UNIVERSITY OF CAMBRIDGE

OCTOBER 2020

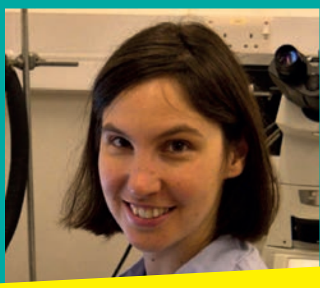
ISSUE 24

CAVMAG

News from the Cavendish Laboratory





Graduate Student Edition







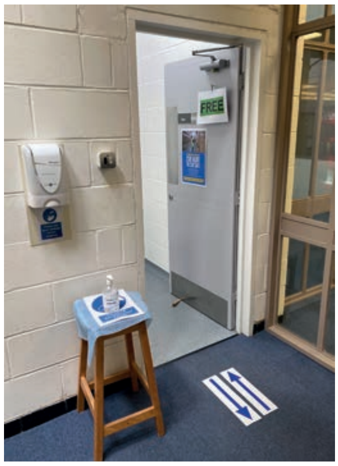

EDITORIAL

This edition of CavMag is dedicated to our Graduate Students. They are a remarkable body of young researchers and we are only too well aware of our responsibilities in encouraging and educating this next generation of research physicists who will be become the leaders of the discipline. We highlight the activities and views of 32 of our current crop of graduate students about their experiences. It is very encouraging that, although their responses to our questionnaire were received at a time of strict lockdown because of the Covid-19 pandemic, their responses are all very positive and constructive. It is also very helpful that, in asking the students to describe in two sentences their research projects, we obtain an enlightening view of the breadth and depth of the research activity in the Laboratory.

The lock-down resulted in a massive effort to enable staff and students o get back to work safely. Our dedicated health and safety team and infrastructure support personnel did a magnificent job in ma ing the Laboratory safe once access to the Laboratory was permitted. Our safety officer des ibes what was involved. We are still very far from back to normal, but we are working our way round all the problems and are getting used to the 'new normal'. We hope all readers are remaining well and healthy.

INSIDE

Cover image: Graduate Student Array



The New Normal *(clockwise from top left). The masked Cav3 team counting furniture. A one-person rest-room. The one-way snakes and ladders. The glassed-in reception with masked Catherine Clifton. Typical entrance to the Rutherford Building with signs. The mandatory signing-in system.*

The Cavendish during Lock-down:

‘This too shall pass’

***Saba Alai*, the Cavendish’s Departmental Safety Officer, gives a personal account of how the Laboratory coped with the Lock-down caused by the 2020 Covid-19 pandemic and the sterling efforts of so many people to maintain a safe working environment through an era of quite unprecedented difficu y and uncertainty.**

Even if I’d had a crystal ball this time last year (summer 2019), I would not have believed the change in our work and home lives brought about by the 2020 Covid-19 pandemic. After the Christmas break I was away for fi e weeks. Returning in February, I wondered what the Department was doing about preparation for the pandemic. Within a couple of weeks, it seemed as if we were feeling our way through a thick fog of confused information and vague advice about how to stay safe. There was no clear understanding of what we should do practically, other than avoiding shaking hands, cleaning door handles and keeping apart when having meetings. Some of my friends were saying they couldn’t wait to get the virus so we could reach the heralded ‘herd immunity’. How naïve we were!

The Physics Emergency **Silver Team** went into full action. Each department has one for managing the short and long term impacts of events with the potential to hurt large numbers of people and bring research and teaching to a halt. Its members are the Departmental Administrator Gillian Weale (Chair), Deputy Head of Department Neil Greenham, Director of Graduate Studies Ulrich Keyser, Director of Undergraduate Studies Ulrich Schneider, Finance Manager Jo Kibble, Laboratory Superintendent Peter Norman and me - Leona Hope Coles acted as Secretary and Mike Moriarty, Head of IT Transformation, was co-opted to help with communication and related issues. The **Gold Team**, comprising the Head of Department Andy Parker, Neil Greenham and Gillian Weale set the strategy - stay open safely, and break the chain of infection.

The Silver Team had only just started planning to achieve this with guidance from the Safety Offi , World Health Organisation, and our Biological Safety Offic , Tim Fitzmaurice, when the Vice Chancellor announced the lockdown of the University and closure of most buildings by 20th March – only about 7 days away. The Silver Team accelerated their efforts with help from the Facilities Team and the indefatigable Departmental Safety Technician, Anya Howe. Procedures for a safe and effective lockdown were put in place as well as continuing minimal maintenance to allow the work of the Department to restart quickly afterwards. The entire Department sprang into action: Principal Investigators, managers and their staff and students orked long and hard during those few days, deciding what equipment should be powered down, how the systems that had to stay running would be managed and by whom. Everyone in the IT team worked tirelessly, enabling large numbers who had never before worked from home, to do so. The Laboratory was shut down at 5:35 pm on Friday 20th March 2020. It was Iranian and Baha’i New Year that day - I celebrated it by walking round the Department with Andy Parker, Fred John, David Rudderham and Alan Turner. We checked every laboratory, offi , kitchen and toilet in every building and were satisfied that all nine buildings were empty and that there were no obvious safety issues.

During the next two weeks, we all tried to figu e out how to work productively at home, how to cope with not seeing anyone outside the home circle, and what new routines to adopt to stay sane and productive. It was unbelievable how quickly our collective knowledge and experience of using conferencing apps increased and became normalised.

After these first ew quieter weeks, I realised that reopening the Department was going to be much more complicated than locking down. The Silver Team resumed meetings with a vengeance, and the Facilities, Safety, HR, IT, Hub Admin and other teams geared up to support PIs and managers to assess risks, arrange return to work conversations, and consider safety procedures for a safe return. Every lab to be reopened was given a maximum occupancy and new safety precautions by its ‘owner’. For about six weeks, many people worked 9 to 11 hour days.

Once the Department risk assessment and protocols for safe working were completed, we drew up a detailed safety briefing and est to be passed by all returners, and consulted on these with the Departmental Safety Committees and by direct contact. We held two all-Department information/discussion meetings by Zoom which led to fin -tuning of our proposals.

The rule was that everyone should work from home, unless attendance in the Laboratory was vital and essential. The Facilities team began to re-authorise ID cards for access after Department users had passed the mandatory test and completed the other requirements. The buildings were deep cleaned, safety signs were made and put up, restrictions were put in place and the first buildings opened on 24th Jun . Protocols were adopted to break the chain of virus transmission in case anyone with symptoms came into the Department. From 13th July working hours were extended into the evening and more researchers were able to return to their experimental work.

At the time of writing (August 2020), the support teams are continuing to provide limited access, advice on new risks, disinfection cleaning, and anything practicable to restore research and teaching safely. Plans are being made for a safe Michaelmas term 2020, face covers are being distributed, and all buildings are being opened although we are still working on the Lord’s Bridge Radio Observatory. Despite the very hot weather, staff h ve continued wearing face masks in shared areas of the Department. We monitored people who had reported suspected symptoms but the few such cases were found to be ‘negative’. PIs and line managers are now considering reopening shared offices and th e are new developments every couple of weeks.

We are living a ‘new normal’. We have become much better at washing our hands, cleaning our equipment and thinking about the needs of other people, and we have adopted safer ways of working. We still miss chatting to our friends and colleagues face to face even if we are back at work. None of us knows if and when life will return to what it was like before the pandemic. I remind myself of the words of the Persian Sufi poets who said, ‘This too shall pass’. I can only hope it happens soon.

PostGraduate Students –
A Powerhouse for the Future of UK and International Science


PostGraduate students are a key component of the lifeblood of the Cavendish Laboratory. This issue of CavMag is dedicated to their efforts and achievements. Their research spans the complete range of activities in the Laboratory and brings to life their vibrant ambitions. *Ulrich Keyser* and *Karishma Jain* describe the programme, bringing to the attention of readers the increasing challenges in securing financial sup ort for them.

The (post-)graduate student programme of the Laboratory is central to our research activities. Typically, we host about 500 such students from all over the world. They are embedded in the research activities of the Laboratory from the moment they arrive. This is a major commitment and adventure in which the students get the opportunity to display their talents and originality for research, supervised by staff member , who are all working on cutting-edge problems of physics and its cognate disciplines. These challenges span the whole range of our research activities, from deeply theoretical fundamental physics to the equally challenging physics of everyday life, as is vividly illustrated by the portraits and programmes of the 32 students who contributed to this article.

We are very lucky to be able to attract outstanding students from all over the world and it is a joy to see them develop as researchers. In some cases, we find their hD research resulting in the subsequent award of Nobel Prizes, as in the cases of Lawrence Bragg, Brian Josephson and Didier Queloz. In our experience, the most cherished moments of supervising a graduate student are when supervisors set problems, which they themselves cannot solve, only to find that their graduate students solve them in a matter of weeks. The fresh minds of the students, their energy and ability to focus their attention are among their greatest assets. On graduation, many of our students go on to research fellowships where they have the opportunity to display to the full their abilities at independent research and begin to become fully-fledged esearch physicists. Many others go into industry, commerce and the financial se tors, where their problem solving skills are of the greatest value in contributing to the national and international good.

This is a particularly exciting time in the history of the laboratory as we plan the move into the Ray Dolby Centre in 2022/23. This move will provide enhanced state of the art facilities for graduate students to pursue their researches in an environment designed to encourage interdisciplinary research in its many different guises.

But let us hear from the graduate students themselves.

The Graduate Students

To encourage the interchange of ideas and techniques, the research programme can be divided into seven themes supported by theory and computation (see CavMag18). We selected four students at different stages of their PhD programmes in each of the themes and invited them to give us responses to a number of questions which give an impression of their enthusiasms, as well as their concerns and the advice they would give to students wishing to join our PhD programme.

We introduce the students by research theme, indicating their country of origin, the year in which they started their programmes and their research topics. These provide a remarkable survey of the breadth of physics research being carried out in the Laboratory.

What the students think

Why did you choose to study for a PhD at the Cavendish Laboratory?

- Everyone is working together and helping each other, and there is an infectious excitement for research.
- The Cavendish has a reputation for research excellence, and there is some really exciting physics research that I wanted to be part of.
- The combination of world class facilities and world class researchers makes it the ideal place to come to learn and contribute to the field of science.
- I was really excited about the project being offered!
- The largest theoretical condensed matter group in the country containing many leading academics.

ASTROPHYSICS

Dominic Anstey (UK) (2018). I work on the REACH experiment to detect the very first stars that ormed in the universe. I develop the techniques and software for the radio telescope and the analysis of the results.

James Luis (UK) (2016). I prototype optical hardware for the MROI in New Mexico. This interferometer will observe, for example, planet-forming regions at higher resolution than single telescopes.

Amy Tuson (UK) (2019). The aim of my research is to use data from two telescopes (TESS and CHEOPS) to discover and characterise longer period exoplanets similar to those in our own Solar System.

Simcha Brownson (UK) (2017). I analyse data obtained from a number of telescopes to investigate what processes regulate star formation within galaxies.

HIGH ENERGY PHYSICS

Fionn Bishop (UK) (2019) I work on the LHCb experiment at CERN using precision measurements of the decays of heavy hadrons, searching for fundamental Physics beyond the current Standard Model.

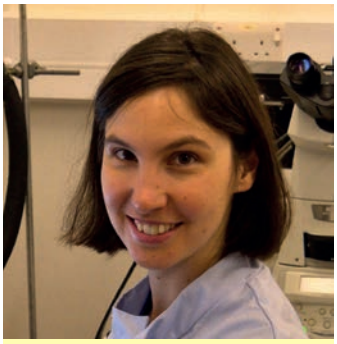
Holly Pacey (UK) (2016) I search for new particles created in proton collisions at the LHC ATLAS detector. They would be added to the Standard Model and might explain Dark Matter and the relative weakness of gravity.

Rupert Tombs (UK) (2018) I analyse data taken by the LHC Atlas detector. I aim to devise the best tests of our physical models and perhaps they will contradict the current Standard Model of particle physics.

David Rousso (Canada) (2019) I am searching for long-lived particles in the ATLAS detectors that may be candidates for the dark matter by looking for displaced vertices.

BIOLOGICAL AND BIOMEDICAL PHYSICS

Michael Hunter (UK) (2018) I study the spatial growth and resultant evolution of bacteriophage and its host bacteria. I study how the system grows and evolves in space where conditions can vary, such as in the gut of an animal.



Viola Introini (Italy) (2016) I study how malaria parasites infect human red blood cells. I use real-time live microscopy, optical tweezers and microfluidics o investigate the biophysics of invasion.

Filip Boskovic (Slovenia - Serbia) (2019) My work concerns deciphering the underlying details of biological structures at the single-molecule level by developing cutting-edge techniques from the physical sciences.

Michaela Taylor-Williams (Australia-USA) (2019) I am developing haemoglobin imaging sensors to detect and image the oxygenation of blood. This will aid diagnosis of diseases from cancer to rheumatic conditions.

What the students think

What do you like best about your research experience in the Cavendish?

- My favourite aspect of the Cavendish is how little established hierarchy there is. There is a great amount of collaboration between researchers at all stages in their careers.
- I really value the balance I have experienced between being given the independence to follow my ideas and develop my own research direction, and having help available from anyone in my research group when I needed it.
- If I have a question, need access to equipment or I am running into problems with experiments, there is always someone who can and will help me.
- The highly international, friendly, collaborative and interdisciplinary nature of the group, which facilitates ample opportunities for stimulating discussions, has been the best part.
- My favourite events so far were the Cavendish Inspiring Women talks at the start of this year.
- The Cav has a great environment where it feels that everyone is working on something exciting and is aiming to do something great. Everyone is really nice and friendly, and are very open to answering non-judgementally the many, many dumb questions I had starting out!

What activities do you take part in outside your studies?

There was a huge range of activities which students were involved in outside their research work. Cambridge offers a vast range of clubs which the students enjoy. Examples of activities include board gaming, running, photography, music, outreach activities, cooking, dancing, weightlifting, knitting, hiking, musical comedy, basketball, trampoline, gamelan, college choir, archaeology, violin making, golf, Australian rules football, …

What are your future career plans?

Most respondents were concentrating strongly upon their research work. A large proportion hoped to continue doing research in the University or industrial sectors. Many realised that the next step is to obtain post-doctoral experience through the winning of research fellowships.

ENERGY MATERIALS

Liam Nagle-Cocco (UK) (2019) I study Li-ion battery cathode materials to help develop the next class of materials for applications such as energy storage in electric vehicles.

Aswathy Girija (India) (2019) I focus on understanding and developing new molecular coupling avenues with light to enhance solar energy harvesting by combining ultrafast optics and energy materials.

Alice Merryweather (UK) (2019) I use optical scattering microscopy to study dynamic changes and phase transitions in electrode materials for lithium-ion batteries in order to guide future battery design.

Haralds Abolins (Latvia) (2017) My research concerns new device structures for light management and the study of charge carrier dynamics in perovskite-based solar cells.

What the students think

What more could the Laboratory be doing to enhance your research programme?

- I would like to see more opportunities for members of the Cavendish with non-overlapping research areas to come together and develop the community further.
- When applying, the one unpleasant surprise was to find out h w hard it is to get funding. Even though I was lucky enough to get it, I think the Laboratory should be able to fund more PhD students on its own.
- More opportunities to put outreach training into practice and connect with the general public
- I found quite confusing the fact that some scholarships required you to have already been selected by a supervisor and written a detailed research proposal before applying and others did not.
- Slightly more structured learning opportunities for instance on research techniques could be helpful
- I think there is still some way to go with encouraging diversity among the graduate student intake.
- I found that there was a gap between the techniques taught during my undergraduate studies and the skills required for independent research.
- It would be great if the Cavendish provided resources on managing mental health during a PhD.

'My favourite aspect of the Cavendish is how little established hierarchy there is. There is a great amount of collaboration between researchers at all stages in their careers.'

EMERGENT QUANTUM PHENOMENA

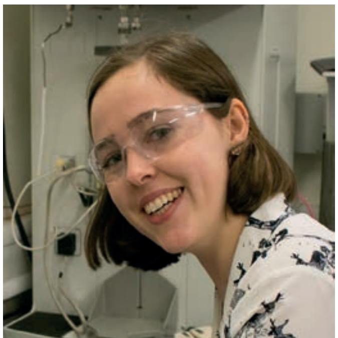
Emmanuel Gottlob (Belgium) (2019) I design physical models for predicting the quantum dynamics of electrons moving through quasi-crystals, which are very similar to disordered media such as glasses.

Georgia Nixon (New Zealand) (2019) My research focuses on quantum many-body systems for quantum simulation. I explore Hamiltonian quantum dynamics to model interesting physical regimes and topologies

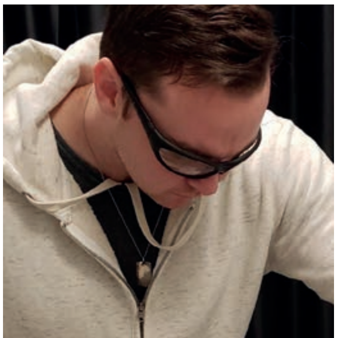
Luca Donini (Italy-Germany) (2019) I work in the field of quantum simulation with ultracold atoms in optical lattices. We can effectively simulate condensed matter systems in a highly controlled environment

Jiří Etrych (Czech Republic) (2020) I use ultra-cold atomic gases as a highly controllable experimental platform to study out of equilibrium phenomena, or systems with reduced dimensionality.

ASSEMBLY AND FUNCTION OF COMPLEX SYSTEMS



Aoife Gregg (Ireland) (2019) I work on making surfaces covered with movable nanostructures to produce metre-scale surfaces with switchable optical properties using carbon nanotubes & hydrogels.



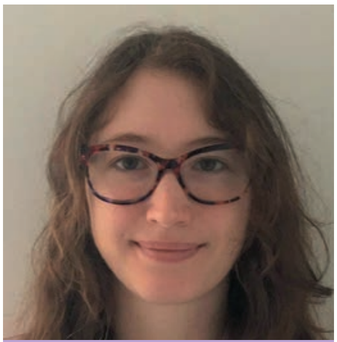
Jonathan Pinnell (South Africa) (2020) My research involves structured light and its applications. My plan is to use complex light fields o study and manipulate nano-particles in new and exciting ways.

Mike O'Donnell (UK) (2019) I work on the additive manufacture or 3D printing of complex materials, such as highly viscous pastes. The goal is to understand how their properties affect their printing performance.

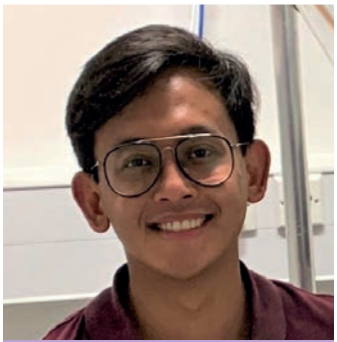
Alexandra Gablier (France/ Italy)(2018) My research focuses on the intersection between Liquid Crystalline Elastomers and Vitrimers, a subset of the 'renewable polymer networks' family, to make them easily processible .

QUANTUM DEVICES AND MEASUREMENT

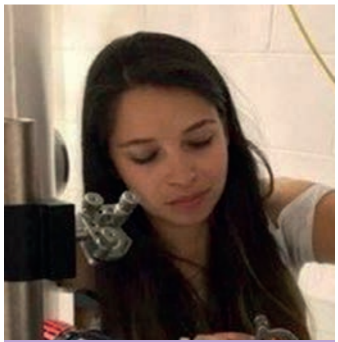
Tarig Mustafa (Sudan/UK) (2019) I study the mechanisms of electron and nuclear spin relaxation in organic semi-conductors. Specificall , how spin polarisation is transferred between electrons and nuclei.



Ginny Shooter (UK) (2017) I work with quantum dots which emit in the C-band at 1550 nm. I fabricate quantum dot LED devices for experiments in quantum entanglement in collaboration with Toshiba.



Farhan Nur Kholid (Indonesia) (2016) I study spin current injection in magnetic insulator hetero-structures with the aim of understanding the roles of magnetic ordering & interfacial exchange interactions in spin transport.



Cathryn Michaels (UK) (2019) I use diamond defects for quantum computing. With lasers, we address individual implanted atoms and measure and control their quantum properties.

THEORETICAL AND COMPUTATIONAL PHYSICS

Alice Shipley (UK) (2017). I study materials under extreme pressure using electronic structure methods, focusing on the potential for high-Tc superconductivity and the effects of anharmonicity.

Ollie Hart (UK) (2017) I study quantum spin liquids at fini e energy density, and the behaviour of systems with a large number of local symmetries, motivated by recent experiments on quantum spin liquid candidate materials.

Clara Wanjura (Germany) (2018) I engineer the interplay between dissipation and topology in quantum devices, such as directional amplifier . This has applications in telecommunication and quantum information processing

Heather Muir (Australia) (2018) I work in the Centre for Scientific omputing, using advanced methods in computational physics. We model fully coupled fluid-solid-plasma sys ems in *multi-physics* simulations.

What the students think

Any advice for prospective students?

- Don't be afraid to ask questions, if there's something you don't understand. No one will hold this against you, and it makes your research a lot easier.
- A PhD is a marathon, not a sprint. Make sure to choose a topic that you are passionate about because you will inevitably need to overcome rough patches in your research.
- Make sure you consider both the project and the supervisor before choosing a PhD - both are equally important. Don't measure your success against other students because every PhD is unique!
- Make sure that you share similar expectations for your PhD with your prospective supervisor. Talk to both past and present students to get an idea of the general work/life culture in the group, and clarify what level of guidance and mentorship you can expect from your supervisor and/or more senior members of the lab.
- Take the time to look into the different groups and programmes here and apply to whatever you're interested in. Feel free to take things at your own pace.
- Your research project will likely deviate from your plan at the start. It will be essential to adapt to the circumstances and persevere to get through your PhD.
- It's really important to choose a project you're passionate about and a group you get on well with.
- A PhD is not a small commitment. You might spend a long time down dead ends and you will try many things that don't work before you find things that do – this is the natu e of trail-blazing research!
- Pursuing a PhD is a rewarding yet stressful journey. I would advise prospective students to carefully evaluate their options before deciding whether to do one, and in which research group to do it.
- Enjoy your research and make the most out of your experience at the Cavendish and in Cambridge! A PhD is hard work and can be an emotional roller-coaster from frustration to excitement,
- Don't worry about the learning curve! It takes time to learn about your area of research and to develop your own research skills. It can be intimidating to be surrounded by experts, but every expert started off as a student
- I had heard of the extremely competitive nature of the application process, which almost dissuaded me from applying for a PhD at the Cavendish Laboratory. My advice would be to apply and see what happens; like me, you might be pleasantly surprised.
- As a mature PhD student, I was a little anxious about coming back to academia after almost a decade. I needn't have been. Everyone at Cavendish has been very supportive.
- To prospective applicants - Just give it a go. Take time to identify research groups you are interested in joining, get in touch with them if possible, and prepare the application well in advance. Focus on your skills and what you will uniquely bring to the table.
- Undertaking a PhD at the Cavendish can be a very rewarding experience. Don't be afraid to discuss your ideas with others in the department, or to take a break if you are stuck.
- Be patient. It can be a rather long run from starting the application to having a place confi med, potentially including a few months of funding insecurity. But I do believe it's worth it.
- Don't be afraid of changing fields! y undergrad was in engineering and I had no formal training in particle physics before coming here.

'I really value the balance I have experienced between being given the independence to follow my ideas and develop my own research direction, and having help available from anyone in my research group when I needed it.'

FUNDING GRADUATE STUDENTS

Continuing to support a wide range of graduate students is at the heart of the Department's strategy, but we live in challenging times, which directly impact studentship funding for graduate students. From 2021-22 EU students will no longer be eligible for the government subsidies for their University fees and will be paying the significantly higher overseas fee rate. This will mean a significant dr w on the studentship funds normally available to fund graduate students at the Cavendish, as we endeavour to fund the best students irrespective of their fee status as far as possible. This will be on top of the progressive reductions in the UK research council funding for research students at the Cavendish as the general drift in research council funding has been towards more applied areas over the past decades. There are fewer opportunities for funding the type of fundamental work that could lead to ground-breaking discoveries.

The recent Covid-19 pandemic has added a new dimension to the experience of research students at the Cavendish, with safety related measures significantly estricting the pace at which experimental research would normally be conducted and fewer opportunities for the chance conversations with colleagues that enrich the research experience. The Department's Safety Team has done an amazing job in ensuring that the impact of the pandemic on students' research is minimal. The department has also been working with various funding bodies to ensure that all research students can obtain additional funding to offset the delays resulting from the pandemic.

To support graduate students further in these changing times, we are putting together a new Cavendish Graduate Programme that will focus on:

- ensuring that we can continue to recruit the best and brightest research students from across the world,
- providing structured training and avenues for interaction in core subject areas for incoming students so that they can make the most of the immense expertise available within the department, and develop into more rounded physicists better suited for delving into new areas in future,
- enhancing career development skills that would allow research students to excel in careers as physicists in academia and industry, or in a different field if th y choose to do so.

These are uncertain times, but we are confident that e can continue to be the world leader for training physics researchers who will continue to have strong impact on the world around us.

HOW YOU CAN HELP

We take on typically about 60-70 PhD students each year, but we have a large number of supervisors and many more exciting projects than can be funded. We make full use of many sources of studentships, including: UK Research Councils (EPSRC, STFC, NERC, MRC), Winton Programme for Physics of Sustainability, Cambridge Trusts and their partners for specific count ies, Gates Cambridge Scholarships, Harding Distinguished Postgraduate Scholars Programme and PC Ho Cavendish Scholarships. Despite this significant menu of oppo tunities, the graduate student programme is being seriously impacted by the external circumstances discussed above. In concrete terms, in 2018-19 49% of students who were offered places (73/147) were accepted for PhDs. This gap is largely because of funding. In 2019-20 the number was 40% (55/137) and is expected to be lower in 2020-21. We are therefore appealing to alumni and our many supporters to help with the funding of the graduate student education programme. Contributions at any level will be gratefully received, from the endowment of named studentships to contributions which will help students carry out their research programmes.

Online Giving

The University's Office or Development and Alumni Relations (CUDAR) has made it easier to make donations online to the Department. If you wish to support the graduate student programme, please go to: **campaign.cam.ac.uk/giving/physics/graduate-support**

If you would like your gift to be applied to some specific aspe t of the Graduate Student Programme, please contact Josh Bowerman (**Josh.Bowerman@admin.cam.ac.uk**), Senior Associate Director for Physical Sciences at CUDAR, or Malcolm Longair (**msl1000@cam.ac.uk**), Cavendish Development Director. They will be very happy to talk with you confidentially about a y aspect of this appeal.

A Gift in Your Will

One very effective way of contributing to the long-term development of the Graduate Student programme is through the provision of a legacy in one's will. This has the beneficial e ect 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 your intentions should be spelled out explicitly in your will. We can suggest suitable forms of words to match your intentions. Please contact Malcolm Longair (**msl1000@cam.ac.uk**), Josh Bowerman (**Josh.Bowerman@admin.cam.ac.uk)** or Samantha Stokes (**departmental.administrator@phy.cam.ac.uk**) who can provide confidential advic .

Thermal Energy Harvesting

We congratulate warmly *Henning Sirringhaus* on being awarded a prestigious Royal Society Research Professorship to enable him to concentrate on his research for the next fi e years. Here he describes the very challenging programme of basic research he will explore in thermal energy harvesting.

Across the global energy economy, only about one third of the primary energy is converted into useful energy services, the other two-thirds being rejected in the various industrial, transportation and residential energy conversion processes. Given the urgent need to transition to a carbon-free energy supply to mitigate the dangerous consequences of climate change, a waste of energy on this scale is unsustainable. Most rejected energy is wasted as heat, about 60% as low-grade heat below 400C.1For heat emitted at higher temperatures and from a small area, there are efficient hea recovery engines, such as Rankine cycles, but for low-grade heat generated over large areas, for example, along industrial process pipes, there are currently no efficient wa e heat recovery technologies. Finding better ways of efficiently h vesting thermal energy constitutes a difficult, but i eresting, physics challenge.

Multiple approaches are being pursued for thermal energy harvesting. They require expertise from different branches of physics, including thermodynamics, semiconductor physics, optoelectronics and photonics. Thermophotovoltaic devices, for example, work essentially like solar cells but the bandgap of the semiconducting absorbers needs to be matched not to the Sun's 5800K blackbody spectrum, but to the much lower temperature of the heat source. This becomes challenging for temperatures of a few 100K because of fast non-radiative recombination in semiconductors with bandgaps < 100 meV. Approaches are being developed to modify the emission spectrum of the thermal source through up-conversion and photonic crystal engineering2or to enhance the radiative transfer in nanoscale gaps3 Reasonably efficient ectification of THz radiation in ultrafast solid-state tunnelling diodes integrated into photonic resonators has also been demonstrated.4

An alternative approach for converting waste heat into electricity is to utilise the thermoelectric effect. When heat fl w through a metal or semiconductor results in a temperature gradient, an electromotive force is generated as a result of the *Seebeck effec* . The Seebeck coefficien α provides a measure of the thermodynamic entropy associated with adding a charge carrier to an electronic system. A good thermoelectric material should have a high Seebeck coefficient, hig electrical conductivity α, but low thermal conductivity κ to maximize the energy efficie y figu e of merit $ZT = \alpha^2 \cdot \sigma \cdot T / \kappa$. ZT values greater than 2-3 are likely to be needed to make grid-scale waste heat harvesting feasible and cost-effective. With a ZT of 3 a thermoelectric converter operating between room temperature and 400C could operate at approximately 40% of the efficie y of an ideal Carnot engine5and could harvest waste heat with about the same energy efficie y as silicon solar cells harvest sunlight energy.

Thermoelectric materials have been actively researched since the discovery of semiconductors in the 1960's. At present, a broad range of new materials, including half-Heusler and Zintl compounds, are being researched with reported ZT as high as 1.5-2.8, though mainly at high temperatures.6There are no known fundamental limits to the maximum value of ZT. Improving thermoelectric performance is however a challenging task because of the transport physics in inorganic semiconductors, which couples the individual transport coefficients and m es it difficult o optimize them independently. For example, with increasing carrier concentration electrical conductivity increases, but unfortunately the Seebeck coefficient de eases. Similarly, the so-called Wiedemann-Franz law implies that the electronic contribution to the thermal conductivity cannot be kept low while increasing the electrical conductivity.

So far, my research has mainly focussed on elucidating the unique charge transport physics of molecular, organic semiconductors (OSCs), which differ fundamentally from those of inorganic semiconductors.7 OSCs exhibit soft, non-covalent intermolecular bonding, leading to large thermal lattice flu tuations, strong electron-phonon coupling and a transient localization charge transport regime, in which charge, spin and structural dynamics are intimately coupled.[7,8] I have become convinced that this unique physics makes OSCs very promising thermoelectric materials. They are environmentally sustainable and have inherently low thermal conductivities; in some molecular semiconductors, we have recently measured lattice thermal conductivities as exceptionally low as 0.05 W/mK.

We have also recently discovered a family of organic semiconductors with thermoelectric performance levels approaching those of the best low temperature inorganic thermoelectric materials. There are as yet unexplored aspects of their thermoelectric physics, which I believe could be utilized to decouple the thermoelectric transport coefficients more easily than in inorganic semiconductors. The low-dimensional electronic structure of OSCs and their unique transient localization physics may make it possible to violate the Wiedemann-Franz relationship and to enhance the Seebeck coefficient by electron-phonon coupling. Furthermore, the structural heterogeneity of many organic systems on length scales < 100 nm could be utilized to improve their thermoelectric properties. Thermal conductivities can be reduced by interface scattering. It may also be possible to arrange local temperature gradients to develop over different interfaces than those over which electric fields develop and in this way decouple charge and heat transport. However, heterogeneity also makes it more difficult to understand the underpinning physics. What is needed are local probes of thermoelectric properties and temperature distributions on less than 100 nm length scale to relate microscopic processes to macroscopic transport coefficients.

My aim is to develop deep fundamental understanding of charge and heat transport in OSCs on the nanoscale by applying a combination of scanning probe measurements, such as scanning Kelvin Probe Microscopy (SKPM), and Scanning Thermal Microscopy (SThM, Figure 1) to working device structures. The insight gained will be used to design novel materials systems with improved performance for efficient waste heat harvesting. I am very grateful to the Royal Society for providing me with this opportunity.

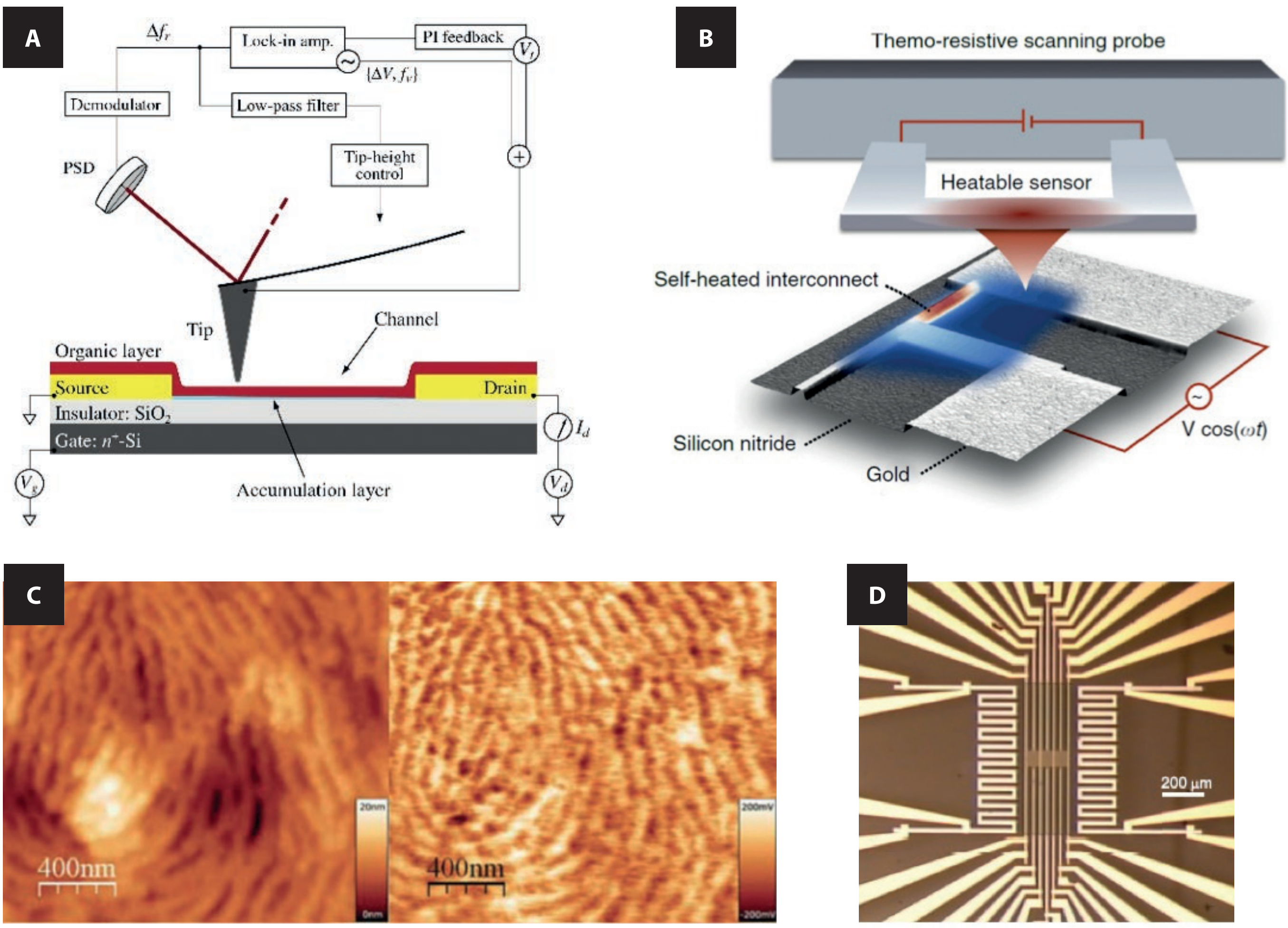


Figure 1: *Schematic diagrams of (A) Scanning Kelvin Probe Microscopy (SKPM) and (B) Scanning Thermal Microscopy (SThM); (C) SKPM mapping of electrostatic potential variations in conjugated polymers with resolution less than 20-50nm; surface topography (left) and electrostatic potential (right) (from Ref.9); (D) Photograph of micro-fabricated thermoelectric device architecture.*

References

1. Schierning, G. Bring on the heat. *Nature Energy* vol. 3 92–93 (2018).
2. Lenert, A. *et al.* A nanophotonic solar thermophotovoltaic device. *Nat. Nanotechnol.* **9**, 126–130 (2014).
3. Fiorino, A. *et al.* Nanogap near-field thermophotovoltaics. (2018) doi:10.1038/s41565-018-0172-5.
4. Davids, P. S. *et al.* Electrical power generation from moderate-temperature radiative thermal sources. *Science (80-.).* eaba2089 (2020) doi:10.1126/science.aba2089.
5. Vining, C. B. An inconvenient truth about thermoelectrics. *Nat. Mater.* **8**, 83–85 (2009).
6. Tan, G., Ohta, M. & Kanatzidis, M. G. Thermoelectric powear generation: from new materials to devices. *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.* **377**, 20180450 (2019).
7. Fratini, S., Nikolka, M., Salleo, A., Schweicher, G. & Sirringhaus, H. Charge transport in high-mobility conjugated polymers and molecular semiconductors. *Nature Materials* vol. 19 491–502 (2020).
8. Schott, S. *et al.* Polaron spin dynamics in high-mobility polymeric semiconductors. *Nat. Phys.* **15**, 814–822 (2019).
9. Hallam, T. *et al.* Local charge trapping in conjugated polymers resolved by scanning Kelvin probe microscopy. *Phys. Rev. Lett.* **103**, 256803 (2009).

The challenges of multi-scale, multi-physics computational research

We are delighted to welcome *Hrvoje Jasak* who has taken up a lectureship funded by the Gianna Angelopoulos Programme for Science, Technology and Innovation (GAPSTI) based in the Maxwell Centre.

The focus of my work is Scientific Computing, based upon my extensive experience of numerical simulation in continuum mechanics and the development of practical software. Is Computational Fluid Dynamics (CFD) going out of fashion? I have been told a number of times that at the continuum level there is very little 'new physics' to be discovered and that real challenges lie in cold atoms and fundamental building blocks of nature. However, the scientific literature is full of references to macro-scale instabilities, turbulence, free surface effects and other phenomena where the number of fundamental particles involved simply does not allow mass-scale atomistic simulation. This is the realm of continuum mechanics.

At the other extreme, aerodynamicists and ship designers simulate fluid flow, heat transfer, fluid-solid interaction and chemical reactions using CFD software, barely acknowledging the laws of physics underpinning their work. Good models produce results quickly, reliably, accurately and at a scale that allows engineers to design the machines we use every day. The explosive growth of available computating power and the experience of practitioners have by themselves expanded the reach and impact of such simulations.

Commercial simulation software for solid and fluid dynamics has been around since the 1960s and has reached a remarkable level of reliability and accuracy, commanding a substantial, and sometimes unjustified, price. However, its versatility beyond simple solid mechanics, fluid flow and heat transfer remains limited. In contrast, numerical methods developed for these purposes allow us to solve continuum equations in general and not just simple fluid and solid problems. This has been amply proven by the work of the Centre for Scientific Computing.

Democratising Simulation via Open Source

OpenFOAM, the software which I co-authored in the 1990s and have developed ever since, perfectly illustrates how a combination of known (and improved) numerical methods, good software practices (C++ in a sea of FORTRAN), focus on HPC and Open Source produces results exceeding all expectation. The idea is to apply the principle of object orientation to computational continuum mechanics, recognise the natural language of the problem – partial differential equations – and mimic it in software as closely as possible.

Consider the example of the turbulence kinetic energy transport equation:

$$\frac{\partial k}{\partial t} + \nabla\bullet(\vec{u}k) - \nabla\bullet[(\nu + \nu_t)\nabla k] = \nu_t \left[\frac{1}{2}(\nabla\vec{u} + \nabla\vec{u}^T)\right]^2 - \frac{\epsilon_o}{k_o}\, k$$

This is represented in the software as:

```
solve
(
    fvm::ddt
  + fvm::div

  - fvm::laplacian(turbulence->nuEff(), k)
 == nut*magSqr(symm(fvc::grad(U)))
  - fvm::Sp(epsilon/k, k)
);
```

The elegance of the source code is impressive, aimed at rapid implementation of new equation sets. The difficult parts of data management, I/O, discretisation schemes, HPC support, dynamic mesh, post-processing and others are readily available. A wealth of pre-implemented physics models serve both as ready-to-use tools and as examples for further development.

***Figure 1**. Jet breakup and preferential evaporation of a multi-component fuel.*

FIgure 3. *Production of polyurethane foam involves multiple scales: chemical kinetics models, bubble growth and pseudo-fluid model at the s ale of the final p oduct.*

The idea of Open Source software has been crucial to my career, making a major impact in the realm of simulation tools. It is no longer necessary to convince commercial software developers to implement new physics models: this can be done independently. The Open Source release of OpenFOAM in 2004 has been crucial for its subsequent acceptance by the community. Today, OpenFOAM serves tens of thousands of users in industry and academia and has become a dominant simulation and collaboration tool. It has revolutionised the approach to complex physics model development and completely undermined the price of competing commercial tools. I am particularly pleased to observe researchers tackling problems which were considered impossible when Open-FOAM was conceived, or to use the software as a means of knowledge transfer between research groups or industrial partners. OpenFOAM is also the 'work-horse' simulation tool of choice across industrial sectors, demonstrating its capacity in practical product design and delivering powerful simulation capability at low cost.

This is a true democratisation of simulation ability, both for current and future requirements, matching the remit of the Maxwell Centre and UK Research and Innovation (UKRI): the deployment of blue-sky research into industry.

Modelling Multi-Scale Phenomena

Continuum mechanics is a convenient tool for analysis of 'human-sized' objects consisting of billions of fundamental particles: the behaviour of the basic building blocks of matter can be successfully 'averaged out' to simulate macroscope behaviour. The fluid flow equations are just one such example.

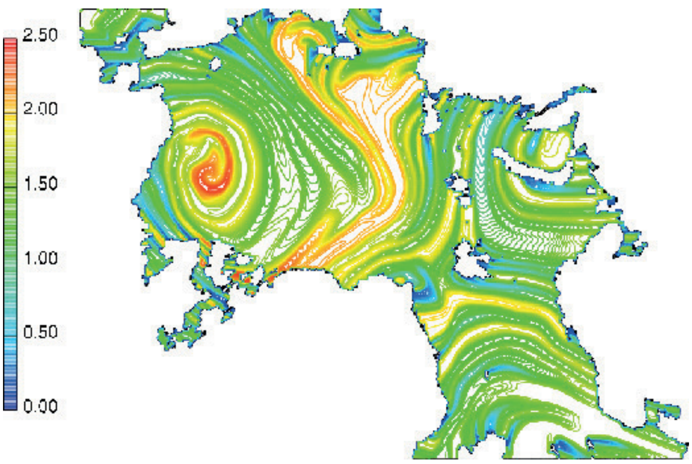


Figure 2. *Polar sea ice modelled as a '2-D continuum' of broken-up floes in a global clima e model. Sub-scale effects a e captured as a viscous-plastic deforming plate.*

More often than not, molecular phenomena break this idyll: lubricated surface-to-surface contact, multi-phase fl w in porous structures, surfactant physics or contact angle effects often break the continuum assumption. The fundamental answer is at the atomic scale.

Suddenly, continuum equations are not simply providing up-scaling, but require detailed information on underlying atomic phenomena. Direct atomistic simulation remains impractical: the number of fundamental particles is unreasonably high or requires excessive computing power and time, be it in surface interaction of chemical compounds that control friction or in the sheer number of 'fundamental particles' in a galactic-scale simulation. Up-scaling of atomistic effects and coupling to continuum-type models with data exchange across scales has the potential to become a driving force in new product development and optimisation. Applications range from photo-voltaic materials, electrostatic deposition, catalytic surfaces, new types of electro-chemistry and optimisation of batteries, surface friction effects, magneto-hydrodynamics simulation, fusion reactors, simulation of the four states of matter and micro-scale fluidic . I see these challenges as the future of multi-scale, multi-physics computational research.

A Short CV

Hrvoje graduated in Mechanical Engineering at the University of Zagreb, Croatia and continued with a PhD in CFD at Imperial College London. During this time he has initiated the work on the Open-FOAM numerical simulation library for computational modelling in continuum mechanics, which is the basis of his work.

After a stint with commercial CFD companies working on methods and software development, Hrvoje created a research group at the University of Zagreb, focused on practical applications of CFD tools, from turbo-machinery, naval hydrodynamics, free surface fl ws, turbulence modelling, solid mechanics and other areas. He has contributed to the numerical methodology and HPC support of modern simulation software, with a special enthusiasm for complex heat and mass transfer systems and computational multi-physics.

Antiferromagnets and Ultra-fast Magnetic Storage

Many congratulations to *Chiara Ciccarelli* on her appointment as a Harding University Lecturer in the Laboratory. Here she describes her research on overcoming the problems of creating ultra-fast magnetic storage devices operating close to the fundamental limits.

In my group, research focusses on magnetically ordered materials such as ferromagnets and anti-ferromagnets. Our aim is to use new quantum and topological notions in condensed matter physics to read and write their magnetic state at a speed and with energy consumption close to the fundamental physical limits. This is important in the context of magnetic storage, where the explosive growth of cloud computing over recent years has put a great strain on existing storage technologies.

Ferromagnets are now extensively used for the non-volatile storage of information. Non-volatility means low energy since the stored information does not need to be continuously refreshed as is the case in other charge-based memories such as DRAM. Non-volatility and speed have, however, so far been considered incompatible since ferromagnets have typical switching times of 100's of picoseconds. Pushing this limit down to the switching speed of a charge transistor (<5 picoseconds) would allow integrating the memory component to the logic plane, substantially reducing the energy and time wasted during the continuous exchange of information between these two elements. This is the reason why we recently became interested in antiferromagnets, which naturally combine long-range magnetic order with magnetic dynamics that are three orders of magnitude faster than ferromagnets..

Despite these optimal characteristics, the magnetic state of an antiferromagnet is not so easy to read and manipulate with macroscopic methods, since from the macroscopic point of view an antiferromagnet is a non-magnetic material. Our approach is to explore new fundamental physics that allows us to access the microscopic order within the antiferromagnet on ultra-fast timescales. The questions we ask ourselves are : Can an antiferromagnet emit a net spin-current, despite having an overall zero-magnetisation? How well can spins travel in an antiferromagnet? How do the staggered moments within an antiferromagnet react to a spin stimulus? One concept that we are exploring to answer some of these questions is how symmetry breaking can be used to transduce the magnetic state into an easily readable electrical signal.

Symmetry breaking has interested us for some time. Symmetry and symmetry breaking are what define the laws of our Universe. In the context of spintronics, we found that when symmetry is broken within a spin-orbit coupled crystal, spin and charge become entangled and it is possible to change from one to the other. This leads to the possibilities of switching a magnet by a current pulse or, vice-versa, and of reading out magnons (the quanta of magnetic excitations) electrically. Being able to write and read a magnetic state electrically is extremely important for the design of miniaturised devices that operate on printed circuit boards and points the way towards solid-state solutions for memory and sensing.

Another exciting direction that we are exploring in the context of low-energy computing is superconductivity. In collaboration with Jason Robinson of the Department of Materials Science and Metallurgy, we have been investigating the possibility of using a superconductor as a dissipationless track to transport spin, the natural carrier of the information. This seems initially paradoxical since Cooper pairs are in a singlet state, but we have recently shown that a triplet condensate emerges when the superconductor is coupled to a magnetic element and a heavy paramagnet. The next question is how quickly this can occur.

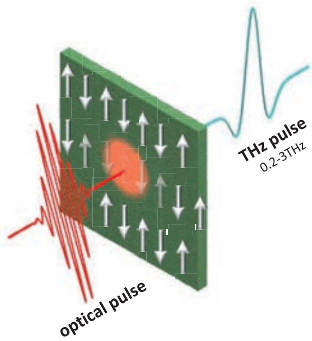
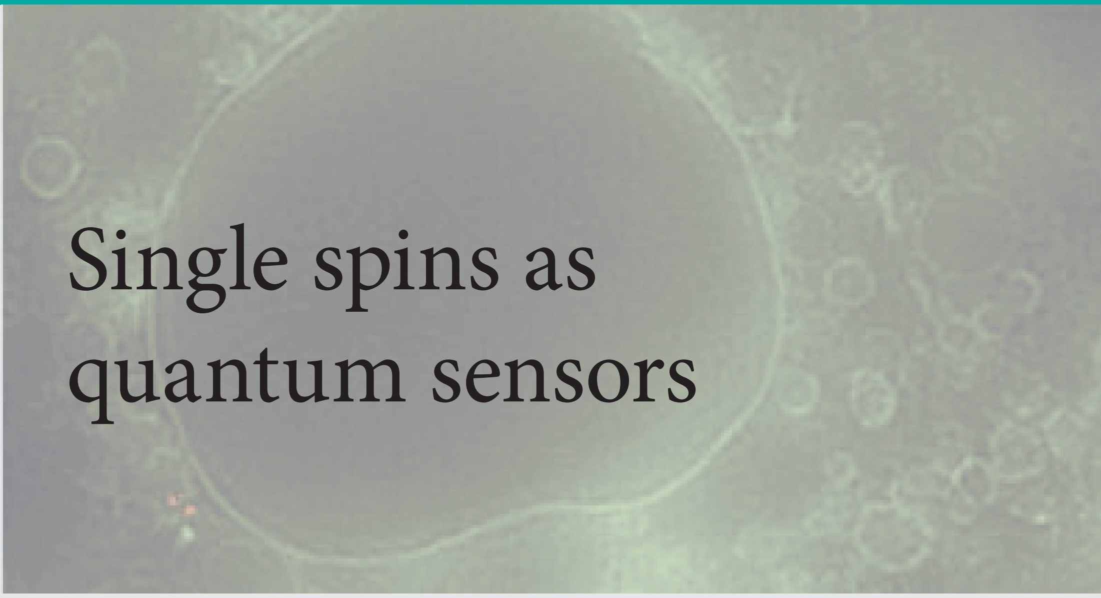


Fig 1. *Reading an antiferromagnet on picosecond timescales involves time-resolved THz spectroscopy. We excite spin dynamics with a femtosecond optical pulse and read the THz electromagnetic radiation that is generated as a consequence. Our THz lab is located in the Maxwell Centre and is run jointly with Hannah Joyce, Reader in the Department of Engineering.*

The experimental techniques that we use for most of these studies need to possess the right time resolution. In our laboratory we have different set-ups that allow measuring electrical signals with a bandwidth that spans from DC up to the THz frequencies. A Winton Advanced Research Fellowship in 2016 allowed me to setup a time-resolved THz spectroscopy laboratory in the Maxwell Centre, which has been absolutely crucial to approach the study of sub-picosecond spin processes in magnetically ordered materials and enter the field of ultra-fast spintronics.

A Brief Biography: Chiara graduated in Theoretical Condensed Matter Physics at Tor Vergata University in Rome in 2008. She received her PhD from Cambridge in 2012 and from 2012 to 2016 held a Junior Research Fellowship at Gonville and Caius College. In November 2016 she set up her research group at the Cavendish Laboratory thanks to a Winton Advanced Research Fellowship. In October 2017, she became a Royal Society University Research Fellow and since October 2019 has been a Harding Lecturer in the Department.



Single spins as quantum sensors

We congratulate warmly *Helena Knowles* on her appointment as a University Lecturer in the Laboratory. Here she describes how she and her colleagues control interacting spins for nanoscale sensing and quantum simulation.

Observing physical phenomena without perturbing the system of interest is a fundamental problem in experimental research. The more fragile the system, the harder the task. This is especially challenging when probing nanoscale phenomena, where the laws of quantum mechanics govern the static and dynamic behaviour of a system. A probe needs to interrogate the system without disturbing its quantum coherence or local properties.

In my laboratory, we use a single electronic spin as a quantum sensor of local, nanoscale properties of soft and solid state matter. The spin is trapped to an impurity in a diamond crystal, which allows coherent quantum control of its spin state through optical and microwave excitation. This defect, the nitrogen-vacancy (NV) centre in diamond, is exceptional, in that it maintains long spin coherence even at room temperature, allowing its application to a diverse range of systems. The spin energy levels respond to changes in its nanoscale surroundings, shifting in characteristic ways depending on whether it is subjected to changes in external magnetic field, electric field, temperature or pressure.

The NV-centre sensor provides the ultimate spatial resolution, because of its size extending over only a single atomic site, and non-invasive operation because its sensing mechanism only involves the response of a single electronic spin to its environment. This allows us to detect single electronic spins tens of nanometres away from the NV centre and single nuclear spins a few nanometres away.

Conventional nuclear magnetic resonance (NMR) spectroscopy relies on acquiring a signal from a macroscopic volume of identical molecules to provide structural information on the single molecule level. Transferring this technique to nanoscale sample sizes would enable the probing of local chemical environments in biologically relevant samples on the sub-cellular scale. We use NV centres embedded in diamond nanocrystals of only about 20 nm diameter to perform NMR experiments that are sensitive to nanoscale volumes of the order of thousands of molecules.[1] These sensors can be applied to complement fluorescent-dye based indicators that are widely used to measure the concentration of chemical species within cells, but suffer from several challenges, including bleaching, low chemical specificity, high toxicity and the need for careful calibration of factors such as temperature and pH (Figure 1).

Together with colleagues in Physics and Biochemistry, we are also investigating the nanoscale temperature landscape in living cells, in a project aimed at shedding light on the effects of the rise in ocean acidity and temperature on the symbiotic relationship between single cell algae and corals.

NV centre probes can also help reveal the underlying physics of complex electronic systems in novel materials. To that end, we are building a diamond-based scanning probe system with a 3-axis external magnetic field, which allows us to probe spin textures and conductance features in thin film materials on the nanometre scale. We will be exploring the dynamical behaviour of chiral domain wall motion in synthetic antiferromagnetic materials, which are a promising system for low energy, ultra-dense memories. The interplay of competing interactions at interfaces results in unexpected phenomena, which we aim to image at the nanoscale.

The goal of non-invasive probing is closely linked to another task: extracting information about a complex quantum system acting as a quantum simulator. Two-dimensional interacting dipolar systems are currently out of reach for simulations using a classical computer and are of fundamental interest for the behaviour of many-body interacting quantum systems. Quantum simulators built of cold atoms to investigate many-body localisation effects have already produced exciting insights into the ergodicity and localisation behaviour of interacting arrays. Trapping particles with long range interactions, such as dipolar interactions, remains however a challenge and finite atomic motion complicates the interpretation of the results.

Continued overleaf

We are building the capability to simulate dipolar interactions in two dimensions using different types of defects in diamond, interfaced with a nuclear spin array hosted in a 2D material. 2D materials naturally provide a perfect, static 2D spin array, with dipolar interactions between non-zero spin nuclei. We aim to study thermalisation behaviour and many-body quantum phenomena using these nanoscale quantum simulators. Through local spin injection using the NV centre, we can generate out-of-equilibrium spin states on the nanoscale and probe their evolution over time. The interacting spin array can be tuned to different regimes of interaction type and disorder strength thanks to a new toolbox for Hamiltonian engineering that we have recently developed[2,3] (Figure 2). Such a tunable quantum simulator can allow us to map out the phase space of complex interacting spin systems and lead to a better understanding of quantum thermodynamics and open quantum systems.

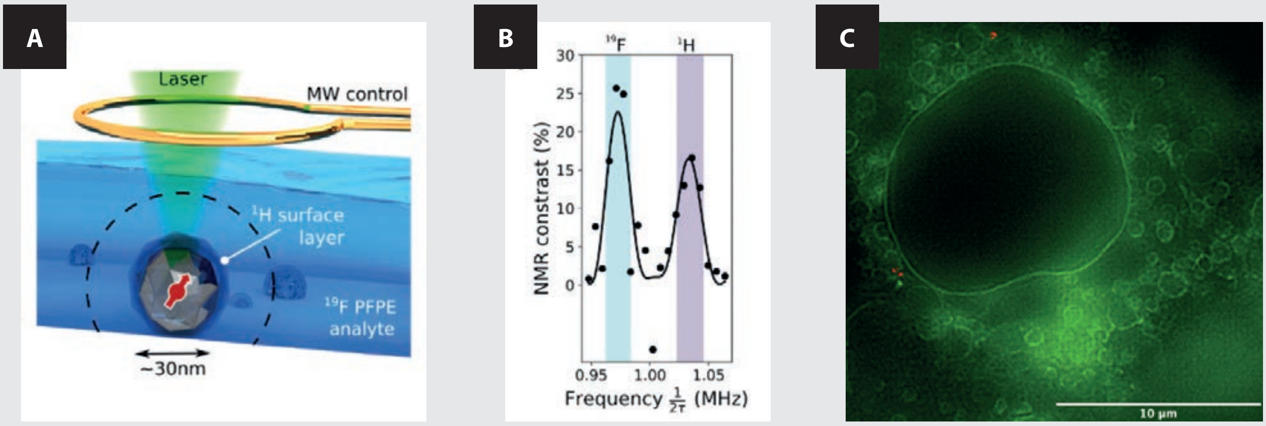


Figure 1: a) Illustration of the nanodiamond NMR probe b) NMR signal from ~10,000 ^{1}H and ^{19}F nuclear spins surrounding the nanodiamond in Fomblin oil.[1] c) Structured Illumination Microscopy image of a human kidney cell with nanodiamond sensors emitting red photons.

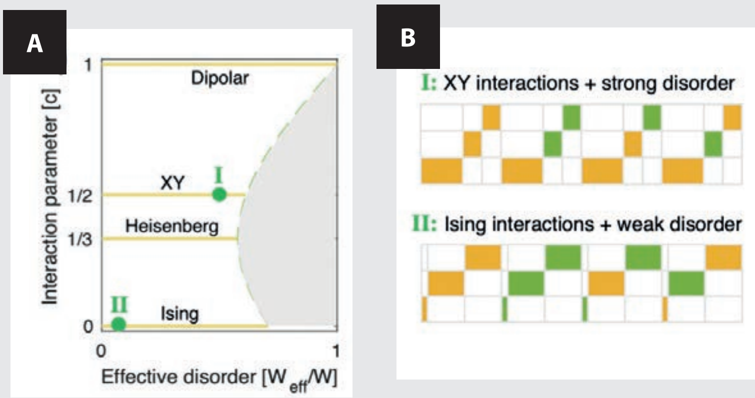


Figure 2: a) Interaction and disorder tuning for Hamiltonian engineering and b) pulse sequences designed using the toolbox.[2,3]

'Observing physical phenomena without perturbing the system of interest is a fundamental problem in experimental research. The more fragile the system, the harder the task.'

Helena Knowles

References

1. Liquid NMR in a nanoscale volume using diamond nanocrystals: J. Holzgrafe, Q-S.Gu, D. M. Kara, H. S. Knowles and M. Atature. Phys. Rev. Appl. 13 044004 (2019)
2. Robust Dynamic Hamiltonian Engineering of Many-Body Spin Systems: J. Choi, H. Zhou, H. S. Knowles, R. Landig, S. Choi, and M. Lukin. Phys. Rev. X 10 031002 (2020)
3. Quantum Metrology with Strongly Interacting Spin Systems : H. Zhou, J. Choi, S. Choi, R. Landig, A. M. Douglas, Junichi Isoya, Fedor Jelezko, S. Onoda, H. Sumiya, P. Cappellaro, H. S. Knowles, H. Park, M. D. Lukin. Phys. Rev. X 10 031003 (2020)

The 1931 Maxwell Centenary Celebrations

'The number of these centenaries is becoming a nuisance'

Ernest Rutherford to William Bragg, 1928

***Grace Exley* describes some remarkable recent discoveries which cast a revealing light on the 1931 Centenary Celebrations of Maxwell's birth.**

The years 1927 to 1931 were overfl wing with scientific anniversaries. 1929 saw the centenaries of the deaths of Alessandro Volta, Humphry Davy and Thomas Young; the Society of Chemical Industry celebrated its fi tieth anniversary in 1931, and the bicentenary of the death of Isaac Newton took place in 1927.

So numerous were these commemorations that both Bragg and Rutherford were required almost to become part-time party planners, most notably in 1931. Marking the centenaries of Michael Faraday's discovery of electromagnetic induction, the birth of James Clerk Maxwell and the founding of the British Association for the Advancement of Science, the events of 1931 attracted the largest celebrations. They took place on the eve of 1932, the 'annus mirabilis' of nuclear physics, which would see the discovery of the neutron by James Chadwick, that of the positron by Carl Anderson, and Cockcroft and Walton 'splitting the atom'. As discussed elsewhere,[1] the Faraday and BA centenary celebrations were held in London and were on a very much larger scale than the Cambridge events, which commemorated the life of James Clerk Maxwell.

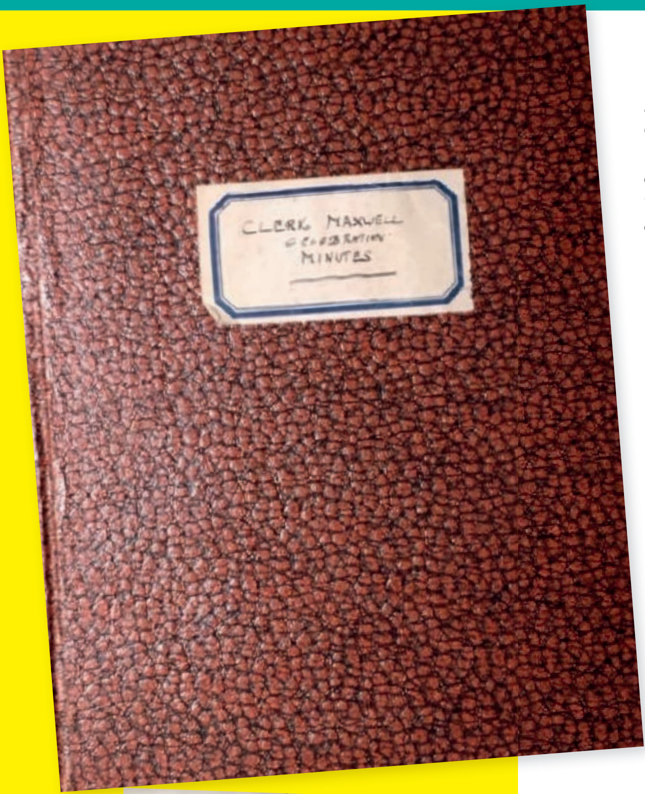
Recently, extensive primary source material has come to light about the organisation and activities surrounding the Maxwell Centenary Celebration in Cambridge. With the move of the Cavendish Laboratory to the new buildings in prospect, the cataloguing and preservation of historic materials have been carried out, during which a number of significant finds ere made. These included the Minute Book of the Committee to organise the Maxwell Celebration, the handbooks for the Celebration itself and, perhaps most remarkably, a very early colour film of the ceremonial procession from Corpus Christi College along King's Parade to the Senate House. The film was ound in a small, rusting canister during the clear-out of the Cockcroft Lecture Theatre (Fig. 1, bottom).

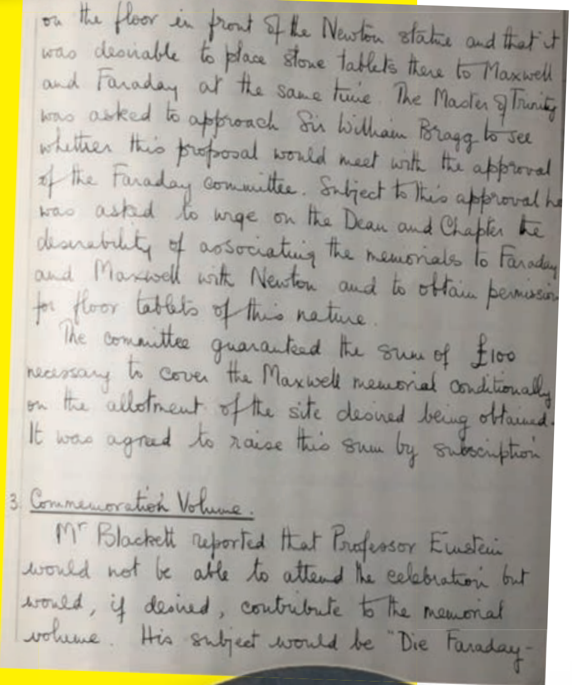
Ernest Rutherford, the Cavendish Professor of Physics, called a preliminary meeting to discuss the possibility of holding a Maxwell Centenary Celebration on Wednesday 30th September 1930. The Committee included Will Spens, the University's Vice-Chancellor and Master of Corpus Christi, J.J. Thomson, George Searle, Piotr Kapitsa, John Cockcroft and C.T.R. Wilson. The suggestion that Maxwell should be celebrated met with unanimous agreement. Rutherford 'stressed the desirability' of the University's involvement in the festivities, with Thomson remarking on Maxwell's lack of recognition during his lifetime. Searle suggested that the Large Lecture Room, in which the meeting was held, should be renamed the Maxwell Lecture Room in his honour. The minute also suggests that a centenary celebration would benefit the standing of the Uni ersity, whilst James Jeans remarked that the celebration ought to 'bring home to the world the practical uses of the mathematical physicist'.

Rutherford also sat on the committee for the Faraday Centenary and suggested that the Maxwell festivities immediately follow the Faraday Celebrations. The dates were fi ed for 30th September to 2nd October 1931. The first official comm ee meeting took place forty-fi e minutes after the preliminary meeting and a provisional programme was devised.

A remarkable list of lecturers and attendees was drawn up, including representatives of many major national and international learned societies. Because of the deliberately close proximity in time of the three major celebrations, the international representatives could 'kill three birds with one stone.' In a remarkable table in the *Reporter*, there is a long list of the guests and the Cambridge academics who offered accommodation and hospitality in their own homes.

1 *Grace Exley, Part II dissertation, The 1931 Maxwell Centenary Celebrations, Department of History and Philosophy of Science, University of Cambridge.*





on the floor in front of the Newton statue and that it was desirable to place stone tablets there to Maxwell and Faraday at the same time. The Master of Trinity was asked to approach Sir William Bragg to see whether this proposal would meet with the approval of the Faraday Committee. Subject to this approval he was asked to urge on the Dean and Chapter the desirability of associating the memorials to Faraday and Maxwell with Newton and to obtain permission for floor tablets of this nature.

The committee guaranteed the sum of £100 necessary to cover the Maxwell memorial conditionally on the allotment of the site desired being obtained. It was agreed to raise this sum by subscription.

3. Commemoration Volume.

Mr Blackett reported that Professor Einstein would not be able to attend the celebration but would, if desired, contribute to the memorial volume. His subject would be "Die Faraday-

Figure 1: (top) The Minute book of the Maxwell Centenary Celebration Committee. (middle) The page of the minutes recording Einstein's inability to attend the celebrations with his offer to contribute to the memorial volume. (bottom) The canister containing the colour film of the procession on 1 October 1931.

Following the unveiling of the commemorative plaques to both Maxwell and Faraday in Westminster Abbey on the 30th September by J.J. Thomson, the programme of activities began in earnest with lunch courtesy of the Vice-Chancellor in Corpus Christi College on 1st October. The formal procession to the Senate House was filmed in colour to be shown at the end of the following day's proceedings. The inaugural lecture was given by J.J. Thomson followed by tea at Peterhouse. The next morning, lectures were given by Max Planck, Joseph Larmor and Neils Bohr and in the afternoon by former associates of Maxwell, William Garnett, Ambrose Fleming and Oliver Lodge as well as by James Jeans. Einstein was invited but was unable to come, though he contributed to the subsequent memorial volume.

Finally, the Laboratory was host to a display of Maxwell's personal effects and experimental apparatus as well as those of Rayleigh and Thomson (Fig. 2). In addition, there were rooms reserved for demonstrations of current Cavendish research, with exhibitors including Rutherford, Chadwick, Cockroft, Walton and a number of others.

As a final entertainment, the colour film had been processed overnight and was shown to delegates in the Cavendish Laboratory after the Celebration Dinner. The film was produced by Thomas Thorne-Baker, of Messrs Spicer Ltd., a company based in Sawston. Thorne-Baker was also charged with reconstructing Maxwell's original three-colour projection of a tartan ribbon, to be shown before the film itself. The film was made using a process called 'Dufay Colour', which had only been invented in the previous year. The result was a colour film lasting just over a minute of the academic guests making their way to the Senate House on October 1st (Figs. 3 and 4). This was a unique celebration of Maxwell's work in the fields of colour and light. The film was professionally digitised in 2019 and is a remarkable achievement.

The film shows the procession from Corpus Christi College down King's Parade with people lining the streets, but with a distinct sense of normality. A window cleaner goes about his business, and people seem to be enjoying the passing show.

It was agreed that the lectures should be bound in a volume published by Cambridge University Press. *James Clerk Maxwell: A Commemoration Volume* (1931) features contributions from all of the above speakers, and also essays by Einstein, Richard Glazebrook, and Horace Lamb. Two striking aspects of the volume are , first, the promotion of Maxwell as deserving much more recognition than he had received during his lifetime, and, second, as a 'Cambridge man'.

It is planned that this unique film of the Maxwell celebration will be made available on-line in the near future.

This project began as a part of a 2019 Summer UROP project in the Cavendish Laboratory supervised by Isobel Falconer and Malcolm Longair.

Figure 2: A photograph of the 1931 exhibition in what was normally Searle's practical class. The numbered tables corresponded to the Handbook, in which the artefacts on display were explained. The exhibition includes the portraits and manuscripts of Maxwell on the back wall.

Figure 3: A still taken from the beginning of the film, sh wing the figu es of Oliver Lodge and Francis Aston in their doctoral gowns leaving Corpus Christi College as they processed to the Senate House.

Figure 4: A still from the film. In the bac ground, the window cleaner can be seen going about his business, whilst in the foreground the 'brilliant blue of Prof. Cabrera's robes being particularly well reproduced' makes Blasé Cabrera easily identifiabl .

Figure 1. David Harding introducing the 8th Winton Symposium

2020 Winton Symposium - Fusion Power

The 2020 Winton Symposium went ahead on Thursday, 3 September, 2020. Because of the Covid-19 pandemic, David Harding, sponsor of the Winton project, generously made available the outdoor setting of his estate near Henley-upon-Thames for a meeting on a topic in which he has a special interest, nuclear fusion power (Fig. 1). The Government's rules about social distancing and all the necessary precautions were strictly followed. We thank the Winton team for making this rather special meeting possible.

The theme of the 8th Winton Symposium was **Fusion as an Energy Source: Challenges and Opportunities to Accelerate Development**. The scene was set by **Mikhail Gryaznevich** and **David Kingham**, founders of the company Tokamak Energy, a spin-off from the Culham Centre for Fusion Energy, also known as UKAEA. As they summarised:

'The world needs new, clean, safe, sources of energy. Fusion is a promising source, but development has been very slow in the hands of large government projects. Public investment has been primarily in conventional tokamaks and more recently spherical tokamaks. Private investment in fusion is now accelerating, but the technical challenges are huge. Innovative approaches will be required to accelerate development. Tokamak Energy is particularly interested in using scientific and engineering techniques developed outside fusion energy research in order to progress more rapidly.'

Mikhail and David described the considerable progress, which has been made in developing sustainable fusion reactors. Adopting the spherical Tokamak configuration, they have already constructed successful machines, achieving temperatures of 15 million degrees, the central temperature of the Sun. The experience of the JET tokamak at Culham and the scientific evidence assembled to guide the design of the huge international ITER project have shown that sustainable fusion energy is achievable. The objective of the Tokamak Energy programme is to construct a commercial machine on a scale a third or less than that of ITER at increased speed and at very much reduced cost

Fig. 2. The lecturers: Mikhail Gryaznevich and David Kingham, David Cardwell, Judith Driscoll, Nikos Nikiforakis and Chris Pickard.

The challenges remain very considerable. In order to create large enough confinement ma netic fields within the okamak, high temperature superconducting magnets need to be developed to carry the huge currents needed to confine the high emperature plasma within which nuclear generation of energy through the deuterium-tritium reaction chain takes place.

David Cardwell and **Judith Driscoll** of Cambridge University described the many challenges in creating both bulk high temperature superconductors and tapes which can form the windings of the superconducting magnets. David described how (RE)-Ba-Cu-O[1] high temperature superconductors (HTS) have significant po ential for high field en ineering applications at temperatures above 50 K when fabricated in the form of large single grains by the so-called top seeded melt growth process (TSMG). He described the evolution of these technologically important materials over the past thirty years, the current state of the art and highlighted likely areas for future development.

Judith noted that there are two approaches to confining the plasma in which fusion can occur. The first, adop ed by the major publicly-funded $20bn international project ITER and its planned successor DEMO, is to use conventional low-temperature superconductors but increase the size of the reactor. The second, now possible with the advent of commercial-scale high temperature superconductor tape manufacture, enables the strength of the confining ma netic field o be increased. She discussed how engineering of the materials is central to achieving the very high fields equired.

After a splendid outdoor barbecue lunch, **Nikos Nikiforakis** discussed the *Multiphysics* modelling of fusion reactors. Numerical simulation has contributed significantly o the design and optimisation of these devices, accelerating their development and reducing development costs. Recent reviews have identified limitations of the cu rent models, in terms of their numerical capabilities and their ability to capture the strongly nonlinear interaction of the physical processes taking place at the various regions of the reactor.

Fig. 4. After the rains came, we all moved into a marquee. The panellists, chaired by Andy Parker, are (left to right) Judith Driscoll, Matthew Aragwala, Simon Taylor, and Simon Bittleston. In the front row, from the left, The British Ambassador of the UAE, David Harding and Stephen Toope.

The multiphysics approach can directly resolve more physical processes and their nonlinear interactions across a broader range of temporal and spatial scales than current models. The proposed framework will eventually be the most complete description of fusion reactors to-date, going beyond the predictive modelling capability of current models. It will accelerate the hardware development, complement and support experimental campaigns, augment the understanding of experimental results and provide the opportunity for scientific disc very.

Fig. 3. The rains came!

Chris Pickard discussed powerful computational techniques to study materials under extreme conditions, specificall , at extreme compressions and/or temperature. The development of robust algorithms for the quantum mechanical simulation of materials properties, and a dramatic growth in computational power, allow virtual experiments to be performed, which have dramatically changed our understanding of materials under extreme conditions. This includes the solid phases of hydrogen, superconductors operating at close to room temperatures, and a surprising complexity in dense matter.

The meeting concluded with a **Panel Discussion** entitled P*athways to Fusion Energy Commercialisation*. The Panel members were Judith Driscoll, Matthew Aragwala (Cambridge Bennett Institute for Public Policy), Simon Taylor (Cambridge Judge Business School), and Simon Bittleston (previously Vice-President of Research, Schlumberger Cambridge). There seem to be no insurmountable scientific and engineering barriers to the construction of commercial fusion reactors. More complex are the political and social contexts within which these programmes could go ahead. In recent years, the *Fusion Industry Association (FIA)* has been created as the voice of the blossoming industry to tackle some of these non-scientific challenges to commercial fusion power. There does not seem to be public reaction against nuclear fusion reactors, which are a 'clean' form of nuclear energy generation. There is a good case that, even in an era of maximum use of renewable energy generation, there will always be times when natural renewable sources of power are not available. The costs of the new generation of fusion reactors are large, but not impossibly large, for the UK to take a major leap into the future.

The closing remarks were made by **Stephen Toope**, Vice Chancellor, University of Cambridge, who emphasised Cambridge's ability to respond to the major challenges described during the meeting. The current construction of the new Cavendish Laboratory provides a state-of-the-art facility for taking up some of the most difficul problems facing the physicists and engineers for the benefit of socie y.

1 *(RE)BCO, where RE = rare earth element such as Y, Nd, Sm, Eu, Gd, etc.*

The Ray Dolby Centre –

Progress during the 2020 Pandemic

Fig. 1. Chillers on the roof.

Fig. 3. First fix Mechani al, Electrical and Plumbing (MEP) and partitions in wing 4.

Fig. 2. Central Utilities Buildings Wing 4 facades

Fig. 4. Wing 5 lecture theatre inclined slab

Fig. 5. The Shared Facilities Hub facades with orange panels.

***Neil Pixsley*, Project Director, Bouygues UK, has kindly provided the following description of progress on the Ray Dolby Centre through a very demanding period.**

Since the last edition of CavMag, the world has been hit by the Covid-19 pandemic and the construction site was not immune to it. Operations were put on hold for several weeks in order to complete a full risk assessment and to ensure that the site staff could eep working safely. Several key improvements have been implemented, including an upgrade of the welfare facilities, extended staggered shifts, mandatory use of medical masks when the 2m distance cannot be guaranteed, and so on.

The number of people on the site has increased steadily since activities resumed at the end of April reaching 400 people at the end of July, with a peak over 500 expected in the autumn. This mobilisation has driven impressive progress in all work areas.

The concrete structure of the Ray Dolby Centre is 90% complete, with around 30,000 m^3 of concrete already poured and the 5,000 T steel structure is in progress. The first of the entral Utilities Buildings (CUBs) is now host to some of the main plants of the project, with the high-voltage switchboards, the ground source heat pumps and the chillers now delivered. (Fig. 1). It also gives a glimpse of the finished façade works, with the first 12 panels of polished whi e concrete installed (Fig. 2). Just 1,118 to go…

Works are also in progress in some of the building's ten courtyards, which are essential to achieving the water-tightness of the envelope.

The first fix dis ibutions of mechanical and electrical trades flou ish throughout, with most areas in the teaching wing (wing 4) and in the offices of the upper vels (in wing 3) now filled with wa er pipes, ductwork, electrical cable trays and partitions (Fig. 3).

The deposition clean rooms are also progressing as all the concrete is sealed with epoxy paint and getting ready for the MEP installations. The fi -out works have started in the low-vibration basement and are expected to take 8 to 10 months due to the high complexity of the services. The cryostat halls in wing 1 have been cleared of all their concrete formwork and still have two floors of office o be constructed above.

The public wing (wing 5) is the last one in the sequence. It already displays some polished concrete columns on the main façade fronting JJ Thomson Avenue and the inclined floor o the future Ray Dolby auditorium. (Fig. 4).

Outside the site boundaries, essential infrastructure upgrade works are still on-going and following a complex phasing to minimise impact on adjacent buildings. The new buildings are now (almost) connected to the water, gas and power networks, while the drainage connections are in progress.

Also included in the overall construction contract, the Shared Facilities Hub building is starting to take shape. The structure and the roofing have been completed and the facades are in progress, with the start of the signature orange cladding panels (Fig. 5). Internally, the trades are in full speed and one can start to get a feel for the future spaces: the entrance atrium, the café and the cafeteria in the ground floo , the teaching rooms and study areas in the upper levels.

Ondrej Krivanek - Winner of the 2020 Kavli Prize in Nanoscience

Photograph of Ondrej Krivanek. Courtesy of Creative Commons, photographed by Tlovejoy125.

***Ondrej Krivanek* has received the 2020 Kavli Prize for Nanoscience, along with German researchers Harald Rose, Max Haider, and Knut Urban, for his work on 'sub-ångström resolution imaging and chemical analysis using electron beams'.**

Fig 1. The original Krivanek/Dellby aberration corrector for Scanning Transmission Electron Microscopes, now on display in the Cavendish display of historic scientific instruments.

Since completing his Ph.D. in the Cavendish Laboratory under Archie Howie in 1975, Ondrej has been at the forefront of pioneering advances that have endowed electron microscopy with the ability to image and analyse matter atom-by-atom. His early work improved an existing electron microscope and used it to image directly, for the first time, the atomic structure of defects in semiconductors. He next designed several instruments for electron energy loss spectrometry (EELS). These techniques are now used by hundreds of researchers world-wide. He also co-authored an EELS atlas, which is a standard reference source for spectra. His development of the electron optical systems for the spectrometers enabled him to understand how to correct the aberrations inevitably suffered by traditional round electron lenses.

In 1994, Ondrej, Mick Brown and Andrew Bleloch were successful in winning funding from the Paul Instrument Fund of the Royal Society to support the building of an aberration corrector at the Laboratory. Niklas Dellby joined the project and by 1997 they had built a practical aberration corrector, thereby reaching a goal that had remained elusive for some fifty years. Attempts in the 1960s at the Cavendish to produce a corrector by Deltrap and others were bedevilled by the problems of tuning using analogue controls and imaging. An essential ingredient of the Krivanek/Dellby corrector for a scanning transmission electron microscope (STEM) was the use of computer control and analysis that quantifies parasitic aberrations arising in complex electron-optical systems and nulls them one by one (Fig. 1).

Their novel microscopes, manufactured by Nion, the company they founded in 1997 near Seattle, are now able to map chemical elements in solid samples with atomic resolution and single atom sensitivity. Such is the resolution in both space and energy that one can observe and analyse both chemical bonding and vibrational modes of individual atoms. The UK's national centre for scanning transmission electron microscopy, SuperSTEM at the Daresbury Laboratory, provides access to these types of facilities for research ranging from monolayer structures such as graphene to semiconductor interfaces and molecular dynamics.

We are delighted that Ondrej is a joint recipient of the prestigious 2020 Kavli Prize.

Philip (Phil) Anderson

1923-2020

The Department was very sorry to learn of the death of Philip (Phil) Anderson, who died on 29 March 2020.

Phil Anderson was arguably the pre-eminent condensed matter theorist of the twentieth century. He made numerous foundational contributions to the understanding of magnetism, superconductivity and disordered materials. He was awarded the 1977 Nobel Prize in Physics, shared with John van Vleck and Nevill Mott, for 'fundamental theoretical investigations of the electronic structure of magnetic and disordered systems.'

Phil was an important and influential figure within the Cavendish Laboratory. Nevill Mott was successful in inviting a number of world-leading many–body physicists to the Laboratory and among these Phil came for the Academic Year 1961-62. When John Ziman moved from Cambridge to Bristol in 1964, Nevill Mott succeeded in creating a new Professorship of Physics (1966) and Phil held this post half-time from 1967 to 1975. He also became Head of the Theory of Condensed Matter Group, assisted by Volker Heine and Sam Edwards. He delighted to point out that, in naming this group, he introduced the term 'Condensed Matter Physics.'

The TCM group burgeoned under his leadership. As he wrote:

'From the mid-1960s, we began to get really first rate UK students including Richard Palmer, Alan Bishop, John Armitage, Mike Cross, Duncan Haldane, Roger Bowley and John Inkson on the many-body side, with Dave Bullett, John Inglesfield, John Pendry and Denis Weare on the 'one-electron' theory.'

On the scientific side, among his notable achievements while in Cambridge was the *theory of spin glasses* which he carried out with Sam Edwards and published in 1975.

Phil was a major agenda setter in condensed matter physics for more than 50 years, both through his own work and through his inspirational influence on those around him. His research papers and more general writings defined the subject, notably through his textbook 'Concepts in Solids' based on his Cavendish lecture course. His 1972 article 'More is Different' pointed out the limitations of reductionism and emphasized that fundamental laws of nature can have 'emergent' properties markedly different from those of the constituents. He used his insights in superconductivity to explain how mass can be generated by the breaking of gauge-symmetry and pointed out the relevance to fundamental particle physics.

His time in Cambridge, and his ongoing connections and support for the work carried out in the TCM Group, made Phil a colleague and friend to many members of the Cavendish. He will be much missed, not only by us, but by the whole physics community.

4 August 1972, Volume 177, Number 4047 **SCIENCE**

More Is Different

Broken symmetry and the nature of the hierarchical structure of science.

P. W. Anderson

'He used his insights in superconductivity to explain how mass can be generated by the breaking of gauge-symmetry and pointed out the relevance to fundamental particle physics.'

James (Jim) Scott
1942 - 2020

Jim Scott was a larger than life personality, who made major contributions to the field of erroelectrics. After studying at Harvard and working at Bell Laboratories, he spent a long period on the faculty at the University of Colorado, where he integrated ferroelectrics with silicon, co-founded the Symetrix Corporation and paved the way towards the commercial applications that we enjoy today. There followed many years in Australia, where he both occupied high offic and maintained his research output.

Jim joined the Department of Earth Sciences in Cambridge in 1999. On reaching the statutory retiring age, the then Head of the Cavendish Peter Littlewood brought him to the Laboratory as a Director of Research. In both Departments, he continued to make major contributions to his core field of erroelectrics, while returning to multiferroics in Earth Sciences and working on quantum criticality at the Cavendish. After finally etiring from Cambridge, Jim had more very productive years in St. Andrews, before retiring to Cambridge in fading health in early 2020. Jim's many achievements include writing the canonical book *Ferroelectric Memories* (2000) and being elected a Fellow of the Royal Society in 2008. His citation refers to him as 'the father of integrated ferroelectrics,' meaning ferroelectric crystal memory thin films attached o silicon or GaAs computer chips.

Jim was awarded the Materials Research Society (MRS) gold medal in December 2008 'for fundamental contributions to the materials science of oxides underlying current and future electronic devices', and the Jozef Stefan Medal from Slovenia in March 2009. Of the 20 Top Papers selected each year by the editors of the Journal of Physics Condensed Matter, Jim was author of 3 in 2008 and 2 in 2007.

Jim had a huge following amongst his former students and collaborators around the world, to whom he was both a wonderful mentor and a great friend.

We pass on our condolences to his wife Galya and family.

John Adkins
1934 – 2020

Figure (right): John at the opening of a new helium liquefier acility in the Low Temperature Physics group. Behind him is the earlier Ashmead liquefier used in the Mond aboratory before the move to West Cambridge.

Members of the Department will be saddened to learn of the death of John Adkins. He did his PhD in Atmospheric Physics under the supervision of Thomas Wormell before joining the Mond Laboratory in 1959, where he quickly showed himself to be an outstanding experimentalist by completing a daunting microwave experiment in superconductivity suggested by Brian Pippard.

He was appointed a University Lecturer in 1964, and played a key role in equipping the Mond to prepare high quality metallic film , initially to investigate the newly discovered Josephson effect. The same techniques provided the foundation for much of his later work. Initially he investigated a wide range of phenomena in superconductors and other materials using quantum mechanical tunnelling, but later, stimulated partly by Nevill Mott, he turned his attention to electronic conduction in disordered systems and the metal-insulator transition. He went on to lead the Low Temperature Physics Group from 1982 until his retirement in 1999.

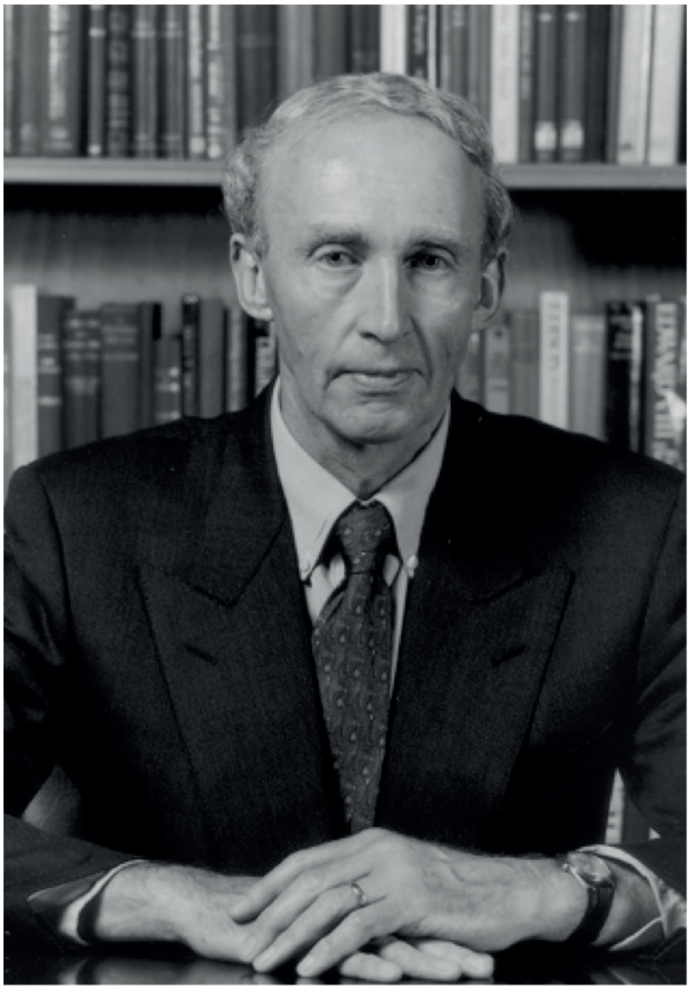
John was a most supportive research supervisor, and an outstanding teacher who was heavily involved in all aspects of the Laboratory's teaching programme. His book *Equilibrium Thermodynamics* has long been a standard and much-appreciated text for undergraduate students, its third edition being published in 1983 and it was published on-line in 2013. He was also much concerned with physics in schools through his work with the Local Examinations Syndicate.

John was an excellent musician, playing the oboe to a high standard and being President of the Jesus College Musical Society for 33 years, from 1976 to 2009. He was President of Jesus College from 1982 to 1985.

We pass on to Tess and their family our sincere condolences.

John Field

1936-2020



We were very saddened to learn of the death of John Field on 21st October 2020 following a short illness. John will be sadly missed by his family and numerous former students and group members, technical and administration staff as well as numerous members of the industrial and wider research community.

John was a distinguished graduate of University College, London and came to Cambridge in 1958 to study for a PhD under Philip Bowden, founder of the Physics and Chemistry of Solids Group. John's thesis was entitled 'High speed liquid impact and the deformation and fracture of brittle solids', paving the way for many different studies of what can broadly be described as energetic phenomena. In 1964, he became a research fellow at Magdalene College and College Lecturer in Physics and then in 1966 a University Demonstrator in the Laboratory. He proceeded up through the academic hierarchy, becoming Professor of Applied Physics in 1994.

The list of topics to which he, his colleagues and students made pioneering advances is very large indeed: strength properties of solids, fracture, impact, erosion by both liquid and solid impact, reactivity of solids, explosive initiation, shock physics, laser damage, acoustics, and diamond physics. John was seriously involved in all these areas. Having provided unswerving support to the successive Heads of the PCS Group, Philip Bowden, David Tabor and Abe Yoffe, John became head of the Group in 1987, a role which he continued until his retirement in 2003. He put an enormous amount of effort and energy into this role, in particular, in winning a large number of grants from the research councils, industry and national research establishments. His efforts were recognised by the award of an OBE in 1987 'for Scientific Advice' to Government and Fellowship of the Royal Society in 1994. Among numerous recognitions of his distinction, he was awarded the Duddell Medal and Prize of the Institute of Physics in 1990 for 'Advances in Instrumentation' and the Technical Achievement Award of the MOD in 1993. John received honorary degrees from the Universities of Luleå (Sweden) in 1989 and Cranfield (UK) in 2003. In 2014, the University of Luleå named a laboratory in his honour. He supervised 84 doctoral students, wrote over 460 papers and edited two books on Diamond Physics.

John will be greatly missed. As Deputy Head of the Cavendish from 1995 to 2002, he provided responsive and unstinted support through challenging times, never shrinking from the tasks allotted to him.

We pass on to his wife Ineke and his family our sincere condolences.

Stephen Walley **and** ***Bill Proud***

Outreach during the Pandemic

Jacob Butler

Physics at Work

The usual programme of face-to-face talks and activities could not go ahead this year but we could not allow Physics at Work's 35-year run to end. This year, we moved to an online event, with exhibitors providing recorded demonstrations and online question and answer sessions. The demonstrations will be available to teachers as a learning resource, accessible at any time, and the Q&A sessions were held throughout the week of the 21st-25th September 2020. This allowed students to ask questions and learn more about people working in a variety of physics-related fields and, we hope, capture some of the face-to-face experience that previous events have provided. A key aim of Physics at Work is showing students that people much like themselves work in a variety of interesting roles, and that studying Physics can lead to many different sorts of career. Though it is a shame our usual event could not take place, we hope the online replacement meets these aims.

The Cambridge Physics Experience

For the last eight years, the Cambridge Physics Experience (CPE) has formed the backbone of the Outreach programme. Previously, it consisted of a day spent at a Cambridge college and the Cavendish Laboratory, showing students from areas with low uptake to higher education that there is no reason why they should not feel able to pursue a degree and, through hands-on experiments, that physics is a practical, problem-solving enterprise. We have many contacts in schools who are keen to continue this programme in a new, socially-distanced way and we are working with them to develop events that safeguard everyone involved. The recent partial-reopening of the Laboratory has enabled us to take stock of our resources and look to ways of getting them into the hands of teachers, and we hope to have a new programme in place shortly.

Please see **http://outreach.phy.cam.ac.uk/paw** and **http://outreach.phy.cam.ac.uk/cpe** for more information about these events, and contact me (**jbb48@cam.ac.uk**) with any questions.

'As one might expect, the pandemic has had a particularly strong impact on the activities of the Outreach Office. However, we have been hard at work adapting our programme for the new academic year, so that we can continue to work with schools to engage with and help to inspire the next generation of physicists.'

Cavendish News

NEW APPOINTMENTS

We welcome the following who have joined the Laboratory in the roles indicated.

Lecturers


Paula Alvarez Cartelle, University Lecturer, HEP (left)
Gemma Bale, University Lecturer (joint with Engineering) BSS (right)

Research Fellows



Ibrahim Dar, Royal Society University Research Fellow, OE (left)
William Handley, Royal Society University Research Fellow , AP (centre)
Alpha Lee, Royal Society University Research Fellow, TCM (right)
Mindaugas Gicevicius, Marie Curie Fellowship , OE
Urs Haeusler, Marie Curie Fellowship, AMOP
Ran Tivony, Marie Curie Fellowship, BSS

Administrative, Technical and Support Sta˜

Fred Dulwich, Senior Research Associate , AP
Ingrid Murray, Teacher Support & Ogden Isaac Fellowship Manager, Isaac Physics
Abbie Lowe, Research Lab Technician, SP
Ilaria Sperduto, Accounts Assistant, Accounts
Peter Sims, IT Helpdesk Officer IT
Liam Callaghan, IT Customer Service Representative IT

CONGRATULATIONS

We warmly congratulate ***Didier Queloz*** and ***Sarah Teichmann*** on being elected Fellows of the Royal Society.

We are delighted to report that, ***Sarah Bohndiek***, ***Claudio Castelnovo***, ***Alex Mitov*** and ***Nikos Nikiforakis*** have been promoted to Professorships and ***Benjamin Béri***, ***Hugo Bronstein***, ***Andy Jardine*** and ***Tina Potter*** to Readerships in the 2020 promotion round.

Mete Atatüre and ***Jeremy Baumberg*** have each won a prestigious European Research Council (ERC) Advanced Grant, totalling nearly £5M for their research in Quantum Optics and Nanophotonics. They both work on diverse ways of creating new and strange interactions of light with matter on the nanoscale.

The Institution of Engineering and Technology has awarded ***Hugo Lepage***, a graduate student in Prof Crispin Barnes' Thin Film Magnetism group, an IET Postgraduate Scholarship for an Outstanding Researcher.

Claire Donnelly, a Leverhulme Fellow in Prof Russell Cowburn's group, has been awarded the European Magnetism Association's Young Scientist Award 2020 'for advances in the experimental characterization of spin textures and their dynamics in three dimensions with X-ray techniques.'

Theo Lundberg, a PhD student in the Optoelectronics Group, has been awarded a prestigious IBM PhD Fellowship to support his doctoral research on the implementation of spin-based qubits in silicon.

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 described in CavMag18 and can be viewed online at: **www.phy.cam.ac.uk/alumni/files/CavMag18Aug2017online.pdf**

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 Samantha Stokes (**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 Andy Parker (**HoD@phy.cam.ac.uk**) or Malcolm Longair (**msl1000@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
www.phy.cam.ac.uk

Head of Department
Professor Andy Parker
Tel: +44(0)1223 337429
E-mail: HoD@phy.cam.ac.uk

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

Celebrating our

Graduate Students