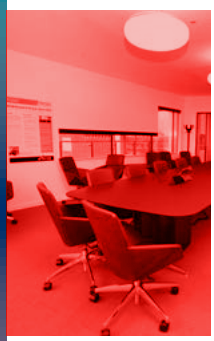
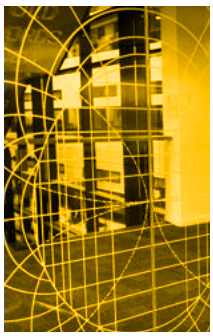
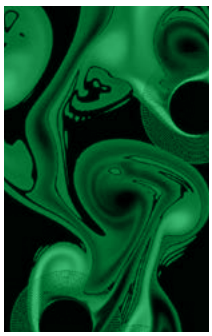
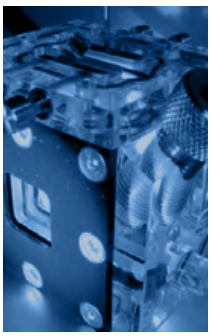
Maxwell Centre

Maxwell Centre Report

2016/17






UNIVERSITY OF CAMBRIDGE

"The Maxwell Centre is a tremendous asset for the University, as well as for our industrial partners worldwide and the UK overall. It provides a perfect environment to grow meaningful partnerships, identifying and tackling big challenges through research. Working together, and kept aligned by the ongoing dialogue, we will optimise translation of scientific and technological breakthroughs through innovation to impact."

Professor Andy Neely, Pro-Vice Chancellor for Enterprise and Business Relations

From the Director

Prof Sir Richard Friend FRS FREng
Cavendish Professor of Physics
Director, Maxwell Centre

The Maxwell Centre is playing a central role in the very exciting journey that lies ahead for West Cambridge. 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 we now 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, of £21M, has come from the Higher Education Funding Council for England through their capital funding programme, the UK Research Partnership Investment Fund. The rules for this competitive scheme required us to double match this with support from our partners for the science programmes that will be enabled, and mention many of the partners that contributed to this. We are delighted that David Harding opened the Maxwell Centre in April 2016. David's gift of £20M, that provided much of this matching funding, has established the Winton Programme for the Physics of Sustainability within the Cavendish Laboratory and this is now based in 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 impact. The Maxwell Centre is allowing these links to develop further. We have office space for long term and short term industrial collaborators and our laboratories will provide the state-of-the art facilities that industry needs access to.

The building is designed to bring a lot of people together, and we have a good number of meeting rooms and communal spaces to encourage interactions. We hope this is the ecosystem where chance conversations on the stairs lead to great things. These may be between people in different university departments or between university and industry. Several of our industrial partners are already up and running in the Centre, SKF with their laboratories on the ground floor and ARM on the second floor. The National Physical Laboratory's East of England hub in the Maxwell Centre continues to grow. We are also filling up the space we have set aside for industrial 'hot-desking' presence.

We continue rolling out our 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. With support from the EPSRC and the Winton Programme, we have opened the 'Advanced Materials Characterisation Suite', and will soon be installing equipment for materials processing and characterisation as the Cambridge node of the Henry Royce Institute for Advanced Materials. 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.

This is our first annual report, and it picks out just some of the activities in the Centre and the University. We are presenting more of what happens here at the first annual Research Showcase on 17 March 2017.

West Cambridge hub for academia-industry interactions – 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 in Cambridge: linking across Physical Sciences, Technology and beyond.

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

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 explicitly come under the Maxwell Centre umbrella for 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.

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 betwen industry and the University of Cambridge.

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

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…

Pro-VC = Pro-Vice Chancellor
HoD = Head of Department
KTF = Knowledge Transfer Facilitator
SRI/SRN = Strategic Research Initiative/Network
CDT = Centre for Doctoral Training
CE = Cambridge Enterprise
TRL = Technology Readiness Level

Maxwell Centre

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 focuses on programme of delivery of the Maxwell Centre vision.

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

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 the West Cambridge, with a model that is available to be adapted in all departments and facilities

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 interesting problems we can help solve. Synergies are exploited when interests align in **joint research, conversations, mutual inspiration and flow of people**.

Recognises value of understanding 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 foster entrepreneurship amongst Physical Science and Technology students and researchers, offering new programmes to teach and promote entrepreneurship specifically with physical science / tech flavour in mind.

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

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!

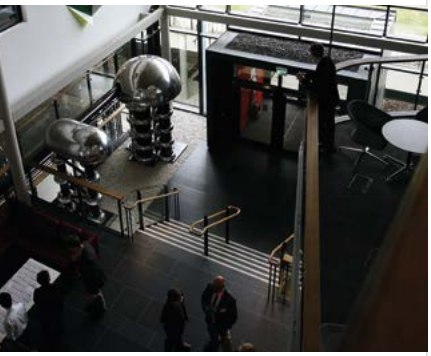
is not suitable to host isolated pockets of activity, be it industrial or academic in origin. Broader **engagement is essential** – either in ongoing research collaborations or willingness to develop them.

We are ever evolving and developing to best serve the interests of all stakeholders.

First year at the Maxwell Centre

Dr Aga Iwasiewicz-Wabnig
Maxwell Centre Programme Manager

The concept for the Maxwell Centre originated from the Cavendish Laboratory. The successful bid to HEFCE in 2013 was supported by numerous industrial partners: Accelrys/Biovia, AWE, Base4 Innovation, Boeing, BP, CDT/Sumitomo Chemical Company, Chinuka, Hitachi, Jaguar Land Rover, Mars, Merck Chemicals, NPL, Orica, Oxford Nanopore Technologies, Plastic Logic, QinetiQ, Rolls-Royce, Schlumberger, Shell, SKF, Tata Steel and Toshiba. Their support, together with co-investments by the Winton Programme for the Physics of Sustainability, the Herchel Smith Trust Fund and the Raymond and Beverley Sackler Foundation, provided the required double matching for the £21M award we received from HEFCE. From its inception, the Centre was designed to be multi-disciplinary, jointly serving the Physical Sciences departments in Cambridge. Subsequently it has expanded to Engineering, and other Departments within the School of Technology.



David Harding, Founder and CEO of Winton Capital, unveiling the plaque at our opening ceremony

Spread over four floors, the Maxwell Centre building provides office space for over 230 people, state-of-the-art laboratories, and a variety of meeting rooms and communal spaces to encourage interaction. The Maxwell Centre vision and community extend beyond the new building alone, acting as a gateway to Physical Sciences and Technology in West Cambridge.

The Maxwell Centre was officially opened on the 7th of April 2016. The day begun with brief speeches by the Chancellor and Vice Chancellor of the University, followed by the Centre Director, Anna Marie Greenaway (Vice-President Science and Technology at BP-Cambridge) and our distinguished benefactor David Harding (Founder and CEO of Winton Capital), who officially opened the Maxwell Centre. The event programme boasted a broad celebration of research and partnerships – from industrial collaboration case studies, through posters, talks, demos to lab tours. The day culminated with a spectacular Arts-Science exhibition, 'Into Boundless Space I Leap' featuring work including a specially commissioned live dance and sound piece by leading choreographer Wayne McGregor and artist Haroon Mirza. The exhibition, created in collaboration between the Cavendish Art-Science Project (directed by Dr Suchitra Sebastian) and the Kettle's Yard, continued at the Maxwell Centre until June 2016.

Since the opening, we have embarked on an exciting journey, from which I would like to mention a few Events and Highlights. The Maxwell Centre now regularly hosts company visits and collaboration workshops (with ARM, Jaguar Land Rover and others) exploring mutual interests and expanding research connections in Cambridge.

In January 2017, in partnership with the Cambridge Network, we trialled a new Maxwell event aimed at industrial audiences, providing a glimpse into what goes on within the University walls. Prof Mete Atatüre gave a talk on "Quantum Technologies – from discovery science to industrial applications", followed by engaged discussion and networking. This format offers a forum for companies to hear about ongoing cutting-edge research and where it may go next. The aim is to communicate the key ideas and opportunities behind the recent research that is ordinarily presented in specialist journals and conferences. We now plan to expand the new meeting format into a series, encouraged by the fact that the inaugural talk was so well received by our target audience. Watch this space!

Further notable events include: Cambridge Enterprise's Physical Sciences Commercialisation Workshop and Enterprise Champions meeting, Molecular Engineering Industry event, and most recently the launch of the Maxwell Centre's new entrepreneurship programme – Impulse for tech innovators (see page 20 for more detail).

This report is written just ahead of our inaugural Maxwell Centre Annual Research Showcase on 17th of March 2017, celebrating the breadth and quality of Cambridge research in the context of external partnerships, opportunities and collaborations. Programme includes introduction and "The Efficient Century" talk by Prof Sir Richard Friend, a keynote address by Tony Raven, Chief Executive of Cambridge Enterprise, as well as case studies, 2 minutes' research highlights talks and posters from our stakeholder departments and collaborators. There will be and ample opportunities to explore the Centre, network, make new connections and meet future collaborators. For instance, Dr Nikos Nikiforakis (Director of the Laboratory for Scientific Computing) will talk about ongoing research collaborations between his group and industry. This work is concerned with complex, multi-scale and multi-physics problems arising in science or technology, which cannot be solved by current computation approaches. The work is predominantly funded by industrial projects and aims to produce the next generation of unique software products.

Being in the Maxwell Centre can create non-trivial opportunities. For instance, Prof Richard Jones FRS chose to spend his sabbatical here, after having recently stepped down as the Pro-Vice Chancellor for Research & Innovation at the University of Sheffield. His visit has resulted in a new collaboration on stabilising colloidal nanocrystals, but it also led to valuable inputs to the work of the House of Lords. Through their joint interest in shaping energy policy, Professors Jones and Friend contributed written evidence to the Select Committee on Economic Affairs, and their testimony is quoted on several instances in the report entitled 'The Price of Power: Reforming the Electricity Market'. In particular, the report recommendation to "Create a world-class National Energy Research Centre which would search for new methods of producing cheap, clean energy and translate them into commercial applications" is based on their suggestions that the UK needed such an overarching body. You will also find accounts of what the Maxwell residence can lead to from the point of view of our industrial partners further in this report.

We look forward to growing the Maxwell Centre Programme further over the coming years, welcoming new collaborations and expanding our portfolio of activities. Please do get in touch and come visit the Centre, we are always keen to explore new opportunities.

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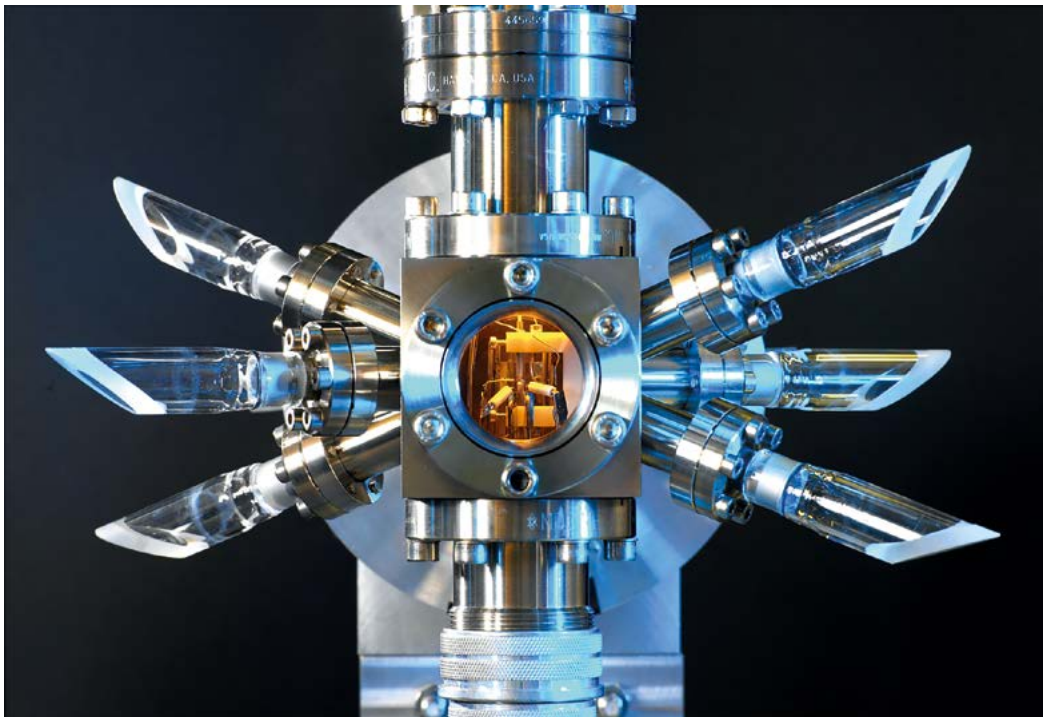
The NPL hub at the Maxwell Centre

Dr Peter Thompson
CEO, NPL

NPL
National Physical Laboratory

NPL is the UK's National Measurement Institute and one of the top three institutions of its kind in the world. NPL's mission is to deliver the measurement capability for the UK, and making this measurement infrastructure fully accessible across the UK is crucial to facing global challenges relating to environment, sustainability, security, safety, energy and health. These challenges require good measurement in order to be effectively quantified and understood, and potential solutions sought.



As Dr Peter Thompson, CEO of NPL explains "The NPL East of England base in the Maxwell Centre is enabling local industry to benefit from the National Measurement System. NPL partnerships enhance our regional offering, through initiatives such as the recent NPL Data Science workshop held in Cambridge which attracted 100 UK academic and industrial delegates. The collaboratively scoped projects from that day ensure that relevant research and innovation solutions are developed to encourage growth across the country."

Co-location with the research capabilities of the University and support from knowledge transfer community has resulted in deeper engagement with the strategic research initiatives and networks, which has substantially increased the number and variety of opportunities to interact with additional academic and industrial partners. Activities include joint research appointments, postgraduate studentships and multidisciplinary collaborations across the boundaries of the traditional physical sciences; alongside a Product Verification Programme working directly with local SMEs to improve manufacturing processes.

Knowledge exchange opportunities including industrial training and consultancy, are now being developed from the world class science and innovation capability delivered collaboratively by NPL, University of Cambridge and industry based within the region.

ARM and the Maxwell Centre

Dr Chris Doran
Director, Research Collaborations and Entrepreneur in Residence, ARM

Throughout ARM's history it has been closely tied to the University of Cambridge and the wider 'Cambridge Phenomenon'. In 2015 ARM celebrated its 25th anniversary, and all the current staff were presented with a book describing ARM's history printed to mark the occasion. One of the most notable features was just how many of the key people profiled in the book had some relation to the University. From the earliest researchers at Acorn, to the early management team and beyond, University of Cambridge has been a constant feature in ARM's history.

We are now entering a new period in the history of ARM, one that is drawing the company back to its research roots. A key reason for this is the impending end of the 'free lunch' in semiconductor design embodied in Moore's law. Throughout ARM's growth in the mobile sector we have been able to rely on improvements in processor manufacture to design ever more complex chips that perform inside an ever-improving power envelope. The combined effect of smaller process nodes, better physical design and more complex and efficient processor design has enabled processor power to double every 18 months; a trend that has lasted for nearly 50 years.

But we are now heading into the world of features of the scale of 10nm, and there simply is not much more room left. Future improvements will require more radical changes: far greater parallelism; discrete units to accelerate specific functions; and novel architectures for new compute models. Many of these innovations have been developed in university research groups, and we are entering a time when some of these will become the new mainstream technologies that help us eke out more performance. In addition, future demands for computing look rather different to the market drivers of the last decade. Mobile phones are now ubiquitous, and future growth is going to come from the 'Internet of Things', large numbers of devices loosely connected to a cloud infrastructure. The future of computing lies in making these devices secure and intelligent, which brings new research challenges.

12 years after I left the Cavendish, it is a great privilege to be able to take a team from ARM back onto the West Cambridge campus and locate it inside the Maxwell Centre. We have active collaborations with many of the Departments on West Cambridge, including physics, computer science, materials science, nanoscience and astrophysics. The Maxwell Centre will provide our focus for all of these activities. A goal of the Maxwell Centre is to encourage serendipitous conversations that can also spark new ideas, and already we are seeing this concept start to bear fruit as we develop collaborative research proposals.

In December 2016, the Maxwell Centre also served as the host for a novel collaborative workshop that brought together senior staff at ARM with academics from multiple departments and disciplines across the university. This was very well received on both sides and has already led to some new collaborative activities and proposals for new projects.

We have only been in the Maxwell Centre for a few months, but already we are starting to see the benefits of how the building is set up. The next decade promises to be a very exciting time for ARM, the Maxwell Centre, and the West Cambridge campus.

Henry Royce Institute at the Maxwell Centre

Prof Sir Richard Friend FRS FREng
Royce Academic Champion

£10m funding for advanced materials research has been awarded to the University of Cambridge. The new funding is part of a £128 million Engineering and Physical Sciences Research Council (EPSRC) investment in the Henry Royce Institute for Advanced Materials, which comprises seven partner Universities: Manchester, Sheffield, Leeds, Liverpool, Cambridge, Oxford and Imperial College London.

The EPSRC funding will be distributed across the Institute's seven partners to support investments in new equipment and infrastructure. In turn, these new facilities will enable the Institute to accelerate the design of advanced materials and explore their possible applications, including their use in existing and emerging industrial sectors within the UK.

Focused on promoting translation from discovery to application, the Institute will play a major role in driving forward key elements of the Government's industrial strategy, which lays a particular emphasis on enhancing the commercialisation of the UK's world-leading basic research.

Cambridge's award will enable the University to purchase additional equipment to support its leadership of the Henry Royce Institute's Materials for Energy Efficient Information and Communications Technology activities. This will focus on improving energy storage technologies, reducing power consumption and developing new materials and devices able to harness energy from the environment.

The new equipment will enable Cambridge researchers to fabricate new energy-efficient devices, such as batteries and solar cells, and to undertake the advanced characterisation of materials and machines. These techniques will, in turn, help to hasten the development of energy technologies that are safer and more efficient, including longer-life phone batteries and electric cars with extended ranges.

The Cambridge Henry Royce Institute activity, which is being supported by the Energy@Cambridge Strategic Research Initiative, will run out of the Maxwell Centre where most on the equipment will be housed. This funding will be vitally important in terms of enabling what we do with advanced materials to be enhanced both in terms of upstream university work but also in its industrial application.

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EPRSC Networking Grant for the Centre of Advanced Materials for Integrated Energy Systems (CAM-IES)

Prof Clare Grey FRS
CAM-IES Director and PI

On the 1st of December 2016 a new EPSRC network was established at the Maxwell Centre. The Centre of Advanced Materials for Integrated Energy Systems (CAM-IES) is a £2.4 Million EPSRC Networking Grant which is a partnership between four UK universities: Cambridge, Newcastle, Queen Mary and University College London and our industry partners.

CAM-IES, which is led by Clare Grey, focuses on the development of advanced materials for energy conversion and energy storage. The overarching goals is to help build a UK-wide community of cross-disciplinary materials researchers focused on energy applications.

CAM-IES will:

- Create a UK-based community of researchers focused on materials for Integrated Energy Systems.
- Facilitate access to experimental facilities for interested users, in particular unique tools for energy materials characterization and deposition that are currently being set-up in Cambridge as part of the Henry Royce Institute.
- Develop advanced materials for energy storage, specifically solid-state batteries, coatings for high voltage electrode battery materials, and flow batteries, and energy conversion, specifically solid-oxide fuel cells, CO_2 gas separation membranes, hybrid thin film photovoltaics and large-area thermoelectrics.
- Help identify new research directions, working closely with industry.

From left: Henning Sirringhaus (Co-Director CAM-IES), Elizabeth Castillo-Martinez, Richard Friend, Akshay Rao, Clare Grey (CAM-IES Director and PI), Hugo Bronstein (UCL), Sian Dutton, Christian Nielsen (QMUL), William Gillin (QMUL), Judith Driscoll, Stephan Hofmann, Ian Metcalf (Co-Director CAM-IES).

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Energy@Cambridge Strategic Research Initiative

Dr Isabelle de Wouters
Director of Scientific Development

Dr Shafiq Ahmed
Coordinator

Prof Lynn Gladden CBE FRS FREng
Chair

Energy @Cambridge

In January 2016 the Energy@Cambridge Strategic Research Initiative (SRI) moved into the Maxwell Centre. Energy@Cambridge links the activities of around 250 academics working in energy research, at all career levels and across 30 departments and faculties.

From left: Richard Friend, Suchitra Sebastian, Al Gore, Abir Al-Tabbaa, Markus Kraft and Jim Leape at the World Economic Forum in Davos January 2016.

The aims of Energy@Cambridge are to:

- Leverage the University of Cambridge's expertise to tackle grand technical and intellectual challenges in energy, integrating science, technology and policy research.
- Work with industry, funding agencies, UK and foreign governments and other sponsors and benefactors to secure funding for research in energy.
- Develop strategic academic and industrial partnerships around the world.
- Ensure that multidisciplinary, cross-university projects have support and backing from the University leadership and research community to maximise success and impact.

Over the past year Energy@Cambridge has worked with Maxwell Centre researchers on a range of new initiatives and activities, including industry partnerships, work with the World Economic Forum on IdeasLab at Davos in 2016, the establishment of the Cambridge Henry Royce Institute and CAM-IES at the Maxwell Centre.

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Big Data Strategic Research Initiative

Michael Simmons
Big Data SRI Interim Coordinator

Prof Paul Alexander
Chair

CAMBRIDGE BIG DATA

The Cambridge Big Data Strategic Research Initiative is one of the key interdisciplinary themes in the University, involving all 6 Schools, over 50 departments and units, and more than 250 researchers. We recognise that the datasets that research – as well as industry and society overall - now deal with are not only large, but complex. Containing unstructured, heterogeneous data, human language, images and video, they necessitate completely new approaches to handle them. From physics to the life sciences, from image analysis to social networks, the challenges in managing and analysing large and high-dimensional datasets require increasingly interdisciplinary work.

Cambridge Big Data addresses this multidisciplinary research challenge by bringing together expertise from across the University, from underpinning technologies and concepts to applications. Cambridge Big Data website receives over 10,000 visits a month, and the Twitter feed, @CamBigData, has more than 1,600 followers.

Among the recent highlights was a research showcase we held with ARM Ltd in December 2016 in the Maxwell Centre. This brought together delegates from ARM and the University to discuss new and emerging possibilities for joint research. Topics explored reflected the breadth of Cambridge's expertise - including research in ICT, computer architectures, intelligent sensor networks, High Performance Computing, materials and devices, software and applications, security, spintronics and quantum computing; as well as further afield: energy harvesting, civil infrastructure monitoring, bioinformatics and data processing in genomics.

Beyond Cambridge, the University is a founder member of the Alan Turing Institute, and through close links with the Big Data Initiative mutual benefit is derived especially for big data issues at a national level.

It is essential for us to have a physical as well as a virtual presence in the University. The Big Data team moved into the Maxwell Centre in 2016. Our vision at Cambridge is to bring together Big Data research work to form a Data Sciences Institute to strengthen the intrinsically cross-disciplinary research and to provide a way of helping to address new exciting and challenging problems within the research environment and industry. Our new residence in the Maxwell Centre is a major step towards this goal.

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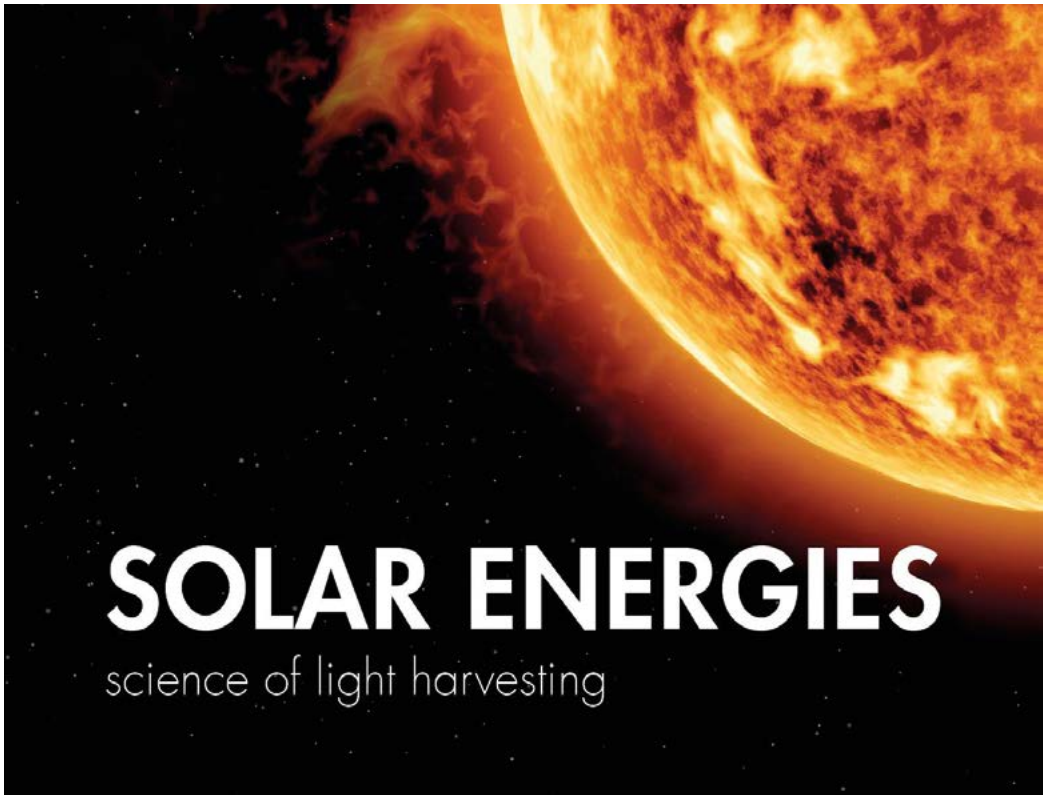
The Winton Programme for the Physics of Sustainability

Dr Nalin Patel
Winton Programme Manager

The Winton Programme for the Physics of Sustainability was established in 2011 through a donation of £20M by David Harding. It had been central to the development of the Maxwell Centre where it is based. The Programme is directed to 'blue-skies' research that has the capacity to bring revolutionary changes to the technologies we need for a sustainable future. The research supported is not 'more of the same', but truly original and innovative, including high-impact high-risk areas that are beyond the normal scope of research grants.

The Programme has a number of schemes: Advanced Research Fellowships, PhD Scholarships, Pump-prime awards and a new Exchange Programme with the Kavli Energy NanoSciences Institute at University of California, Berkeley. To explore the full breadth of the Winton Programme please visit our website.



The annual Winton Symposium is an opportunity to invite world-leading experts to debate, with a large audience of scientists, an issue related to sustainability. The topic for the 2016 symposium was Solar Energies; discussions on the underlying science and future developments were held in the context of mitigating climate change and building viable businesses based on new technologies.

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THE WINTON PROGRAMME FOR THE
Physics of Sustainability

Dr Ottavio Croze
Winton Advanced Research Fellow
in Biological and Soft Systems

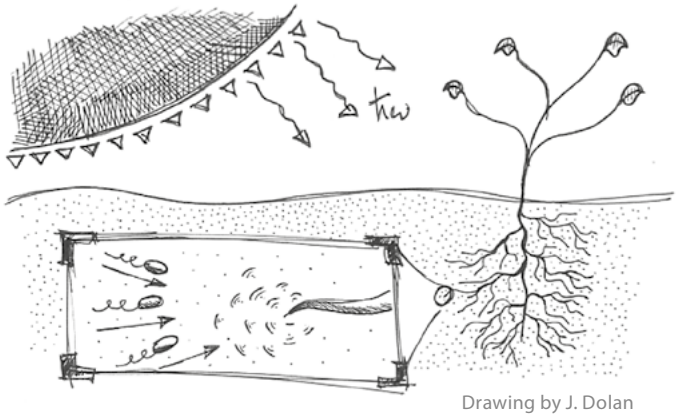
Here we put a spotlight on one of the 5-year Winton Advanced Research Fellowship holders:

Dr Ottavio Croze: Winton Advanced Research Fellow in Biological and Soft Systems

My group studies the physics of microbes in biotechnological contexts. We use experiments and mathematical modelling to investigate the dynamics of microalgae in photobioreactor flows, the migration of soil bacteria in porous media, and the interaction of bacteria with algae and plants.

Many industrially useful microalgae swim, but the physics of swimming algae in flows is not exploited in photobioreactors in which they are grown. Mathematical models we have developed predict how gravity and flow reorient swimming algae, causing populations to self-concentrate within photobioreactor flows. This peculiar behaviour could be exploited industrially for energy-efficient algal harvesting. My PhD student Di Jin is testing our model predictions by imaging swimming algae in pilot-scale photobioreactors. Two of these are sited in the new Algal Innovation Centre (Cambridge University Botanic Garden). Recently, in collaboration with biotech company LabXero, we have also started investigating how low-energy ultrasound fields can also be utilised to concentrate algae, of interest for harvesting non-swimming species.

Our research on soil bacteria concerns their ability to migrate up chemical gradients to microbial or plant partners in soil. Theresa Jakuszeit recently started her PhD investigating the mechanisms of migrations of rhizobia bacteria in porous gels. This work will shed light on agriculturally important symbioses between rhizobia and legume plants. We are also studying a different symbiosis: My PhD student Hannah Laeverenz Schlogelhofer investigates the growth of well-mixed 'co-cultures' of vitamin B12-synthesising rhizobia bacteria and soil algae who need the vitamin, providing photosynthetic sugars in return. This work, a collaboration with Prof Alison Smith (Plant Sciences, Cambridge) and Dr Rachel Foster (Plant Sciences, Stockholm), furthers our understanding of microbial interactions, which could improve the industrial culture of algae.



Drawing by J. Dolan

Populations of vitamin-dependent soil algae and vitamin-producing bacteria interact at a distance. Our mathematical model can predict the conditions necessary for survival or crash of these populations at a given distance, which is relevant to understanding how microbial colonies interact in soil.

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Designing nanopore sensors with DNA nanotechnology

Prof Ulrich F. Keyser
Department of Physics

Using DNA base pairing discovered by Watson and Crick we can now build three-dimensional objects by mixing short DNA strands together. Self-assembly leads to formation of billions of identical structures with near atomic precision without the need for complex manufacturing.

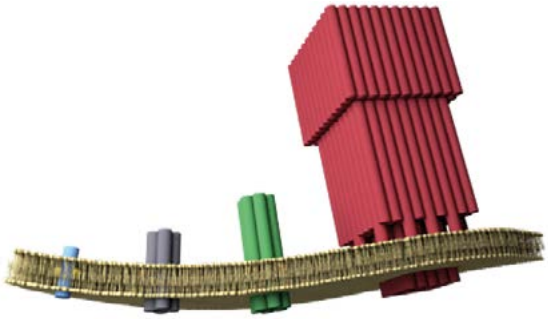
DNA origami nanopores for DNA sequencing and molecular sensing

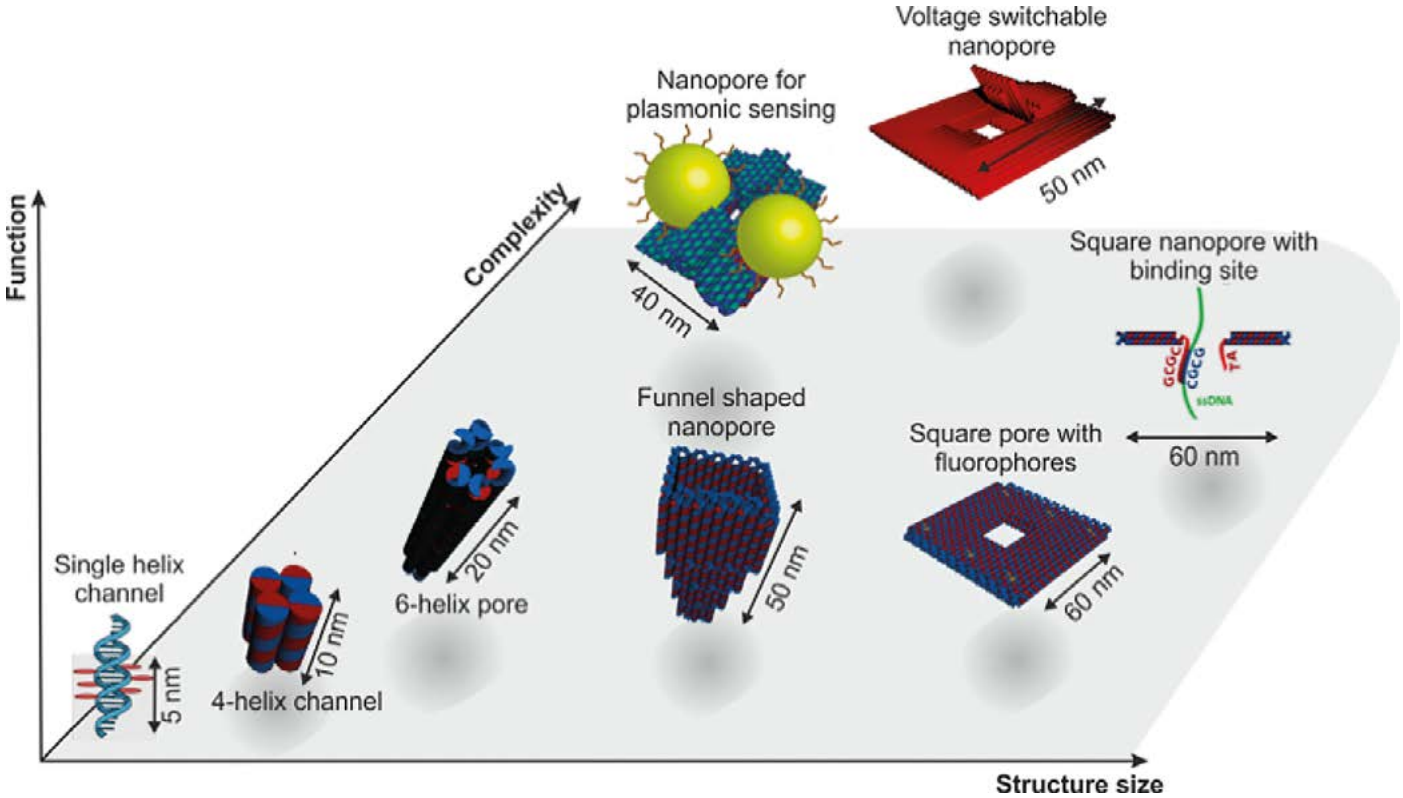
Miniaturisation of biosensing technologies will revolutionise medical diagnostics and care as well as biological research. DNA sequencing is a key technology for the identification of pathogens, reliable assessment of cancers and other diseases. Oxford Nanopore Technologies developed the first hand-held sequencing devices based on reading DNA, base-by-base, by pulling DNA through a tiny hole in a membrane. We are currently developing DNA origami nanopores for use in the MinION sequencing platform developed by Oxford Nanopore Technologies. In parallel we are using designed DNA carriers with digitally encoded information for protein identification in a new collaboration with industry.

Design space of DNA nanopores for biosensing

Building designer nanopores allows for controlling molecular motion at the atomic level. This is essential for understanding physics of transport through membranes and creating the best possible nanopore sensors in the future. We aim to create designer nanopores that will outperform biological protein channels for single molecule sensing.

DNA nanotechnology allows for designing nanopores spanning several orders of magnitude in size and introducing complexity. Combination with optical detection techniques will allow for enhanced sensing accuracy. Understanding of physics of membrane transport will impact development of drug molecules, fuel cells, desalination membranes and single-molecule detection.





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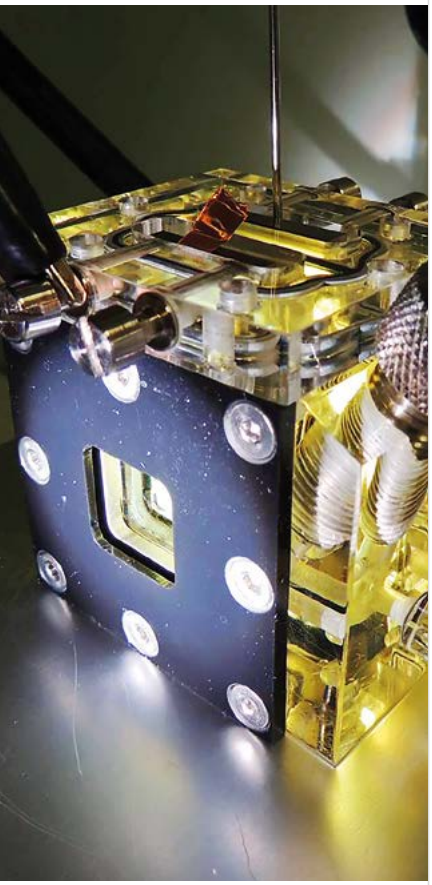
Splitting water into fuel

Dr Erwin Reisner
Department of Chemistry



The overall research challenge in solar fuel production is to develop materials and technologies that can harness and convert the sun's energy into sustainable fuels. Solar fuels are one of the most promising means of meeting global energy demands in a clean and sustainable way. Our group develops hybrid systems for both sides of the water splitting reaction, optimising efficiencies of light absorption, charge separation and redox catalysis to generate the fuel hydrogen and by-product oxygen. It is a highly multidisciplinary effort: we use biological and bio-inspired materials as catalysts, transition metal complexes as photosensitisers and redox catalysts and nanostructured materials as photoactive agents and for conductive support. The overall goal is to integrate these systems into a solar fuels device. Some aspects of our work are carried out in collaboration with the Austrian company OMV, the Christian Doppler Research Association (CDG) and the NanoDTC in Cambridge.

A real problem for scientists looking to find renewable sources of hydrogen has been finding a catalyst that is both efficient and inexpensive, and functions under real-world conditions. At present many solar fuel generator prototypes use more expensive metal catalysts such as platinum. Recently, we demonstrated a precious-metal-free photoelectrochemical device that uses molecular catalysts and sunlight to split water into hydrogen and oxygen. This development is a very early step towards the possibility of industrial scale water splitting, which would represent the ultimate renewable source of hydrogen for chemical fuel, feedstocks and fuel cells. What's exciting about this solar water-splitting device is that it uses Earth-abundant elements, in this case nickel, iron, tungsten and titanium, which might enable scalability in the future. Furthermore, we confirmed that the molecular structure of the metal catalyst remains intact after prolonged hydrogen production; proving molecular catalysts are suitable for the development of effective hybrid materials that may also catalyse a range of other transformations in the future.

While this is encouraging, there are many more hurdles ahead, not least the efficiency of the device, which requires a dramatic boost. The challenges of efficiency and stability in solar fuel production are accompanied by an engineering challenge. Our devices are anywhere from 1 to maybe 2 or 4 square centimetres. We're used to our centimetres and we're very comfortable with that. But ultimately we are talking about technologies that need devices with square metres and kilometres of surface area. Sometimes it's difficult to think of scaling up into tonnes or square kilometres. Although it is too early for the implementation of such technology, we should also be aware of these engineering challenges.

It's extremely important to bring all sorts of people from different backgrounds together to have them share their views; it clearly opens your horizon quite tremendously. Without exchange this task is pretty much impossible, so, I would say, solar fuel production is really a global effort now.

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Nanomaterials for high impact industrial applications

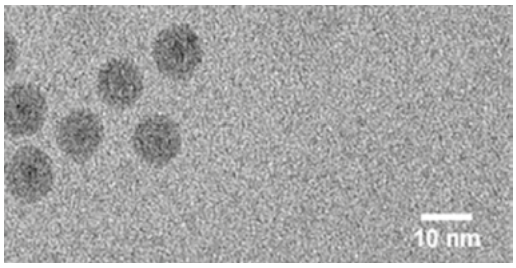
Dr Laura Torrente
Department of Chemical Engineering and Biotechnology

The Department of Chemical Engineering and Biotechnology is renowned not only for its world-leading research but also for its large number of spin-off companies and close links with a wide range of industries. As an illustration, the Catalysis and Process Integration group, which I lead, combines aspects of catalysis development (nanostructured materials and metal nanoparticles) with reaction engineering (membrane reactors, microdevices and modular processes) to enable a range of new sustainable technologies in the fields of renewable energy, air pollution remediation and bio-derived feedstocks amongst others.

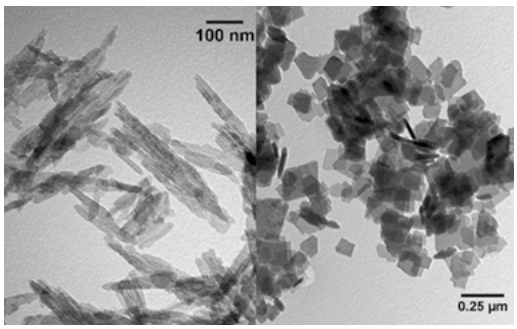
One of our main efforts, as part of an EPSRC Fellowship, is the development of a novel manufacturing technology for the continuous synthesis of nanoparticles with controllable sizes and tuneable chemical compositions. Our unique approach consists of the exploitation of transitional flows in microdevices for the continuous synthesis of metal nanoparticles in the absence of capping ligands integrated with their in-situ stabilisation following a novel method recently developed in the group in a single device. This approach allows us the design of well-defined stable catalysts. In this context, we are currently developing fundamental understanding of cobalt-based catalysts with SASOL Ltd directly linked to their industrial processes in Fisher-Tropsch.

Such control of catalytic active sites provide exclusive capabilities in previously forgotten and/or forbidden systems. For example, we are developing new fuel cell technologies for the direct use of ammonia as low-temperature hydrogen vector by combining mechanistic studies, design of catalysts and nanoparticle size control in collaboration with Bath and Liverpool Universities and Johnson Matthey Fuel Cells.

In addition, the exquisite control of nanomaterials in large-scale manufacturing systems opens up new avenues. Our research is enabling the design, development and deployment of new additives to working fluids for enhanced heat transfer predicted by computational methodologies. It is a part of a project aimed at minimising primary-energy use in the UK industry, led by Imperial College London in collaboration with Brunel and Birmingham universities and over 20 companies, including: EDF Energy, DRD Power, Sainsbury, Sabic Americas and Synthomer, bringing together contributions from all aspects of the multiscale chain molecules-components-technologies-systems.



Core-shell nanoparticles with uniform sizes



Nanostructured alumina with tuneable sizes and morphologies

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Launching Impulse for tech innovators

Yupar Myint
Head

Dr Alexandra Hüner
Coordinator

impulse
MaxwellCentre
for tech innovators

Are YOU an aspiring entrepreneur?

Impulse for tech innovators is a new entrepreneurship programme established in autumn 2016, with an initial HEIF funding for the pilot stage in 2017. It operates from the Maxwell Centre, within its mission for academia-industry engagement across Physical Sciences and Technology, and fostering innovation between the research base and businesses.

The specific objectives of the Impulse programme are to:

- deliver a high-impact learning with strong multidisciplinary underpinning for researchers and aspiring entrepreneurs from Physical Sciences and Technology, including: Biotechnology, Chemical Engineering, Chemistry, Computer Science, Engineering, Materials Science, Mathematics and Physics,
- foster entrepreneurship collaborations with business community and industry partners,
- work closely with the entire West Cambridge community, together supporting entrepreneurial individuals (from academia, start-ups and big industry) and creating a strong interdisciplinary learning environment.

The ethos behind this programme is "high-growth" oriented. We place strong emphasis on the people, their personal development and skills - enabling participants to apply their new understanding of commercialisation strategies to their novel ideas.

Core Values

- **The spirit of cooperation and collaboration - this spirit already exists within the Cambridge ecosystem and we will expand it by inviting entrepreneurs and practitioners to teach, mentor and to interact with entrepreneurial scientists.**
- **Inclusive approach - in which people from a variety of disciplines, industries and countries are brought together and enabled to pursue opportunities, building meaningful connections.**
- **Strong action, with real, measurable outcomes – the delivery is based on the impact-oriented curriculum. We ensure that the programme is quick to identify and adapt to changing demands. We will track our alumni progress in order to understand the programme's impact.**

Entrepreneurial Advisory Board

The board has been formed to advise on the programme development and future growth opportunities. We will be guided by a powerhouse group of entrepreneurs, all of whom also have strong links to the University of Cambridge.

With their in-depth, first-hand experiences and extensive connections to the industry, they will not only act as senior role models for Impulse participants, but also can provide real practical guidance on commercialising innovative ideas.

Programme

Through Impulse, the participants will get the opportunity to develop commercialisation strategies for their ideas, receive expert advice and mentoring from successful entrepreneurs, innovators and investors, and benefit from networking with over 80 contributors from the Cambridge entrepreneurial community and Maxwell Centre's industry partners.

The pilot programme is comprised of two three-day intensive residential modules (in June and September) with time to continue working on individual assignments in between. Both mentoring and regular clinics-discussions with business professionals will happen over the three-month interim period. In this way, we give our participants ample time to build up their idea with the sustained access to help and advice they need. This also keeps momentum and spirits alive for the next stages of business development.

From experience, the majority (something like 70%) of the necessary entrepreneurial know-how and skills are common to everyone seeking to make new ideas happen. The other 30% is context specific and crucially different between individual cases. We will therefore run a set of parallel sessions in order to best meet specific needs of individuals, from contextualising industry requirements to supporting those seeking to develop an internal venture in corporate environment.

Visit our website and register today!

IMPULSE PROGRAMME 2017		
Module A (Residential) 27-30 June 2017	Preparing a business case	Knowledge, information, inspiration Expert mentoring One-to-one clinics Market research activity Pitch practice Investor pitch Preparing action plan Networking with 80+ entrepreneurs and innovators
Individual Assignments July - Sept 2017	Refining your ideas	
Module B (Residential) 25-27 Sept 201	Validating your business case	

impulse@maxwell.cam.ac.uk
www.maxwell.cam.ac.uk/programmes/impulse

Institute for Manufacturing

IfM MANAGEMENT TECHNOLOGY POLICY

The Institute for Manufacturing (IfM) is part of the University of Cambridge's Department of Engineering. It aims to create new insights into manufacturing and it works closely with businesses and policymakers to put those insights into practice. Its definition of manufacturing is broad: alongside its work on new manufacturing processes, IfM also addresses the management and policy aspects of manufacturing which are critical if new technologies are to be translated into significant social and economic benefit.

IfM Education and Consultancy Services (IfM ECS) Ltd

IfM ECS plays an important role in ensuring that IfM's research has real impact. It helps companies of all sizes and national and regional governments put into practice new ideas and approaches developed by researchers at the IfM. It does this through consultancy and executive and professional development. Its profits are gifted to the University to fund future research.

Case studies

- Roadmapping

  The IfM is a world centre of excellence for the study and application of roadmapping. Roadmapping is a powerful tool for developing strategy and building consensus. It can be used in any kind of organisation and to bring different organisations together to develop a shared vision.

  A recent example is a roadmapping workshop IfM ECS ran for the Bulk Superconductivity Group at the Department of Engineering. It brought together academics and industrialists to develop a research strategy that would most effectively meet the needs of industry.

  Professor David Cardwell, Bulk Superconductivity Group Leader and Head of the Department of Engineering, said: "In just one day, [the workshop] managed to achieve consensus between the industrial and academic participants … leading to a practical plan for the short, medium, and long term. The final report … effortlessly aligns fundamental academic research with industrial needs and highlights the most important areas for both worlds."

- Digital supply chains

  The application of digital technologies and data-driven processes is transforming manufacturing. Digitalisation is a major focus of research across the IfM. One of the ways in which IfM is working with industry is through the creation of a new Digital Supply Chain Consortium. Companies can come together in a pre-competitive forum to access IfM research and to address the challenges and opportunities digitalisation presents across the supply chain, from automated e-sourcing and smart factory design through to digital supply network design and product lifecycle management.

ifm-enquiries@eng.cam.ac.uk
www.ifm.eng.cam.ac.uk

Maxwell Centre is home to SKF University Technology Centre for Steels

Prof Sir Harry Bhadeshia FREng FRS FNAE
Director

Dr Pedro Rivera
1st Deputy Director

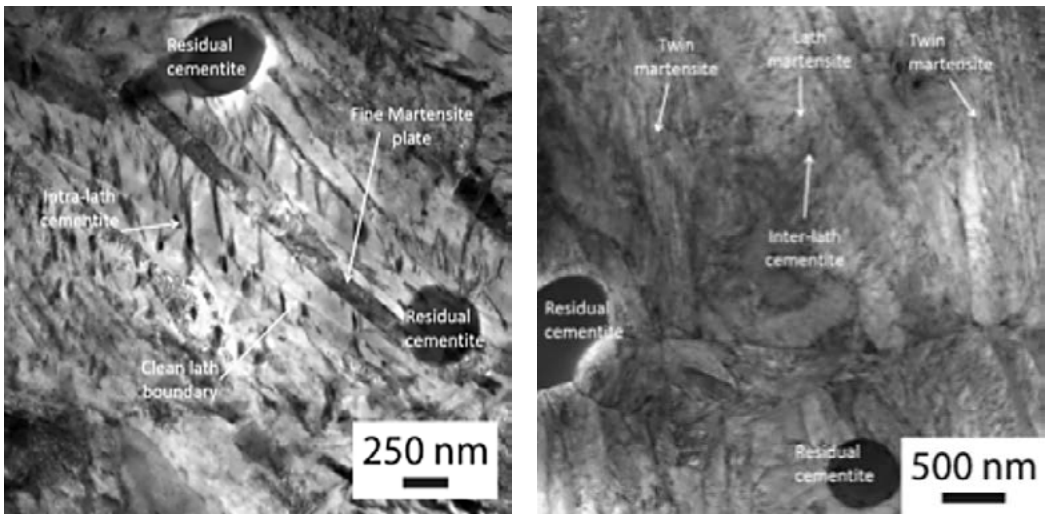
Dr Steven Ooi
2nd Deputy Director

For over a century, bearings have been an essential element in mechanical industry. Automotive, aerospace, power generation and heavy machinery products rely on bearings to ensure safe, reliable and efficient operation. The most important material in bearings is high performance steel. Its composition has evolved throughout the last century both to satisfy the needs of specific demands, and to incrementally improve its properties.

For example, the needs of a jet turbine bearing are very different than those for a windmill or an electric car. Bearing steels can be conceived to address different properties and concerns such as high loads, corrosion, durability, operation temperature and impact. For the materials scientist those concerns are translated into properties of the materials themselves.

The objective of the centre is to rapidly advance SKF's knowledge of the physical metallurgy of bearing steels and hence generate new and improved products. We focus on steel composition and its heat treatment to understand better the microstructure-property relationships as a means to mitigate rolling contact damage in bearings.

Our research is addressing some of the most pressing concerns in materials science: understanding the relationship between steel microstructure to achieve the desired properties. We currently focus on rolling contact fatigue, hydrogen embrittlement, developing novel nanostructured steels and in understanding the effects of steel processing on bearing properties. We also employ state of the art characterisation techniques to understand the microstructures of high performance steels from the atomic level.



The microstructure of a bearing steel produced by two different types of heat treatment.

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The University hosts a number of themed Centres for Doctoral Training (CDTs). Three from amongst the EPSRC-funded centres (www.epsrc.group.cam.ac.uk) have direct links to the Maxwell Centre: CDT in Computational Methods for Materials Science, the Nanoscience and Technology CDT, and the Sensors CDT.

Spotlight: EPSRC Centre for Doctoral Training in Nano (NanoDTC)

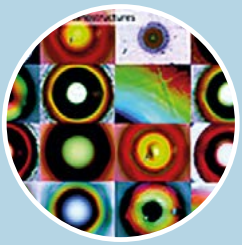
Dr Karishma Jain
Centre Coordinator and Teaching Fellow

Prof Jeremy Baumberg FRS
Director

The EPSRC CDT in Nano (NanoDTC) is a Centre for interdisciplinary doctoral training and research in Nano, and is strongly networked with >150 academics across the Departments of Physics, Chemistry, Engineering, Materials Science, Chemical Engineering actively engaging with the Centre.

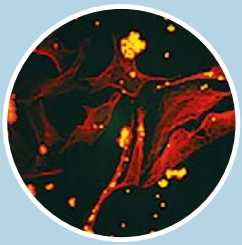
The research themes that the centre focuses on include Nanoelectronics and Photonics, Energy Materials, Bionanotechnology and ways for using and making materials sustainably.

Research Themes:



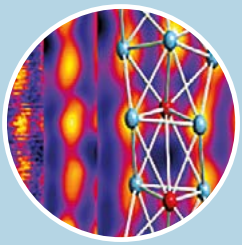
Nano Electronics & Photonics

- Graphene
- Organic electronics
- Spintronics
- Piezoelectrics
- Nanophotonics



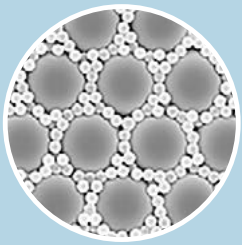
Nano Bio Technologies

- Celular imaging
- Sensing
- Targeting of disease
- Microfluidics
- Scaffolds



Energy Materials

- Photovoltaics
- Batteries
- Photocatalysis of H_20
- Solar fuels
- Supercapacitor



Sustainable Nano

- Functional nanomaterials
- Green processes
- Efficient nano-assembly

Students at the Centre follow an MRes + PhD (1 + 3) programme, with based on science courses, practicals and short projects in their 1st year, before the selection of an interdisciplinary PhD topic for research in Nano for the remaining 3 years. In addition to core scientific research, a significant element of the programme is the Business, Innovation and Science Communication training that students undergo during their 1st year and also in later years, which makes them particularly suitable for engaging with industry and helping industrial collaborations flourish.

The Centre has a number of industry partners it engages with in different ways, including sponsored studentships, joint projects, talks, visits, workshops, brainstorming and others. The projects running at the centre are normally at the pre-competitive IP stage so that they can benefit from the full scale and network of the Centre.

The centre has different models for industry sponsorship, including an annual subscription based model.

Translation of nanotechnology research emerging from the Centre to commercially relevant applications is of strong interest to the Centre, and in the past year the Centre has launched a pilot scheme, the Translational Prize to help support its students take their research closer to commercially viable systems.

› www.nanodtc.cam.ac.uk

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 Physical Sciences and Technology and beyond. The University currently holds 591 live industry research projects, with 201 different industry sponsors, and the annual research funding in this space has grown by 58% between 2012/13 and 2015/16. The University has grown its research staff (postdocs) headcount from 3,000 to nearly 4,000 over the last five years.

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 an unexpected conversation over coffee is often just as important as strategic planning.

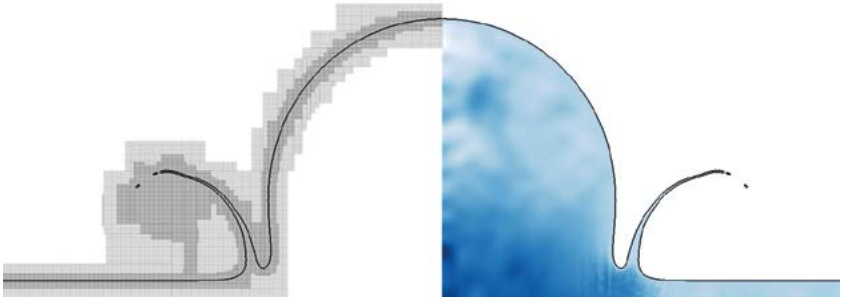
We are constantly on the lookout for new partnerships with industry - the Maxwell Centre is set up to facilitate and foster these interactions. We strongly welcome new collaborations that involve innovative and ambitious research approaches to solving real-world challenges. Collaborations come in all shapes and sizes and the University has adopted a flexible approach with a broad spectrum of interaction models which have already been implemented and 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. 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 and let's explore how we can work together!

Programmes currently hosted by the Maxwell Centre include:

- ARM-Cambridge collaborative partnership
- SKF University Technology Centre
- National Physical Laboratory's East of England Hub
- Maxwell Centre Industrial hot-desking scheme
- Winton Programme for the Physics of Sustainability
- Energy@Cambridge, Cambridge Big Data and links to several other University's Strategic Research Initiatives and Networks, as well as the Interdisciplinary Research Collaborations
- EPSRC CDT in Nanoscience and Nanotechnology (NanoDTC)
- EPSRC CDT in Computational Methods for Materials Science
- MPhil in Scientific Computing
- Several research groups from participating departments
- Impulse for tech innovators – our brand new practical entrepreneurship programme

› For more information about the Maxwell Centre research activities please visit: www.maxwell.cam.ac.uk



Understanding impact (of high-speed water-droplets): a collaboration between Laboratory for Scientific Computing and Boeing.

Industry collaboration

The Maxwell Centre community has a growing number of links with industry, ranging from joint research projects, partnerships with the Centres for Doctoral Training, collaborations between individuals, research groups, and networks, through to established industrial presence in the Maxwell Centre. Beyond companies and organisations already mentioned in the report, our current connections include:

Structure and Governance

Maxwell Centre Steering Committee

Prof Lindsay Greer, Head of the School of Physical Sciences, **Chair**

Prof Sir Richard Friend FRS FREng, **Director** of the Maxwell Centre

Prof Andy Neely, Pro-Vice Chancellor for Enterprise and Business Relations

Prof Chris Abell FRS FRSC FMedSci, Pro-Vice Chancellor for Research

Prof Richard Prager, Head of School of Technology

Prof John Dennis FIChemE, Head of Department of Chemical Engineering and Biotechnology

Prof John Pyle FRS, Head of Department of Chemistry

Prof David Cardwell FREng, Head of Department of Engineering

Prof Mark Blamire, Head of Department of Materials Science and Metallurgy

Prof Andy Parker FInstP, Head of Department of Physics

Prof Neil Greenham, Deputy Head of Department of Physics, Finance & Resources

Dr Tim Minshall, Deputy Head of the Institute for Manufacturing

Dr Peter Hedges, Head of University Research Office

Dr Tony Raven, Chief Executive, Cambridge Enterprise

Dr Aga Iwasiewicz-Wabnig, Maxwell Centre Programme Manager, **Secretary**

"In 1874, the first Cavendish Professor, James Clark Maxwell, began a tradition of industry relevant research which continues to this day. The Maxwell Centre is taking this work forward into a new dimension across the huge range of cutting-edge projects with our industrial partners."

Prof Andy Parker, Head of Department, Cavendish Laboratory

"Hot-desking at the Maxwell Centre provides an opportunity for networking within the University and with other Maxwell Centre industrial collaborators. It enables us to meet collaborators on the West Cambridge site, keep in closer contact with knowledge transfer facilitators and raises awareness of Beko R&D's interests and presence in Cambridge."

Dr Natasha Conway, Manager – Technology Networking and R&D, Beko

"I have enjoyed my first 12 months at the Maxwell Centre. It has proven to be an excellent place for my multidisciplinary research and collaboration with industry."

Dr Raj Jena, Consultant Clinical Oncologist, Computational Radiotherapy

"Through the Maxwell Centre I closely collaborate with industry, promoting the development of directly exportable technologies from my research. I develop valuable transferable skills, ranging from academic and research to commercial and technology transfer. The recognition I get from our industrial partners is undoubtedly rewarding; it's inspiring to see our research being applied to genuinely overcome real-world bottlenecks."

Dr Louisa Michael, Postdoctoral researcher at the Laboratory for Scientific Computing

Get in touch

We welcome more ways of engaging with external partners and industry – the Maxwell Centre is set up to facilitate and foster these interactions. We look forward to new collaborations that involve innovative and ambitious research approaches to solving real world challenges.

Contact information:

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UNIVERSITY OF CAMBRIDGE

Maxwell Centre