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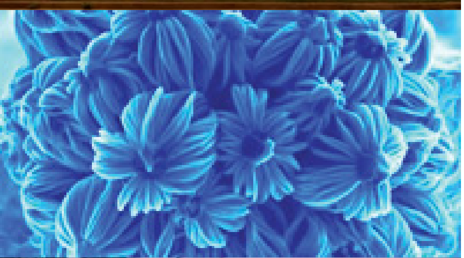
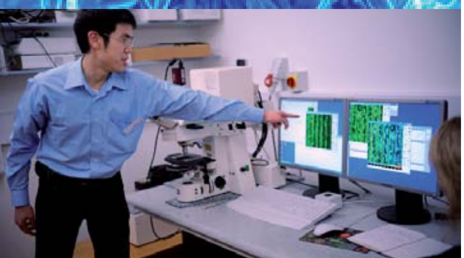
January 2010 Issue 3

News from the Cavendish Laboratory

Inside...





www.phy.cam.ac.uk

Royal Opening of the Kavli Institute for Cosmology

The next stage of the Cavendish development programme became a reality in November 2009 with the opening of the Kavli Institute for Cosmology at Cambridge (KICC) by the Chancellor of the University, HRH Prince Philip, Duke of Edinburgh. Sited in the grounds of the Institute of Astronomy on Madingley Road, the Institute will form part of an international network of research centres funded by the Kavli Foundation at other universities around the world, and will collaborate with its sister centres in China and the USA. The research programme spans a broad range of topics from the physics of the early Universe, to the formation of the first stars and galaxies.

The Kavli Institute brings together, in a specially designed building, about 55 research scientists and graduate students from three participating departments in the University of Cambridge: the Institute of Astronomy (IoA); the Cavendish Laboratory; and the Department of Applied Mathematics and Theoretical Physics (DAMTP).

Mr Fred Kavli, founder, Chairman and Chief Executive Officer of the Kavli Foundation said, "Cambridge has such a stellar record of making fundamental discoveries in science throughout the ages and, with its traditions of excellence and leading-edge science teams, I have great hope that the Kavli Institute at Cambridge will make major discoveries in the future."

Professor George Efstathiou, founding Director of the new Institute said, "We are honoured that the Chancellor has agreed to open this new building. I would like to thank Fred Kavli for his generous donation and the University for their strong support."

The next development challenge is Phase 2 of the consolidation of the activities of the Insititute of Astronomy and the Cavendish Astrophysics Group.

From the left: Mr Fred Kavli, Professor George Efstathiou, the Chancellor and Professor Alison Richard, Vice-Chancellor

Editorial: the Return of the Alumni

It was with some trepidation that we organised our first Open Day for all alumni on Saturday 26th September 2009. We had received a wonderful response to the various communications we had sent out over the last year, but inviting all the alumni back to the Laboratory could have been a disaster in one of two directions – either no-one turned up, or the place was inundated and we could not cope. The actual event was the ideal compromise. We entertained about 350 alumni and their guests; we were just able to cope and all 14 exhibition areas seemed to be busy all afternoon. The major innovation was to open the whole Laboratory for alumni and their guests. We are delighted that everyone responded so positively to our efforts. In fact, with so much on show, few people completed the full circuit of the Laboratory, but we hope that this means that we will have the pleasure of their company next year. As usual, the crowning glory was the enthusiasm of all those explaining the science to the alumni, particularly the research students and post-docs. We are most grateful to everyone who made it such a memorable day.

Among the alumni, pride of place must go to Mrs Marie Constable (née Sparshott) who was 101 this year and who was a graduate student under James Chadwick from 1930 to 1933. She has kindly allowed us to reproduce in this edition of *CavMag* her reminiscences of that remarkable period.

We have already decided to repeat the exercise during Alumni Weekend 2010. There will be some slight variations on the programme of 2009. First of all, we will just have one large Saturday event rather than a small, selective event on the Friday and the big show on the Saturday. The numbers will be unlimited on the Saturday. One feature of the Friday event which was much appreciated by alumni was a presentation by one of the senior staff on exciting new developments in physics, especially recent achievements in the Laboratory. We are planning that this will now take place on the Saturday.

The plan would be:

Laboratory open:	2.00 to 5.30 pm during which all the research areas can be visited
General lecture:	4.15 to 5.00 pm
Refreshments:	Available all afternoon
Wine and nibbles:	From 4.00 onwards

We were delighted to see many young people accompanying the alumni. We will welcome young people in 2010 again – we hope we can inspire them by the work that excites us so much. So, put the date in you diary now – **Physics Alumni Open Day: Saturday 27 September 2010**. We look forward to seeing as many of you as can make it.

Malcolm Longair

The Living Past The Cavendish in 1932

1932 was one of the most remarkable years in the history of the Cavendish Laboratory. It marked the discoveries of the neutron by James Chadwick and of the 'splitting of the atom' by John Cockcroft and Ernest Walton, details of which are described on the Cavendish Physics website at www-outreach.phy.cam.ac.uk/camphy/.

To our delight, once the 2009 Alumni Open Day was announced, we were contacted by the son and daughter-in-law of Mrs Marie Constable, née Sparshott, who had joined the Laboratory as a graduate student in 1930. Mrs Constable celebrated her 100th birthday in 2008. She and members of her family were guests at the Open Day and were able to see the historical material from the 1930s, as well as the research being carried out now. Very kindly, Mrs Constable has written up her experiences as a lone female graduate student during the 1930s. Suddenly, this remarkable period was brought vividly to life by someone who had been witness to these events. She writes:

In 1930, when I gratefully accepted a research studentship from

Cavendish Laboratory staff and graduate students in 1932. There are 9 Nobel Prize
N.S. Alexander. P. Wright. A.G. Hill.
W.E. Duncanson. E.C.Childs. T.G.P. Tarrant. J.M. McDougall. R.C. Evans. E.S
P.C. Ho. C.B. Mohr. H.W.S. Massey. M.L. Oliphant. E.T.S. Walton. C.E. Wyn
J.A. Ratcliffe. P. Kapitza. J. Chadwick. R. Ladenberg. Prof. Sir J.J. Thomson. Prof. Lord

Girton College, I never imagined that, in 2009, I would write a piece about what life in the Cavendish Laboratory had been like. The Cavendish in the days of Lord Rutherford was housed in Free School Lane. The two main lecture theatres remain unchanged with seating that is no more comfortable now than it was then. When taken recently by Dr Squires to identify the space where I had worked under the supervision of Dr Ann Davies, I had to rely on finding the window with the view I remembered of the tower of St Botolph's Church. There we had pored over the spectra of soft X-rays as caused by bombarding a single crystal of iron with electrons.

In those days the Cavendish was a small organisation. Lord Rutherford was already a much-respected figure. A big, bluff and hearty New Zealander, I found him friendly and helpful. I recall his habit of making random visits around the laboratory to his research students. Such a visit would start with a loud knock at the door followed by 'How are you getting on?', then 'Tell me all about it' and 'Anything you want doing?' He and Lady Rutherford made a point, once a year, of inviting all research students to lunch, six at a time at his house on the corner between Silver Street and the Backs. The food was excellent as was the company.

Lord Rutherford also instituted the practice of the laboratory afternoon tea break. Tea and buns were served every Wednesday afternoon in the Library, providing an opportunity for anyone to have a few words with anyone else, and were much valued. After tea, all present went to the lecture theatre for a presentation. The subject matter might be an interesting idea, or a dry run of a paper being prepared for publication. The presenter might be a senior member of staff or just a research student. Occasionally, we would have a visiting speaker; for example I recall listening to Niels Bohr who described some of his recent experimental work. A key point about these occasions was that anyone present could comment and, if appropriate, challenge the views expressed.

I knew Professor Chadwick as the head of the laboratory services staff. He was seen as second-in-command to Lord Rutherford. His reputation among research students was that 'You had to be careful with Chadwick because he could get cross' and, indeed, anyone

winners in this picture. Marie Sparshott is second from the right in the second row.

J.L. Pawsey.   G. Occhialini.   H. Miller.
S. Shire.   E.L.C. White.   F.H. Nicoll.   R.M. Chaudhri.   B.V. Bowden.   W.B. Lewis.
n-Williams.   J.K. Roberts.   N. Feather.   Miss Davies.   Miss Sparshott.   J.P. Gott.
d. Rutherford.   Prof. C.T.R. Wilson.   F.E. Aston.   C.D. Ellis.   P.M.S. Blackett.   J.D. Cockroft.

who misused the lab services or who made silly mistakes was likely to be informed very clearly of his/her failings. However, I always found him friendly and kind. Paul Dirac was often seen in the Cavendish and regularly attended the Wednesday afternoon tea-break.

Dr Patrick Blackett was tall, handsome and helpful. For a professional physicist his background was unusual in that he started as a commissioned officer in the Royal Navy, had a distinguished record in the First World War, and fought in the battle of Jutland. Professor Kapitza, who ran the Mond Laboratory and its low temperature work, was a remarkable addition to the Cavendish staff. Of several contributions he made to life at the Cavendish, one was to dispel any presumption concerning a lack of Russian competence in advanced physics. Dr (Daddy) Searle ran the practical courses in the Cavendish and was a friend. He was notable for the meticulous nature of his work and the care he took to ensure that every single item of apparatus required for the practical classes functioned as it should. Turning to fellow research students, Geoffrey Aston had many talents and, for example, was a strikingly competent classical pianist. Jack Constable was an engaging, full-of-beans research student who worked in the basement where, under the supervision of Chadwick, he did interesting things with high energy α particles - we were married soon after I left the Cavendish.

So what was life really like in those days? I would describe the Cavendish culture as being serene and decent. Attitudes seemed to be collaborative rather than adversarial. Supervisors seemed willing to publish papers with their research students as co-authors. I still have copies of the paper presented to the Royal Society by 'Chadwick, Constable and Pollard', this paper being an interesting precursor to Chadwick's discovery of the neutron and subsequent Nobel Prize.

Although we were witnessing scientific history in the making, I doubt whether any of the research students thought so at the time. We may have felt that we were privileged to be associated with one of the world's premier scientific research establishments, but none of us suspected that the outcomes of the knowledge thereby gained would become strategically important and, in certain circumstances, deeply menacing. The overwhelming motivation was to do with the excitement of revealing new knowledge and penetrating hitherto unexplored intellectual territories.

In the light of the long process of obtaining equal university rights for women, it might be wondered whether I encountered any such difficulties at the Cavendish. As an undergraduate doing Part 2 Physics, females were expected to sit only on the reserved front bench during lectures, for fear their attention might be distracted by too much male proximity. Also, females could quote the qualification but were not entitled to receive a degree at the Senate House - a fine distinction. There was very little discrimination against female research students - after all, at that time there was only me. I can recall just one occasion when difficulties arose. It had been decided that research students ought to have some familiarity with workshop practice. A short course was set up in the lab workshop but I was informed it was not deemed suitable for females. Outraged, I joined forces with a friend, Helen McGaw, who was doing research in crystallography, and we enrolled at the local technical college for a course in workshop practice. Quite soon the use of hand and machine tools was no longer a total mystery.

After Jack's unfortunate death in 1939, I needed some form of employment. Eventually, I applied to what was then called H M Inspectorate of Factories and became an inspector. I doubt whether this job would have been mine without the workshop course, although I later became a safety expert in fields where my Cavendish experience was highly relevant.

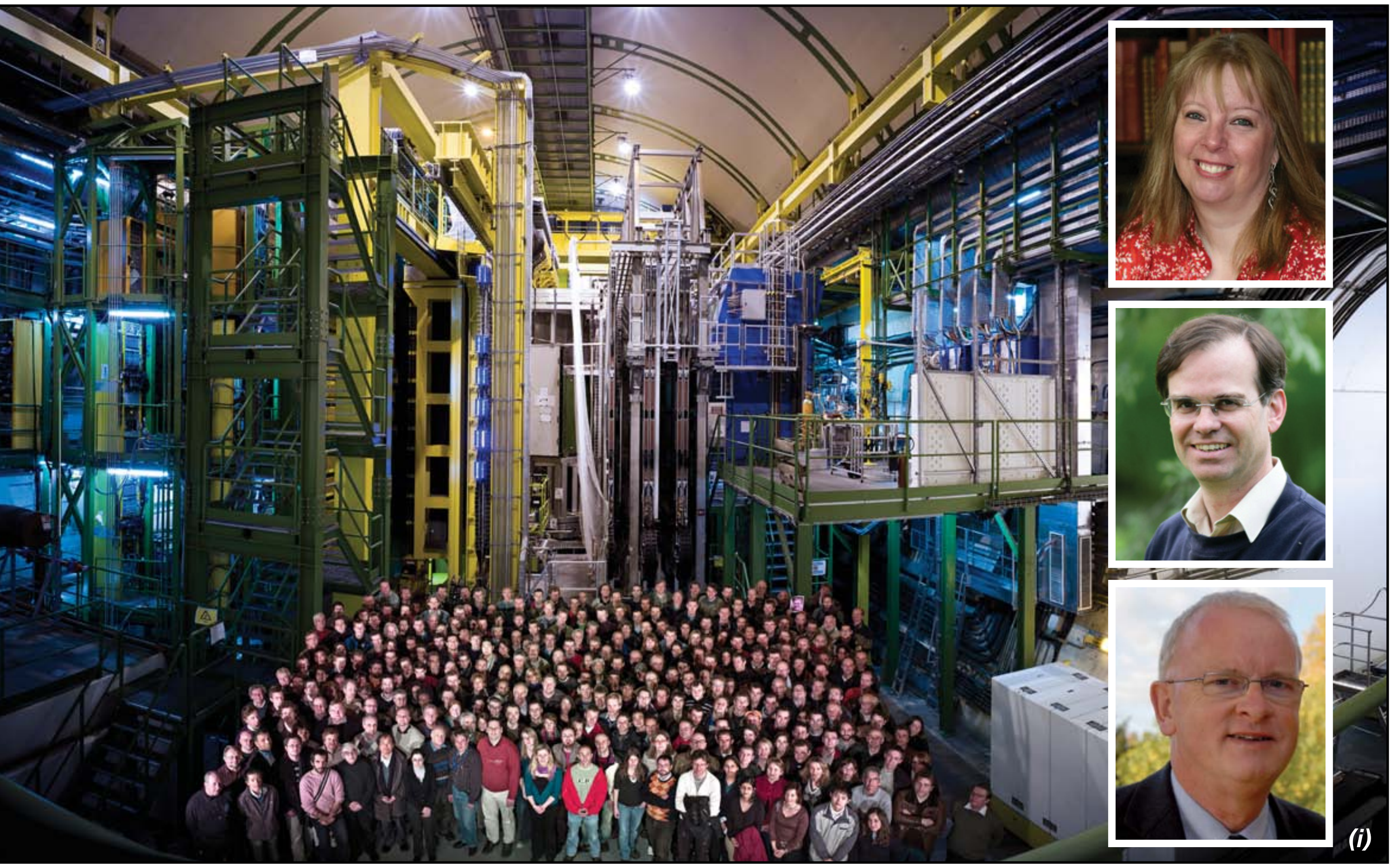
Mrs Marie Constable

Geoffrey Constable, Marie Constable (née Sparshott) and Malcolm Longair view the apparatus with which Chadwick discovered the neutron.

Our Understanding of the Universe is About to Change...

The **Large Hadron Collider (LHC)** is a gigantic scientific instrument near Geneva, spanning the border between Switzerland and France about 100m underground. It is a particle accelerator used by physicists to study the smallest known particles - the fundamental building blocks of all things. It will revolutionise our understanding, from the minuscule world deep within atoms to the vastness of the Universe.

Two beams of protons - the nuclei of the hydrogen atoms - will travel in opposite directions inside the circular accelerator. By colliding the two beams head-on at very high energy, physicists will use the LHC to recreate the conditions just after the Big Bang. Teams of physicists from around the world will analyse the particles created in the collisions using special detectors in a number of experiments dedicated to the LHC.



There are many theories as to what will result from these collisions. For decades, the ‘Standard Model’ of particle physics has served physicists well as a means of understanding the fundamental laws of Nature, but it does not tell the whole story. Only experimental data using the higher energies reached by the LHC can push knowledge forward, challenging the Standard Model and looking for evidence of a more fundamental ‘unified’ theory.

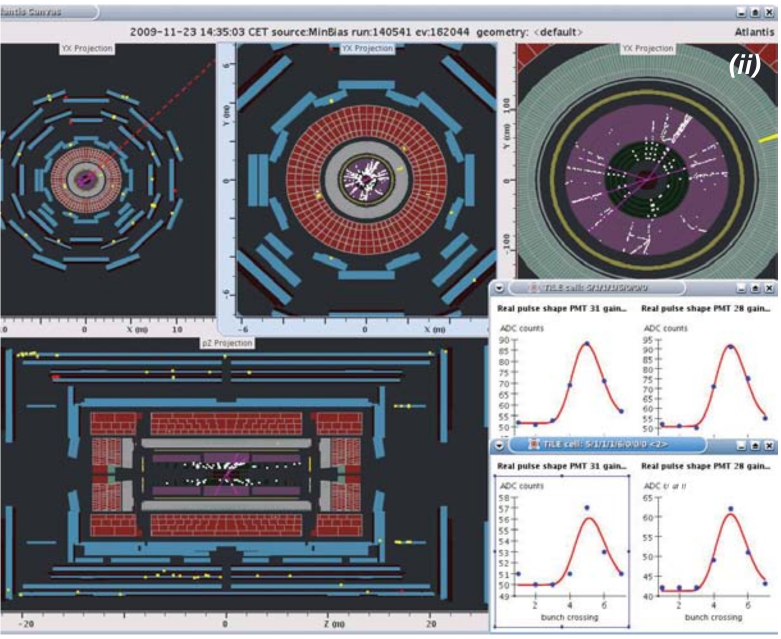
Cavendish Laboratory physicists have been heavily involved in the design and construction of two LHC detectors, ATLAS and LHCb. ATLAS is the largest particle detector ever constructed, roughly the size of Westminster Abbey, but packed with sensors and electronics to record and measure the particles produced when the LHC proton beams collide. Among the debris, scientists hope to find traces of the infamous Higgs boson, the missing piece in the Standard Model. Theory suggests that all of space is filled with a Higgs field, which is responsible for giving all particles their masses as they plough through it. At the Cavendish, the team is looking for even more exotic effects. In supersymmetric theories, every particle we know of, such as electrons, quarks and neutrinos, would have a ‘super-partner’. Detecting and measuring these would revolutionise our view of physics. Another suggestion, that the Universe has more than three space dimensions, is equally startling and could open the way to an understanding of quantum gravity.

LHCb is an experiment designed to uncover the mystery of the matter-antimatter asymmetry in the Universe and to search for new phenomena in quantum loop processes involving heavy quarks, in particular 'bottom' quarks. Although absent from the Universe today, these quarks were common in the aftermath of the Big Bang, and will be generated in their billions by the LHC, along with their antimatter counterparts, anti-bottom quarks. These particles are unstable and short-lived, decaying rapidly into a range of other particles. By comparing the decays of bottom and anti-bottom quarks we can gain useful clues as to why nature prefers matter over antimatter. LHCb is complementary to ATLAS and together they will be capable of discovering new physics over a large energy regime and determining its origin. The UK is the major contributor to LHCb; the Cavendish Laboratory team has provided the readout electronics for a major component of the experiment, the Ring Imaging Cherenkov detectors. These detectors will provide the particle identification required to separate out the ‘signal’ from the ‘background’. The Cambridge team also has the responsibility to provide the particle identification software and to ensure the experiment provides excellent quality data.

Both the ATLAS and LHCb teams are very much looking forward to the first data and are well prepared to make measurements in key areas of the physics programme. Cavendish theorists also have an important part to play. For many years they have been working alongside their experimental colleagues to help refine the predictions of the Standard Model and to devise data analysis techniques for uncovering various types of new physics. Thanks in part to this unique combination of experimental and theoretical activity, which other groups around the world are seeking to emulate, the Cavendish HEP group as a whole is well placed to play a leading role in LHC physics in the decade to come.

For more information visit the HEP group's web page at www.hep.phy.cam.ac.uk

Val Gibson, Andy Parker and James Stirling



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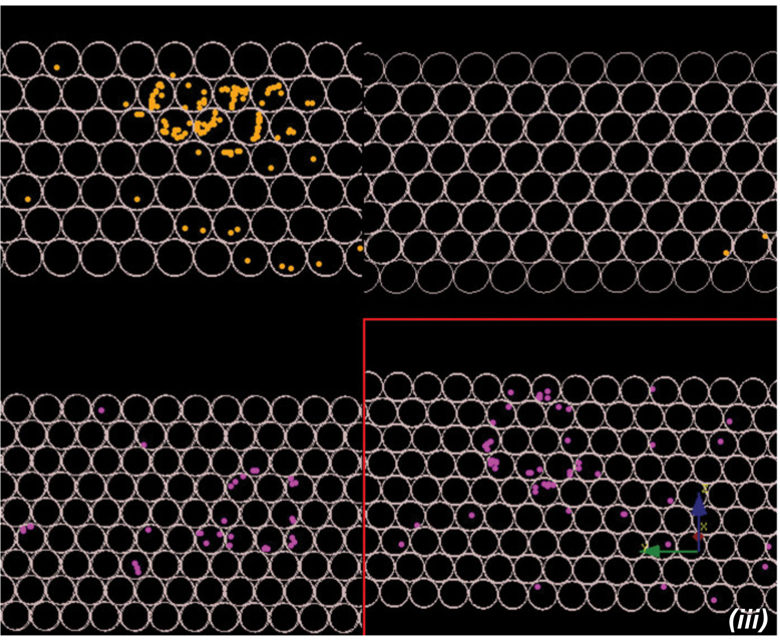


i. LHCb Collaboration in front of LHCb detctor © CERN (photography Maximilien Brice), November 2008 with photographs of the authors.

ii. The first collisions observed in the ATLAS experiment of the LHC in November 2009.

iii. The first images from the Ring Cherenkov detector obtained in November 2009.

Helium Spin-Echo

A Revolution in the Study of Surface Motion

Members of the Surface Physics group have recently developed an important new approach to the study of how atoms and simple molecules move on surfaces. The technique called 'helium spin-echo' (HeSE) involves directing a beam of helium-3 atoms at the surface and measuring the changes in its properties induced by the diffusion of atoms on the surface. The technique provides unique information on time-scales of the order of 10^{-12} seconds and on sub-nanometre length-scales, thus opening up a huge new field of nanoscale surface dynamics research. The nature of atomic scale motion is a subject of intense interest as it provides the basis for a vast number of technological activities worldwide, in fields as diverse as semiconductor development, industrial catalysis, and fuel cell research. There is a long history of helium atom scattering research in the Cavendish, dating back over 25 years. With the development of HeSE, we now house one of the world's largest and most influential 'atom scattering' centres.

Measuring the two-dimensional motion of atoms on surfaces is a simple idea but, because free atomic motion is extremely fast, with the atoms travelling between adjacent sites in about a picosecond, it is extremely difficult to measure. Conventional techniques, using for example various forms of scanning microscopy, are either much too slow or do not provide the necessary resolution, as in the case of optical scattering. Despite decades of research, only rather crude measurements of surface motion have been possible and so understanding diffusion, vibration and friction at the atomic level remains a central experimental challenge in surface science.

Helium atoms provide an ideal surface probe. High quality beams can be formed that diffract like other experimental probes, such as electrons or photons. More importantly, they do not cause damage or influence the surface because they are chemically inert and the atoms need only have very low energies. Typical helium energies are about 10^6 times lower than the energies of the electrons in an electron microscope and helium does not cause localised heating, as is the case with the scanning tunneling microscope.

The HeSE apparatus and a quantum mechanical explanation of the technique are illustrated in Figs. 1 and 2. A classical analogy of the underlying physics is that the apparatus can be thought of as an atomic scale version of the familiar radar speed trap. Instead of radio waves, helium atoms are scattered from atoms or molecules moving over the surface of the sample and the Doppler-like changes in the helium atom frequency are measured. From these, we can infer the surface motion of the particles on time-scales from 50 femtoseconds to about 1 nanosecond.

Surfaces are a particularly flexible and accessible workbench, on which structures or devices can be examined, and where fundamental theories can be tested. The HeSE approach enables fast nanoscale motion to be studied directly for the first time. Although many atom-surface combinations have now been examined, three particular examples stand out which illustrate the breadth of new science.

- Spin-echo measurements have been able to identify and characterise new, unobserved forms of surface diffusion. For example, benzene on graphite performs unique atomic scale Brownian motion, driven by strong coupling to lattice vibrations, rather than the ubiquitous 'hopping' mechanism, as illustrated in Fig. 3.

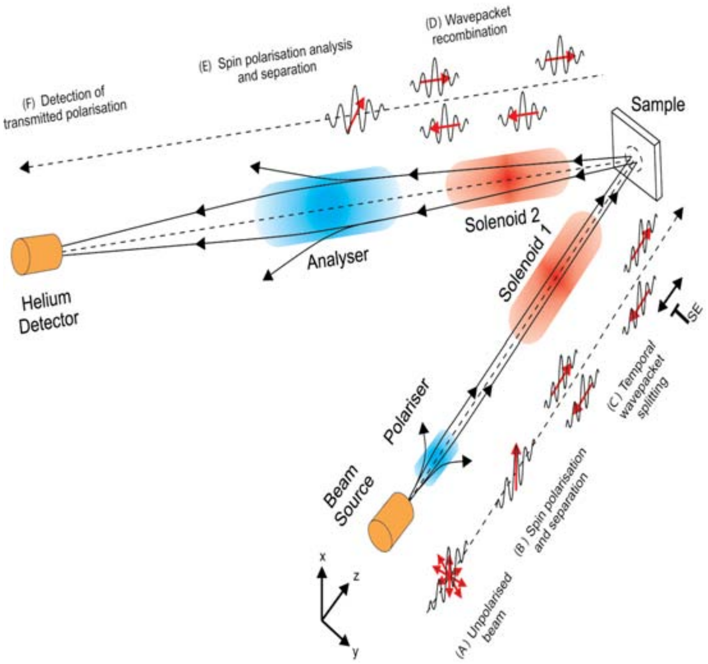


Fig. 2: In the spin-echo technique, the nuclei of helium-3 atoms in the beam are spin-polarised using a hexapole magnet. The spins are aligned parallel or anti-parallel to the magnetic field in the solenoid and so are quantum mechanically split. The two components move at different speeds in the field and so are separated by the 'spin-echo time'. These components scatter successively off any species moving over the surface of the sample. The scattered components are recombined in the second arm to form a signal called the 'echo', the strength of which provides a measure of how much the surface species have moved during the separation time interval.

- By measuring the motion of molecules on surfaces we can determine the forces between them. We have found that several important, well-established models for the interactions between molecules are incorrect, as the information contained in the dynamics of the system has not been considered. In particular, models describing the behavior of carbon monoxide molecules on platinum, probably the best studied catalytic system because of its importance in the automotive industry, are seriously flawed.

- Surfaces provide a simplified geometry for testing theory. Recent measurements of hydrogen diffusion show a transition between classical hopping and quantum tunnelling. The results test and support well established, but previously unproven analytic models for simple quantum tunnelling scenarios.

A measure of the success of the HeSE programme is the $1M investment to replicate the Cavendish approach in Israel. The different experiments performed to date have barely scratched the surface of those possible and so, rather than competition, we regard the new instruments as strengthening the emerging field we have pioneered and now lead.

The HeSE technique has already had substantial impact in the surface science community. Given the emphasis on the challenges facing modern society, such as climate change and new chemical and fuel technologies, we see an even more important future role for HeSE through the application of science and technology in understanding the basic underlying physics and chemistry. For example, the first phonon driven nano-mechanical systems have recently been constructed and spin-echo studies of phonon driven systems already provide fundamental physics relating to these technological devices. There is a rosy future for what we expect will become the standard approach to the study of diffusion, vibration and even phase transitions on surfaces.

Andy Jardine

Fig. 1: The HeSE apparatus consists of a long V-shaped vacuum system. The high inte the left and the detector on the right. Development of the HeSE technique was a ma Cavendish workshop facilities. The instrument is fully automated and typically runs 24

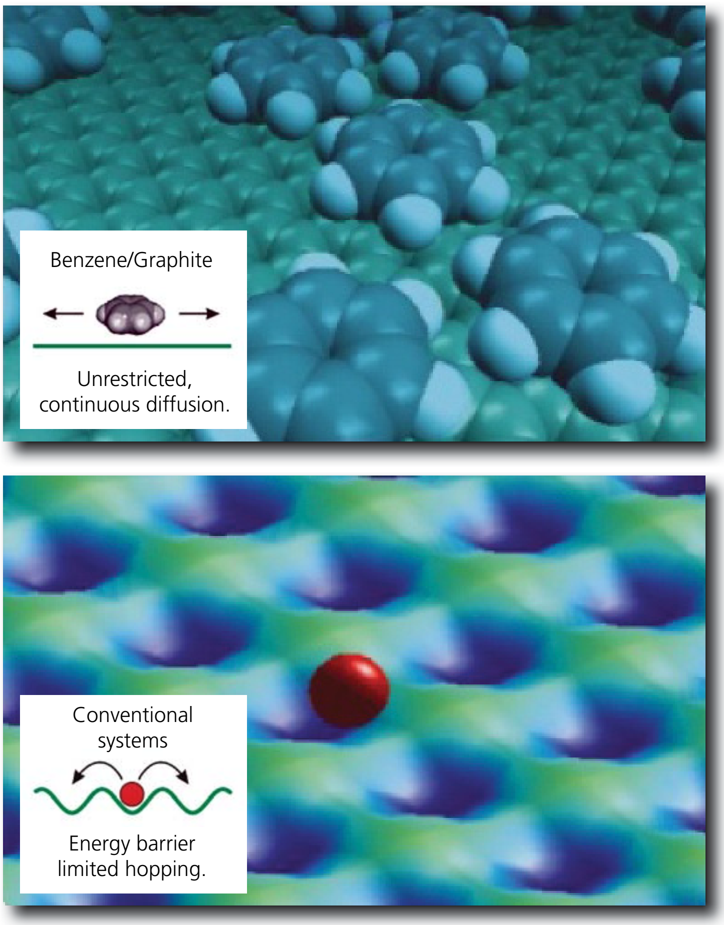
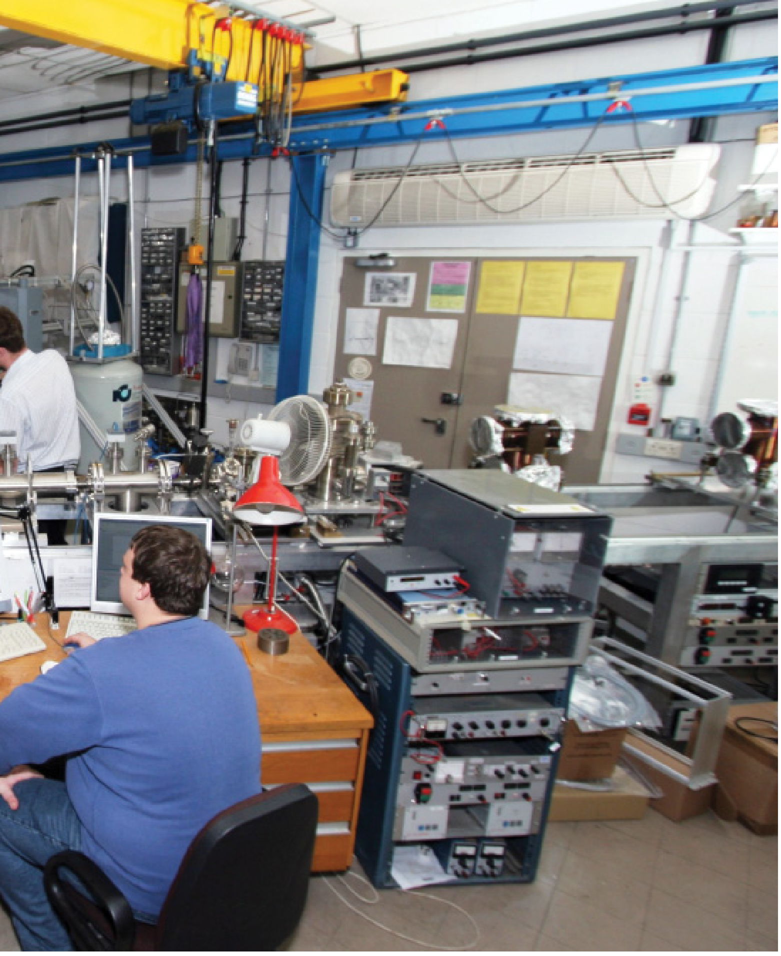


Fig. 3: Diagrammatic comparison of the interaction between the mobile species and surface for the recently observed atomic scale Brownian behavior for benzene on graphite (top), and for conventional hopping between sites on a surface (bottom).



nsity helium source is at the top centre, the ultra-high vacuum sample chamber to
jor undertaking, only made possible through the substantial support provided by the
x7, under the supervision of members of the group.*

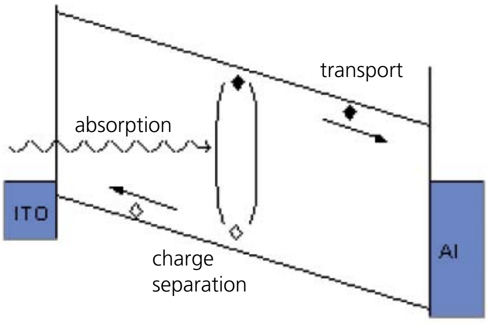
Organic Solar Cells

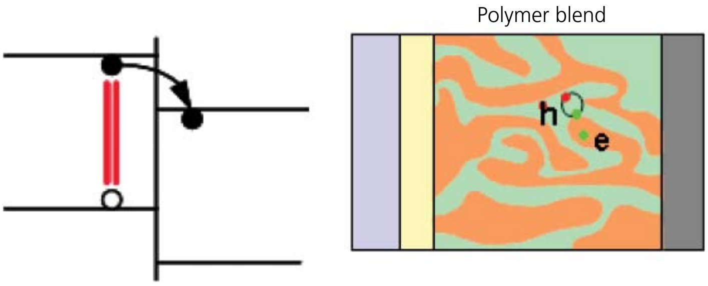
Sunlight is the most abundant source of energy on Earth. It is the origin of the energy for fossil fuels and for renewable energy sources such as wind and wave power, but it is considerably more efficient to use sunlight to generate useful energy directly. There are two choices – firstly by concentrating sunlight with mirrors to generate heat that can be used to drive conventional electricity generators, and secondly by using arrays of photovoltaic, or 'solar', cells. Both are feasible technologies, but are still considerably too expensive to deploy on the large-scale at present.

Solar cells use semiconductors to capture light. Each absorbed photon raises an electron to a high energy state and this electron is then arranged to drift away from the net positive charge left behind, termed the 'hole', so that each can be collected at the two electrodes to either side of the semiconductor layer. Silicon is an excellent material for solar cells. It is the right colour, absorbing across the visible and near infra-red parts of the solar spectrum, and makes reasonably efficient cells. Silicon is not, however, a good absorber of light and so relatively thick slabs, typically 0.2 mm, are used and considerable quantities of the material are needed. Unfortunately, semiconductor-grade silicon is expensive and it will be very difficult to bring down the costs much lower than at present.

This concern has stimulated a world-wide drive to find other semiconducting materials that may provide cheaper solar cells. If we are to reduce the cost of deployment seriously, we need to bring down not just the cost of the semiconductor materials, but also all the other materials used in solar cell assembly, such as the substrate and encapsulation. The best solution may well be to print the active semiconductor layers and metal electrodes and tracks directly onto plastic film. The fastest way to do this would be to use continuous roll-to-roll printing, as in the newspaper industry. This would be a very practical way of producing the vast areas of solar cells that will be needed when we switch from fossil fuels. These solar cells will be lightweight and flexible and so much cheaper and easier to deploy than current systems, which are enclosed in glass sheets.

Roll-to-roll printing presents us with some big challenges. We need to develop a completely new materials set, redesign the solar cell semiconductor architecture and develop the manufacturing skills that allow precise control of the printed film thickness. Within the University we now have a broad programme of science and engineering to cover this full set of research tasks. Those involved include Professors Sir Richard Friend, Neil Greenham, Henning Sirringhaus, Ulli Steiner and Dr Chris McNeill in Physics, Professor Wilhelm Huck in Chemistry, Professors Mark Welland and Andrea Ferrari in Engineering, and Professor Judith Driscoll in Materials Science.



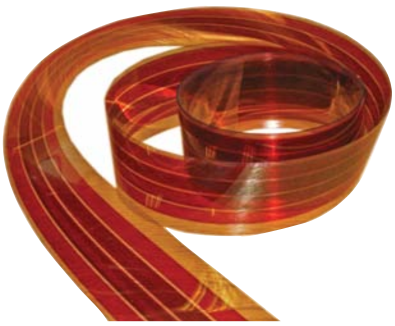


Illustrating the electronic structure of interfaces between two different polymers. These might be in so-called 'blends' where polymers are mixed on a fine scale, sufficiently small to be similar to the exciton diffusion length. Various deposition techniques are used to create many state-of-the art polymer photovoltaic diodes.

Roll-to-roll printing means that the semiconductor materials have to be handled as 'inks' that can be printed at room temperature, a very different world from the traditional high temperature and high vacuum processing world of silicon technology. One very attractive set of materials are the polymeric organic semiconductors that Friend, Greenham and Sirringhaus have developed for use in light-emitting diodes. These are already exploited through Cambridge Display Technology Ltd and printed transistors, as used in electronic paper displays, now developed by Plastic Logic Ltd. There is however a catch. While silicon readily liberates an electron from an electron-hole when a photon is absorbed, the excited electron generated in an organic semiconductor is very reluctant to leave its positively-charged hole. Nature solved this design problem by the process of photosynthesis in which the excited electron is generated at the interface between two semiconducting molecules that have different electron affinities. This causes the electron to move to the adjacent molecule, leaving the hole behind. Subsequent steps in photosynthesis use the reducing power of the electron and the oxidising power of the hole to do chemistry.

For solar cells we have the simpler task of arranging that the separated electron and hole can be collected at their respective electrodes on either side of the device. Some time ago we found that single interfaces, or heterojunctions, seem to function reasonably well but the electron would often move no further than to the adjacent site across the heterojunction, bound by its electrostatic attraction to the positively-charged hole. The Cavendish group are just starting a major EPSRC Programme Grant, worth £6.8M over 5 years, in collaboration with Huck in Chemistry and colleagues at Imperial College. The grant supports a large programme of chemical synthesis, materials processing and semiconductor physics measurements that will tackle this problem. We plan to develop more controlled heterojunctions that will be better at separating the two charges from one another. We need to raise the efficiency of energy conversion from current levels of about 5% to at least 10% to be competitive with other solar cell technologies – this is a big challenge but we believe these levels of performance are attainable.

We face a second challenge: the excitation produced by the absorbed photon needs to find its way to the heterojunction before it decays. It is usually short-lived, lasting only about 1 nanosecond and therefore cannot travel very far, typically about 10 nanometres, corresponding to 20 or so intermolecular spacings. We also need however much greater thicknesses of semiconductor than this to absorb all the incident light. The solution being investigated worldwide is to arrange that the electron-accepting and hole-accepting materials form an interpenetrating network with dimensions on this nanometre length-scale. This needs both to give efficient charge separation and also to allow the electrons and holes to move along continuous pathways to the electrodes – a non-trivial set of requirements! One very promising route is to use polymers composed of two blocks of chemically-distinct polymers, the 'diblock copolymers'. When the two blocks are selected so that they repel one another, they form very specific ordered structures with regions of one block tied to regions of the other block by the chemical bond that links them. We are developing these nanostructures in a programme supported by a £1.9M EPSRC grant under the Nanotechnology Energy Grand Challenge programme that draws on Steiner's polymer expertise, with synthesis in Chemistry and solar cell developments in Physics. This and related approaches allow us to use inorganic semiconductors such as titanium dioxide and zinc oxide to form nanocrystalline frameworks that can later be filled with organic semiconductors. These structures are being developed in Engineering by Welland and in Materials Science by Driscoll.



Solar cells can now be produced by roll-to-roll printing (courtesy of Richard Friend).

We have centred the programme of work on printed solar cell process engineering in order to provide the interface between our research and its move to industry. We used the EPSRC-supported Integrated Knowledge Centre to begin the printing project with the result that Ferrari's work in Engineering on conducting carbon nanotube electrodes was naturally incorporated into the programme. Together with the Technology Partnership, the scientific consultancy just down the road in Melbourn, we bid for and won the competition run by the Carbon Trust in 2007 to set up an industrial activity to prove the manufacturability of new solar cell technologies. The Carbon Trust has committed £5M for this and the printing activity is growing rapidly.

Richard Friend

A similar version of this article was published in *Research Horizons*, edition number 10, September 2009, and is reproduced with permission.
See website: www.research-horizons.cam.ac.uk

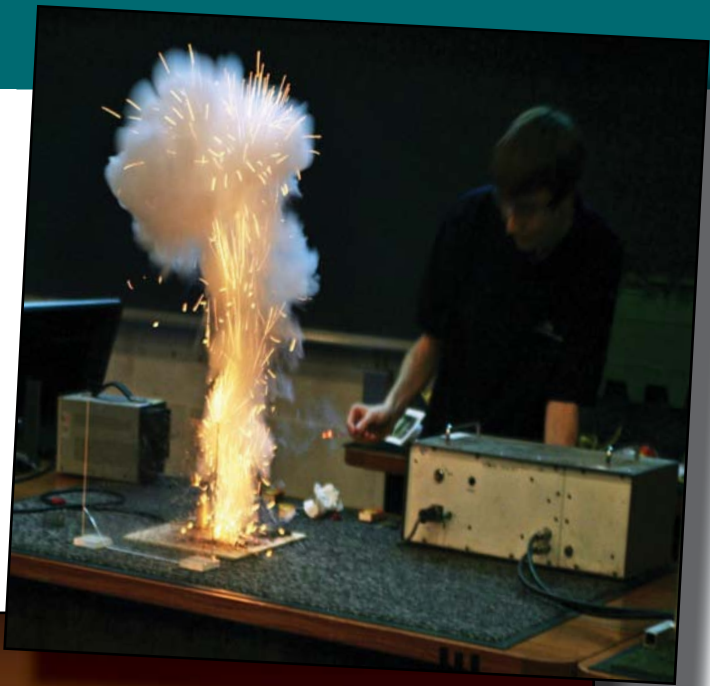
From 15th to 17th September 2009 about 2000 school students, aged between 14 and 16, and their 150 teachers invaded the Cavendish Laboratory in Cambridge with the sole aim of discovering 'Physics at Work'. The Cambridge event began in 1984 and is one of the longest running outreach initiatives in the country, which continues not only to fulfil but also to exceed its objectives, going from strength to strength inspiring students of the new millennium.

To help celebrate the 25th Anniversary of this Cambridge showpiece for Physics, comedian Dara O'Briain dropped in on the Cavendish Laboratory to meet the exhibitors and sign autographs for the visiting students. Dara surprised and delighted some of the two thousand teenagers who attended this year's Physics at Work by sitting in on one of the afternoon sessions. Best known for his wit and easygoing presentation of BBC2's 'Mock the Week' programme, what few people realise is that he holds a degree in Mathematical Physics and has confessed to having been a nerd "insanely in love with maths and theoretical physics" when he was a teenager.

The three-day exhibition is held annually to promote physics in all its forms to schoolchildren, and to show them the wealth of career opportunities that open up if they continue their studies in physics. Students get the chance to come face to face with some of the world's finest physicists who help demystify the subject for those who find it intimidating. All our exhibitors and contributors agree that helping to spread the excitement of modern physics research to students who will soon be making career and exam choices is vital. We are encouraging the next generation of scientists and firing their imaginations about what can be achieved.

This year's exhibition featured stands from industry, university departments and groups from the Cavendish Laboratory. The subject matter was as wide ranging as ever, as can be appreciated from the list of participating organisations in the box. Not only have many of the presenters returned year after year but also a number of the visiting schools, who travel from all over East Anglia, London and the South East. I have been inundated with thanks and requests for further engagement. One teacher wrote "I would just like to say many thanks for an excellent Physics at Work Exhibition. I feel that this year was the best yet and the exhibits we got to see were relevant to the subject material in the A Level Physics course that we teach. Next year would it be possible to do a whole day so the students can get even more out of it?"

One of the keys to the success of Physics at Work is the short, sharp, hands-on exposure to physics combined with the underlying links between the subject and prospective careers. Each exhibitor has just 15 minutes to get the message across, whilst demonstrating how physics fits in to the work that they do, making the presentations innovative, exciting and engaging – this year that meant everything from gunpowder being set on fire to a car built by enthusiasts in the Cavendish's Team Crocodile that can achieve nearly 3,000 miles to the gallon.



2009 Physics at Work Exhibitors

Atomic Weapons Establishment
BAA Stansted: Transit Electronics Dept
British Antarctic Survey

Cavendish Laboratory
Cavendish Astrophysics
Biological and Soft Systems Group
High Energy Physics Group
Laboratory Safety Officer
Optoelectronics Group
Quantum Matter Group
Semiconductor Physics Group
Surface Physics Group
Fracture and Shock Physics Group
Team Crocodile
Theory of Condensed Matter Group

Department of Chemical Engineering
Department of Earth Sciences & Carrack Measurement Technology
Department of Materials Science
Domino Printing Sciences plc
Institute of Materials, Minerals and Mining
LATEST, School of Materials, University of Manchester
The Mathworks Ltd
Mott MacDonald
Nanoscience @ Cambridge
Royal Air Force Police
Rolls-Royce plc
The Technology Partnership
Wolfson Brain Imaging Centre

The climax of this year's programme was a special 25th Anniversary Gala Evening. Prizes were presented to the winners of a competition to design special logos for the anniversary event. The winners were Thomas Andrews, a Year 5 pupil from Woodside Middle School, Bedford, and Catherine Cashman, a Year 8 pupil at Trinity Catholic High School, Essex. A prize was also awarded by Dara O'Briain to the company that the school pupils had voted the best exhibitor - the accolade was won this year by the team representing the Atomic Weapons Establishment.

Guests at the gala evening included CEOs from the companies involved, potential future exhibitors, competition winners and most importantly the exhibitors themselves. During the evening guests were invited to view the exhibition from a students' perspective, one guest remarking, "It was excellent - super physics matched only by the enthusiasm and passion of the presenters - a very powerful combination indeed. An excellent contribution to inspiring not just the new generation of physicists but some of those past their prime too!"

Please note the dates of Physics at Work 2010: 21st, 22nd & 23rd September.

Booking for next year will begin in May 2010. More pictures and information about Physics at Work can be found at **www-outreach.phy.cam.ac.uk/physics_at_work**

Exhibitors:
If you know of organisations who would like to become 2010 Physics at Work Exhibitors, please contact me at

outreach@phy.cam.ac.uk

Lisa Jardine-Wright

The Cambridge Nano Doctoral Training Centre

NanoScience and NanoTechnology are increasingly a focus of optimism and opportunity for new human capabilities. The ability to tailor new materials and device properties, and to understand others, on the size scale of a billionth of a meter involving thousands to millions of atoms, opens up new toolboxes for human ingenuity. Perhaps the best way to understand Nano is not through size, but through its philosophy, which essentially brings a constructionist approach to a domain nestling between chemistry, physics, engineering, materials and the biosciences. Rather than a buzzword or bandwagon, Nanoscience is increasingly demonstrating novel functional properties and highlighting others that depend upon learning how to put things together in intricate ways. Incessantly interdisciplinary, this disparate interweaving of research fields is an extremely challenging environment into which to throw PhD students straight from UK undergraduate programmes.

October 2009 saw the first cohort of 50 PhD students arriving in our new £7M EPSRC-funded Nano Doctoral Training Centre (NanoDTC), which is designed to arm young researchers in a range

The first cohort of interdisciplinary PhD students in the Nano Doctoral Training Centre in Cambridge. Students are doing courses, practicals and projects in Nano across Physics, Chemistry, Material Science and Engineering. Jeremy Baumberg is third from the right in the front row.

of Nano techniques and disciplines before they commit themselves to specific research topics. Built around a strong collaboration of academic champions across the Cambridge Science and Engineering departments, it gives students experience of the cultures of each department as well as creating lasting connections that further develop the individual strengths of Cambridge's Nano groups. The PhD cohort will interact strongly with each other throughout their PhDs, brainstorming particular Nano targets and creating a pool of shared knowledge and know-how.

The Cambridge NanoDTC showcases the Research Council's ambitions in advanced research training partnerships, and is being identified as the future of PhDs in the UK. In the first year, students take a mixture of formal Nano-based courses in areas other than their own undergraduate focus. They work on Nano practicals in every department using state-of-the-art equipment, are challenged with smaller projects in a range of research topics unfamiliar to them, and start to develop their own PhD plans with academics. The Centre has adopted a strong focus on the self-assembly and directed-assembly of nano-materials and nano-devices. In other words, it aims to develop new ways to make useful nanosystems which do not depend on current expensive and restrictive techniques and technologies which carve up and lay down specific layers of atoms. Being able to produce low cost but elegantly assembled nano-machinery is what the natural world does exquisitely, but we have not yet been able to devise equivalent schemes for our electronic, optical and magnetic systems.

The Cavendish is playing a leading role in the new Cambridge NanoDTC under the leadership of Professor Jeremy Baumberg with two embedded research-experienced Teaching Fellows liaising with all the departments involved and the 100+ groups in Nano across the University. Within the Cavendish, many of the research groups are hosting projects and training, including semiconductor physics, physics of medicine, biological and soft solids, optoelectronics, nanophotonics, atomic, mesoscopic and optical physics. Similar efforts in chemistry, materials and engineering demonstrate the scale and significance of this arena which stresses convergence of approach and the richness of the science with deep difficulties balanced by dramatic payoffs.

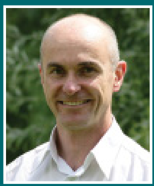
An important part of the NanoDTC is the embedding of innovation within a Nano context right from the start. While spin-offs in Nano space are increasing within the UK, most frequently graduate students do not encounter the issues associated with taking lab-based ideas into technology until near the end of their PhDs, if then. With Nanotechnology, this is too late as many decisions taken early in the research project can have unfortunate implications about take-up and demonstration. Connected with our theme of mass-scale nano components and systems is appreciation of the route to elegant, economic and effective manufacture. Exposing PhD students to what influences these aspects comes in various forms, from our masters-level courses within the MoTI programme at the Judge Business School, to anecdotal seminars on nano-commercialisation from high-tech industries who have partnered our centre, including Nokia, CDT, Hitachi, Merck, HP, Microsoft and many smaller companies. Cambridge is the ideal place in which to demonstrate such connections between the research lab and the production line with numerous successful nano exemplars. NanoTechnology promises to deliver improved energy efficiency (fuel cells, solar cells, clean energy), healthcare (smart nano-encapsulation for anti-cancer, broad ultra-sensitive screening and sensing of the human immune systems), and innovative functional materials for many applications.

While the initial phase of funding will support cohorts over the next 5 years, we are extremely limited in how many students can be brought into the NanoDTC programme. Essentially, an extra funded year is required beyond a normal PhD and has to include the costs of high-value high-tech training on state-of-the-art nano equipment and projects. Working with the Cambridge 800th Anniversary Campaign, we aim to build a portfolio of support enabling us to reach much wider in supporting young scientists with an eye to interdisciplinary science and innovation. Ultimately the efforts to train a cadre of enthusiastic researchers who cheerfully move between departments and disciplines across Cambridge and the world will pay enormous dividends for our futures.

Jeremy Baumberg For more information see www.nanodtc.cam.ac.uk

Honours, Promotions and Prizes

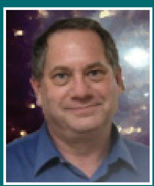
The past year has almost been like the caucus race from Alice in Wonderland – everyone must have prizes. Congratulations to all those below and bask in the reflected glory that these distinctions brings to all their colleagues.




David MacKay and ***Henning Sirringhaus*** were elected Fellows of the Royal Society.

David MacKay delivered the Clifford Paterson Lecture at the Royal Society. He was also appointed Chief Scientific Advisor to the Department of Energy and Climate Change.

Richard Friend won the King Faisel Award, jointly with our 2001 Scott lecturer Rashid Sunyaev, Director of the Max Planck Institute for Astronomy, Garching. Richard also won the Institute of Physics Business and Innovation Medal, jointly with Dr David Ffye.



We congratulate our colleague ***Rob Kennicutt***, Director of the Institute of Astronomy, for jointly winning the Gruber Cosmology Prize for his role in the determination of Hubble's constant.

John Field has been awarded the Dymat 2009 John Rinehard Award for his research into the science and technology of dynamic processes in materials. He was also appointed an Honorary Fellow of Qinetiq for his many contributions to Qinetiq and its precdecessors over the last 45 years.

Montu Saxena was awarded an Honorary Professorship by the A Yasawi Kazakh-Turkish International University, Turkistan, Kazakhstan for his services to education in Kazakhstan.

We are delighted to welcome ***Professor Jim Scott***, FRS to the academic staff of the Laboratory. He has transferred from Earth Sciences to the Cavendish where he will continue his studies of ferroelectric thin films.


In the 2009 round of Senior Academic Promotions, ***Val Gibson*** and ***Neil Greenham*** were promoted to Professorships and ***Jocken Guck*** to a Readership.

Jane Blunt was elected a Chartered Fellow of the Institution of Occupational Safety and Health (CFIOSH). Fellowship is only awarded to "members who demonstrate an outstanding commitment to the health and safety profession". Only 1.6% of the Institution's membership become fellows.

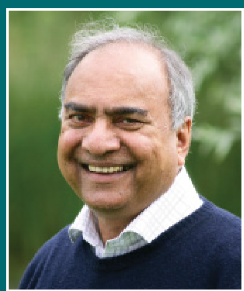
We warmly congratulate ***Adam Brown*** on his CRC Award. Adam was presented with a trophy as well as a tool-spanner kit.

We congratulate the following on winning prestigious fellowships:

Jenny Clark, Royal Society Dorothy Hodgkin Fellowship (Optoelectronics)
Andrew Croxall, Trinity College Junior Research Fellowship (Semiconductor physics)
Anoop Dhoot, Royal Society University Research Fellowship (Optoelectronics)
Farhan Feroz, Trinity Hall Research Fellowship (Astrophysics)
James Frost, Peterhouse College Research Fellowship (High Energy Physics)
Carrie MacTavish, Kavli Fellowship (Astrophysics)
Meera Parish, EPSRC Advanced Research Fellowship (Theory of Condensed Matter)
Suchitra Sebastian, Royal Society Research Fellowship (Quantum Matter)
Nina Steinke, Newnham College Fellowship (Thin Film Magnetism)

The Laboratory will Never be the Same Without...

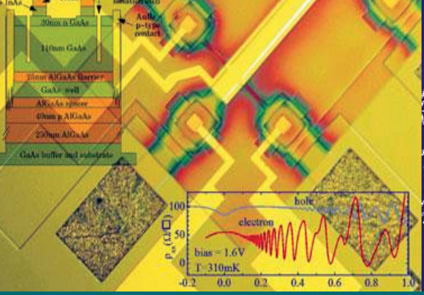
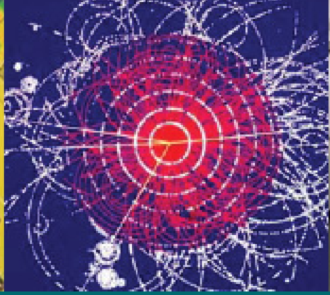
Janet Carter who retired at the end of September 2009 after leading the High Energy Physics Group for the last 20 years. Under her dynamic leadership, the Cavendish played a leading role in the development and construction of the silicon detectors which are at the heart of the Large Hadron Collider.

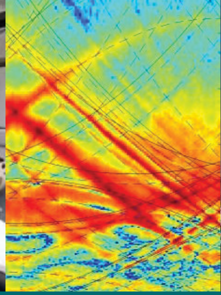


Munawar Chaudhri who retired at the end of September 2009 after a distinguished career in the Laboratory, where he continued and enhanced world-leading research in the area of the fracture of materials and the physics and chemistry of solids.


David Johnson and David Cresswell and his wife at their retirement celebrations with Peter Littlewood, David Peet and colleagues.

Among the Assistant Staff retirements, ***David Johnson's*** is perhaps the most remarkable, having been a member of the Laboratory for 47 years. His cheerful presence and expertise will be long remembered. Few can match that record of service, but some much more recent members of the assistant staff also retired: ***David Cresswell*** (12 years), ***Mick Bretherton*** (9), ***Trevor Fairhead*** (5) and ***Francis Newton*** (4). We are sad to report that ***Brian Bowers*** died in service.

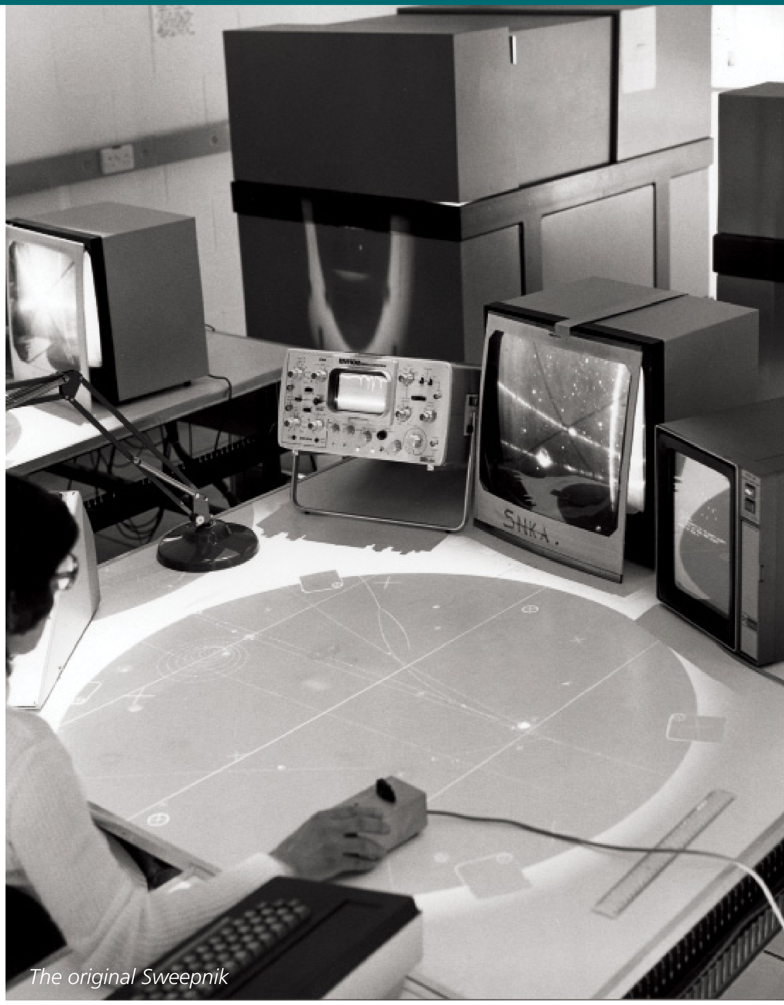



The 40th Anniversary of the Cavendish's First Spin-off Company

40th anniversary celebrations, left to right: Michael Sanderson, Professor Sir Maurice Wilkes, Sir John Bradfield, Graham Street, Peter Woodsford, David Rhind

1Spatial celebrated its 40th Anniversary in November 2009. The company started life in 1969 as Laser-Scan, founded by Professor Otto Frisch, FRS, John Rushbrooke and Graham Street of the High Energy Physics Group. Originally established to commercialise Sweepnik, a machine that used a laser beam moved by mirrors to read lines on photographs, Laser-scan evolved into 1Spatial in 2006 and from a small group of academics into an industry-leading geospatial software and solutions provider, employing over 100 people in several offices around the World. Its core business has been based on mapping and charting organisations such as the Ordnance Survey of Great Britain, the UK Hydrographic Office and No. 1 Aeronautical Information Documents Unit of the UK Royal Air Force. 1Spatial is now a key player in providing solutions for geospatial data integration, transformation, update and quality control as part of enterprise information architectures.

We offer our warmest congratulations on this achievement and wish 1Spatial all success in the future.



The original Sweepnik

If you would like to discuss how you might contribute to the Cavendish's Development Programme, please contact either Professor Malcolm Longair (msl1000@cam.ac.uk) or Professor Peter Littlewood (HoD@phy.cam.ac.uk), who will be very pleased to talk to you confidentially. Further information about how donations may be made to the Cavendish's Development Programme can be found at: **www.phy.cam.ac.uk/development**

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