community of service for the common good. This collaboration, which aims to provide new drugs for tackling antimicrobial resistance – a top 10 WHO threat to humankind – is perfectly aligned with this mission.

There is already wider collaboration with the Department of Chemistry at Bath, and the hope is that the agreement can develop from these positive beginnings to build more extensive links and contribute to the Faculty of Science's overall strategic aims.

Professor Valev, Head of the Department for Physics, who led the MoU proposal, said: "This agreement opens new possibilities for our academics and our students to address global challenges at an international level. It will expand their professional networks and provide access to complementary expertise. As a physicist in the Faculty of Science, I am particularly pleased that our agreement with the chemical engineers from the Faculty of Engineering in Michigan is both interdisciplinary and interfaculty. Such links always bring new perspectives that can lead to impactful discoveries and innovation."



Dean for the Faculty of Science, Professor Duncan Craig, said: "I am delighted to see this formalisation of the relationship with the University of Michigan, a highly prestigious and well-respected institution. The MOU enables and encourages further cooperation both within established collaborative areas such as photonics but also in broader scientific, engineering and health care fields of common interest. I look forward to offering full support to Prof Valev in taking this important partnership forward."

The University of Bath is proud to formalise a relationship with University of Michigan-Ann Arbor and looks forward to seeing the successes of this partnership.


# A delegation from NATO visits the Department of Physics

## A delegation from the NATO Sensors and Electronics (SET) Panel Optical Technology Focus Group visited the Faculty of Science.

On 25 April 2023, the Centre for Photonics and Photonic Materials (CCPM) in the Department of Physics welcomed a seventeen-member delegation from the NATO Sensors and Electronics (SET) Panel Optical Technology Focus Group.

Arriving from a range of NATO countries, the visit was to share knowledge around photonic crystal fibres and fibre lasers. During the visit, the delegation attended a series of talks on the research in these areas that's currently taking place in the Centre; and a tour of facilities in building 3WN, including laboratories for optical fibre fabrication, fibre quantum technologies, fibre tapering and nanophotonics.

Professor Jonathan Knight, Director of the Centre, said: 'It was an honour to host this visit of NATO experts and to understand how we might support them in their work. They were very engaged with the research being done within the Centre and it was a great opportunity to showcase some of our activities. I am confident that we will be able to develop some of the contacts made during the afternoon to develop ideas for research of mutual interest.'

Professor Ventsislav Valev, Head of Physics, noted: 'It's a tribute to the distinctive reputation of our research in photonics that the group chose to spend a few hours in our laboratories. I trust that they left with a clear idea not only of the research that we have done in the past, but also of our plans to build upon that research in the future.'

Professor Duncan Craig, Dean of the Faculty of Science added: 'It is intensely gratifying to see our colleagues in the Centre for Photonics and Photonic Materials hosting this NATO delegation. It shows once again that the Centre not only produces outstanding research but is also an active contributor to the international community in this key area of photonic crystal fibres and fibre lasers.'

# Professor Stijn Wuyts named Hiroko Sherwin Chair in Extragalactic Astronomy

The honorary role celebrates his contributions to astrophysics and the cooperation he has fostered between the University of Bath and East-Asian observatories.

Professor Stijn Wuyts from the Department of Physics has been awarded a named Chair in recognition of his ongoing contributions to the international field of astrophysics research and for his efforts to secure international development opportunities for the Bath Astrophysics group.

Stijn's research is on the formation and evolution of galaxies, from exploring its earliest chapters when the Universe was young to understanding the life cycle in the Universe today. Using multi-wavelength observations, he investigates how and when stars were formed, and how the structure of galaxies has evolved.

In 2019 and 2020, Stijn was featured on the Highly Cited Researchers List, identifying him as one of the world's most influential researchers.

To place on this list, Stijn published multiple, highly cited papers that ranked in the top 1% by citations for field and year. Overall, less than 0.1% of the world's researchers have earned this exclusive distinction.

Stijn says: "It is a great honour and privilege for me to be named the Hiroko Sherwin Chair in Extragalactic Astronomy. I am grateful for the support the Sherwins have shown to the University over the years, and especially their enthusiasm for Bath's explorations of the deep Universe."

He continues: "With the James Webb Space Telescope, we have an amazing new resource at our disposal, and we are currently using it to zoom in on the physical mechanisms that shape galaxies, at a time when the Universe was just a fraction of its current age.

"Meanwhile, we are also gearing up for a new generation of wide-area observing facilities that will chart large swathes of the Universe. They are excellently suited to provide context about the environments and ecosystems in which the lifecycle of galaxies unfolds.

"Whether via zooming in or zooming out, I believe Bath is well placed when it comes to writing those next chapters of the story of galaxy formation and evolution."

Hiroko Sherwin says: "I am delighted to support Professor Wuyts' work in astrophysics."

## Beyond the Stars

The Hiroko Sherwin Chair in Extragalactic Astronomy was established at the University in 2021. The Chair was named in celebration of long-term supporters, Jim and Hiroko Sherwin, who have funded undergraduate scholarships and PhD positions in the Faculty of Science for over a decade.

A common thread throughout Hiroko Sherwin's published work as an author is her desire 'to build a bridge between the East and the West' – Stijn's work at Bath honours this vision. With his support, the Bath Astrophysics group has hosted Fellows of the Japan Society for the Promotion of Science, post-graduates via the China Scholarship Council and summer students from Chinese talent programmes.

Through this international collaboration, members have engaged in international exchanges, visiting professorships, jointly supervised studentships, and have collaborated on projects together with researchers from across the East-Asian Observatories.

**Scan QR**
to learn more
about the Bath
Astrophysics group

# University of Bath student develops innovative moorings booking system for harbours and marinas

A University of Bath student has developed an innovative online mooring and berth booking system that promises to eliminate one of the biggest worries for boat users - finding a spare mooring in crowded harbours and marinas.

'Moored Solutions', developed by a team led by physics student Jamie Crisp, allows boat users to see what moorings and berths are available, and to reserve and pay for them online, which also resolves the issues many marina and harbour operators face around managing space and collecting fees.

"We think this fully autonomous system is a first for the marine industry, allowing boat users the ability and confidence to turn up and pay, or to book in advance, and helping marina and harbour operators cut their operating costs, manage space more efficiently, and encourage more sailors to use their facilities," Crisp said.

Crisp, a keen sailor and sailing instructor, said his team were in talks with several marinas and harbours about implementing the system, which he expects to launch in 2024. He said the system was suitable for the smallest operator with a single berth up to large harbours with hundreds of moorings and berths.

Users access the Moored Solutions website through the website of their chosen destination and use a map interface to select a mooring or berth based on availability and their vessel requirements, akin to selecting a seat on an airline flight. They make an electronic payment and return to the marina page.

"Some marinas and harbours offer 'online booking' but this really amounts to little more than filling in an electronic form requesting a mooring, which then has to be processed manually by operations staff. Our system can free up staff to fully focus on the guests' experience," he said.

He said operators were particularly interested in how it would improve the customer experience, relieve pressure on their staff, increase occupancy rates, and also potentially attract more bookings from boat users who could now be confident of a safe refuge at their chosen destination.

"Most facilities rely on their own personnel booking moorings and visitors, which can take up considerable time and resource. And many boat users will confirm how hit-and-miss or stressful this process can be if staff are not available, and how difficult it is to plan a sailing trip without knowing mooring space is free. In short, we can improve the convenience for boat users, and productivity for operators," he said.

Crisp said the marina and harbour operators were also interested in the system's ability to accommodate the rise in electric powered vessels, which require predictable availability of charging facilities.

"We will also be able to attach other facilities to the system, such as contacting water taxis, arranging grocery deliveries, securing fuel, or booking local restaurants or repair and maintenance services," he said.

Crisp said the idea for Moored Solutions originated in overhearing conversations by disgruntled harbourmasters who were struggling to collect mooring fees. He pulled together a team of computer scientists, developers and engineers and secured two rounds of funding from the University's 'Dragons' Den' scheme run by the university to support budding student entrepreneurs.

The University of Bath, under its Enterprise and Entrepreneurship programme, offers a range of support and development opportunities.

# Global Chair Professor Nicolas Kotov (University of Michigan)

A pioneering academic in the cross-disciplinary studies of inorganic nanomaterials, Professor Nicolas Kotov is hosted by the Department of Physics.

Professor Nicolas Kotov is an Irving Langmuir Distinguished University Professor of Chemical Sciences and Engineering at the University of Michigan. With his publications being cited more than 72,000 times, Professor Nicolas Kotov leads the Kotov Lab, and centers his research around biomimetic nanostructures.

A recipient of numerous internationally renowned awards, including the 2021 Turnbull Lecture Award from Materials Research Society, 2021 NSEF Award from American Institute of Chemical Engineering, 2020 Newton Award from the US Department of Defence, and the 2018 Soft Matter Award from the Royal Society of Chemistry, Prof Kotov has also chaired four Gordon Research Conferences. Most recently, Prof Kotov was elected into the National Academy of Inventors in 2020 and the prestigious American Academy of Arts and Sciences in 2022.

Prof Kotov will be hosted by Professor Ventsislav Valev in the Department of Physics. His appointment as a Global Chair builds upon his lab's established link with the research groups of Prof Valev here at Bath. A Memorandum of Understanding has recently been signed by the University of Michigan-Ann Arbor and Bath to further enhance research collaboration between the two institutions. Upon Prof Kotov's appointment as a Bath Global Chair, Prof Valev said:

*It brings me immense joy to welcome Professor Nicholas A. Kotov as a Global Chair. He is a renowned academic, whose work has been distinguished with more than 20 major honours from professional chemistry, materials, and engineering societies in the USA and in Europe. Professor Kotov's work has been pioneering, particularly in the areas of cross-disciplinary studies of inorganic nanomaterials. His fundamental contributions include elaboration of the mechanisms of their interactions with light, discovering their self-assembly pathways that mimic those of biomolecules and employing applied mathematical models to understand their complexity. He is also a source of inspiration for early-career and aspiring academics, for whom his mentorship will be invaluable. With his affiliation, I also anticipate numerous opportunities for interdisciplinary collaboration at Bath and the potential for institutional partnerships with The University of Michigan. I am thrilled about Professor Kotov's appointment and eager to collaborate on finding innovative solutions to global issues.*

**Scan QR** to learn more about Bath Global Chairs

# Bath Astrophysicist honoured with IOP Publishing Top Cited Paper Award

Dr Hendrik van Eerten, a reader in the Department of Physics, has co-authored one of this year's most cited papers published in Institute of Physics journals.

A University of Bath Astrophysicist, Dr Hendrik van Eerten, is co-author of a paper receiving the Institute of Physics Publishing's (IoPP) Top Cited Paper Award 2023.

These awards are presented to papers in the top one per cent of the most-cited articles published in Institute of Physics Publishing journals in the preceding three years. For the first time, this year's awards celebrate the significance of North American research and authors.

Among the recipients is a study led by Geoffrey Ryan from the Perimeter Institute for Theoretical Physics in Waterloo, Canada and Dr Van Eerten from the Department of Physics. Their paper on 'Gamma-ray burst afterglows in the Multimessenger era' was written in response to one of the biggest upheavals in high-energy astrophysics for years.

Neutron stars are ultra-dense objects, packing roughly the sun's mass into a star just a few kilometres in diameter. When two of them collided recently, they triggered an explosive event, leading to the first-ever simultaneous direct detection of light and gravitational waves from the birth of a black hole.

When material from neutron stars begins to swirl into a newly formed black hole, jets of near-light-speed gas are emitted. In their paper, Ryan and Van Eerten present a theoretical update on how to model and interpret observations of these jets.

When publishing on the breakthrough detection from 2017, Van Eerten and collaborators had already recognised the jets' structure gives us a glimpse of early jet propagation physics and fundamental plasma physics that is still not fully understood. Updated models in the paper help bring this information to the surface.

The paper further describes a rule-of-thumb method to quickly assess observations, revealing the orientation of the jet in the sky and allowing for more information to be extracted from gravitational wave detections. The team also included a public Python code for data analysis with the paper. A large and growing number of research groups worldwide have since used this.

IoPP is the publishing arm of the Institute of Physics, covering over 100 open access and hybrid journals ranging from quantum technology, material sciences, particle physics and astrophysics to environmental science, sustainability and the biosciences.

# AI and mathematical modelling could light the way for solar cells of the future

Researchers in the Department of Physics are combining device modelling and machine learning techniques to determine the performance of new solar technology.

Professor Alison Walker and her research group in the Department of Physics have developed powerful tools that can simulate perovskite materials and how they apply to solar cells. By combining modelling techniques such as Monte Carlo and drift-diffusion modelling with machine learning, they've enhanced their simulation power even further.

Solar cells have traditionally been made using silicon-based semiconducting materials. While it's one of the Earth's most abundant elements, the silicon used in solar cells must be purified, making it an expensive material to work with. The resulting solar cells are also large and rigid, limiting their uses; for example, the wide, flat panels seen on rooftops.

Perovskite materials are a family of minerals with a unique crystal structure and a range of surprising properties. Not only are the cells cheap to produce, lightweight and flexible when used on their own, the cells can be built into solar panels to provide a significant increase in performance compared to standalone silicon solar cells.

While perovskite cells clearly show potential, one of the challenges facing physicists is the limited stability of the material. Early cells have been shown to degrade rapidly, becoming unusable within minutes or hours, making them unviable commercially.

## Simulating the solution

To optimise stability and performance, fast iteration of fabrication and characterisation of properties is essential. However, current processes to analyse underperformance are complex and time-consuming, slowing down fabrication.

Professor Walker and team have been exploring these challenges and showing how combining machine learning and simulation methodologies allows for much faster and more direct characterisation of materials and devices. Together, they've developed a set of computer codes to create a virtual model that can pinpoint causes of features seen in the measurements using only a few hours of computation.

The virtual model is continuously updated to reflect the current output of a fabricated laboratory device. This allows the team to understand the materials processes underlying changes in the devices' output. By accurately and rapidly simulating the function and performance of the lab device, this opens up the possibility of pinpointing the origins of degradation and allows improvements to be made much more quickly in future device iterations.

## Read the papers

Their studies have been demonstrated in two recently published papers.

**Scan QR** to read the paper published in APL Machine Learning

**Scan QR** to read the paper published in JPhys Energy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