UNIVERSITY OF CAMBRIDGE

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January 2011 Issue 5

News from the Cavendish Laboratory

Inside...

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£20 million donation to revolutionise physics research

David Harding (St Catharine's, 1979, Natural Sciences), the Founder, Chairman and Head of Research of Winton Capital Management, has pledged to donate £20 million to the Cavendish Laboratory to set up and fund The Winton Programme for the Physics of Sustainability. His gift, the largest donation to the Laboratory since its creation in 1874, will create a new programme in the physics of sustainability, applying physics to meet the growing demand on our natural resources.

David Harding

"The Cambridge 800th Anniversary Campaign has an objective: 'The Freedom to Discover' and I am hoping I can give the scientists of the Cavendish more freedom to discover," says David Harding. "I studied theoretical physics at Cambridge, and the Cavendish has always had the reputation of attracting the finest minds in the world. While it is not quite as simple as using physics to save the world, this is an opportunity to use, for example, quantum physics to develop materials with seemingly miraculous properties that could combat the growing effect humans are having on the planet. I want to encourage research to keep the skies blue."

The Vice-Chancellor, Professor Sir Leszek Borysiewicz, said: "The University is most grateful to David for this donation, which is truly exceptional both in its generosity and in its vision of translating fundamental discoveries in physics, to meet one of the most pressing needs of our generation."

The donation will support programmes that explore basic science that can generate the new technologies and new industries that will be needed to meet the demands of a growing population on our already strained natural resources. The programme's director is Richard Friend, the Cavendish Professor of Physics and a world-renowned leading expert on the physics, materials science and engineering of semiconductor devices. Remarking on the impact of the donation, Richard said: "Advances in fundamental physics have always had the capacity to solve very real problems. This programme will support the people with the radical ideas that bring practical solutions - very much the Cambridge way of doing science."

The programme will provide studentships, research fellowships, and support for new academic staff as well as investment in research infrastructure of the highest level, pump-priming for novel research projects, support for collaborations within the University and outside, and sponsorship for meetings and outreach activities.

Since graduating from Cambridge in 1982, David Harding has become one of the most successful fund managers in the world. Early on he recognised the advantages of hiring individuals with science backgrounds. Winton currently employs over 90 researchers with PhDs or Master's Degrees in subjects including extragalactic astrophysics, mathematics, statistics, particle physics, planetary science and artificial intelligence.

"At its core Winton is much more than an investment manager," says David Harding. "We are a scientific research centre using empirical methods to analyse data. The financial markets may be our laboratory but just like the Cavendish we are driven by research."

The Winton Programme for the Physics of Sustainability will launched and fully established in 2011.

Editorial

This edition's news is dominated by the magnificent donation by David Harding described on the front page. The Winton Fund will support research in the general area of what we call the physics of sustainability. The intention is to support a very wide range of fundamental and applied physics in the general area of condensed matter physics, which is fostered by many groups in the Cavendish. All of these activities will contribute to understanding how physics can contribute to the many sustainability challenges that society is facing worldwide. We will also use the resource to facilitate collaborations with other departments in Cambridge and our partner universities. A distinguished international management group will be set up to oversee these activities. The formal opening of the programme will take place in the first quarter of 2011.

At the same time, we are delighted to announce gifts from the Raymond and Beverly Sackler Foundation to support research in the Physics of Medicine and the Lloyd's Register Educational Trust for studentships in Computational Science. These are described later in this edition of CavMag.

The science theme of this edition is 'New Faces'. Recent appointees Jim Scott, Russell Cowburn and James Wells describe their research activities, each of them bringing new approaches and, unquestionably in James' case, extra dimensions to the Laboratory's research portfolio. We wish them all success in their endeavours.

A notable achievement has been the award of Athena SWAN Silver and IoP Juno Champion Awards in recognition of our endeavours in Equal Opportunities, particularly in the support of female members of staff.

Lastly, we have simplified the way in which gifts to Physics may be received online and this is described on page 10. We are most grateful to the Development Office for making this possible. We hope benefactors will find this an effective way of helping with our development efforts.

Malcolm Longair

Ferroelectric and Magnetoelectric Memories

For about twenty years there has been a perceived need in the microelectronics industry, not just for faster, cheaper memories of higher bit-density, but especially for non-volatile memories. 'Non-volatile' means that the stored information is not lost in the event of, for example, a power failure or if a nuclear blast goes off in front of your intercontinental ballistic missile, or more commonly the cat trips over the power cord on your PC. The way most computers work is with dynamic random access memories (DRAM). DRAMs are silicon chips that are very cheap, very fast, and very high density, but they are volatile. So it is not a good idea to store a million bank accounts in them, or even the first draft of your dissertation. In your PC, the information is processed in DRAMs, but when you hit the SAVE key, it is stored on a hard disc that is slow but non-volatile. If the DRAMs were replaced by a non-volatile equivalent, the hard disc could be eliminated resulting in smaller, lighter, and far more robust computers with no moving parts. You could put such a computer in a tank, into a basketball, or into in-line roller skates...

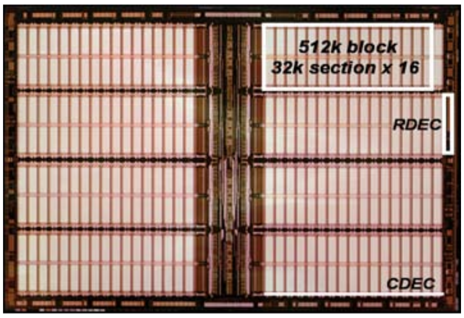


Fig. 1. A Samsung packaged ferroelectric random access memory.

One way to replace DRAMs is with non-volatile **ferroelectric RAMs (FRAMs)**. In a ferroelectric crystal, the ions can be displaced in two or more directions by applying an electric field of order 50 kV/cm. That is a strong field, but across a thin film only 100-300 nm in width, it is a very small voltage, in fact, less than the 5V standard of all silicon chips.

In work I did in the 1980s at the Ramtron Corporation and Symetrix Corporation in the USA, we were the first to make such ferroelectric memories. A good example of a packaged FRAM from Samsung is shown in Fig. 1. This consists of eight 512 kbit blocks each of which has 16 32-kbit sections. The interior of each bit of the state-of-the-art Samsung 64 Mb FRAM is shown in Fig.2. The physics interest of such structures lies in how to optimize the dielectric layer of the ferroelectric material, in the example shown in Fig. 2 the layer being made of lead zirconate-titanate. These devices have already had commercial success. For example, FRAMs are used in the Sony Playstation 2.

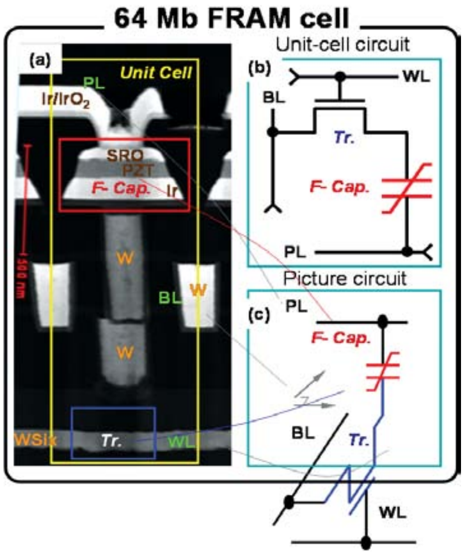


Fig. 2. The interior of each bit of the state-the-art Samsung 64 Mb FRAM.

Basic physics problems have, however, limited the commercial exploitation of this technology. Every two or three years the industry giants in microelectronics - IBM, Texas Instruments, Intel, and Motorola in the USA; Samsung and LG Electronics in Korea; and a host of Japanese corporations such as Hitachi, Toshiba and Fujitsu - publish an 'Industry Roadmap' which shows what the industry needs in the coming few years. The road-map for 2005 required the development of FRAMs with three-dimensional, rather than two-dimensional structures by 2010-2011. This is because the bit-density is limited by the capacitor area, or 'footprint', on the chip surface. In conventional RAMs that involve resistors and transistors, the areas involved are much smaller than those of the capacitors in FRAMs.

One way to get round this problem is to fabricate three-dimensional nanotube capacitors that stick out of the silicon chip and we have achieved this in a collaboration of various Cambridge University laboratories (Fig. 3). Using organic ruthenium compounds we can fabricate good concentric electrodes inside and outside each tube, giving a large area, and proportionately large capacitance, but a small footprint. A related approach is to go down, not up, by fabricating deep trenches with high aspect ratios (Fig. 4).

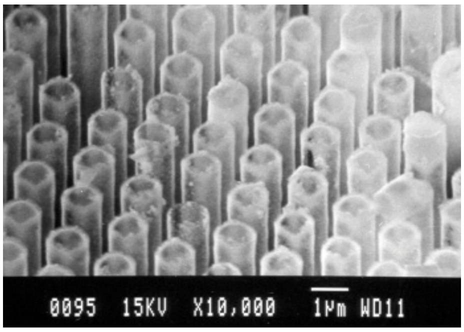


Fig. 3. Three-dimensional nanotube capacitors on a silicon chip.

An alternative approach is to fabricate tiny nano-dots, which are best studied by electron holography. Fig. 5 illustrates such holography of magnetic nano-domains. Related studies are underway on ferroelectric nano-dots in an EPSRC funded collaboration between Cambridge and Belfast.

The newest approach is to try to make memories out of thin film magnetoelectrics. These materials are usually multiferroic, meaning magnetic and ferroelectric, and so there is the concept of writing the data electrically, which is very fast, voltage-driven not current-driven, and uses very low power, and reading the information magnetically which involves no re-set operation, no fatigue and no endurance problems. Present work in several Cambridge groups, including Montu Saxena, Gil Lonzarich and myself in the Cavendish and Mathur and his colleagues in Materials Science is exploring such magnetic ferroelectric devices. The physics is however much harder. We need to address question such as: Why are there no materials that are ferroelectric and strongly magnetic at room temperature? Will ionic fluorides or oxyfluorides have different physics from multiferroic oxides? What exactly is the coupling mechanism between magnetism and ferroelectricity? These are demanding questions that are at the forefront of physics research – watch this space!

Jim Scott

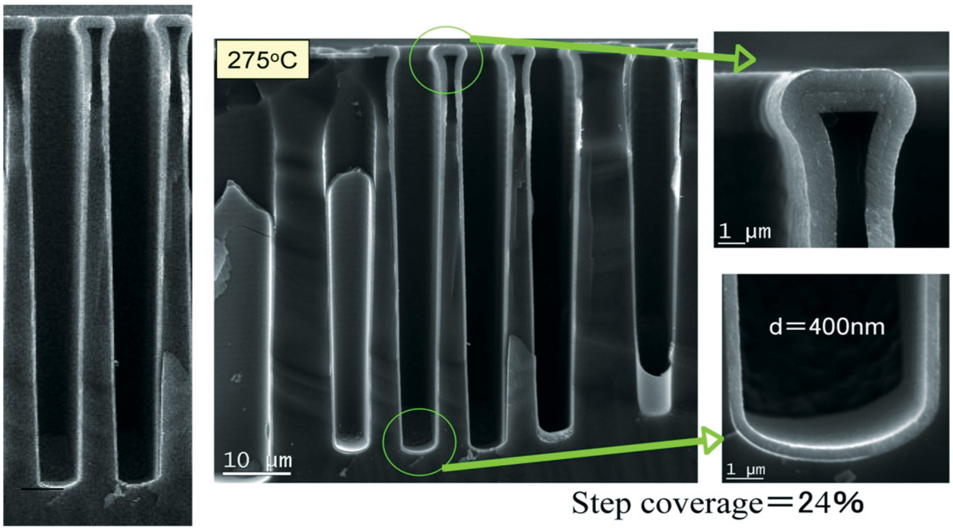


Fig. 4. Another approach to creating nanotube capacitors by fabricating deep trenches in the substrate.

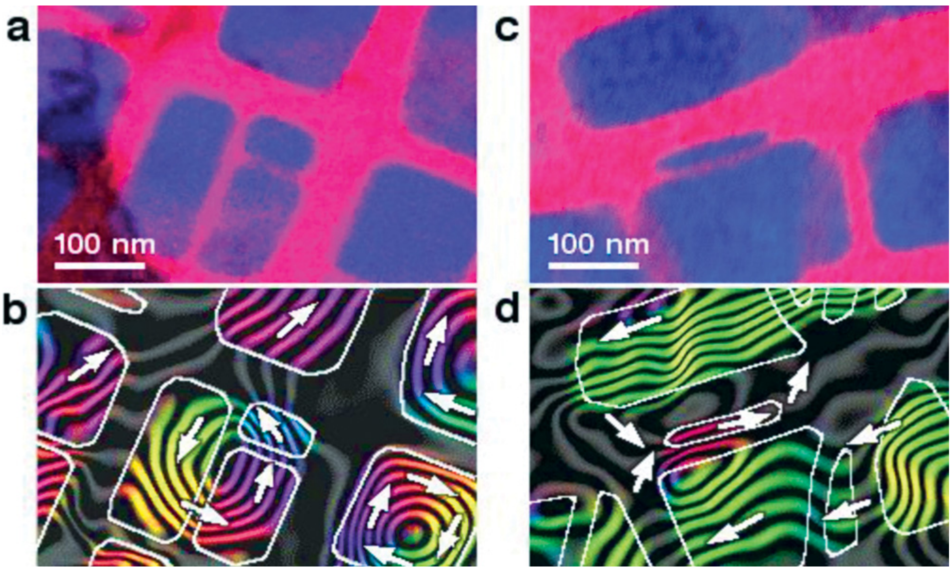


Fig. 5. Holographic images of nano-domains (courtesy of Richard Harrison, University of Cambridge).

The Raymond and Beverly Sackler Fund for the Physics of Medicine

Dr Raymond and Mrs Beverly Sackler.

We are delighted to report a benefaction of £2m to be received over the next four years or earlier from the Raymond and Beverly Sackler Foundation. This benefaction has been provided as a tribute to the Vice-Chancellor Emerita, Professor Dame Alison Richard. In recognition of this generous gift, an area in the new Physics of Medicine Building at West Cambridge will be named the Raymond and Beverly Sackler Research Centre in the Physics of Medicine.

The income of the Fund will be used to promote and encourage research in the Physics of Medicine by initiating studies into innovative research ideas. In addition, it will be used in supporting student training and exchanges of staff at all levels in the field of Physics of Medicine, including international exchanges, internal secondments to the Centre for Physics of Medicine, summer schools, and in supporting visitors to the Physics of Medicine programme. It will also provide Graduate Studentships in the Physics of Medicine, as well as furthering scientific discussion and exchange among those carrying out research in the field of Physics of Medicine in the University through seminars, early stage project development, international exchanges, and collaboration.

The University has benefited enormously from the generosity of Raymond and Beverly Sackler. Among the beneficiaries closest to physics, their provision of the lecture theatre in their name at the Institute of Astronomy and the Annual Sackler lectures in Astronomy and Medicine are of particular significance. In Medicine the Raymond and Beverly Sackler Medical Research Centre has been established for many years within the Faculty of Clinical Medicine in the University.

Nanomagnetism

It is fourteen years since I completed my PhD at the Cavendish in the Physics and Chemistry of Solids group. I have now returned to the Cavendish, having spent time in Paris, Cambridge Engineering, Durham and Imperial College London. My research interests cover the areas of nanotechnology, magnetism and optics. Magnetism and nanotechnology go together very well, both for scientific discovery and technological applications. Nanotechnology is all about materials that have been structured on length scales of 1-100 nm (1nm equals 10^{-9} m), resulting in modified physical properties. Materials are sensitive to such modification for two main reasons. Firstly, the ratio of surface area to volume within the material can be changed by nanostructuring – an extreme version of chopping up vegetables to make them cook more quickly! Surfaces usually possess very different physical properties because the atoms at the surface have a different symmetry from those in the bulk. Secondly, many of the fundamental physical processes that underpin the properties of materials have a characteristic length scale of a few nanometres. For example, electrical conductivity is determined by how far an electron travels between scattering events. If we modify the material on that length scale then we disrupt those fundamental processes. In magnetism, both the surface to volume ratio and the characteristic length scales are crucial in determining magnetic properties, giving us a rich system to play with.

My research has always had a strong bias towards technological application - I find things that are useful more satisfying. Thinking about how to use a piece of physics is also a great way to find out what you really know – technology usually raises new fundamental questions. Consequently, I have founded two start-up companies during the last 8 years. One sells scientific instrumentation to other nanotechnology researchers around the world. The other uses some of the laser scattering techniques that I have developed while studying nanostructures to help stop counterfeiting and smuggling of valuable goods and documents (Fig. 1).

My return to the Cavendish coincides with the start of two new and exciting research projects, which will form the basis of my research over the next five years. The first is concerned with domain walls in magnetic nanowires. Magnetic domains are regions in a ferromagnet where the magnetisation direction is uniform; most magnetic materials contain a large number of domains, separated by boundaries known as domain walls. Domain walls are very tangible – they have a size and a mass, they can be seen using either light or electrons, and can be pushed around by magnetic fields or electrical currents. Most importantly, they can be injected into a nanowire, a long strip of magnetic material just a few atoms thick and tens of nanometres wide, like a marble into a copper pipe. I have been interested in such domain walls for many years – one of my current interests is to see if they can be used for detecting the results of biological assays, potentially leading to ways to detect cancer and other diseases by a low-cost portable chip (Fig. 2).

The second project concerns the physics that underpins computer memory. An article in *The Economist* in 2008 reported that the carbon footprint of computer data centres is set to overtake that of aircraft within 10 years. Reducing the power consumption of computers is therefore an important part of tackling climate change. Most of the waste heat generated by computer chips comes from quantum mechanical tunnelling of electrons through regions that should be electrical insulators. My research aims to find new ways of using nanostructured magnetic materials within chips to counter this problem. The persistence of magnetism in the absence of any electrical current or voltage is the key. If we could find new ways of transferring data into magnetic materials, this would allow sections of the chip that are temporarily unused to be electrically powered down for microseconds at a time but then brought back into service instantly without data loss (Fig. 3). It may seem like a small saving, but it could actually make a huge reduction in the power budget of the chip.

Russell Cowburn

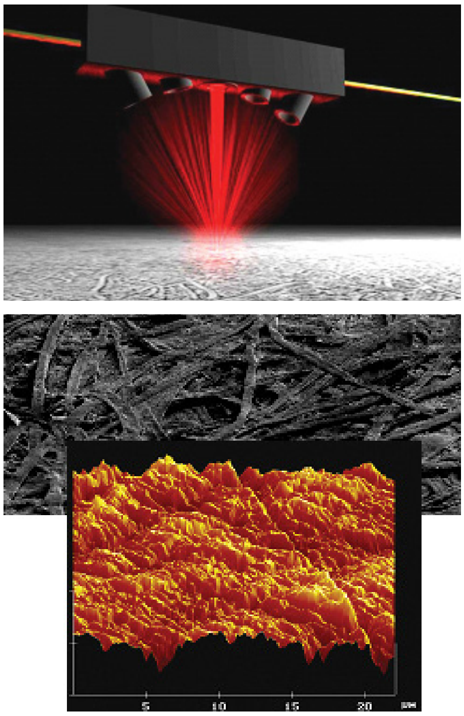


Fig. 1. A laser sensor (top) that probes the naturally-occurring roughness present in virtually all real surfaces such as paper (middle) and plastic (bottom) and which has now been developed into an anti-counterfeiting and anti-smuggling technology known as Laser Surface Authentication™.

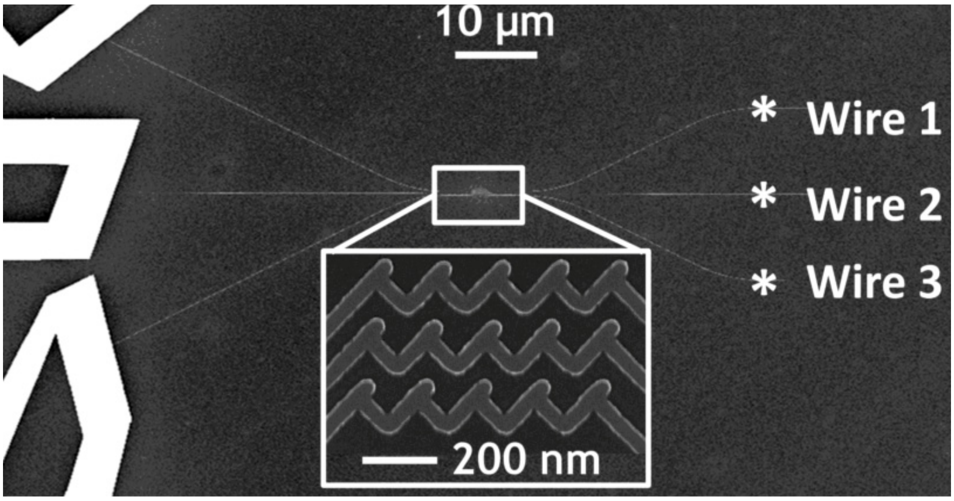


Fig. 2. A small integrated circuit built from magnetic nanowires carrying domain walls instead of electrical conductors carrying currents. The close up of the central section shows a network of domain wall traps that allow a series of domain walls to be shifted backwards and forwards. Similar methods might be useful for biological detection.

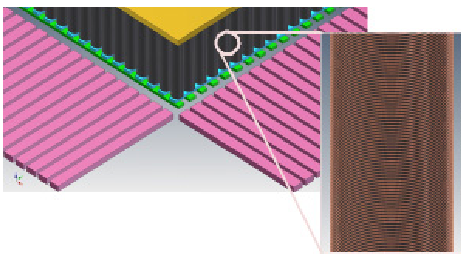
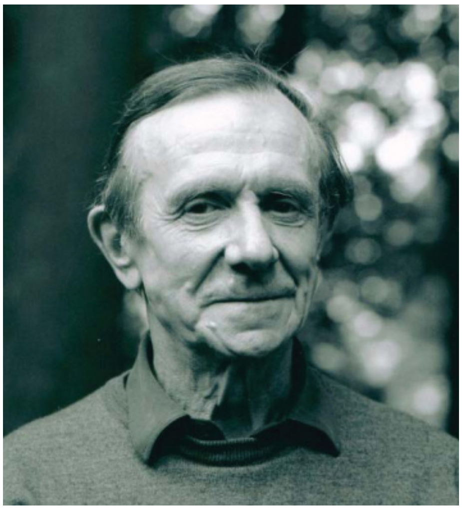


Fig. 3. An artist's impression of a new design of computer memory chip, which injects data from an electrical transistor into atomically thin layers of magnetic material for power-free data storage.

John Baldwin FRS (1931 – 2010)



Readers will be saddened to learn that John Baldwin died on the morning of 7 December 2010 after a short illness which developed during the summer.

In 1949, John came up to Queens' College, where he graduated in Natural Sciences in 1952 and then took his PhD in 1956. He was one of the most distinguished of the 'second generation' of radio astronomers at Cambridge and was to be at the heart of everything in the Radio Astronomy Group during the early years of the development of radio astronomy. The 'first generation' was spear-headed by Martin Ryle whose inspiration and strong personality led to the opening up of radio astronomy as an astronomical discipline - Cambridge and the UK became world-leaders in the new disciplines of high energy astrophysics and astrophysical cosmology. But Ryle could not have achieved this without the efforts of an extraordinary team of brilliant colleagues and graduate students (Fig. 2).

Fig. 2. The Radio Astronomy Group in the early 1950s. John Baldwin is second from the left in the back row. Peter Scheuer is fifth from the left in the back row. In the central row, from the left, are Francis Graham Smith, Martin Ryle and Antony Hewish. In the front row, second from the left is John Shakeshaft and far right Bruce Elsmore.

While Ryle drove the programme of deep surveys for cosmological purposes, John concentrated on more local aspects of radio astronomy. This involved making low-frequency maps of the sky and disentangling from these the radio structure of our Galaxy and the high energy sources within it. His pioneering efforts were recognised in this message from Hugo van Woerden: "I first met John at the IAU Assembly in Dublin in 1955. He gave an excellent talk about the Galactic Halo, very impressive for a 24-year old student. Already then, he was a great scientist."

While Ryle continued the development of the techniques of aperture synthesis to higher frequencies and higher angular resolution with outstanding success, John continued the development of radio astronomy at low radio frequencies, over the years building a succession of world-leading survey instruments. This was a very major challenge because of the instability of the ionosphere at low frequencies. This work culminated in the 6C, 7C and 8C surveys which were the defining low-frequency surveys. As George Miley has written, "The 38MHz 8C survey is still the best survey below 50MHz and was an important stimulus for the next-generation low-frequency arrays, such as LOFAR."

John also pioneered spectral interferometry - the Half-Mile Telescope was the first interferometer to make images in the 21-cm line of neutral hydrogen. Hugo van Woerden remarks, "In the sixties his work on neutral hydrogen in galaxies with the Half-Mile Telescope set the scene for our later work at Westerbork."

John's deep understanding of the fundamentals of interferometry and the ways of eliminating the effects of turbulence in the atmosphere were to prove central to his taking up the challenges of optical and infrared interferometry in the 1980s. This involved a variety of different approaches. From aperture masks on large optical telescopes to the development of the COAST optical interferometer at Lord's Bridge, he demonstrated that optical interferometry is a powerful tool for future optical imaging. Harry van der Laan has written, "When in ESO we pushed VLT Interferometry in the late '80s/early '90s, the work of John and his Cavendish team was admired and served to challenge our team." The legacy of his achievements is the involvement of the Cavendish Astrophysics Group in the optical-infrared interferometer at the Magdalena Ridge Observatory. Right up to the months before he died, he was uncovering new features of the fluctuations in the refractive index of the atmosphere at optical wavelengths which are not only surprising, but which also offer new opportunities for optical imaging.

Appointed University Demonstrator in 1957 and Assistant Director of Research in 1962, John was promoted to a Readership in 1981 and to Professor of Radio Astronomy in 1991, the same year in which he was elected to Fellowship of the Royal Society. He received numerous awards for his research, including the Guthrie Medal of the Institute of Physics, the Hopkins Prize of the Cambridge Philosophical Society and the Jackson-Gwilt medal of the Royal Astronomical Society.

In addition to his distinction as a scientist, John was a brilliant teacher and supervisor of graduate students. Richard Hills, now Project Scientist for the ALMA project, wrote, "John is of course one of the main reasons I am in Radio Astronomy - he was my Director of Studies when I first came to Cambridge and I soon learned that trying to think about things and do them in the way that he did was a pretty good way to go."

For so many of us, it will be John's friendship, good humour and wisdom that we will miss beyond all else. We will miss his cheerful laughter and optimistic approach. In a letter to me only one week before his death, he wrote "Meanwhile my interest in life remains undimmed." We send our most sincere condolences to Joyce Baldwin, in the sure knowledge that we can celebrate the life of someone who undoubtedly changed all our lives for the better.

Malcolm Longair

Fig. 3. The COAST optical interferometer at the Lord's Bridge Observatory.

Fig. 1

Higgs Bosons Provide Bridges to Hidden Worlds

We are accustomed to thinking of physics as a discipline that gives no special attention to things human. Yet, even particle physics, perhaps the science most removed from everyday experience, is a powerful example of how human-centric our past discoveries have been.

Consider all the known elementary particles. The up and down quarks combine to make protons and neutrons. Group the protons and neutrons together and add another elementary particle to the mix - the electrons - and we get atoms. These atoms combine to make hydrogen, oxygen, carbon and other elements, which in turn make cells, hair, lungs and feet. In short, our studies of quarks and electrons are about human beings at the most fundamental level.

We know there are more elementary particles than this - the gluons, the photon, and the W and Z bosons. These are, however, just the force carriers between the charged particles in our bodies. There are even more elementary particles beyond these force carriers, the muons, tau leptons, charm quark, top quark, and so on. It turns out, however, that these particles are merely copies of electrons and up and down quarks, only their masses are much greater.

Two obvious questions arise. First, why should we believe that there is more to the basic building blocks of the natural world than what is manifested by the makeup of our own bodies at the most elementary level, and second how could we discover such new things if they really exist?

Regarding the first question, there is no known reason why the completeness of our catalogue of elementary particles should consist of everything that is 'within us'. The existence of dark matter and dark energy, as compellingly demonstrated by astrophysical and cosmological experiments, suggests that there is more out there than the particles we know about from studies of the material we are made of.

Dark matter particles turn out to be just one example of the vast possibilities of particles and interactions that have nothing to do with our bodies. There can be particles that pop out of the vacuum only ever so briefly when enough energy is concentrated at an interaction point, but have no relic cosmological significance. Some approaches to building models of the particle physics world through string theory, for example, predict thousands of particles of these kinds, of which maybe only one or none could have sufficient abundance to be detected in the future by specific dark matter experiments. Therefore, we must ask what other avenues to discovery are there?

The Large Hadron Collider (LHC) at CERN is one of the bright lights that could illuminate these hidden worlds of particles that have nothing to do with our bodies. In particular, the simplicity of the scalar Higgs boson, whose profile and characteristics are completely invariant to any special relativistic transformation - it looks the same under rotations and shifts in velocity - make it especially sensitive to these new worlds.

The Higgs boson has been feted as the provider of mass for all elementary particles, and therein lies its central fame and importance. In addition to this trait, however, a simple connection can be made between the Higgs boson of our world and scalar bosons of hidden worlds, providing a bridge between them (Fig. 1). This is what Frank Wilczek has recently dubbed the 'Higgs portal'. The reason for this very effective bridge between the two worlds is due to the all-pervasive nature of the Higgs boson. It is said to have a 'vacuum expectation value' which means that, unlike all other particle fields we know, it has a non-zero value everywhere.

Why would a finite vacuum expectation value of the Higgs boson make it an ideal bridge between the Standard Model and the hidden world? The reason is that we expect other fields in the hidden worlds to have vacuum expectation values, just like our Higgs boson. Vacuum expectation values can serve as a gluing agent to join fields together and make them mix. That is expected to be the case when the vacuum expectation value of our Higgs boson meets the vacuum expectation values of other fields. Once glued together, the bridge is complete and particles of different worlds can interact with each other across it.

The LHC is expected to be the first collider in history to be able to create and measure the properties of the Higgs boson (Fig. 2), and therefore, by illuminating this bridge, we may be on the brink of discovering these new worlds. They would show up in experiments at the LHC as exotic decay modes of the Higgs boson. For example, once the Higgs bosons are produced, instead of decaying into two b quarks or W bosons, which is what they would normally do, they could follow their bridges into a hidden world and decay into something else. They might decay into pure hidden world states, which would show up as 'invisible decays' that can be inferred by careful experimentation. Or, they might decay into hidden world states that may transition back across the bridge in the opposite direction, or across another bridge altogether, and decay into lighter visible world states that form a final decay pattern of, for example, four electrons. That would be impossible for normal Higgs boson decays without bridges that go back and

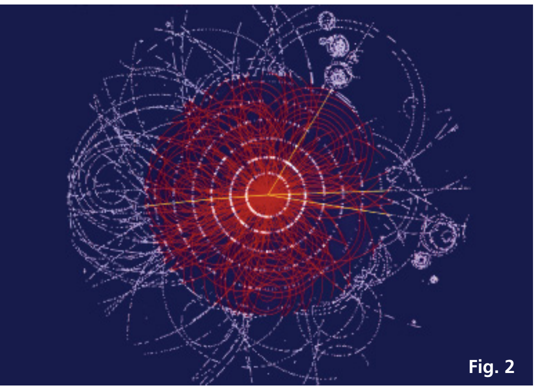


Fig. 2

forth to a hidden world. Such a discovery would inevitably lead to the hidden world hypothesis that could be verified with further experimentation.

In short, our leap to the energy frontier of the LHC and our care in measuring the Higgs boson decays may very well lead us beyond our anthropocentric narrowness of view into vast new territories of hidden worlds. And that would only be the beginning.

James Wells

Fig. 1. A metaphor for the role of the Higgs boson in acting as a bridge to hidden worlds of particle physics, not yet accessible to experiment, but which may well be opened up by experiments at the LHC.

Fig. 2.: A simulation of the decay of a Higgs boson decaying into four muons in the ATLAS detector of the Large Hadron Collider.

Athena SWAN Silver and IoP Juno Champion Success

This summer the Cavendish Laboratory became the first department in the University to receive an Athena SWAN Silver award and only the second physics department in the UK (the first was Imperial College London) to receive both the Athena award and become an Institute of Physics (IoP) Juno Champion. The Athena SWAN and IoP Juno schemes recognise excellence in Science, Engineering and Technology (SET) employment in higher education and the commitment of university departments to the advancement and promotion of the careers of women in science.

In recent years, the Cavendish Laboratory has made many significant advances in improving the working environment for all staff and, in particular, for its female academic and research staff. The Cavendish Laboratory's Personnel Committee has addressed many aspects of the Department's make-up from the breakdown by gender of undergraduate exam results, the career progression of research staff, to the overall culture within the Department. The results of the Committee's investigations informed the Athena and Juno applications and resulted in an Action Plan for the coming years.

Amongst some of the Department's highlights are the support and career advice at key career transition points through its Staff Review and Development scheme and its Continuing Professional Development programme. The Department also continues to develop a culture that is open and comfortable for all and has established a discussion forum for research staff to address issues, such as career advice, mentoring, induction and social activities. It was heartening to read some of the comments in a recent research staff survey: *"The culture is friendly, open, helpful and cooperative; albeit slightly competitive."* *"The Department responds to requests e.g. picnic benches were provided when requested."*

For me, the Athena and Juno ethos is about the *"Small changes which make big differences"*. For example, several years ago, on returning from maternity leave, a female lecturer was asked to give a new lecture course. She did so with all the energy and enthusiasm that she could muster. Half-way through the course, she was admitted to hospital, nearly ending her career. The Department now has a policy that female academics returning from maternity leave are relieved from lecturing in the first term following return and are not assigned a new lecture course in the first year… *a small change that can make a big difference.*

The Laboratory believes that its working practices are by no means perfect; there is still a long way to go in order to achieve a more gender-balanced representation in the Department. These awards have however provided us with a concrete foundation upon which to build activities, particularly in the areas of career advice, mentoring, recruitment and promotion of female physicists at all levels. The Department also expects to spread the word and help the School of Physical Sciences and other University departments to increase awareness and support for women in SET.

Our sights are now on the Athena SWAN Gold!

Val Gibson

For more information, please take a look at :

www.athenaswan.org.uk/html/athena-swan
www.iop.org/policy/diversity/initiatives/juno/index.html

Prof. Val Gibson and Mr David Peet collecting the Athena SWAN Silver award.

Prof. Val Gibson receiving the IoP Juno Champion certificate from Dame Jocelyn Bell Burnell.

From the Hubble to the James Webb Space Telescope

2010 marked the 20th Anniversary of the Hubble Space Telescope (HST) in space and there were numerous celebrations of what has unquestionably been one of the most dramatically successful space science missions ever carried out. I was involved with the HST programme from the time the project was approved in 1977 as a member of the Science Working Group. Now in 2010, I am a member of the Science Advisory Committee for its successor, the James Webb Space Telescope. It is worthwhile reflecting on the success of the HST and the issues that have faced both the HST and JWST – history is repeating itself.

It is salutary to remember that in 1977, we were unaware of the existence of extra-solar planets and proto-planetary discs, the most distant known galaxies were relatively nearby, and fluctuations in the Cosmic Microwave Background Radiation had not been detected. We had not found evidence for dark energy or cold dark matter. When we compare what we said we would observe with the HST in 1977 with what has actually been achieved, it has far exceeded our most optimistic expectations and made major contributions to the great revolutions of modern astrophysics and cosmology.

For example, in the Orion Nebula, the region of formation of massive stars closest to the Earth, dusty proto-planetary discs were discovered by the silhouettes they cast on the bright nebula. The atmosphere of the extra-solar planet associated with star HD209458 has been detected and subsequently carbon and oxygen have been found in its atmosphere. Water and methane have been detected in the atmosphere of the exoplanet HD 189733b. This planet is too hot to support life as we know it, but the technique shows how organic molecules can be detected in extra-solar planetary atmospheres.

In the deepest images taken by the HST in a region known as the Hubble Ultra-Deep Field, the Universe of galaxies is observed as it was when the Universe was only about 5% of its present age. This image is very different from that observed at the present day (Figure bottom-left). The galaxies are much bluer, more irregular and smaller than galaxies are today. This is compelling evidence that we are observing galaxies in the process of assembly, as expected in the favoured cosmological models which include Einstein's famous cosmological constant. In addition supernova explosions of a very standard type, the Type 1A supernovae, have been observed to such large redshifts that the acceleration of the Universe under the influence of the cosmological constant has been convincingly measured.

The HST was planned to be serviced by the Space Shuttle and four refurbishment missions have been flown. The first mission had the key role of providing correction optics for the primary mirror, which had been polished to the wrong shape. Subsequent missions enabled failing batteries, gyroscopes and fine-guidance sensors to be replaced. In addition, much more powerful cameras and spectrographs replaced the initial instrument complement. The Advanced Camera for Surveys (ACS) provided much wider field images with greater sensitivity than the original Wide Field Cameras and resulted in spectacular images, such as that of the Carina Nebula and its environment (Figure top-left)).

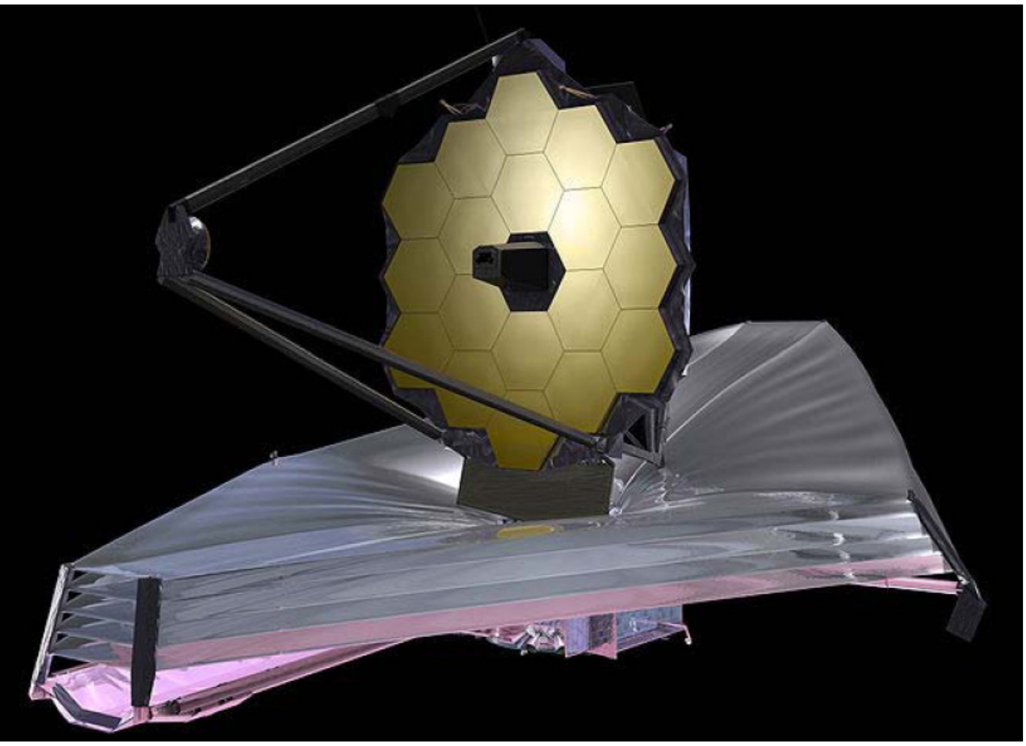
The last servicing mission was a virtuoso act of engineering and technology, the highlight being the replacement by the astronauts in orbit of electronic boxes buried deep in the telescope which involved removing 107 tiny screws, replacing the failed electronics and not losing any of the screws. The HST is now in excellent order for the foreseeable future, that is, until the JWST replaces it (Figure below).

The JWST is named after James Webb, the Administrator of NASA who from February 1961 to October 1968 directed the Apollo programme which resulted in the manned Moon landings. The telescope will be a segmented 6.5-metre telescope optimised for observations at 1-3 μm and longer wavelengths. The reason for this choice is that the two key astrophysical areas described above, star formation and the origin of galaxies, are best studied in the infrared waveband for different reasons. Star formation involves the study of cool regions in the Universe that emit most of their energy in the near and far infrared wavebands. The galaxies we need to observe to understand their initial assembly are at such large distances that their light is redshifted from the optical to the infrared wavebands.

There are also important differences in the deployment of the telescope. Unlike the HST, which was placed in low Earth orbit and serviceable by the Space Shuttle, the JWST will be located at the L2 Lagrangian point 1.5 million kilometres from the Earth in the opposite direction to the Sun. The Planck and Herschel satellites of ESA are already in orbit at L2. Satellites at L2 cannot be serviced. Furthermore, the observatory requires the use of cryogens to reduce the infrared background within the instruments. The nominal lifetime of the JWST mission is therefore only 5 years.

At the moment, the project is being thoroughly reviewed because of cost overruns, not unlike the situation in 1983 when the HST programme almost ran out of money. The good news is that the project, although the most complex space telescope ever constructed, is in excellent technical shape. The less good news is that the launch is likely to be delayed beyond 2014. We must hope that the funding problems can be solved. With a sensitivity about 100 times greater than that of the HST, the JWST represents a further huge leap in astronomical capability and will result in the types of breakthrough we have been fortunate enough to have witnessed with the HST.

Malcolm Longair



Top-left: The area in the vicinity of the Carina Nebula in the Large Magellanic Cloud. This is a region of recent intense star formation. This is one of the most remarkable images obtained by the HST with the ACS camera, showing `elephant's trunk' dark regions which are the birthplace of stars (Courtesy of NASA, ESA and the Space Telescope Science Insitute).

Bottom-left: The Hubble Ultra Deep Field (Courtesy of NASA, ESA and the Space Telescope Science Insitute).

Above: The 6.5 metre James Webb Space Telescope, the successor to the Hubble Space Telescope (Courtesy of NASA and ESA). The sun-shield below the telescope is the size of a tennis court.

The Lloyd's Register Educational Trust supports students in Scientific Computing

The University has recently received a generous donation from The Lloyd's Register Educational Trust (LRET) for the provision of fees-only awards to students admitted to three MPhils, one of which is based in the new Centre for Scientific Computing that was described in the last issue of CavMag. Awards have been made to Lizzy Johnstone and Oliver Strickson who started their graduate study with Nikos Nikiforakis in October 2010. Lizzy is working on numerical simulations of two-phase reactive flows and Oliver on the determination of equations of state by means of atomistic modeling.

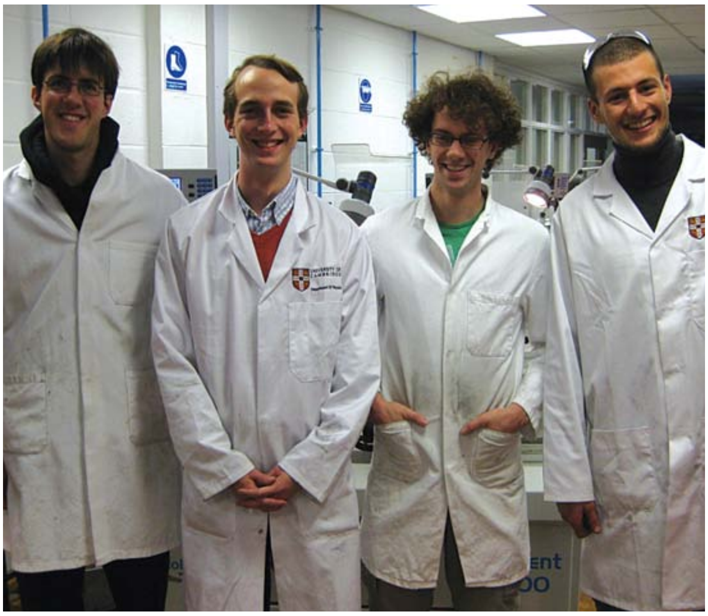
The LRET is an independent charity that was established in 2004. Its principal purpose is to support advances in transportation, science, engineering and technology education, training and research worldwide for the benefit of all. It also funds work that enhances the safety of life and property at sea, on land and in the air. The Department is extremely grateful to the LRET, and especially its Director Mr Michael Franklin for its support of this new initiative.

Lizzy Johnstone and Oliver Strickson

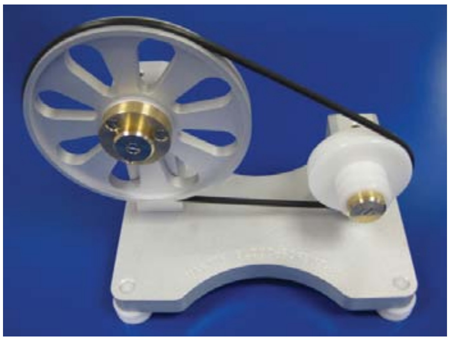
Lloyd's Register Educational Trust

New Workshop Course for Graduate Students

What makes a good experimental scientist? The obvious answer is that they must be able to design and use very sophisticated equipment and instruments. But success can be increased if the scientist knows something about the design and manufacturing processes. Regular readers of CavMag will know that the Laboratory has invested over £1M in refurbishing and re-equipping the mechanical workshops in recent years. Now, under the excellent leadership of Peter Norman and Nigel Palfrey, the Student Workshop has received a major facelift. Three new lathes, along with four mills and associated tooling have been installed in part of the former Mott workshop to provide a facility that postgraduate students can use to make items of equipment. In addition, and perhaps more importantly, they are trained in the basics of mechanical instrument design and manufacture. In consultation with Bill Allison, Nigel has put together a training course for postgraduate students introducing them to the concepts and techniques of mechanical workshop practice. Over the past term, two such courses have run and the photographs show the successful students and their work. The feedback has been overwhelmingly positive: one student wrote 'Walking back to the office was like going along the hall of fame as the different researchers admired our work! We all enjoyed ourselves and are happy to have learnt all these new skills.' Alongside the practical course, similar provision is being made to provide training in basic design skills using AutoCAD.



From left to right: Lars Hermann (nanophotonics), Martin Blood-Forsyth (surface dynamics). Joshua Barnes (AMOP) and Igor Gotlibovych (AMOP) on the first first graduate student workshop training course.



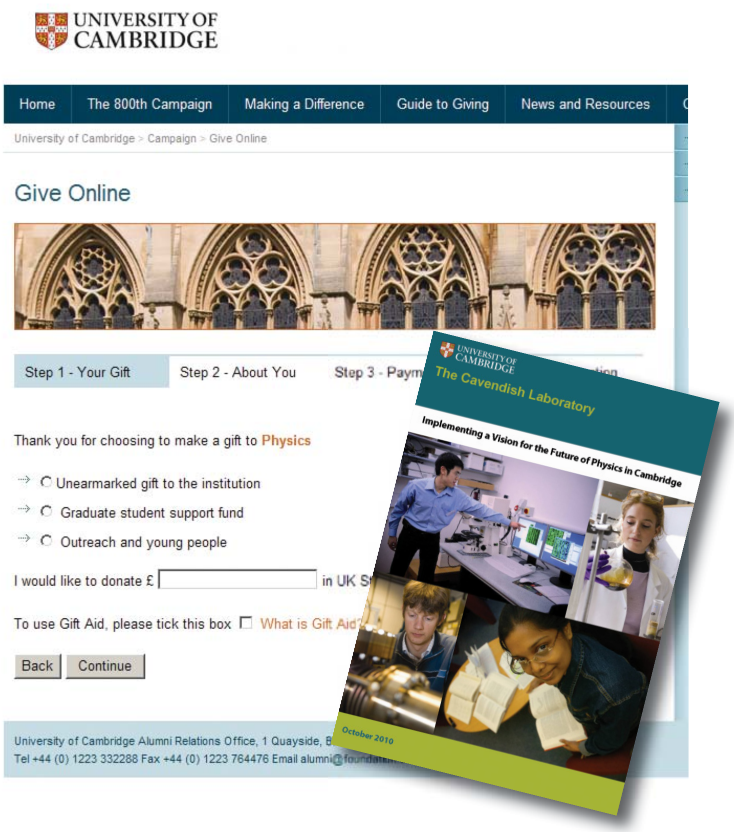
Martin Blood-Forsyth with the product of the workshop training project. Each student built their own version of this drive mechanism.

Developing the Cavendish Development Plan

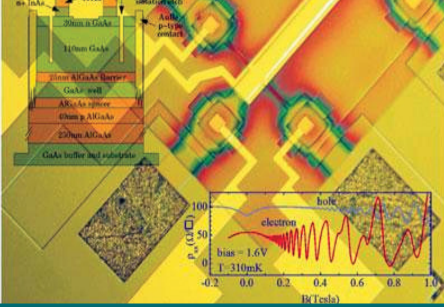
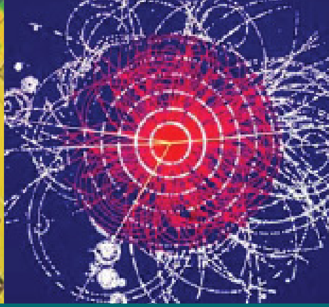
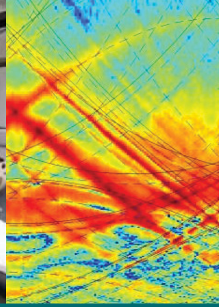
We are very pleased to let you know that the most recent version of our plans for the future development of the Cavendish Laboratory have been approved by the School of Physical Sciences and are now part of the official portfolio of projects that are being supported by the Cambridge University Development Office (CUDO). Our colleagues at CUDO have been very helpful in promoting our proposals and giving us guidance about the presentation of the portfolio.

As we emphasised in CavMag2, the special development edition, the word 'Development' means many things, from studentships and start-up funds for new projects to major initiatives for the large scale redevelopment of the Laboratory. The portfolio of approved projects is now available on our web-site at: **www.phy.cam.ac.uk/development** as a pdf file entitled **The Cavendish Development Portfolio**. We hope you will enjoy learning more about our vision for the future.

At the same time, we have simplified the procedure for making gifts to the Development Programme. If you wish to make a donation, simply go to **www.phy.cam.ac.uk/development** and then click on **University of Cambridge Development Office's secure site**. This takes you to a page that explains the various ways in which donations can be made. Then click on **donate to the Cavendish Laboratory Development Programme** and that takes you to the Give Online page for Physics. There are three options, (i) an un-earmarked gift to physics, (ii) the Graduate student support fund and (iii) Outreach and young people. The value of the gift can be enhanced by using the Gift Aid procedure. The physics web-page for online giving looks like the following:



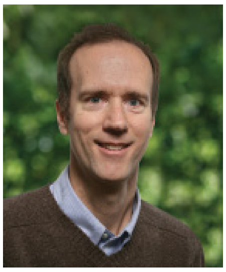
The various projects outlined in the **Cavendish Development Portfolio** span the complete range of activity within the Laboratory and are presented in order of increasing cost. But, it must be emphasised that gifts and benefactions at all levels are of enormous value to the Department. We will be most grateful for your support, at whatever level.



Cavendish News

Two significant retirements occurred in the High Energy Physics Group, **Bryan Webber** (left) and **Jan White**. We wish them long and happy 'retirements'.

We congratulate **Michael Pepper** on the award of the Institute of Physics Business and Innovation Medal 2010.



We congratulate **James Wells** on his appointment to a lectureship in Theoretical High Energy Physics. He describes his work in an article in this issue of CavMag.

Andy Parker and **David Ritchie** have been reappointed Deputy Heads of Department with responsibilities for Finance and Teaching respectively.

We welcome the following new appointments to the Assistant Staff:

Mariusz Naguszewski, Chief Cryogenics Technician and Deputy Manager of Cryogenic facilities.

Stephen Topliss, Electronics Technician in Atomic,Molecular and Optical Physics.

Julie Kite, Personal Assistant to Russell Cowburn.

Felicity Footer, Group Administrator High Energy Physics (internal promotion).

Emily Heavens, Group Administrator Microelectronics.

James Hope. Apprentice, Mechanical Workshops.

Jeremy Lewis, Administrative Assistant, Graduate Students Office

The following have won distinguished research fellowships to be held in the Department:

Stefan Ask, STFC Advanced Fellowship, High Energy Physics (Experimental) Group.

Mark Buitelaar, Royal Society Dorothy Hodgkin Fellowship, Semiconductor Physics.

Alexei Chepelianski, Oppenheimer Research Fellowship, Optoelectronics.

Jesper Levinson, Marie Curie Fellowship, Theory of Condensed Matter Group.

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**

The Scott Lectures, on 7, 9 and 11 March 2011, will be delivered by **Claude Cohen-Tanoudji** of the École Normale Supérieure, Paris. He won the 1997 Nobel Prize in Physics for research into methods of laser cooling and trapping atoms.

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Senior Physics Challenge

The Senior Physics Challenge Summer School took place at the end of June 2010 completing its fourth successful year of operation. We received nearly 300 applications from the highest calibre Year 12 (AS-level) students to participate in this physics access and admissions initiative. From these 300, co-director Anson Cheung and I selected 66 students, each from different schools located all over the United Kingdom. Hosted by several of the Cambridge colleges, students were treated to the full Cambridge experience including attending lectures on kinematics and special relativity and practical laboratory classes on dynamics and optics. The students also attended admissions talks and had the chance to discuss physics and socialise with like-minded students of a similar age. Students responses indicate that we are indeed achieving our aims, comments included, "I didn't realise how much maths was involved", "I enjoyed the challenge of hard, but not impossible, problems and solving for them for the first time" and "meeting like-minded people was very rewarding".

Preparations for the 2011 Senior Physics Challenge are already underway. Student applications are initiated by teacher recommendation and any interested teacher may register online to receive updates and notification of the next application round. To find out more please visit our website www-spc.phy.cam.ac.uk.

Physics at Work 2010

Bookings for the 26th annual *Physics at Work* exhibition reached record numbers this year – we welcomed nearly 2200 students through the doors of the Cavendish. This unique exhibition ran for three days from 21st until 23rd September, with two sessions each day at 9am and 1pm. The school groups saw six different exhibits selected by the organisers, to include both internal and industrial exhibitors, showing the many varied ways in which physics is used in the real world. We were delighted to welcome 24 seasoned and new exhibitors to the event this year.

Each year we ask students and teachers to vote for their favourite exhibit and this year the 2010 award went to the Cavendish's Fracture and Shock Physics group.

Bookings for the 2011 exhibition will open towards the end of May 2011. Interested teachers should refer to our website for regular updates at www-outreach.phy.cam.ac.uk/physics_at_work. The exhibition is targeted at 14 -16 year olds with some schools bringing their gifted and talented year 9 students and others bringing year 12 students who are considering potential careers in physics. Schools are welcome to bring as many students as they can, so long as the teacher to student ratio is about 15. On arrival at the Cavendish, each school party will be split into groups of approximately 15 students with 1 accompanying teacher. Map in hand each group is then led to their first exhibit to follow their own tailored route around the Cavendish. Schools travel from all over London and the South East to attend this event. Approximately **400 FREE places are available for each half day session.**

Science Festival 2011

The Cavendish Laboratory will once again be opening its doors to the public on **26th March 2011** as part of the Cambridge Science Festival. The event will run from 1 – 5pm with lectures, hands-on demonstrations and make and do activities available throughout this time. The keynote lecture will begin at 1:15pm in the Small Lecture Theatre of the Cavendish and will be given by **Professor Sir Richard Friend** on **Greener Solar Cells**.

Every year the number of visitors to this event increases and so, in order to help visitors plan their day and to avoid disappointment, we are planning a more structured programme for 2011. Two 30 – 45 minute lectures will run in parallel from 1:15pm for ages 5+, 8+, 12+ and 14 to adult, including the keynote lecture and lectures on astronomy and experimental physics for all ages presented by myself and 'Naked Scientist' Dave Ansell. To guarantee a seat at these lectures you will be able to pre-book on our website www.cta.phy.cam.ac.uk/outreach/Science_Week/booking.php for a maximum of 3 lectures. Some seats (1/4) will kept open for people turning up on the day but in this case availability cannot be guaranteed. The programme is shown at the foot of the page.

In addition to the lectures and talks there will be many hands-on science experiments and a planetarium. We also hope that some of our sci-fi guests will also be joining us once again. Regular updates can be found on our outreach website at www-outreach.phy.cam.ac.uk.

Lisa Jardine-Wright

'Meet the Physicist' Talks

1:15 – 2pm	**Keynote Lecture: Greener Solar Cells** Professor Sir Richard Friend	Adult, 14+	Small Lecture Theatre (150 seats)
	Crisp Packet Fireworks David Ansell	12+	Pippard Lecture Theatre (400 seats)
2:30 – 3pm:	**Light the Messenger** Dr Lisa Jardine-Wright	8+	Small Lecture Theatre (150 seats)
	Crisp Packet Fireworks David Ansell	5+	Pippard Lecture Theatre (400 seats)
3:30 – 4:15pm	**Cavendish Science** Lisa Jardine-Wright	Adult, 14+	Small Lecture Theatre (150 seats)
	Crisp Packet Fireworks David Ansell	12+	Pippard Lecture Theatre (400 seats)
4:30 – 5pm	**Introduction to Astronomy** Lisa Jardine-Wright	5+	Small Lecture Theatre (150 seats)
	Crisp Packet Fireworks David Ansell	5+	Pippard Lecture Theatre (400 seats)