UNIVERSITY OF CAMBRIDGE

AUGUST 2016
ISSUE 16

CAVMAG

News from the Cavendish Laboratory

Maxwell Centre Open for Business

EDITORIAL

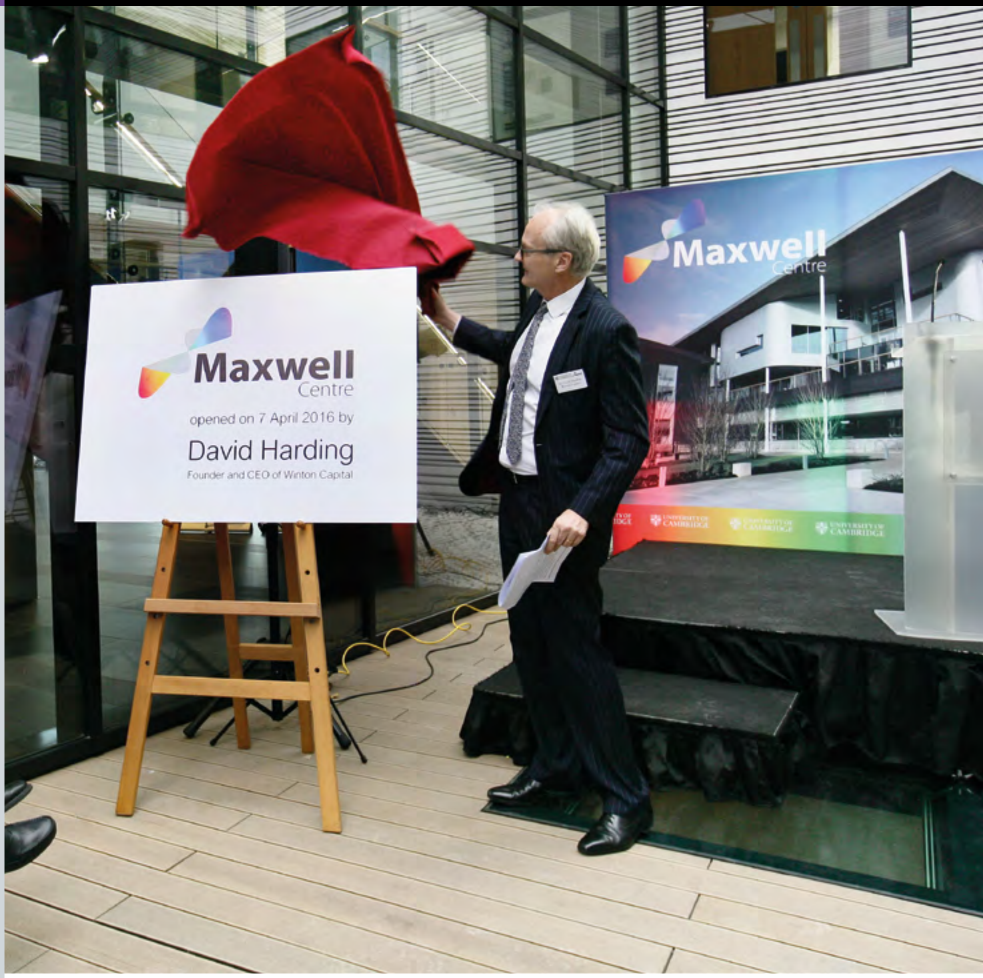
CavMag16 celebrates the opening of the Maxwell Centre and the opportunities it offers for a huge range of modes of collaboration between the physical sciences and industry. The research articles on perovskites, Siân Dutton's activities and the Scientific Computing initiatives give some impression of the science already being fostered in the Centre. The formal opening was another ground-breaker, the ceremony including a spectacular Arts-Science exhibition and an amazing specially commissioned dance piece by Wayne McGregor with sound by Haroon Mizra. These successes set new benchmarks for our ambitions for the New Cavendish Laboratory.

Malcolm Longair

INSIDE

Cover image:
The Maxwell Centre © Kelvin Fagan

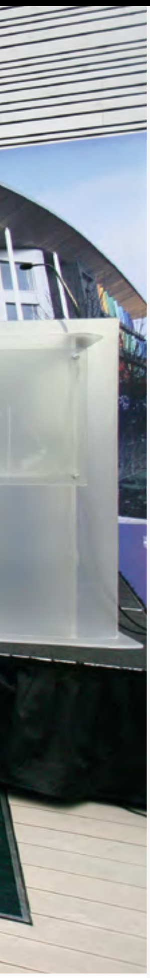
MAXWELL CENTRE OPENING

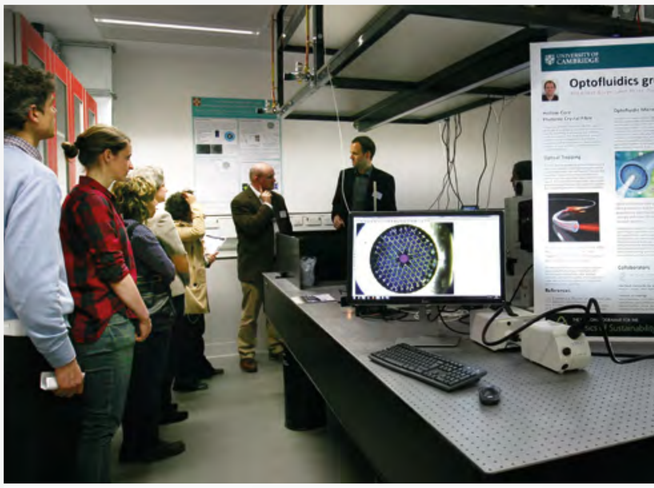


The formal opening of the Maxwell Centre took place on 7 April 2016. This auspicious occasion included brief speeches by the Chancellor and Vice Chancellor of the University, Richard Friend (Director of the Maxwell Centre), Anna Marie Greenaway (Vice-President Science and Technology at BP-Cambridge) and our distinguished benefactor and, on this occasion, opener David Harding.

What we were celebrating was splendidly described by Richard in his address. In his words:

'The Maxwell Centre will play a central role in the very exciting journey that lies ahead for West Cambridge and for the University's long-term strategy. It embodies the special spirit of the Cavendish Laboratory, where whole new fields of science and later, technology, have been created. But the Maxwell Centre is designed to bring together the full spectrum of science and engineering in West Cambridge, and as we open today, we have activities in place from across the university, including Physics, Materials Science, Chemical Engineering, Chemistry and Engineering. The bulk of the funding for the building, the bricks and mortar, has come from the Higher Education Funding Council





for England through their capital funding programme, the UK Research Partnership Investment Fund, thanks to the matched support of our many industrial collaborators and benefactors.

We are delighted that David Harding is here. David has provided £20m to establish the Winton Programme for the Physics of Sustainability within the Cavendish Laboratory. The Winton Programme is directed to 'blue-skies' research that has the capacity to bring revolutionary changes to the technologies we need for a prosperous and sustainable future. The Winton Programme is bringing the brightest and best to Cambridge at the start of their careers.

But it has also given us the time, space and resource to think and set strategy, drawing on the experience of our International Advisors, and detached from externally-imposed agendas. The themes initiated within the programme are now setting our agendas for the Energy@Cambridge Strategic Research Initiative, for the Cambridge activity within the Sir Henry Royce Institute for Advanced Materials, and of course for the Maxwell Centre.

We have a proud tradition of working very closely with industry, both large and small. The best industrial collaborations work both ways. Within the university we want to see our blue skies research make an impact for the good, and we want industry to pick up what we have started. But we also learn from industry where there are important new science questions and we learn to spot what may be capable of being scaled to make an impact.

I hope you agree that the Maxwell Centre has turned out to be a great building. We are all very pleased to be here – the open space, the natural light, the fancy coffee machines are all strong attractors. I would like to thank all those who made this happen, on time and on budget. The architects, BDP have produced a wonderful design for the building, SDC has built this to a high standard, and our local team in the Cavendish and in Estate Management have made sure that this is the building we wanted - our specific technical requirements have been met.

We have ambitious plans for the use of the laboratories. Equipment is not just expensive to buy but it is expensive to operate well. The magic is both to get the best specialist groups to bring facilities to be best in the world, and also to ensure that access to these is democratic. This is the way to cross-fertilise not just techniques but also ideas. We will therefore run these as well-supported user facilities, operating around the clock when appropriate. These will be available to our industrial partners and also to the individual researcher with a bright idea at the start of his or her career or indeed at any stage.'

Working together

The Maxwell Centre is the centrepiece for industrial partnerships, providing a gateway to the research and expertise of the University of Cambridge across the Physical Sciences and Technology. Each academia-industry partnership has its own unique characteristics and needs and we welcome the opportunities to collaborate in many different ways. We work closely with companies to identify the most effective mode of collaboration that adds value and research insights to support our common aims. We cherish this diversity, recognising that serendipity of a random conversation over coffee is often just as important as strategic planning.

Models of academia-industry interaction

Collaborations come in all shapes and sizes and the University has adopted a flexible approach with a broad spectrum of modes of interaction which have already been implemented. The table opposite illustrates twenty different modes of collaboration with industry which have already been established. These range from advice, consultations and one day exploratory workshops to sharing expertise and know-how through strategic partnerships lasting decades. The scale of resource involved also varies considerably between the different models.

The table indicates the key advantages of the various approaches, all of which have already been developed with our collaborators. While this selection hopefully captures the diversity of relationships we foster with a wide range of external partners, it does not claim to represent the full range of flavours nor the full extent of any of the existing relationships. We emphasise that these examples are only a subset of a very much larger number of past, current and developing partnerships.

Get in touch

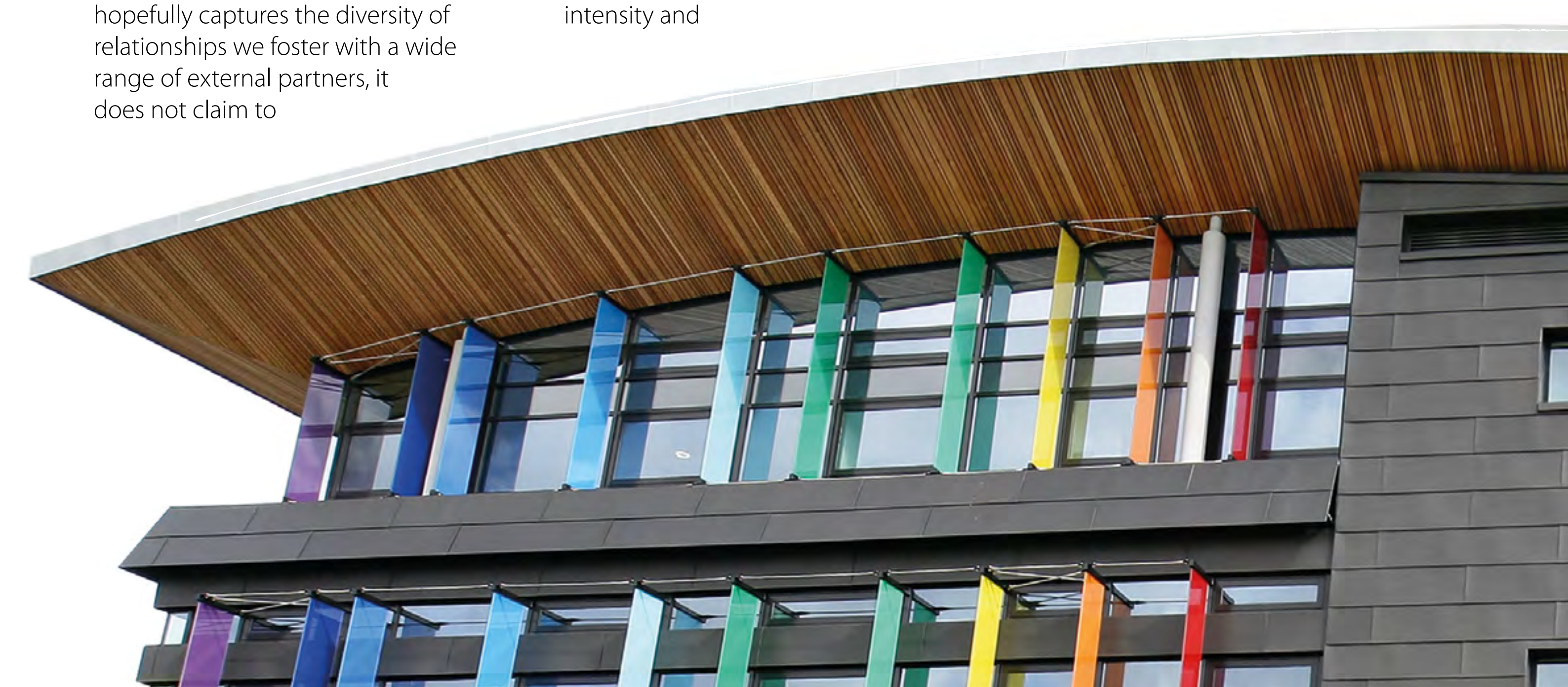
We are constantly on the lookout for new partners and industries - the Maxwell Centre is set up to facilitate and foster these interactions. We strongly welcome new collaborations that involve innovative and ambitious research approaches to solving real-world challenges. The modes of interaction can be matched to the aspirations of both sides.

The primary considerations are communality of interests between partners, capacity, resource intensity and expected duration of each project - each case is slightly different. There is a huge range of possibilities, with countless contexts, scenarios and collaboration areas. Each new avenue feels like embarking on a truly exciting voyage of discovery. Therefore, if you feel inspired to give it a try, or have any questions about the interaction models, please feel free to get in touch with me and let's explore how we can work together!

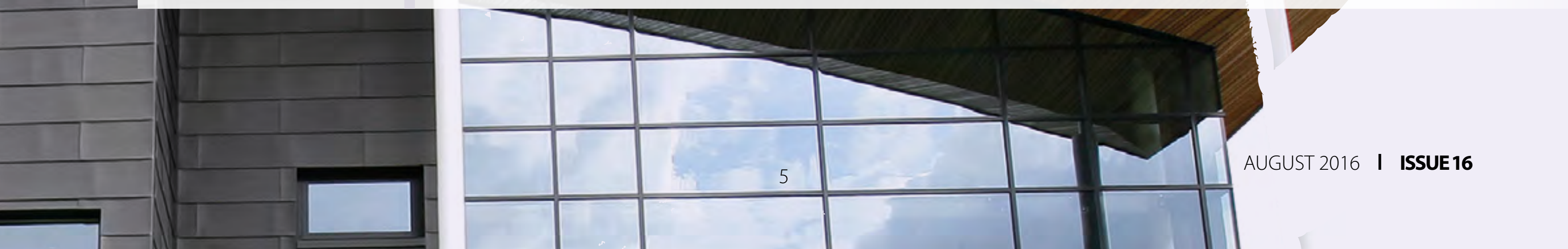
AGA IWASIEWICZ-WABNIG
Maxwell Centre Programme Manager

Email: ai261@cam.ac.uk
Phone: +44 (0)1223 761669

www.maxwell.cam.ac.uk



INTERACTION MODE	TYPES OF ACTIVITY
Residence or hot desk in the Maxwell Centre	Co-location for direct and ongoing interaction across the University's Physical Science & Technology campus; hub for open innovation; place for planned conversations as well as serendipity; scoping & brokering collaborations.
Strategic Partnership	Relationship of strategic importance to both parties; institutional level agreements enabling a portfolio of activities across the University; developing new areas of joint collaborative research.
Expertise Hub for Knowledge Transfer	Converts blue-skies research into disruptive technologies which are transferred across non-competing industries; facilitating step change progress.
Embedded Laboratory	Industrial laboratory embedded long-term within an academic department; sponsored posts & studentships; outputs maximised by bidirectional information flow: joint patents and publications; joint funding from RCUK.
Sharing Expertise and Know-how	Building understanding of the other partner's needs, interest and expertise; direct exchange of knowledge and know-how; regular access to the other partner's facilities; co-application for funding.
Shared Access Equipment	Access to cutting-edge equipment in University laboratories; cost-effective, pay for access when required; optimal use of academic facilities & maximal impact of capital investment.
Pump-priming initiatives	Scoping new big ideas to solve difficult problems; small initial commitment can kick-start discussions, de-risk and test waters for collaborations.
Industry Engagement Forum	Companies gain insight into how Cambridge research & know-how may be applied to their problems; opportunity to identify areas of common interest and forge links.
Summer or Master Projects	Short-term, focussed research projects carried out by students under academic guidance; work best with well-defined research questions and for pump-priming solutions.
University Technology Centre	Long term research generating new knowledge; company-funded academic posts for creatively addressing industrial needs, leading to better products.
Research Collaboration	Funding ground breaking research, for example, by embedded postdoctoral researchers; direct access to novel technologies; close collaboration; research visits.
Spin-outs & IP licensing	Commercialisation of inventions and ideas aimed at solving society's problems; R&D to make technologies accessible; creating strong links with industry and putting IP to use.
Career Fairs & Recruitment	Access to talent; opportunity to showcase your business; University attracts the best people from all over the world; many graduates and postdocs move to 'real-world' jobs.
iCASE / PhD studentship	3-4 years graduate research project; PhD student working in an area of relevance to the company; link to a research group; student may visit the company and maintain the link.
Consultancy & expert advice	Access to world-leading experts and game-changing ideas; consultants who excel in sound critical assessment; accelerating impact of academic work on society and economy.
CDT: cohort interaction	Companies engage with the entire cohort of >50 PhD students and the network of their >150 academic supervisors; all projects are highly interdisciplinary.
CDT: directly sponsored projects	PhD student projects matched to skills & bespoke training; access to research at five participating departments; recruitment of highly qualified graduates.
Knowledge Transfer Partnership	Transfer of knowledge and know-how from university to company, RCUK co-funded, and mediated by a specialist Associate linking Business to University.
Mentorship and co-supervision	Direct interactions with students and postdocs; input into shaping their research, awareness and career choices; providing role models with industry experience.
Consortium for pre-competitive research	Group of companies with overlapping interests jointly funding new knowledge generation to share risks and benefits at pre-competitive research level.



In a nutshell

The Centre's role is to facilitate and amplify engagement and knowledge exchange with industry across Physical Sciences and Technology departments linked to West Cambridge campus. Maxwell Centre Programme operates for the benefit of the entire University, and all of its constituencies, as a value-adding shared resource. The Maxwell Centre...

is **a gateway** for academia-industry interactions across physical science and technology in Cambridge.

is **not a gatekeeper** – industries are welcome to engage directly with academics and we retain the full flexibility of approaches

is not able to deliver its programme without **active participation from the affiliated departments** – linking through HoDs, KTFs and the academic communities.

is **attracting, signposting, matchmaking and facilitating** interactions with industry for the benefit of the University of Cambridge.

is **not going to regulate nor restrict** new interactions with industry nor jeopardise existing relationships. While the Centre has buy-in at departmental levels already, we welcome individual opt-ins from West Cambridge academics and groups wishing to come explicitly under the Maxwell Centre umbrella for the signposting of opportunities.

is **enabling efficient knowledge sharing** about existing partnerships to maintain and grow relationships with industry partners, while being mindful of existing collaborations and contacts.

serves all of West Cambridge, and has a Steering Group comprising Heads of Departments and Schools, as well as Pro-VCs for Enterprise and Research. Connectivity extends through SRIs and SRNs, CDTs, CE, Research Office, Cambridge Network, and more…

is not biased towards any of the departments and operates in a **transparent and inclusive** way, welcoming input and feedback from all. The Maxwell Centre is fully integrated with activities within each Department; it offers a "second-base" - window seat to the outside world option, maintaining open communication policy with your primary department.

is based in, and operates from the Maxwell building, administratively under the Department of Physics.

is not restricted to the Maxwell building nor Physics – it is a shared resource for West Cambridge, with a model that is available to be adapted in all departments and facilities

will foster entrepreneurship amongst Physical Science and Technology students and researchers, offering new programmes to teach and promote entrepreneurship specifically with physical science / technology flavour in mind.

will not impede existing entrepreneurial programmes nor replace any of the avenues to commercialisation, through Cambridge Enterprise or otherwise.

welcomes and encourages industry footfall, from **access to shared equipment,** through **occasional hot-desking** to **permanent collaborative presences in offices and labs**.

is **not offering standalone rental space** to companies on first-come first-serve basis – it is about engagement with the university research

Recognises the value of understanding the culture, needs and priorities of companies. Communicates to external partners the mission, ways and character of academia and highlights benefits of tapping into open academic environment. Bringing people to **work together** to everyone's strengths, rather than exchanging roles between sides.

will not attempt to change the mission of the university. We recognise the university's strength is in research, often pre-competitive (low TRL end), and solving hard problems where generation of new knowledge is needed. Companies focus on product development (high TRLs), and through this encounter we can help solve interesting problems. Synergies are exploited when interests align in **joint research, conversations, mutual inspiration and flow of people**.

is an **open innovation environment**: networking hub, a melting pot and a place for serendipitous chats, where unexpected meetings happen alongside planned activities. Come and see for yourself!

is not suitable to host isolated pockets of activity, be it industrial or academic in origin. **Broader engagement is essential** – either in ongoing research collaborations or willingness to develop them.

can offer **meeting space** for activities supporting the Maxwell Centre mission of academia-industry engagement, e.g. meeting rooms for industry visits.

is **not a general purpose conference and meeting facility**, but focusses on a programme of delivery of the Maxwell Centre vision.

GLOSSARY:

HoD	Head of Department
KTF	Knowledge Transfer Facilitator
SRI	Strategic Research Initiative
CDT	Centre for Doctoral Training
CE	Cambridge Enterprise

Art, Dance and Science at the Maxwell Centre

Specially commissioned dance piece by Wayne McGregor and Haroon Mirza

JENNIFER POWELL Senior Curator, Kettle's Yard

At the opening of the Maxwell Centre on 7 April 2016, the central atrium space was activated by dynamic interactions between the bodies of two dancers, light, electromagnetic waves and sound. This exciting new work by choreographer Wayne McGregor and artist Haroon Mirza was specially commissioned by Kettle's Yard and the Maxwell Centre. It was performed again on the first public Open Day alongside the visual arts exhibition *Into Boundless Space I Leap*. The collaboration was inspired by James Clerk Maxwell's scientific discoveries and the resulting work reflects the Centre's wider purpose – to be a pioneering centre for creative discovery.

Central to this process of creative discovery was the collaborative dialogue between Mirza and McGregor. Both artists are London-based and internationally renowned for the pioneering nature of their work. Mirza's kinetic sculptures, performances and installations reflect his longstanding interest in the interplay of sound, light and electricity, which he playfully manipulates. Science and technology have been life-long interests for McGregor who is Director of Studio Wayne McGregor and resident choreographer at the Royal Ballet. McGregor was the first choreographer with a contemporary dance background to be appointed as resident to the ballet company. Through an endless appetite for experimentation, his choreography pushes the boundaries of the mind and body through performance and multi-disciplinary collaboration. Our commission was Mirza and McGregor's second partnership in which the artists explore and test the dialogues between light, sound, movement and architecture. Their first, was a new ballet *Alea Sands*, which McGregor developed with a lighting system by Mirza that interacted with music by Pierre Boulez and the architecture of the Paris Opera House.

The behaviour of light in space was a fundamental concern for Kettle's Yard's creator Jim Ede. It played a central role in Ede's staging of his home which he opened to visitors in 1957 as a welcoming space to enjoy a remarkable collection of modern British and international art. Art works were meticulously arranged alongside furniture, ceramics, textiles and natural objects to create a carefully choreographed whole. The play of light still dances through windows and skylights around the historic cottages and the 1970s extension designed by Leslie Martin.

Mirza's new light and sound work *Transverse Waves for Wayne (Solar Symphony 10)*, was located centrally in the atrium – a space surrounded by glass panels that physically opens up the heart of the Maxwell building blurring boundaries between social and research spaces. Mirza's work is composed of a photovoltaic panel (a solar panel), a found car door which he repurposed and fitted with a programmed circuit board and LED lights. Speakers and further standing lights are positioned around the edges of the space. Mirza's sound-scape, or score, is generated through the programmed circuit that is powered through the energy transfer from bright standing lights that shine onto the photovoltaic panel. But this relationship can be interrupted at any time: by the slightest disturbance of that energy – by a passing body. It is unpredictable, reactionary, and feels alive.

McGregor's choreography encourages the dancers to use their bodies to disturb this energy field. Their movements inspire the viewer to pay closer attention to the different, but overlapping, sounds; a long flowing développé (the unfolding of the dancer's leg) submerges us in the sculptures hypnotic humming sounds, whilst a quickly flickering hand switches our attention to the harsher repeated staccato notes. The dancers' bodies also react to the space that they occupy. McGregor's choreography both instructs dancers Jason Mabana and Julia Anna Sattler, but deliberately allows them to feel the space and develop their own movements – it encourages their own creativity and they are integral to the conversation. Spectators are also welcomed into the space during the performance shaping and changing it each time as the dancers react to their physical presence.

In 1864, on the occasion of a lecture at the Royal Society, James Clerk Maxwell stated that *'we have strong reason to conclude that light itself – including radiant heat and other radiation – is an electromagnetic disturbance of waves propagated through the electro-magnetic field according to electromagnetic waves.'* McGregor and Mirza's commission tests the transference and the disturbance of energy – through light, through space, through the dancers' movements and the spectators' bodies.

Reflections from the Artist

After learning about Maxwell's work I felt it appropriate to develop a piece that expanded my personal interest in light and electromagnetism by working on a new Solar Symphony (a series of works that convert electricity generated by photovoltaic technology into electro-acoustic compositions), which would offer Wayne a chaotic compilation to work with. Wayne as always was up the challenge of choreographing something to that which has no conventional compositional structure. The title of the piece, 'Transverse Waves for Wayne' alludes the perceptual engagement with the work itself in a metaphysical sense. The project for me has begun a wider curiosity about light, magnetism and electricity and also particle physics in general. So much so that I am now inquiring about artist residencies at CERN, LIGO and other such facilities.

Haroon Mirza

'Into Boundless Space I Leap'

SUCHITRA SEBASTIAN, DIRECTOR, Cavendish Arts-Science Project
GUY HAYWOOD, Curator, Kettle's Yard

To mark the inauguration of the Maxwell Centre, an exhibition '*Into Boundless Space I Leap*' was conceived and created by the newly formed Cavendish Art-Science Project in collaboration with colleagues from Kettle's Yard, who curated the event. The exhibition was a grand experiment in bringing the arts and sciences together, in the tradition of all great experiments in the Cavendish. The willingness and appetite to be at the frontier, to take risks, and to entrust those with just the glimmer of an idea, the backing and the wherewithal to forge ahead and transform their vision into reality are at the heart of scientific enterprise at the Cavendish. The title '*Into Boundless Space I Leap*' is taken from the poetry of James Clerk Maxwell who conceived a world of invisible fields, where electricity, magnetism and light waves interact as one with each other. Decades later, radio, TV, radar, and mobile phones carry information through Clerk Maxwell's electromagnetic fields – a triumph of scientific imagination translated into technology. The visionary culture of the Maxwell Centre is designed to reflect Clerk Maxwell's legacy as the way to the future, and our event is a signpost for things to come.

Science is too often walled off, considered too technical, incomprehensible and the preserve of specialists. The new Maxwell Centre is designed to make science more accessible and its boundaries more porous; to facilitate academic conversations with industry, interdisciplinary partnerships and fluid interfaces between science and the arts. This motivation was what we were seeking to convey through our inaugural exhibition. The worlds of science and art, laboratory and gallery, may often seem conventionally separate, different, worlds apart. One might ask how they can possibly relate to each other. Yet scientists and artists share at least one fundamental trait: a passionate, embedded curiosity and drive to understand more of the world around them. This trait flows through every part of what they do and who they are, and the ideas that they generate have the potential to shift profoundly the way we see and interact with the world around us. Both science and the arts are about concepts and ideas that engage the imagination and offer a portal into new worlds. Our aim was to bring together scientists, artists and a far broader general audience to share this opportunity to explore worlds previously unseen and have their curiosity ignited and challenged in new ways, encountering a deeper desire to enquire about the physical world.

We sought to explore a new interface between science and the arts beyond the niche often occupied by traditional 'arts-science' events, which often face the challenge of attracting an audience beyond those with an existing interest or involvement in this intersection. Historically, the context has often involved a second-hand transcription of scientific outputs into artistic media, which can tend to fall some way short of creating captivating works of art that engage and draw in those beyond the traditional boundaries of science. To transcend such barriers we adopted the approach of recognising the intellectual depth and fiercely demanding, all-consuming quest that drives both scientific and artistic endeavours, without considering either as in a supporting role to the other. Our specially curated exhibition was designed to highlight rich scientific concepts that find expression both in pioneering fundamental research activity

and technological applications, as well as in original artistic creations. The challenge was very considerable both for the artists tasked with grappling with profound scientific ideas, and scientists at the Maxwell centre who interfaced with artists to explore their research vision in broadly accessible and captivating ways. A partnership was designed to inspire new work that was authentic rather than transcriptive.

One of the central pieces in the exhibition was conceived by artist ***Mark Titchner***, who created a monumental graphic text design that now integrates itself into the new architecture of the Maxwell Centre. Titchner, who is concerned with the nuances of language and its relationship to belief systems, found inspiration in poetry written by James Clerk Maxwell while he was in Cambridge. Maxwell, like so many other leading physicists, saw literature and music as another creative output for his research. Titchner extracted a phrase, '*Let Old Words New Truth Inspire*', from one of these poems and turned it into a mantra that now cascades down the Maxwell Centre's feature staircase in the heart of the building. The refining of Titchner's ideas and careful selection of words came about through lengthy discussions with curators and scientists working at the Maxwell Centre. Central to these discussions was an exploration of the shared desire – both Titchner's and the scientists involved in the exhibition – to break down contemporary barriers that have caused both their fields to adopt specialised languages that have moved them far from the realm of accessibility and broad engagement. At once responding to the continued sense of endeavour and discovery that is so central to the work that goes on in the building, and those around it on the West Cambridge campus, Titchner's piece also responds to the architecture – new readings of Maxwell's phrase can be made from each of the possible viewpoints around the building – and through the repetition of the phrase he suggests that there is more than one truth to be found, and that by their nature truths may be revealed and hidden depending on your perspective.

Laura Buckley's two stunning new experimental prints came about through a similarly involved dialogue with Maxwell Centre scientists. Buckley is known for working with light as her medium, much as other artists might work with paint or plaster. Consequently, during early visits with curators to the Cavendish Laboratory she was instinctively drawn to contemporary research in the optics laboratories, as well as to historic instruments developed by James Clerk Maxwell for the study of light and colour. Given her longstanding interest in the behaviour of light, Buckley embraced the unique opportunity to interact with renowned scientific minds as well as to access the Cavendish Laboratory's somewhat iconic heritage. Buckley's prints were created by using photographic scanning equipment to 'scan' Maxwell's *Strained Glasses* from 1848, while simultaneously shining pure white light from an external source through the *Glasses*, back into the scanner. This artistic re-appropriation of objects and technology normally reserved for very different purposes in the scientific realm has resulted in the production of something quite unexpected, where unbounded artistic experimentation, as well as aesthetics, reign over function.

A number of other artists worked closely with scientists over several months to develop ambitious new work of the highest standard for the exhibition, including ***Rana Begum***, ***Ulyana Gumeniuk***, ***Issam Kourbaj***, ***Eugenio Polgovsky*** as well as ***Paul Purgas***, who devised a unique sound installation incorporating live electromagnetic waves picked up from advanced scientific equipment in the new quantum materials laboratories at the Maxwell Centre. Other exhibiting artists included ***Benedict Drew***, ***Fischli/Weiss***, ***Gustav Metzger***, ***Hito Steyerl*** and ***Edward Wilson***.

Our exhibition was an exciting celebration of scientific and artistic discovery, and demonstrates what we can achieve when we bring our worlds together. This is only the beginning of the story. We envisage the long-term development of a strong relationship between science and the arts in Cambridge, facilitated by the Maxwell Centre, which we view as becoming an outreach hub for science and the arts in the West Cambridge campus, and the Cavendish Arts-Science Project partnership between scientists, curators, and collaborating artists. It is our hope that '*Into Boundless Space I Leap*' proved a riveting exploration of new worlds, and broadly ignited the scientific and artistic curiosity and imagination of a wide audience – to see further, and dream bigger.

We would like to thank all of the artists, performers, scientists and collaborators who took part in the project. We are particularly grateful for the support of Trinity College, Cambridge; L'Oreal UK & Ireland; the Winton Programme; Lisson Gallery; University of Cambridge Science Festival and the Cavendish Laboratory, which made this inaugural exhibition possible.

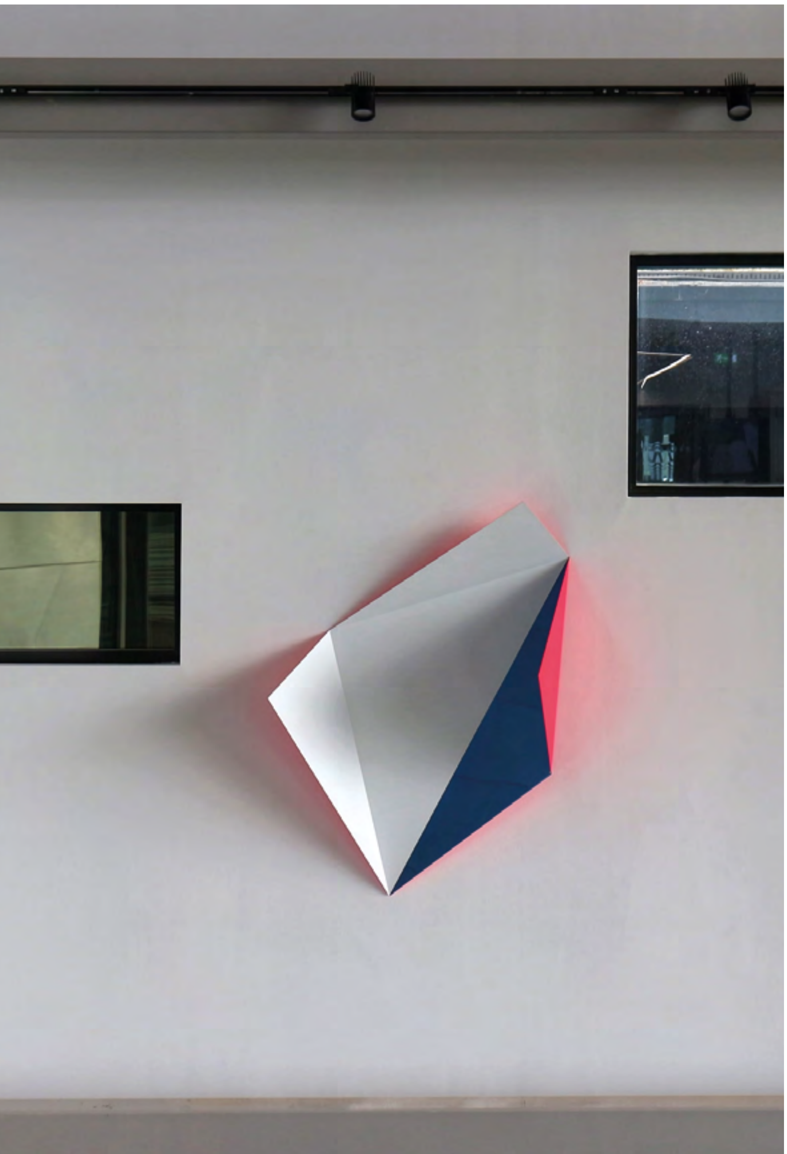
Full list of works:

Rana Begum, *No.657 LFold,* 2016 and *No. 659 LFold*, 2016; Laura Buckley, *White Light Waves 1, 2016 and White Light Waves 2*, 2016; Benedict Drew, *Mainland Rock*, 2014; Fischli/Weiss*, The Way Things Go*, 1987; Ulyana Gumenuik, *Elements 1.1 (Iron),* 2016; Issam Kourbaj, *Camera obscura photographs*, 2016; Gustav Metzger, *Light Drawing*, 2014; Wayne McGregor and Haroon Mirza, film of new dance commission, film by Ravi Deepres; Eugenio Polgovsky, *Lightbyrinth*, 2016; Paul Purgas*, Source/Cell/Magnitude,* 2016; Hito Steyerl, *Strike,* 2010; Mark Titchner, *Let Old Words New Truth Inspire*, 2016; Edward Wilson, *Untitled sketches of the aurora australis*, c.1901 (posthumous reproductions 2016); also displayed were a selection of James Clark Maxwell's instruments from the Cavendish Laboratory Collection, as well as selected exhibits from the Nano^Art Project.

Image, left: Jason Mabana and Julia Anna Sattler.

Images, below: Left: One of Rana Begum's LFold sculptures in the entrance lobby of the Maxwell Centre.

Right: Laura Buckley, *White Light Waves 1 and 2* (on the walls), 2016 and Mark Titchner *Let Old Words New Truth Inspire*, 2016. Installation view at the Maxwell Centre. Courtesy of the artists. Photographer Paul Allitt.



Novel solar cell material can recycle light to boost efficiency

Perovskite materials can recycle light particles – a finding which could lead to a new generation of affordable, high-performance solar cells. TOM KIRK and LUIS M. PAZOS OUTÓN report on behalf of the perovskite group.

It has been discovered that a highly promising group of materials, known as hybrid lead halide perovskites, recycle light – this finding could lead to large gains in the efficiency of solar cells.

Hybrid lead halide perovskites are a particular group of synthetic materials which have been the subject of intensive research, as they appear to promise a revolution in the field of solar energy. As well as being cheap and easy to produce, perovskite solar cells have, in the space of a few years, become almost as energy-efficient as silicon, the material currently used in most household solar panels.

The new study, however, suggests that this could just be the beginning. Solar cells work by absorbing photons from the Sun to create electrical charges, but the process also works in reverse, because when the electrical charges recombine, they can create photons. The research shows that perovskite cells are very efficient at doing this, and have the ability to re-absorb these regenerated photons, a process known as 'photon recycling'. This creates a concentration effect inside the cell, as if a lens has been used to focus lots of light in a single spot. According to the researchers, this ability to recycle photons could be exploited with relative ease to create cells capable of pushing the limits of energy efficiency in solar panels.

The study builds on an established collaboration with Henry Snaith at the University of Oxford on the use of these materials, not only in solar cells but also in light-emitting diodes and was carried out in the Cavendish Optoelectronics group

Richard Friend with the Perovskite team. (From left to right). Johannes Richter, Robin Lamboll, Mejd Alsari, Richard Friend, Luis M. Pazos Outón, Monika Szumilo, Micaela Crespo-Quesada, Felix Deschler.

led by Richard Friend. Felix Deschler, who works with a team studying perovskites at the Laboratory, said:

'It's a massive demonstration of the quality of this material and opens the door to maximising the efficiency of solar cells. The fabrication methods that would be required to exploit this phenomenon are not complicated, and that should boost the efficiency of this technology significantly beyond what we have been able to achieve until now.'

Perovskite-based solar cells were first tested in 2012, and were so successful that in 2013, *Science* Magazine rated them one of the breakthroughs of the year. Since then, researchers have made rapid progress in improving the efficiency with which these cells convert light into electrical energy. Recent experiments have produced power conversion efficiencies of around 22%, a figure already comparable with silicon cells. By showing that perovskite-based cells can also recycle photons, the new research suggests that they could reach efficiencies well beyond this.

The study, reported in *Science*[1], involved shining a laser onto one part of a 500 nanometre-thick sample of lead-iodide perovskite. Perovskites emit light when they come into contact with it, so the team was able to measure photon activity inside the sample based on the light it emitted. Close to where the laser light had shone onto the film, the researchers detected near-infrared light emission. Crucially, however, this emission was also detected further away from the point where the laser hit the sample, together with a second emission consisting of lower-energy photons. Luis Miguel Pazos Outón, the paper's first author, said,

'The low-energy component enables charges to be transported over a long distance, but the high-energy component could not exist unless photons were being recycled.'

As part of the study, the team also manufactured the first demonstration of a perovskite-based back-contact solar cell. This single cell proved capable of transporting an electrical current more than 50 micrometres away from the contact point with the laser, a distance far greater than the researchers had predicted, and a direct result of multiple photon recycling events taking place within the sample. Pazos Outón, explained:

'Recycling is a quality that materials like silicon simply don't have. This effect concentrates a lot of charges within a very small volume, produced by a combination of incoming photons and those being made within the material itself. The concentration of charges enhances the voltage produced by the device, increasing its energy efficiency.'

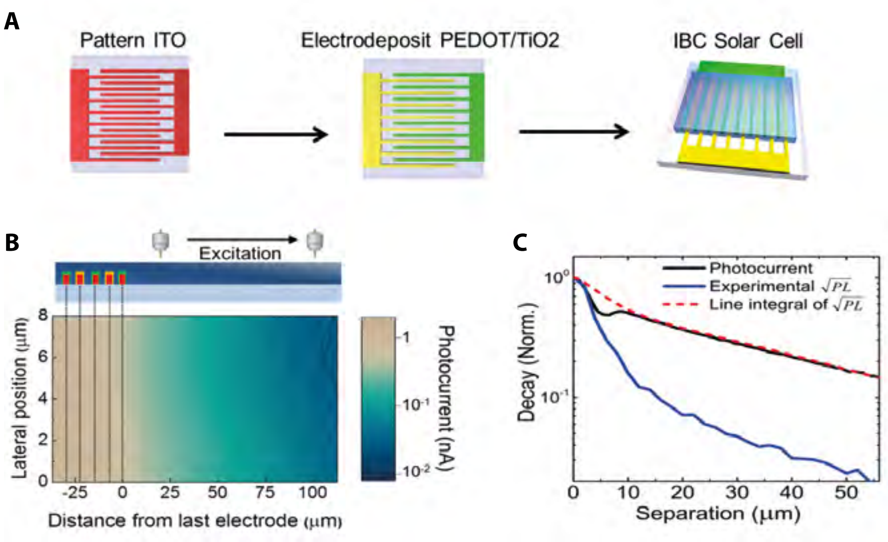
To harness fully the benefits of photon recycling, the photovoltaics community must now make some modifications to the design of solar cells. Photovoltaic devices have two electrodes, a transparent electrode on top and a reflective electrode in the back. If the reflectivity of the back electrodes is improved, the photons generated by the perovskite material will be reflected back into the cell increasing further the concentration of photons, and consequently the concentration of charges, leading to voltage gains. Seemingly, an increase in the luminescence efficiency of the perovskite will also lead to a higher concentration of charges.

These optical design rules cannot be applied to silicon solar cells because their luminescence efficiency is far too low, due to the nature of its indirect bandgap. However, Alta devices has first applied these concepts to GaAs solar cells and smashed the world record in power conversion efficiency going from 26.4% to 28.8% in a few years.

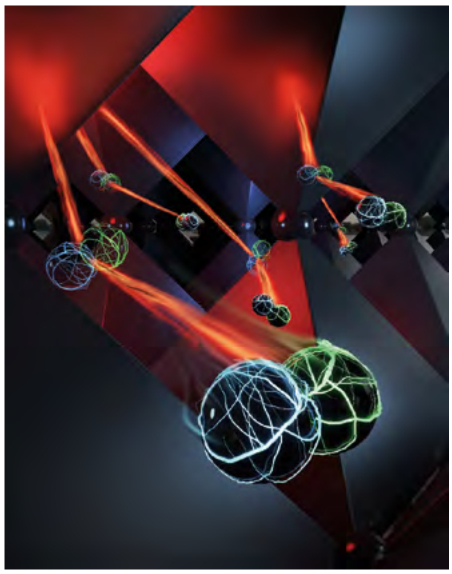
The researchers at Cambridge now believe that perovskite solar cells, may be able to reach considerably higher performance. Richard Friend stated,

'The fact that we were able to show photon recycling happening in our own cell, which had not been optimised to produce energy, is extremely promising. If we can harness this it would lead to huge gains in terms of energy efficiency.'

1. Pazos-Outón et al.,'Photon recycling in lead iodide perovskite solar cells', *Science*, 2016, **351**, 1430-1433.



Photocurrent mapping of an interdigitated back contact (IBC) perovskite solar cell. A) Fabrication process of back-contact perovskite solar cell: pattern a flat sheet of ITO, electrodeposit TiO2 on half the fingers and PEDOT on the other half, spincoat the photoactive perovskite layer. B) Photocurrent map at the edge of the active area of the perovskite device. We observed photocurrent several tens of microns beyond the last electrode. C) Comparison between spatial decay of photocurrent and square root of PL ($\sqrt{PL}$ α carrier density). These results suggest that electrons traveling over large distances through the material assisted by photon recycling, can be extracted as photocurrent.



Artistic visualisation of photon recycling inside a perovskite crystalline structure.

Functional Energy Materials Group in Quantum Matter

We congratulate Siân Dutton on her recent appointment as a University Lecturer. We also introduce her interdisciplinary research team which explores new materials for electrodes in Li-ion and other rechargeable battery technologies, solid-state cooling and novel magnetic materials. Siân writes:

‘I am fascinated by the interplay between the properties of a material and its composition and structure. Unlike in organic materials where the properties are well understood, inorganic systems are less predictable. Despite this they play a critical role in new technologies including rechargeable batteries - improving their performance is crucial for the sustainability agenda.

The properties of inorganic materials are determined by the interactions of multiple electrons, more than 10^{23}, which together result in materials with myriads of different behaviours. These include ferroelectrics and multiferrocs used in RAM memory and piezoelectrics used in information and telecommunications. Understanding how a material behaves as it does and why is critical for continued development.

In my group we explore how the composition (what we put in) and the structure (how things are arranged in space) relate to the physical properties (what the material does) with a particular focus on materials for use in rechargeable batteries or solid-state magnetic cooling. We make new materials using a variety of methods designed to give us fine control over the final product, and then characterise the structure and measure the properties (see Fig.1). In the case of our work on rechargeable batteries we test our materials in prototype batteries to understand both the performance and explore what happens as they degrade and eventually fail.’

The Dutton group is exploring materials for a range of different applications, including established technologies such as Li-ion batteries, emerging technologies including magnetic cooling and all-solid state batteries and more exploratory work with potential applications such as Mg-ion batteries. In all these cases understanding the function of materials is essential as is developing experimental protocols to evaluate changes in performance over the lifetime of the materials.

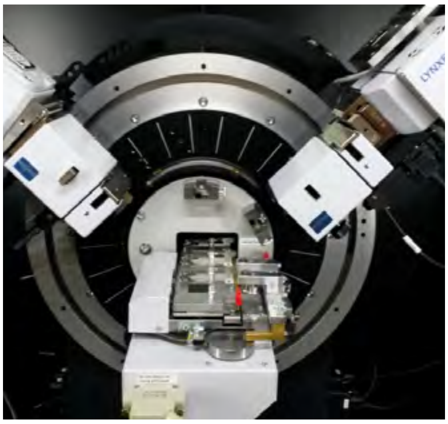


FIG 1. Powder X-ray diffractometer

FIG 2. Furnace units in Siân's and Suchitra's laboratories

A brief CV

I was an undergraduate at Cambridge, completing a MSci in Natural Sciences in Part III Chemistry. I then went to Oxford to complete a DPhil in the Inorganic Chemistry Laboratory under the supervision of Peter Battle. At Oxford I studied the synthesis and characterisation of mixed-metal oxides with a focus on understanding their magnetic properties. I then moved to Princeton University to work with Bob Cava as part of the collaborative Institute of Quantum Matter with The Johns Hopkins University. At Princeton I worked on geometrically frustrated magnets, specifically hole doping in chromium systems and low dimensional $S = ½$ systems. In 2012 I moved back to Cambridge joining the Cavendish Laboratory as a Winton Advanced Research Fellow working on functional energy materials. In October 2015 I was appointed as a University Lecturer in the Physics Department and in early 2016 the group moved into new laboratories within the Maxwell Centre. In addition to personal laboratory space shared with fellow University Lecturer Suchitra Sebastian (Fig.2), the new space includes the *EPSRC Advanced Materials Characterisation Suite* and the *Maxwell Centre X-ray Diffraction Facility.*

Scientific Computing at the Maxwell Centre

Scientific Computing at the Cavendish has seen rapid growth over the past few years, successfully realising the Maxwell Centre vision of meeting research objectives relevant to industrial and societal economic opportunities by means of blue-skies activities. NIKOS NIKIFORAKIS, Head of the Laboratory for Scientific Computing elaborates.

Accommodated at Level 3 of the Maxwell Centre, Scientific Computing (SC) brings together the research activities of the Scientific Computing research group (LabSC) and the training offered by the MPhil in Scientific Computing and by the EPSRC Centre for Doctoral Training (CDT) in Computational Methods for Material Science. Underpinning the research and teaching activities is the active participation of more than 20 industrial partners.

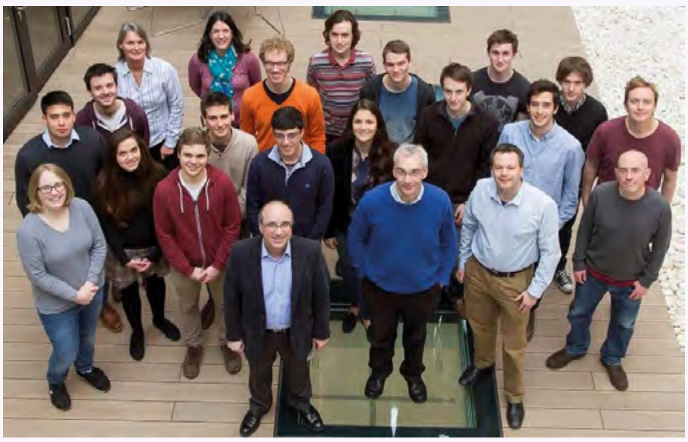
The MPhil in Scientific Computing has seen a year-on-year increase of very strong applications at a time when similar courses in the UK are experiencing a decline in numbers due to a shift of applicants to CDTs. As a result, the majority of our successful applicants already have Master's level degrees and/or 1st class bachelor degrees. Not surprisingly, every single graduate of this course to date has been offered fully-funded PhD studentships or jobs in the high-tech industries.

A similar success story can be relayed about the **CDT in Computational Methods for Material Science**, co-directed by Mike Payne (Cavendish Laboratory) and James Elliot (Materials Science), which enjoys an excellent ratio of EPSRC to industry funded studentships, highly qualified students and a broad participation of supervisors from five University Departments. The Maxwell Centre has been catalytic for the student-led CDT cohort interaction, offering elegant and functional space for initiatives such as informal seminars, social events with other CDTs and coding competitions.

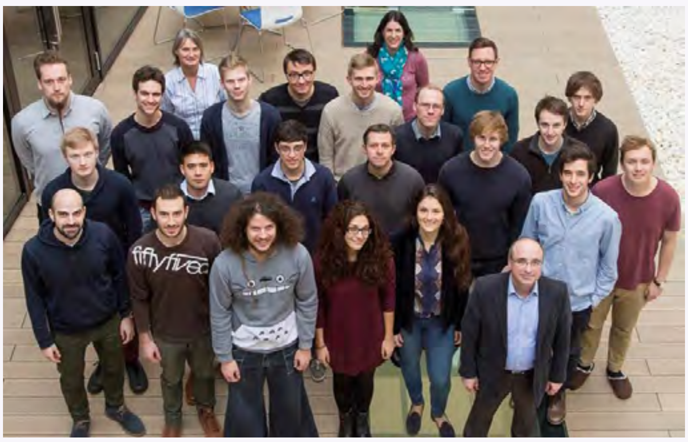
The research of LabSC on the numerical simulation of multi-scale and multi-physics problems has attracted significant investment from industry on stand-alone projects and large national and international initiatives. Office space has been made available in the Maxwell Centre for regular short- and long-term visits by the industrial partners, thus successfully facilitating a two-way knowledge transfer between the academics and the industrial partners, who consider this research as a key differentiator to their technologies.

Looking ahead to the future, SC research aims to take the theme of multi-physics and multi-scale simulation to a different level by taking coupled continuum/atomic-level models outside the highly-specialised research domain and making them an every-day commodity for academic and industrial research and development. This highly-disruptive technology will bring a step-change in academic research and a significant competitive advantage to SC's industrial partners.

Some examples of both aspects of Scientific Computing are illustrated on pages 14 and 15.



Nikos with participants in the CDT in Computational methods for Materials Science.



Nikos with the research team of the Laboratory for Scientific Computing.

EPSRC CDT for Computational Methods in Materials Modelling

The EPSRC Centre for Doctoral Training for Computational Methods in Materials Modelling trains students in the development and application of computational methods for predicting, understanding and enhancing properties of materials. The development of new materials lies at the heart of many of the technological challenges we currently face, for example creating advanced materials for energy generation.

Computational modelling

Computational modelling plays an increasingly important role in the understanding, development and optimisation of new materials. The Centre aims to train a critical mass of young scientists, not only in the use of existing software but also in the underlying computational and mathematical methods, so that they can develop and enhance the software and introduce new capabilities and functionalities.

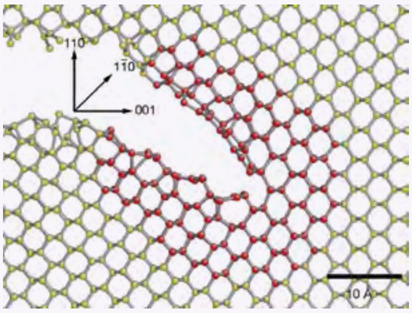


FIG. 1. Molecular dynamics simulation of crack propagation. Kermode et al, Nature 455, 1224-1227, 2008.

'This training system is a significant step change in the capabilities of scientific graduates for AWE and UK industry in general.'

Peter Roberts
AWE Chief Scientist

EPSRC Centre for Doctoral Training | Computational Methods for Materials Science

Working with Schlumberger to understand the properties of complex fluids

Understanding the physics of complex fluids is important for the oil and gas industry because of their use in drilling operations. These fluids possess a variety of exotic characteristics such as visco-plasticity or history-dependent behaviour.

Schlumberger Cambridge Research sponsors a CDT project which aims to characterise the properties of these materials.

FIG. 2. Resolved modelling of sedimentation in a particulate fluid.

This is achieved by means of resolved simulations of non-Newtonian particle-laden flows, where the effect of large particle additives on the bulk rheology of the working fluid is being quantified.

'We look forward to contributing to the success of the Maxwell Centre, strengthening industrial collaborations in fundamental physics and advanced scientific computing.'

Anna-Marie Greenaway
Director, University Relations, BP plc

Computational multi-physics enhances ORICA's R&D

A number of research projects on the performance of commercial explosives confined by high-impedance geological materials are helping ORICA to predict better the fracture and heaving process during blasting operations.

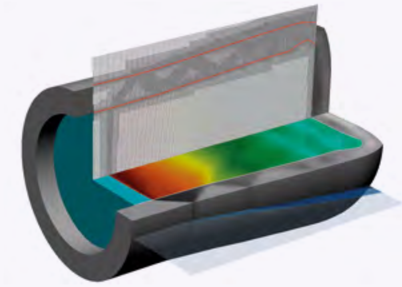


FIG. 3. Multi-physics, multi-scale simulation of a confined detonation in a non-ideal explosive.

The project resulted in a new mathematical formulation for the complex multi-physics behaviour of the system and a new numerical algorithm for its solution on massively parallel computer architectures. This knowledge was transferred directly into ORICA's Research and Development programme.

'The industry is continually seeking alternative formulations and the ideal technique to determine this is through computational methods.'

Simon Bittleston
Manging Director
Schlumberger Cambridge Research

The Laboratory for Scientific Computing

Research at the Laboratory for Scientific Computing is concerned with complex, multi-scale and multi-physics problems arising in science or technology, which cannot be solved by current computation approaches, or which involve mathematical formulations based on incomplete physical models. Research at the Laboratory is guided and predominately funded by industrial projects from companies and organisations including the Atomic Weapons Establishment, BAE Systems, Boeing Research and Technology, BP Exploration Operating Company, Jaguar Land Rover, Orica Mining Services, QinetiQ and Schlumberger Cambridge Research amongst others.

Machine learning makes sense of BP's seismic data

The quality of seismic surveys depends on the regularity and resolution of the sampled data. Research at the Laboratory aims to produce algorithms which can process data sampled by an irregular array of receivers, and which can achieve the same data quality with fewer samples.

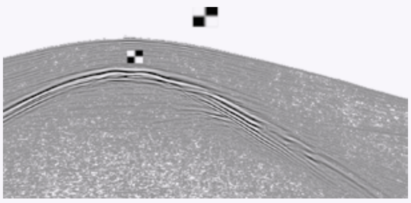


FIG. 4. Reconstructed seismic data using Compressive Sensing.

This is achieved by means of Compressive Sensing, which is a framework that allows reconstruction of sparse signals from fewer measurements compared to conventional sampling rates.

Given that the cost of deployment and retrieval of seismic sources and receivers can be as high as $1m per square km, successful outcome of this project could deliver substantial financial savings to the company.

'The research on the interaction of explosives with other materials is of profound importance as a key differentiator for the mining business.'

Alan Minchinton
ORICA Manager for Blast Modelling

Working with Boeing on ultrasonically-excited substrates

The Laboratory has been working with Boeing Research and Technology to understand the behaviour of high-speed water-droplet impact on ultrasonically-excited substrates. Non-intuitive behaviour has been observed experimentally, which could have profound impact on systems design of Boeing's next generation aircraft.

FIG. 5. The impact of a high-speed water droplet on a wet substrate.

Results, obtained by means of a new multi-physics and multi-scale computational model, have identified the key mechanism behind the observed behaviour. Current work aims to optimise the effects of ultrasonic excitation, to take the process to the next technology readiness level.

'This investment will support the Government's industrial strategy by boosting the UK's manufacturing capability and helping to keep us globally competitive.'

The Rt Hon. Vince Cable MP
Secretary of State for Business, Innovation and Skills at the launch of the PSI initiative, 7 June 2013

Simulation Innovation for Jaguar Land Rover

The Laboratory is part of strategic multi-million EPSRC-industry initiatives such as the Programme for Simulation Innovation (PSI) with Jaguar Land Rover, which aims to develop the capability of the virtual simulation industry in the UK and will give manufacturers access to new, world-class simulation tools and processes.

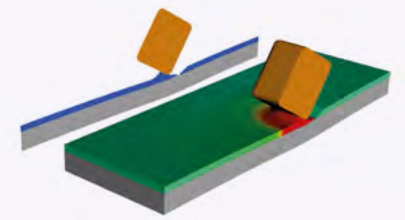


FIG. 6. Multi-material simulation of impact on a PMMA-coated aluminium sheet.

Research at the Laboratory aims to produce the next generation of unique software products for design and manufacturing which will give a competitive advantage to Jaguar Land Rover.

'We have been very impressed by the talent, dedication and professionalism of the research staff at the Laboratory, as together we move our research agenda forward'

Gary A. Fitzmire
Vice President
Advanced Boeing Military Aircraft

New fixed-term Lecturers

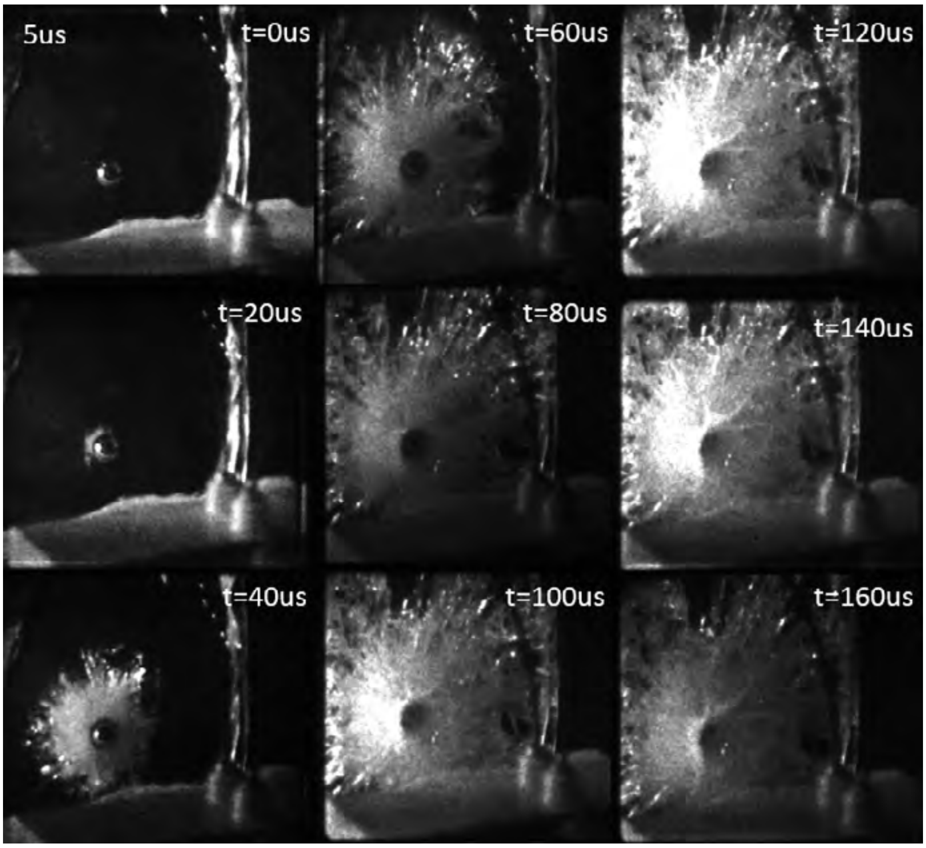
We congratulate CHRIS BRAITHWAITE and CHRISTINA (TINA) POTTER on their appointments as fixed–term lecturers.

Chris writes:

I have now been at Cambridge for 16 years, having come up as an undergraduate to King's in 2000. Growing up in Southport in the North West of England, I had always been interested in science but unable to choose between physics and chemistry - hence my application for natural sciences. Over the course of my degree I came to appreciate both the fundamental nature of studying physics but also the breadth it offers and the relevance of its applications to real world situations. This led to a PhD in the Surfaces, Microstructure and Fracture (SMF) group and subsequently to a postdoctoral position.

My research and physics interests are in tying underlying physical processes to macroscopic manifestations of these and applying this understanding through collaboration with industry. This is an area in which the SMF group and its predecessors have had a long and successful history. My PhD research was sponsored by an international mining consortium including DeBeers, Rio Tinto and Anglo American to examine the properties of geological materials under rapid, high stress loading. Through careful laboratory measurements it was possible to gain insight into how the physical properties changed with material type and how this could be predicted. Ultimately this found utility in computational modelling of the blast mining process, improving the efficiency with which natural resources can be extracted.

More recently I have been involved in projects examining areas as diverse as scintillation from helicopter rotor blades in sandy environments, improving oil prospecting methods in difficult terrain, the fundamental properties of granular materials under loading, development of novel intermetallic oil well perforators and space exploration through the use of penetrators.



A high-speed photographic sequence showing the impact of a metal (steel?) sphere upon a sheet of ice.

It is my intention to continue to promote the interactions I have with industry and to ensure that I and my research team have a strong applied stream without losing sight of the fundamental underpinnings. Work on space penetrators is an example of this, where I will be supervising a PhD programme to further the idea. The penetrator system allows scientific instruments to be placed on extra-terrestrial bodies. Specifically the plan is for a hard landing on Europa as this confers substantial cost benefits. This requires however careful understanding of both the penetrator system and the target material. While it is known that the outer surface of Europa is made of water ice, it is not clear what the exact composition of the material is with respect to impurities and crystalline structure, including defects. It is not possible to know all the parameters in advance and so it is essential to map out some of the parameter space in the laboratory. It can be shown that the presence of porosity in the ice causes increased resistance to penetration, as does lowering the temperature. However, the challenges of creating controlled samples of ice with varying characteristics, maintaining temperatures and conducting dynamic experiments cannot be underestimated. Unlike traditional cryogenic experiments, it is often more difficult to do in-situ cooling owing to the likelihood of destroying the cooling apparatus during the experiment.

In addition to a passion for experimental research, I have also tried over the years to pass on some of the knowledge and enthusiasm that I have gained through teaching in the undergraduate tripos and also through outreach work in the department. I am hoping that in my new role I will be able to do enhance these endeavours.

Tina writes:

I began my physics career at the leafy campus of Royal Holloway University as a PhD student with the ATLAS experiment. Just as the Large Hadron Collider was turned on, I joined a new ATLAS group at the University of Sussex. I spent many happy years there (and many long nights and weekends) as a very hard-working postdoc. During this time, we collected a staggering amount of data and developed original and elegant searches for new physics. I attended many international conferences in Italy, Turkey, Israel and Canada, presenting the latest ATLAS SUSY results in an LHC seminar and even leading the electroweak Supersymmetry (SUSY) searches within ATLAS.

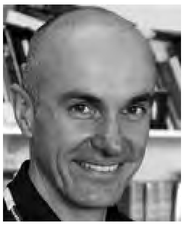
The huge unanswered questions in the Standard Model suggest new particles – such as SUSY particles – may be discovered at the LHC. SUSY predicts the existence of a massive superpartner for every Standard Model particle. The lightest SUSY particle is stable, neutral and weakly interacting and is an excellent candidate for the mysterious dark matter in the universe. This promises a dazzling array of new particles to be searched for at the LHC. My research focuses on electroweak SUSY production at ATLAS, with a particular interest in the SUSY partners of the Higgs boson. These so-called "higgsinos" need to be light to stabilise naturally the mass of the Higgs boson. They are, however, challenging to disentangle from the everyday Standard Model particles which come flooding out of the proton-proton collisions at the LHC.

The LHC is currently colliding protons at record-breaking energies and at rates that could allow us to search for the awkward higgsino particles. The ATLAS experiment is a 5000-strong collaboration of scientists from all over the world using a cathedral-size detector to measure the smallest constituents of the universe. ATLAS produces data at a very high rate - at one petabyte per second! We are also faced with stiff competition on the other side of the LHC ring from the CMS experiment. This means we have to work together, and move at a very fast pace to analyse the data and beat the competition to what would be a great discovery. It's a stimulating and exciting working environment, which I hope will soon become even more thrilling with a discovery of new (maybe SUSY?) particles.

I am now here at Cambridge for three years as an Early Career Lecturer and this is a fantastic opportunity for me to develop my teaching alongside my research. Contact with students has always been a core part of my work: whether on a one-to-one basis passing on knowledge to PhD students, or the more traditional group teaching of undergraduates. I have really enjoyed teaching my lecture course and practical classes this year. The challenging and inquisitive questions students ask never fail to surprise me! I am also enjoying expanding my research into other areas, such as the High Luminosity LHC, where we are planning to increase the proton collision rate to even higher values than we have attained today.

The move to the Cambridge area has been a chaotic, but fun experience. My family and I are exploring a new, and very flat landscape, meeting lots of new people, and our two dogs adore running through the endless fields and jumping into the many rivers!

David MacKay
1967-2016



At the funeral of James Clerk Maxwell in 1879, the following tribute was made by the Reverend Dr Butler, Head Master of Harrow School

'It's not often, even in this great home of thought and knowledge, that so bright a light is extinguished as that which is now mourned by many illustrious mourners, here chiefly, but also far beyond this place.'

The same thought was brought to mind by the untimely death of our brilliant colleague David Mackay at the age of only 48, the same age as Maxwell when they both succumbed to stomach cancer.

David was a true original. He completed a brilliant undergraduate degree in Physics and Theoretical Physics at the Cavendish Laboratory in 1988 and then studied for his PhD at Caltech on the topic of *Computation and Neural Systems* under John Hopfield – this research was to set the pattern for some of his most distinguished contributions. On his return to Cambridge, he took up a Royal Society Smithson Research Fellow and began his association with Darwin College. His remarkable researches on error correcting codes, building on the work of Robert Gallager, was a major breakthrough in understanding how information could be accurately transmitted through noisy communication links, approaching the fundamental limits set by Shannon's Theorem. These codes are now used universally in devices such as computer disk drives, mobile phone networks, digital broadcasting and Wi-Fi. The summation of his pioneering work in these areas was his book *Information Theory, Inference and Learning Algorithms* (2003).

His appointment to a University Lectureship in the Cavendish Laboratory in 1995 was widely applauded and he soon set up his own Inference Group which was to attract many brilliant students. They went on to apply his Bayesian probability theory and other approaches in a very wide range of diverse fields. His meteoric rise through the academic hierarchy was signposted by this Readership in 1999 and his Professorship in 2003, for both of which he chose the title 'Natural Philosophy'. In 2009, he was elected to Fellowship of the Royal Society.

His expertise in statistics resulted in his involvement in the Sally Clark case – she had been wrongly imprisoned in 1999 after being accused of murdering her two babies. David was horrified by the misuse of statistics, which had formed a central part of the prosecution's case. David demolished the incorrect statistical arguments and then became involved in the campaign for her release, which was successfully achieved in January 2003.

One of the most striking inventions which followed from his interests in statistical inference was the Dasher human-machine interface of 1999. He used a predictive language model to allow users create complete text with minimal gestures. Simple applications were developed using eye movements, head movements or breathing to create text at an amazing speed with a little practice. This opened up amazing possibilities for severely debilitated patients and has been successfully implemented in over 100 languages. As with all his work, he made this code freely available to anyone who wanted to use it.

One of his great skills as a teacher was his ability to carry out order of magnitude calculations using simple physics concepts which provided deep physical insight. The culmination of these efforts was his highly influential book *Sustainable Energy: Without the Hot Air* (Cambridge UIT Publications, 2008). This remarkable book includes many simple calculations which convincingly demonstrate in quantitative terms the magnitude of the energy problem facing all nations and what different sources of renewable energy can contribute to solving it. The book has been rightly praised for its calm non-polemical tone: at one point, he typically writes 'Please don't get me wrong: I'm not trying to be pro-nuclear. I'm just pro-arithmetic.' Again, the book is freely available on-line.

A consequence of the success of the book was David's appointment in 2009 as Chief Scientific Advisor to the Government's Department of Energy and Climate Change (DECC), a post he was to hold for the next four years. He turned out to be very effective in this role, perhaps his greatest triumph being to convince the government to publish a carbon plan in December 2011 that drew extensively on his simple but compelling quantitative approach to energy and climate change.

As part of that activity, he developed a 2050 calculator which enabled even a non-expert user to evaluate the consequences of different strategies for meeting the UK's requirement to reduce its carbon emissions by 80% by 2050. This was developed into an interactive lecture demonstration which was presented at many cities in the UK. The 2050 calculator was then expanded by his colleagues to create a global calculator, which used the same approach to allow anyone to determine strategies for restricting the global temperature rise to less than 2C by 2050. One of the more remarkable results of this programme was that, if everyone on Earth became vegetarian, that would solve the global warming problem at a stroke. In the 2016 New Year Honours, he was appointed a

Knight Bachelor 'for services to Scientific Advice in Government and Science Outreach'.

In 2013, David moved from the Cavendish to the Engineering Department as Regius Professor of Engineering. His cancer was diagnosed in 2015 but, undaunted, he was determined to live life to the full as recorded in his inspiring blog *Everything is Connected*. In everything he did, he held to and practiced high-minded principles – making the fruits of his research freely available to all, living in as eco-friendly a manner as possible, including turning down radiators in the homes of his friends. To all his activities, he brought a formidable intellect which gained him world-wide recognition as one of the most inspiring scientists of his generation.

We pass on our deepest sympathies to his wife Ramesh, whom he married in 2011, and their two young children, Torrin and Eriska.

MALCOLM LONGAIR

A Tribute to David MacKay[1]

Maxwell of age by cancer was bereft
Bright with great thoughts he mostly had elsewhere
But in this home of knowledge also left
A great laboratory founded there!

We may be dazzled by a source too bright
But useful memories we can retain -
The after-image of extinguished light -
A stimulant for retina and brain!

So in the century and more that's passed,
Maxwell could posthumously mount
The ladder to a fame that's unsurpassed:
Admiring physicists his deeds recount.

Now passing of our colleague Dave Mackay
Suggests a second Maxwell exemplar
Where brilliant range and playfulness ally:
In life and death how closely similar!

Faster and much more nearly error-free
Mackay could send with his sparse message code
With "Dasher" type as fast as eye can see
Beating by far my own one-fingered ode!

There's no excuse to miss a key lecture
With "talks at cam" - another legacy.
To cover everything it must abjure
No listing of a session of frisbee!

Patents, he thought, to progress close the gate
His guiding principle was open source
Through widespread blogs to educate
Free from hot air - depend on brain's resource!

With our last private breath we call it quits
But then a much more public wave wafts out
Past family grief, rites custom-built, obits
In seeking sense of what it's all about.

For childless Maxwell, horses were on hand
Nodding black-plumed: for Dave Mackay's cortege
We strolled sun-kissed behind a samba band
And children blew soap bubbles at grave's edge!

But later times can verdicts re-arrange
Should work's impact remarkably increase.
Progress or lack of it with climate change
Will tell if Dave Mackay can rest in peace.

Archie Howie 9 May 2016

[1] The editor is most grateful to Archie Howie for permission to publish his heartfelt poem which adds a human touch to the facts of David's remarkable career. It is appropriate that the poem appears in an edition of CavMag largely devoted to the Maxwell Centre. Maxwell wrote a very large amount of poetry, using it as a vehicle for clarifying his thoughts and understandings. But there is also a very strong human element to his poetry, particularly the poems written for his wife. Archie's poem fits beautifully within the Maxwellian tradition of celebration and enrichment of experience through poetry.

Isaac Physics spreads its wings

Isaac Physics is funded as a **National** project in England to develop problem-solving skills to prepare students for STEM study at university. We now have in post four **widening participation fellows** who have joined our growing team to help deliver Isaac Physics student workshops, masterclasses and teacher continuing professional development events across England. We are delighted to welcome:

Aimilia Smyrli an assistant lecturer at the University of Central Lancashire

Catherine Hayer a postdoctoral researcher at the University of Oxford

Robert Firth a postdoctoral researcher at the University of Southampton.

Nic Bonne astrophysicist and Australian Endeavour Fellow at the University of Portsmouth.

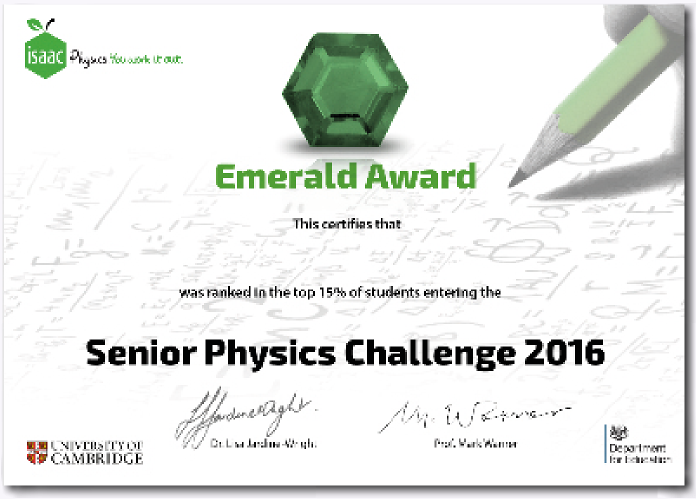
We are delighted to report that engagement with Isaac Physics continues to rise:

	CavMag 14 (Aug 2015)	CavMag 15 (Jan 2016)	CavMag 16 (Aug 2016)
General Users (students)	4,000	14,864	21,873
Teachers	600	1,032	1,605
Number of question attempts		1,649,218	3,026,555

These numbers can be attributed to the hard work of our event managers going out to schools and working with teachers but also to our prize boards and senior physics challenge residential.

Isaac Physics' Senior Physics Challenge Residential Prizes

The Senior Physics Challenge (SPC) residential summer school began in 2006 and up to 2 students from any one school could be nominated by their physics teacher. From these nominations typically 60 students would be invited to attend a residential in Cambridge at the end of June/ beginning of July.



A new model for 2016 senior Physics Challenge

Isaac Physics now reaches out to many more than 60 students through its student workshops all over the country. This year we have offered 40 places to students as prizes for continued engagement with Isaac Physics along with prize certificates for those in the top 15%, 20% and 25% of entries. The differences from previous years are:

- students nominated themselves by joining the SPC group on Isaac Physics
- there is no restriction on the number of entries from a given school
- the reward and encouragement is for continued practice and engagement

We were delighted to receive more than 570 entries from which we identified

Residential (27th June – 30th June): 40 students

Emerald certificate (top 15%) + prize DVD / Book: 34 students

Sapphire Certificate (top 20%) + Isaac book: 25 students

Ruby Certificate (top 25%) + Isaac book: 25 students

New Features & Content (isaacphysics.org)

Our content continues to expand in topic and level and now includes questions on:

Waves - Optics - levels 4 & 5
Circuits - Capacitors - level 5
Fields - Gravitational - level 6

Why not try your hand at these problems. Hints and answers are available on the web-links.

Camera lens

This problem involves *the lens equation,* which is not covered in some Physics A Levels. For more information, please check with your teacher.

> A camera has a single converging lens of focal length 50 mm. It is required that, by moving the lens along the optical axis, the lens can produce a clear image of any object which is further than 0.50 m from the photographic film.
>
> What range of movement of the lens is needed?

Hints and answers: **https://isaacphysics.org/questions/camera_lens**

Capacitor Energy Bank

> A circuit consists of a battery, four resistors in series with resistances 8Ω, 12Ω, 16Ω and 20Ω, each of which is connectd in parallel with a capacitor of capacitance 20μF, 16μF, 12μF and 8μF respectively (20μF in parallel with 8Ω, etc.). The battery has an e.m.f. of 36 V and and internal resistance of 4Ω.
>
> When the circuit is in a steady state, what is the total energy stored in the capacitors?

Hints and answers: **https://isaacphysics.org/questions/capacitor_energy_bank**

Speed in an Elliptical Orbit

> An object moves in an elliptical orbit with semi-major axis *a* = 4.44 x 10^9 km about a star of mass 2.15 x 10^{32} kg. The mass of this object is much less than the mass of the star.
>
> What is the speed of the orbiting object when it is at a distance of 3.27 x 10^9 km from the centre of mass of the star?

Hints and answers: **https://isaacphysics.org/questions/speed_in_elliptical_orbit**

Events Programme (isaacphysics.org/events)

Isaac Physics Teacher CPD Workshop Aims

- Work through challenging physics problems in the context of Vectors, Exponentials and Calculus, developing your problem solving skills and confidence.
- Introduce more advanced arithmetic that can be used to stretch, challenge and inspire enthusiastic and capable students.
- Introduce the Isaac Physics Partnership and explain how you can become a Partner Teacher.
- Show how you and your students can benefit from using isaacphysics.org.

Teacher Introductions

- See how isaacphysics.org can mark your homework online for free, saving you time and giving your students immediate feedback that's also much more useful.
- See how "skills mastery" questions lead on to more challenging "problem solving" tasks.
- Learn how to use isaacphysics.org to help prepare your students to thrive on Physics
- related degree courses.

The scale of the operation is indicted by the following events which took place during the summer of 2016. Please go to **isaacphysics.org/events** for information on future events in your area.

Isaac Physics Teacher CPD Workshops

Isaac Physics Teacher CPD Workshops are fully funded. In addition to being free to attend, travel expenses and costs of supply cover are paid by Isaac Physics for teachers in schools in England.

In June and July 2016, workshops were held at: Long Sutton, Hampshire; London; Cambridge (twice); Sheffield; Birmingham; Carlisle; Bolton; Nottingham; Portsmouth; Manchester; Leeds.

Teacher Introductions to isaacphysics.org (free to attend)

In June and July 2016, the introductions were held at: Exeter; Durham; Cosford; Charterhouse; Liverpool; Preston (twice).

Student Workshops (free to attend)

These were held during June and July 2016 at: Preston; Birmingham; Caterham; Barking, Essex; UCL, London; York; Thamesmead, London; Newcastle; Sheffield; London; Orpington; Richmond, N Yorkshire; Carlisle; Northwood, Middlesex; Gainsborough; Ipswich; Bolton; Newcastle; Leeds; Preston; Portsmouth; Manchester.

Nick Bell and Ulrich Keyser win the 2016 Helmholtz Prize


The identification and quantification of proteins in complex mixtures using nanopore sensing with high specificity was published by Nicholas Bell and Ulrich Keyser in a recent article in Nature Nanotechnology (**www.nature.com/nnano/journal/vaop/ncurrent/full/nnano.2016.50.html**) .

Their combination of DNA nanotechnology with nanopore based detection of single molecules allowed the multiplexed identification of antibodies. Nick and Ulrich were awarded the the Helmholtz Prize for this ground-breaking work. The 'Helmholtz Preis' is awarded by the Physikalisch-Technische-Bundesanstalt and Helmholtz Fond and is one of the most important honours for research in applied metrology.

New Senior Managers in Graduate Education and Human Resources and Projects

Surayya Khan has come to the Cavendish from City & Guilds where she was a Qualification and Assessment Development Manager. She has previously held positions at the University of London, University of Roehampton, Brunel University, Brent Council and Westminster and City Council covering roles in project management, academic programme development, quality assurance, performance management, and service improvement. She began her career as a Research Fellow at University College London in Intelligent Systems. Surayya is also a member of the charity Asthma UK and is currently involved in the work of their Research Review Panel.

Surayya has been appointed to the new senior post of **Graduate Education Manager**.

Following a long stint as Departmental Administrator in the School of Psychology at the University of Exeter, **Liz Hewitt** moved to Cambridge and in 2003 took up a post in a small research group headed by a certain Dr Andy Parker. In the intervening years she held various posts across the University in the Department of Public Health and Primary Care, Department of Plant Sciences, Centre for Business Research and latterly in Murray Edwards and St Edmund's Colleges. She specialised in Human Resources, completing her CIPD Diploma three years ago, because fundamentally she likes working with and helping people. She will be working hard to ensure that the Department's HR administration runs smoothly and provides the time to solve the thornier problems, work on major projects and plan and implement improvements. A major remit in Physics is retaining our Athena Swan Gold Award and many of the initiatives she will introduce will be with this in mind.

Liz has been appointed to the new senior post of **Human Resources and Operations Projects Manager** and looks forward to meeting as many of the staff as possible and working with everyone to create an efficient and effective HR function which will benefit us all.

Ulrich Schneider awarded the Rudolf-Kaiser-Prize 2015

Ulrich Schneider has been awarded the Rudolf-Kaiser-Prize 2015 in recognition of his important scientific contributions to the study of non-equilibrium dynamics in many-body quantum systems, the experimental realization of negative absolute temperatures and interferometric studies of the quantum geometry of synthetic quantum materials. The Rudolf-Kaiser-Foundation yearly awards the prize to an young experimental scientist with extraordinary scientific achievements. The prize is one of the most prestigious awards for young scientists in and beyond Germany.

Three minute Wonder – Kerstin Goepfrich

This year's East Anglia Branch of the Institute of Physics 3 minute wonder winner was **Kerstin Gopfrich** from the Laboratory. We congratulate her also in coming second in the national final.

New Appointments

We welcome the following on their appointments to posts in the Laboratory:

Liz Hewitt – HR Operations and Project Manager
Clare Bates HR Administrator
Charlene Howell Graduate Office Assistant (temporary cover)
Adam Brown Maxwell Centre Senior Technical Officer
Robert Foster Maxwell Centre Administrator (temporary cover)

Leavers

We wish the following best wishes for their future activities.

Maxine Flynn HR Manager
Charles Harpur Stores
Suresh Mistry Technical Support, BSS

Prizes

Harry Cliff of the HEP Group has been awarded the 2015 IoP HEPP "Science in Society Prize" for his work as Curator and Head of Content for the successful "Collider" exhibition and other outreach work with the Science Museum, CERN, and the Cavendish Laboratory.

Promotions

We congratulate the following on their promotions during the 2016 Promotions Exercise:

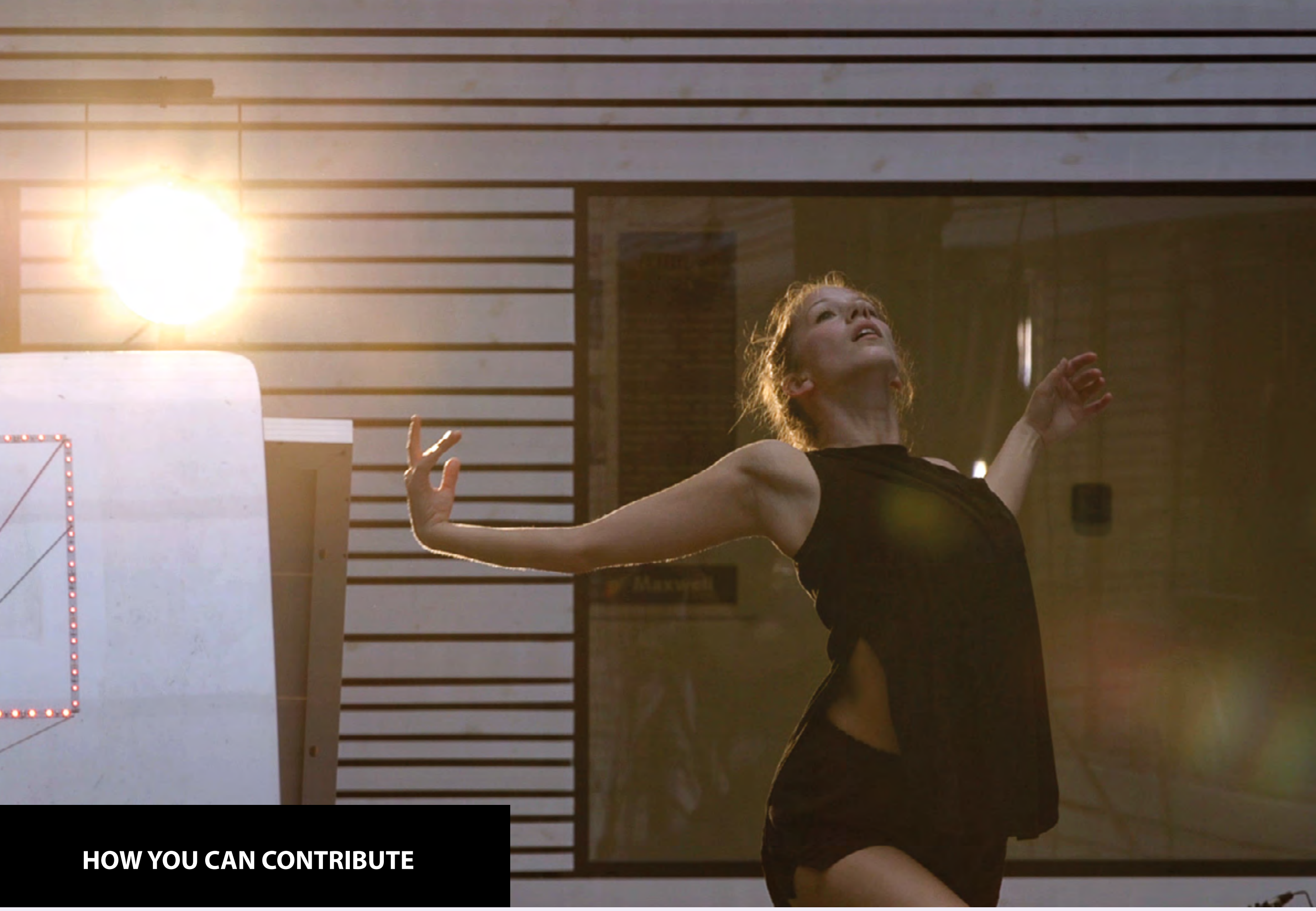
Pietro Cicuta and **Ulrich Keyser** (see opposite) are promoted to Professorships **Nikos Nikiforakis** has been promoted to a Readership (photograph page 15)

Antimatter at the Royal Society Soirée

Val Gibson and her colleagues presented an exhibition on the matter-antimatter problem at the Royal Society's 2016 Summer Soirée. Val is a former UK Spokesperson for the CERN LHCb experiment designed to understand the asymmetries between matter and antimatter in the Universe. As she said: "Antimatter might sound like science fiction, but it is one of the biggest mysteries in science today. We are explaining to everyone just why it matters so much – from what it can tell us about the earliest universe, to how we study it at the frontiers of research, to how it has everyday uses in medical imaging." The photograph shows Val and her UK collaborators, from left to right, Neil Masden (anti-atom experiment, University of Swansea), Val, Cristina Lazzeroni (LHCb, University of Birmingham), Sneha Malde (LHCb, University of Oxford) and Glen Cowan (LHCb, University of Edinburgh).

Suresh Mistry retires

Suresh Mistry retired earlier this year after almost 16 years of service in the Biological and Soft Systems Sector. His work was central to the success of the Group in the general area of soft matter. In addition, he carried out the role of Chemical Safety Officer for the whole Laboratory. In the photograph, he is seen at the left at a joyful moment during his retirement party with members of the BSS group. His contributions were applauded by Andy Parker (second left) and Pietro Cicuta (third left), the Head of the BSS Group



HOW YOU CAN CONTRIBUTE

» Online Giving

The University's Office for Development and Alumni Relations (CUDAR) has made it easier to make donations online to the Department and to two of our special programmes. If you wish to make a donation to the Department, please go to:

campaign.cam.ac.uk/giving/physics

If you wish to support the graduate student programme, please go to:

campaign.cam.ac.uk/giving/physics/graduate-support

If you wish to support our outreach activities, please go to:

campaign.cam.ac.uk/giving/physics/outreach

If you would like your gift to be applied to some other specific aspect of the Development Programme, please contact Andy Parker or Malcolm Longair. The Development portfolio is at:

www.phy.cam.ac.uk/development

» A Gift in Your Will

One very effective way of contributing to the long-term development of the Laboratory's programme is through the provision of a legacy in one's will. This has the beneficial effect that legacies are exempt from tax and so reduce liability for inheritance tax. The University provides advice about how legacies can be written into one's will. Go to: **campaign.cam.ac.uk/how-to-give** and at the bottom of the page there is a pdf file entitled **A Gift in Your Will**.

It is important that, if you wish to support the Cavendish, or some specific aspect of our development programme, your intentions should be spelled out explicitly in your will. We can suggest suitable forms of words to match your intentions. Please contact either Malcolm Longair (**msl1000@cam.ac.uk**) or Gillian Weale (**departmental.administrator@phy.cam.ac.uk**) who can provide confidential advice.

If you would like to discuss how you might contribute to the Cavendish's Development Programme, please contact either **Malcolm Longair (msl1000@cam.ac.uk)** or **Andy Parker (hod@phy.cam.ac.uk)**, who will be very pleased to talk to you confidentially.

CONTACT

The Cavendish Laboratory
JJ Thomson Avenue, Cambridge, CB3 0HE
Tel: +44 (0)1223 337200
Email: hod@phy.cam.ac.uk
www.phy.cam.ac.uk

Head of Department
Professor Andy Parker
Tel: +44 (0)1223 337429
Email: hod@phy.cam.ac.uk

Director of Development
Professor Malcolm Longair
Tel: +44 (0)1223 765777
Email: msl1000@cam.ac.uk