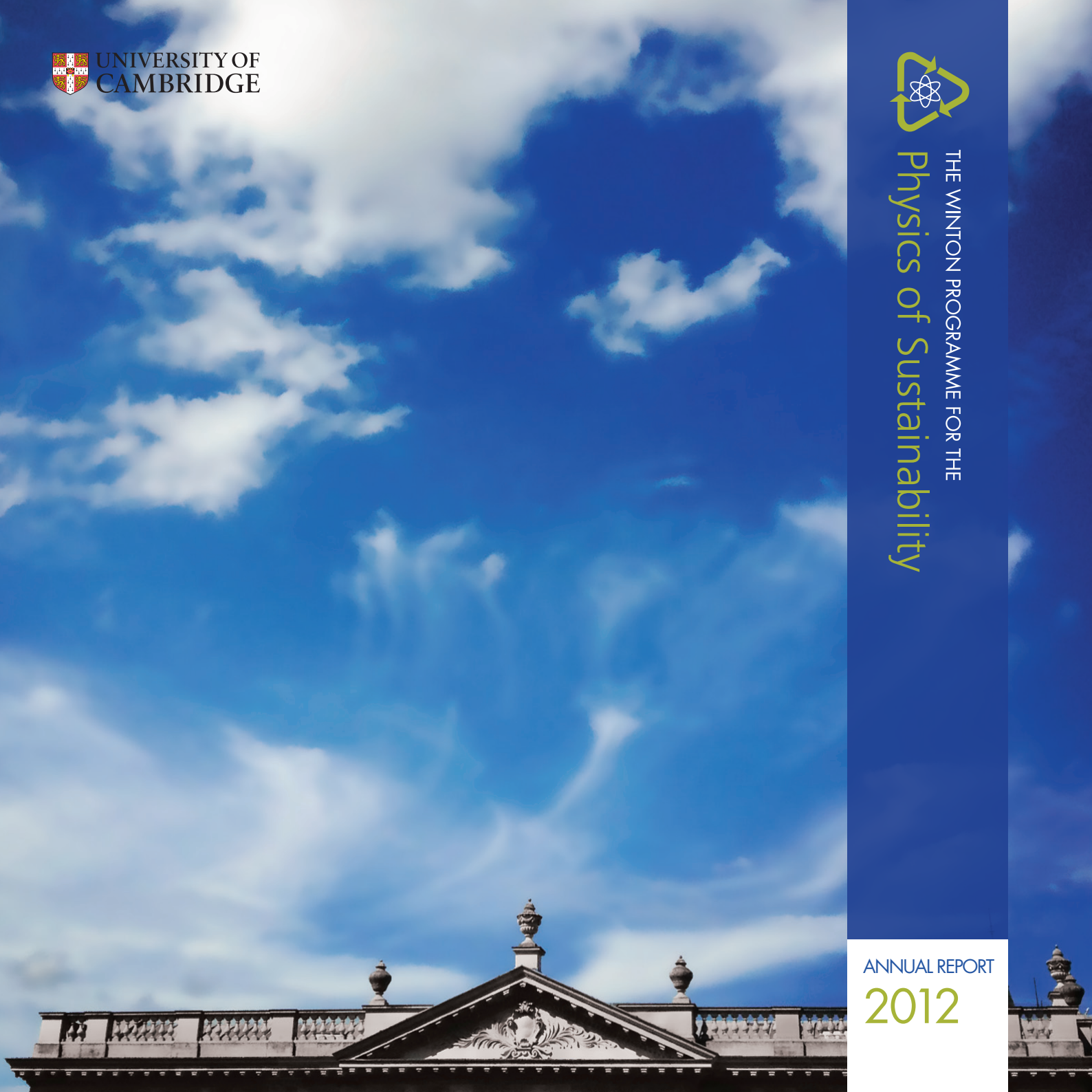


UNIVERSITY OF CAMBRIDGE

THE WINTON PROGRAMME FOR THE

Physics of Sustainability

ANNUAL REPORT

2012

REVIEW

Richard Friend, Cavendish Professor of Physics

The Winton Programme is now live and it is starting to make its impact on the Cavendish Laboratory. It is bringing us real freedom to try out new ideas and to expand the bounds of physics research. It is already clear that we are creating research in areas new to the Cavendish, and indeed to other university physics departments around the world. Where this will lead is impossible to predict, but the scope to explore territory that does not yet qualify as 'mainstream' gives us many chances.

Support from the Winton Programme for new projects and people does not replace or supplant regular channels of external funding, from the Research Councils, the European Commission or Industry. Rather, it will allow us to bring new ideas and projects to the level of readiness needed to bring in these external funds and thus allow us to multiply the Winton investment many times over.

We are now supporting some outstanding young scientists, at PhD and Advanced Fellowship levels, we have set up some high-risk small-scale projects. We are now setting up to support the currently-advertised lectureships, providing start-up funds at the level required to bring entirely new research areas to the Cavendish.

PROGRAMME ACTIVITIES

Nalin Patel, Programme Manager

This year has seen the transition from the ideas that were set out at the Inaugural Celebration in March 2011 for the Winton Programme for the Physics of Sustainability, to an active and growing community of people working on a wide range of research topics centred at the Cavendish Laboratory.

The Winton Programme for the Physics of Sustainability has made significant progress in this first year. The Inaugural Celebration was held in March 2011 providing the occasion to recognise the significance of this donation, the largest received by the Cavendish since its creation in 1874, and the opportunities this brings to apply physics to meet the growing demand on our natural resources.

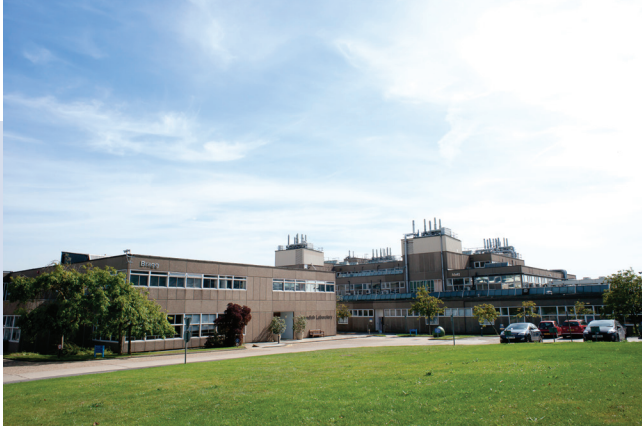
To assist with the operation of the programme and support the Winton Fund Managers, who have overall responsibility for the activities of the programme, I was appointed as Programme Manager, and started in August 2011. The list of Winton Fund Managers is provided at the end of the report. In this first operational year, the main focus was to set up the three main areas that were detailed in the Graces that were submitted to the University when the Programme was established. These included:

- **International Advisory Board (IAB)** of distinguished scientists to advise on the future strategic direction of the Programme
- **Winton Advanced Research Fellowships** to be awarded to outstanding scientists that will allow them to develop an independent research career based at the Cavendish
- **Winton Scholarships** to be awarded to high calibre students studying for PhD degrees in the broad field of the Physics of Sustainability

The IAB has been set up with Professor Paul Alivisatos as chairman, along with twelve other distinguished scientists from a host of institutions around the world, the full list is provided in the side panel on the next page. Professor Alivisatos also provides leadership of the "Carbon Cycle 2.0" initiative at Lawrence Berkeley National Laboratory, a multidisciplinary approach to developing ways to help restore the balance in Earth's carbon cycle.

The first set of Winton Fellows and Scholars are now well established at the Cavendish; six Scholars joined in October 2011, followed by two Fellows in January 2012. Further detail of the Fellows and Scholars and their activities are provided later in this report. The second rounds of appointments are also now made, which will see the community of Winton supported scientists approximately double.

The Winton Programme also launched a **pump-prime scheme**; a mechanism to encourage new innovative research within the department. This provides up to £50k for speculative, high-risk activities that have the potential for major impact, which otherwise would be difficult to resource through conventional funding routes. A number of applications were generated within the Cavendish Laboratory including several seeking funding for collaborations with other departments in Cambridge. Four awards to date have been granted, and the scheme remains open for further applications.



The central event this year will be the hosting of the **Inaugural Winton Symposium** at the Cavendish laboratory. The symposium on 1st October 2012 will cover the topic of Energy Efficiency and explore the fundamental physical limits to the generation, storage and use of energy. The emphasis will be on the science with the symposium of general interest to a wide audience, including young and established scientists, industrialists and also policy makers. The symposium is expected to become a major annual event in the calendar for the Cavendish Laboratory, with an opportunity to invite world-leading scientists to highlight recent advances and current challenges that can have a significant impact on how we cope with the increasing demands on natural resources.

In this first year, the 'bottom-up' activities of the program have been put in place to fund very bright young physicists. This Winton community will grow steadily in the coming years. Though the research interests are broad there is a common mission to make scientific progress in areas related to sustainability. Bringing together these and other like-minded people to discuss their work as well as enabling them to become aware of some of the current issues will be an important activity. Discussion meetings, 'teatime conversations' and other informal events are currently taking place and will continue to be used to enable physicists and other scientists to exchange ideas and be aware of how their activities have the potential to make a real difference to the world we live in.

IAB Members

Chair - Professor Paul Alivisatos
Director, Lawrence Berkeley National Laboratory, CA, USA

Professor Flemming Besenbacher
Director of Interdisciplinary Nanoscience Center, University of Aarhus, Denmark

Professor Emily Carter
Director, Andlinger Center for Energy and the Environment, Princeton University, USA

Professor Tony Cheetham
Department of Materials Science and Metallurgy, University of Cambridge

Professor Clare Grey
Department of Chemistry, University of Cambridge

Professor Sir Peter Knight
Principal, Kavli Royal Society International Centre, Chicheley Hall, UK

Professor Sir Christopher Llewellyn Smith
Department of Theoretical Physics, University of Oxford

Professor David MacKay
Cavendish Laboratory, Cambridge

Professor Dr. Jürgen Mlynek
President, Helmholtz Association, Germany

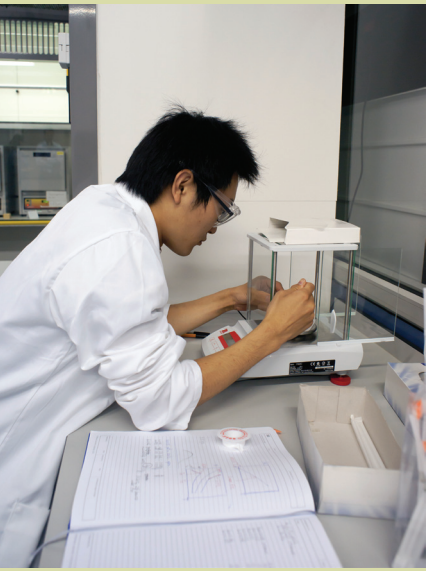
Professor Stuart Parkin
IBM Corporation, San Jose, CA, USA

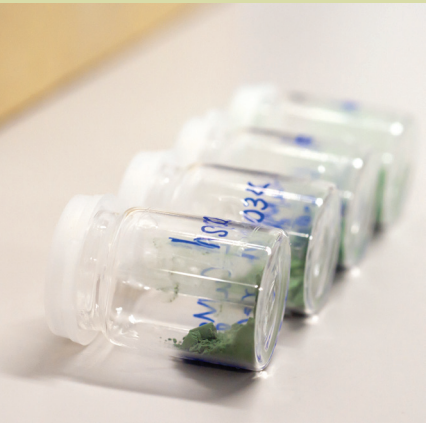
Professor Ajay Sood
Department of Physics, Indian Institute of Science, Bangalore, and, President, Indian Academy of Sciences

Professor Andrew Wee
Dean of Science, National University of Singapore

Professor Claude Weisbuch
École Polytechnique, Palaiseau, France, and Department of Materials Science, University of California, Santa Barbara, CA, USA

FELLOWSHIPS





Two Winton Advanced Research Fellows were appointed in January 2012, to tackle very different but equally challenging problems that could have an impact on how we generate and store energy in the future.

Dr Alex Chin has been following the compelling experimental and theoretical evidence that has emerged over the last few years which suggests that non-classical properties of quantum mechanics may play an important role in the remarkably high efficiency and sensitivity of important biological processes, such as avian navigation, olfaction and photosynthetic light harvesting. His fellowship programme will look for the general (quantum) design principles which optimise the performance of light-harvesting in natural photosynthesis, and then go on to explore how these biologically engineered strategies might be used to improve artificial technologies, such as photovoltaic devices.

Alex has been participating in the development of a new theory that explains how quantum coherence may actually be stabilised in the hot and wet conditions found in photosynthetic pigment-protein complexes, as well as looking at related problems in quantum optics, metrology, optoelectronic materials and dissipative quantum systems. Combining state-of-the art numerical techniques for simulating non-equilibrium quantum dynamics with atomistic modelling and mathematical analysis, this work has started to reveal some unexpected mechanisms through which coherence and environmental effects - which were previously thought to simply degrade coherence - may interact to drive new physics at the boundary of the quantum and classical worlds.

Dr Siân Dutton's work involves the chemical manipulation of materials to optimise their physical properties. She will work on new electrode materials for use in Li-ion batteries for improved performance. These materials are often closely related to the strongly correlated electron systems investigated in the Quantum Matter group, and this connection will be developed. Siân's work will focus primarily on materials synthesis and characterisation. She aims to explore a number of new oxide-based materials and by chemical manipulation of the properties optimise their performance. This work will bring new opportunities within the Cavendish and the University for developing these materials and enable interactions with existing groups to expand the scope of her research programme. In particular the role of theoretical calculations to optimise materials and suggest new materials to study will allow for a more directed approach to materials discovery.

Siân has overseen the installation of her new laboratory space in the Cavendish and has commenced investigating new complex oxide materials with potential as electrodes in Li-ion batteries. This summer

Dr Alex Chin

Dr Siân Dutton

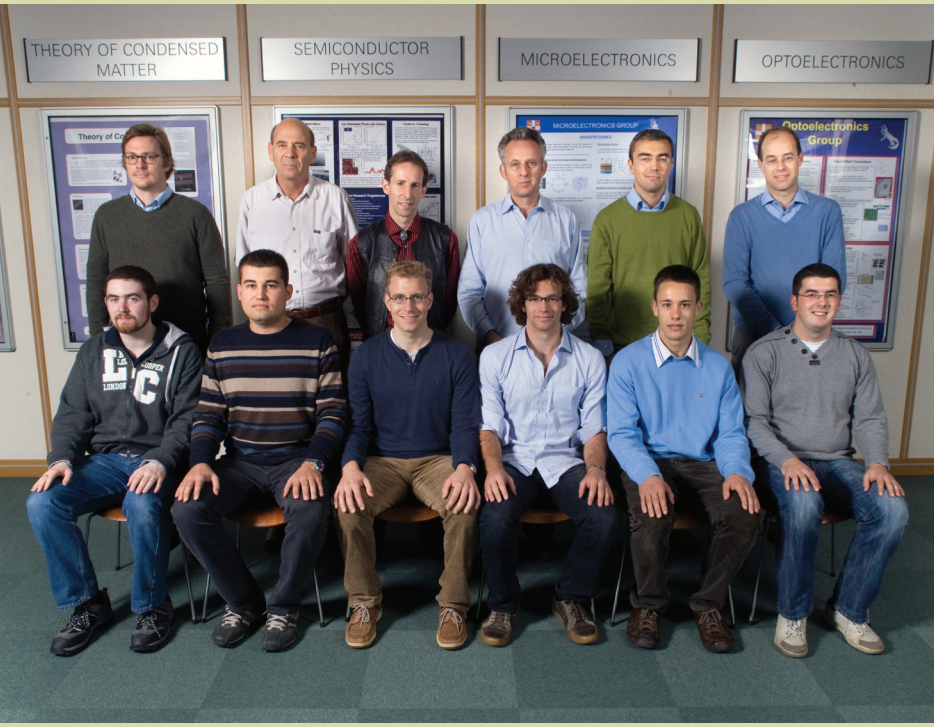
Siân has been joined by a project student from Japan who has been using chemistry to manipulate the degree of ordering in materials with structures derived from rock salt. In addition to electrodes for Li-ion batteries Siân is also interested in exploring the role of anion order in lanthanide oxyfluoride phosphors and low dimensional ferroelectrics. Many of the materials Siân will be investigating are also of fundamental interest due to strongly correlated electrons giving rise to novel physical properties and she is working closely with members of the Quantum Mater group. In the past few months she has also been exploring ways to enhance some of the technologies being developed within the department.

Two further Winton Fellowship appointments have been made, with Dr Andrew Morris coming from University College London and Dr Nicholas Hine from Imperial College. Both of these have strong backgrounds in theoretical modelling of materials, and come with complementary expertise. With the recent advances in computational science this brings an opportunity for theoreticians to work alongside experimentalists to discover the materials of the future.

Since completing his PhD, Andrew has been developing a method called ab initio random structure searching (AIRSS) for predicting the structure of materials. since his PhD. He will collaborate extensively with experimental groups, finding the most interesting problems with which to apply AIRSS. He will extend his current collaboration with Professor Grey in the Chemistry department on improving the capacity of Li-ion batteries. By modelling bulk materials, their defects, surfaces and interfaces he will use AIRSS to augment the experimental materials discovery capabilities of the university.

Nicholas has been one of the leaders behind developing density-functional theory (DFT), working on approaches to enable larger numbers of atoms to be modelled as well as improving the accuracy of predictions. His work will enable the simulation of whole nanostructures of realistic sizes, with unprecedented accuracy and speed, obtaining ground-state properties such as formation energies, atomic positions, and dipole moments. One application will be to study titanium dioxide (TiO_2) nanoparticles: these have been the subject of extensive investigation due to TiO_2's uses both in photocatalytic water splitting and for photovoltaics, and hybrid systems combining the two.

SCHOLARSHIPS

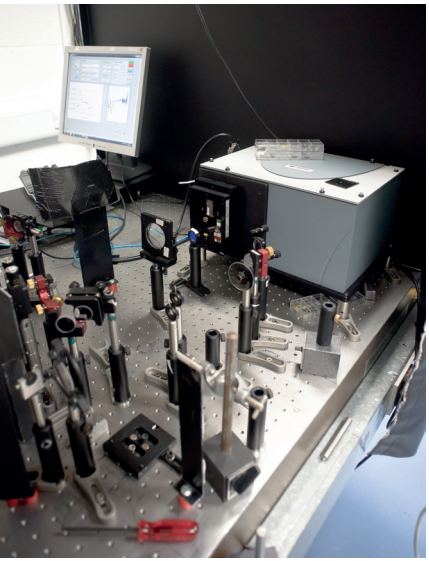


Front row Scholars and back row their respective supervisors

Student – **Nicholas Paul**	Supervisor – **Erwin Reisner**
Student – **Milos Knezevic**	Supervisor – **Mark Warner**
Student – **Jan Mertens**	Supervisor – **Jeremy Baumberg**
Student – **Michael Price**	Supervisor – **Richard Friend**
Student – **Breanndan O'Conchuir**	Supervisor – **Alessio Zaccone**
Student – **Milan Vrucinic**	Supervisor – **Henning Sirringhaus**

Six Winton Scholars joined the Cavendish in October 2012 to start PhD programs; the first cohort with their respective supervisors are shown in the picture. The Scholars come from around the world to work in established groups at the Cavendish on a range of research topics. Two are based in the Theory of Condensed Matter group, exploring thermally and optically induced mechanics of new materials (Milos Knezevic) and dynamics of aggregate break-up (Breanndan O'Conchuir). The work may lead to advances in energy harvesting systems and understanding the properties of exciton dissociation, which is a key process in solar cells. Other Scholars are working on plasmonic-based sensors in the NanoPhotonics group (Jan Mertens), charge separation dynamics in solar cells (Michael Price) in the Optoelectronics group and investigation of high mobility organic systems (Milan Vrucinic) in Microelectronics. Finally, Nicholas Paul is developing new bio-inspired materials for hydrogen production in a project that involves the group of Dr Erwin Reisner in the Chemistry Department together with the Optoelectronics group in the Cavendish Laboratory.

PUMP PRIME



The Winton pump-prime scheme has been set up to provide the initial support to projects that bring new ideas and activities to the Department. Untested ideas, although have the potential for high reward, can be difficult to resource through conventional funding routes.. The pump-prime scheme has thus been set up for academic and research staff at the Cavendish Laboratory to encourage trials of new innovative ideas with relevance to the broad field of sustainability.

Funding for projects is available for up to £50k. This scheme also provides opportunities to collaborate with researchers in other departments. Four awards have been granted to date covering a broad range of topics, with the scheme remaining open for new applications.

Grants awarded to date are:

Dr Pietro Cicuta from the Biological and Soft Systems group and **Prof Alison Smith** from the Department of Plant Science will work together on "Optimisation of algae growth for biofuels". The funding will be used to develop a continuous growth micro-chemostat for algae culture in which to screen growth rates and interactions with beneficial symbiotic species.

Prof Michael Köhl from the Atomic, Mesoscopic and Optical Physics group will explore a new method to achieve ultra-low temperatures in the project "Cooling by sorting". This work paves the way for emulating and understanding high-temperature superconductors, by studying these systems at temperatures that have never been achieved in the past.

Dr Michelle Moram from the Semiconductor Physics Group and Materials Science and Metallurgy department and **Prof Dave Ritchie** from the Semiconductor Physics Group, plan to assess the feasibility of a new material system in their project, "(Sc,Al,Ga)N materials for energy harvesting". Recent predictions suggest this unexplored material system has dramatically improved figure of merit for converting mechanical vibrations in electrical energy. MBE growth will be used to produce materials for proof-of-principle energy harvesting devices.

Dr Brian Walker from the Optoelectronics group will work on "Singlet Fission: Towards a universal mechanism and high efficiency photovoltaics". The award will provide funding to explore a new mechanism whereby a single photon absorbed in a solar cell can produce two sets of charges, thereby enabling higher efficiency solar cells to be realised. The dynamics of these singlet and triplet states will be studied to understand the underlying photo-physics and the material properties that give rise to efficient fission.

EVENTS

In addition to the annual Symposium, a range of smaller events has also been held. These include discussion and 'teatime conversations', which are vehicles for the Winton community and others to meet informally to exchange ideas on topics related to sustainability. Other social events have also been held, including a dinner with all new Scholars and their supervisors, and informal dinners with Scholars and Fellows. These are opportunities for these people who are working on a wide range of physics related topics to exchange their different ideas and experiences.

The discussion meetings are an opportunity for academics from different groups at the Cavendish to come together to hear about new activities. The presenters provide a brief overview of their work and future plans with the audience encouraged to participate in related discussions. Two well-attended events were held last year. At the first, the four Winton pump-prime grant holders presented their projects and at the second, the two Winton Fellows provided an overview of their previous work and future research plans.

The 'teatime conversations' were hosted by Professor David MacKay, who is currently Chief Scientific Adviser at DECC (Department of Energy and Climate Change). **Those involved in Winton projects were invited to select topics and the meetings were open to anyone who has an interest in** discussing sustainability issues. For each conversation an expert in the area was invited to attend, and provide a few words on their research interests to kick-start the discussion. A broad range of topics from new lighting technologies to financing climate change projects was discussed, with experts from various departments in Cambridge as well as outside attending. Listed in the sidebar are some of the topics and invited experts.

We would like to thank the people who have participated in these events through the year, and we will continue to have a range of events, which enable Winton people and others to connect together to exchange ideas related to sustainability.

'Teatime conversation' topics

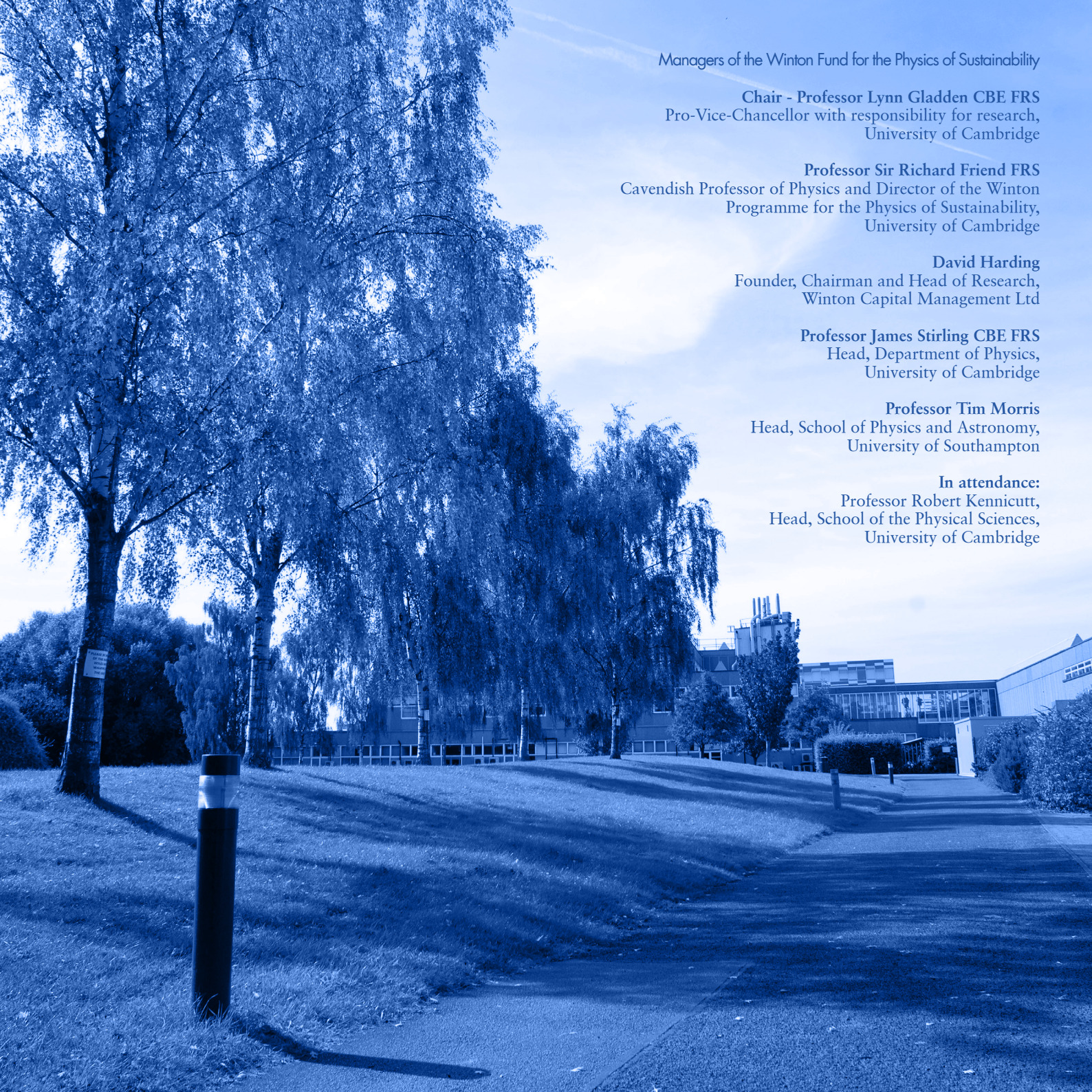
Climate finance: barriers and opportunities
Dr Aled Jones, Anglia Ruskin University, Global Sustainability Institute

What scientists can do for sustainability that CEOs and Ministers can't
Dr Matthew Brown, CBI (Confederation of British Industry)

The limits to energy and material efficiency
Dr Jonathan Cullen, Engineering Department

Sustainable Manufacturing and the Myth of Efficiency
Professor Steve Evans, Centre for Sustainable Manufacturing

Energy Efficient Lighting
Dr Julian Carter, Cambridge Display Technology & Dr Rachel Oliver, Materials Department



Managers of the Winton Fund for the Physics of Sustainability

Chair - Professor Lynn Gladden CBE FRS
Pro-Vice-Chancellor with responsibility for research,
University of Cambridge

Professor Sir Richard Friend FRS
Cavendish Professor of Physics and Director of the Winton
Programme for the Physics of Sustainability,
University of Cambridge

David Harding
Founder, Chairman and Head of Research,
Winton Capital Management Ltd

Professor James Stirling CBE FRS
Head, Department of Physics,
University of Cambridge

Professor Tim Morris
Head, School of Physics and Astronomy,
University of Southampton

In attendance:
Professor Robert Kennicutt,
Head, School of the Physical Sciences,
University of Cambridge

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