Volume 47 Number 2 March/April 2010

Australian Physics

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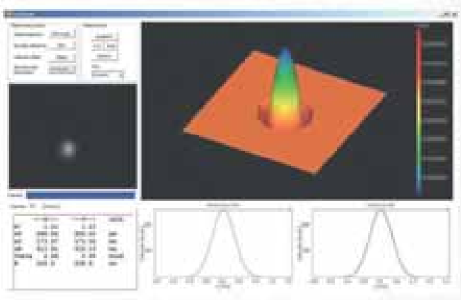

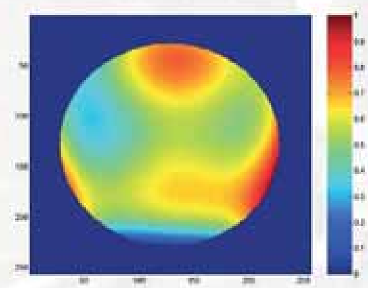

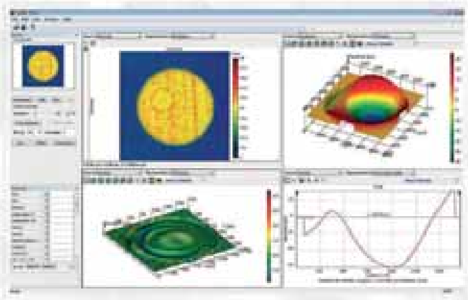

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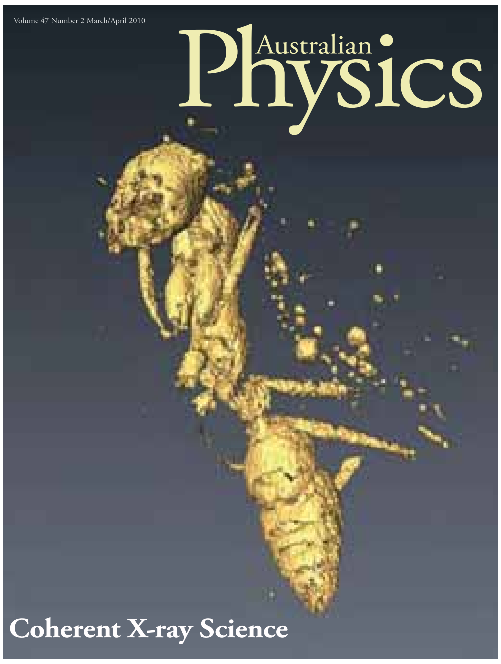

Cover

X-ray phase contrast imaging is a field that has been pioneered by Australian scientists. One unexpected and important application of synchrotron-based X-ray phase contrast imaging that has emerged is the ability to create three-dimensional (tomographic) imaging of fossilized animals within amber. As part of the ARC Centre of Excellence for Coherent X-ray Science (CXS) “Growing Tall Poppies” outreach partnership (see article by Nugent & Peele), high school students were set the task of working with CXS scientists to determine whether such imaging could be performed using smaller university-based X-ray sources.

This image was obtained by students from Santa Maria College, Northcote and is one view of a three-dimensional reconstruction of a fossil ant embedded in amber. This is an absorption (not phase) contrast image of the ant. It was found that the “ant” seen within the amber is in fact an ant-shaped void and so contains little or no genetic information; the students were disappointed to realize that the next stage of the project was not going to be a small scale re-enactment of “Jurassic Park”.

Editorial

You and the new Australian Physics

Welcome to the new ***Australian Physics***.

Our magazine provides you with a unique space for pleasant discussions that physicists usually have around morning and afternoon teas: new experiments, awards, seminars, educational programs, special events, policy, science and technology, products, book reviews, the future of our professional activities, ways to develop ouselves, activities around Australia, inspiring histories about physics in Australia, ways to promote Australian Physics and much more. This is your magazine. Here you can express your ideas, share your histories and be read.

As our former editor said in the previous issue we need you to volunteer to send us your articles and histories... and he was correct: it is incredibly difficult to produce a magazine without our community providing its contribution. Please, I ask you to consider writing an article, a book review, news from your laboratory, concerns or science highlights.

I also am looking forward to hearing your opinion about the magazine. This would include design, style and topics you feel that we should cover. Please write to me. Tell me what you like most and what you think we should change or add. You can contribute enourmously to our magazine. As so, you should expect the ***Australian Physics*** to change over coming issues from your feedback.

"This is your magazine. Here you can express your ideas, share your histories and be read."

In this issue we have some interesting histories for you. The coherent X-ray science by ASD and ASA is a successfull case of collaboration among Australian organisations: great science, research outcomes and exciting educational and outreach activities. The void "jurassic ant", our cover in this issue, came alive again in our imagination thanks to the work of students. Another good article talks about laser isotope separation.

We also feature a great history of 40 years of research on superconductivity in Australia. It is a very interesting insight and vivid case of the venture of a group of scientists working in cutting-edge technology and a very active science area. This is a very interesting history and an appropriate warm up for next year's centennial anniversary of the discovery of superconductivity.

Who could resist a book review? In *Book Reviews* we have selected five books for you. In the next issue we would like to include a book you would recommend your colleagues or your students to read. What is your favourite book? We would like to add a few classical books in our review. Are they worth reading? Tell us... and we will spread the news!

At the end we provide a list of good conferences for your information. Is there any important conference not listed here? Please, let me know.

Another good session is our *Product News*. The companies advertising in our magazine are our great partners. Send this magazine to your colleagues. Show them the products we are advertising here. I would like to thank you on behalf of these comapanies for your support.

As our President said last issue (AP, *President's Column*, Vol. 47, 1(2010)5) I am willing to develop an online presence for ***Australian Physics***, which will take advantage of our planned new AIP website, posting current and past issues, podcasts, blogs, short coming events and more. All just a few clicks from your favourite platform.

Finally, I would like to express my gratitude to all colleagues at AIP. I have received incredible support from John Daicopolous, our Editor-in-chief, editorial board and associate editors.

I hope you enjoy this new issue!

Paulo de Souza

President's column

Role of Physics

An extended period of supervising students in a senior (third year) undergraduate laboratory has given me an opportunity to appreciate the laboratory as a teaching venue. In junior years, and at high school I suspect, laboratories are often seen by both students and staff as an adjunct to the real teaching venue: the lecture theatre and the classroom. Indeed students at university often complain if the topics in a laboratory are not in synchronism with lecture material as they see them as support for lectures rather than an occasion for independent learning. Laboratories, however, have many features that are considered to be pedagogically desirable: one-on-one interaction between student and teacher, a hands-on requirement to accompany any instructional material, the opportunity for peer-to-peer interaction, and, frequently, team work. Even if the benefits are recognised, the cost provides a disincentive, and is partly to blame for a tendency towards reduced laboratory experience for physics majors. A compromise is the concept of 'studio teaching', which combines many of the features of lectures, tutorials and laboratories. Some universities are experimenting with studio teaching, but to my knowledge this is not widespread.

One of the pleasures of laboratory teaching is the personal interaction with students. While relevant physics is discussed, of course, talk often drifts beyond topics directly related to the experiment at hand. Such encounters have alerted me to one of the consequences of changes in degree structures, which have occurred widely across the Australian university system. At some time in the past the opportunity to complete a major in physics was largely restricted to the Bachelor of Science degrees. Such degrees are still the main path for physics majors, but they often allow double majors. In my experience, a major in physics is most commonly paired with a major in mathematics, but there are increasing tendencies for physics to be paired with chemistry or biology, the former probably related to the growth of materials science and the latter to the relatively new quantitative developments in biological sciences. Increased competition among universities has led to more specialised science degrees (nanotechnology, photoelectronics, astronomy, etc), which effectively provide a major in physics, with some targeted restriction in the range of physics covered in order to accommodated the speciality. The programs that have been of particular interest to me, however, are combined degrees and degrees of the liberal studies kind. Many universities have long offered a combined degree in engineering and science which has allowed students to gain an engineering qualification as well as study one or more science disciplines at much greater depth that would be available in the engineering degree alone. Such combined degrees are still popular but it is noticeable that those students completing a major in physics in the science degree are commonly in electrical, information technology, aeronautical, space, mechanical or mechatronics engineering streams, and rarely in civil, chemical or mining engineering streams. As many universities have reduced the science content of engineering degrees in favour of topics which are related to professional practice, the double degrees provide graduates with a valuable mix of qualifications: an understanding of engineering practices as well as deep understanding of one or more science disciplines.

Many more combined degrees are now available and it is not unusual to find physics majors doing Science/Arts, Science/Law, Science/Commerce and Science/Education degrees. In the case of the latter it is pleasing to note that students are usually intending to be high school teachers and will help meet the demand for adequately qualified teachers of high school physics. Liberal arts degrees usually require a major in a science discipline and a major in a humanities discipline, with majors in physics paired with a wide spectrum of humanities majors: philosophy, sociology, art history. psychology, anthropology, archaeology, Japanese are just some of the examples of I have encountered recently. Such students are often uncertain about which area they will pursue. I encounter them as physics majors, but often the student intends to pursue the other discipline and are undertaking a physics major because that is the science discipline they find most interesting. It is also quite possible that students will find a future for which their particular combination is particularly apposite (and perhaps give themselves an employment advantage). One consequence is that we will see professionals in a wide range of non-scientific disciplines that have a deep understanding of physics (or another science discipline) and an appreciation of the significance of science and scientific technique – surely something to be applauded.

"One consequence is that we will see professionals in a wide range of non-scientific disciplines that have a deep understanding of physics (or another science discipline) and an appreciation of the significance of science and scientific technique – surely something to be applauded."

The ARC Centre of Excellence for Coherent X-ray Science

Working at the interface of Physics, Chemistry and Biology

by Keith A. Nugent and Andrew G. Peele

X-ray sources are developing at an enormous rate with the growth of the coherent output significantly exceeding that well known benchmark for runaway growth, Moore's law. By one estimate, X-ray output is increasing by an order of magnitude every eighteen months (*1*). While modern synchrotron sources, such as the Australian Synchrotron, are extremely powerful, the coherent output is relatively low. For example if a conventional X-ray is analogous to a light globe then the synchrotron is perhaps analogous to a bright arc-lamp. The increase in brightness is extraordinarily useful, and the applications are tremendously valuable, but the science is generally an extension of what has been done before. Conventional X-ray sources allowed the field of crystallography to develop into an important and mature technology and the advent of synchrotron sources has enabled the analysis of more challenging samples. To extend the analogy, then, the development of the laser fifty years ago this year, enabled completely new science. Laser science is not simply an extension of pre-1960 optical sciences; it is qualitatively different. X-ray lasers offer a similar revolution.

Fig. 1. An image of our endstation, nicknamed FRIEND (FResnel Imaging ENDstation) located at beamline 2-ID-B at the Advanced Photon Source. Collaborative LIEF funding has been acquired that enable this facility to be moved to the Australian Synchrotron. This facility is able to hold a sample in place to a precision of a few nanometers over many hours.

The idea of free-electron lasers has been discussed and developed for the last thirty years or so. They are now being put into practice at a number of laboratories around the world. The basic idea is that a relativistic electron passing through a periodically varying magnetic field will be laterally accelerated and so will radiate. If the radiated field is sufficiently intense, the electrons will interact

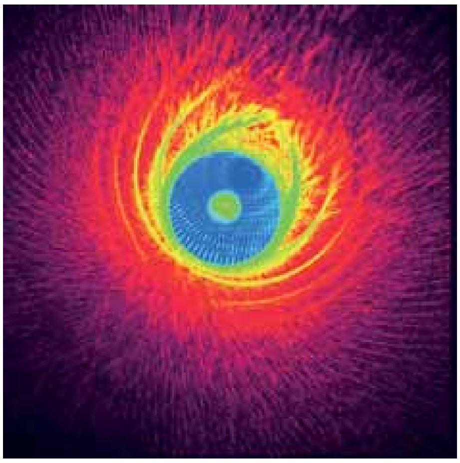

Fig. 2. Sample experimental X-ray diffraction pattern obtained from FRIEND using photons with an energy of about 2keV. This data was obtained using a novel diffraction configuration developed by CXS in which the sample is illuminated using a well-characterized spherically curved X-ray wavefront. The data is shown on a highly non-linear scale and carries information to a spatial resolution of 20 nm.

with it in such a manner that they are compressed into a series of very small bunches. Radiation then emitted from those bunches will appear to come from the same cell in phase space – which means that the light is coherent. This is the Self-Amplified Spontaneous Emission (SASE) process.

Free-electron lasers have been operating in the ultra-violet region for the last few years. The facility known as FLASH at the DESY laboratory in Hamburg (*2*) has delivered some exciting results in a number of areas, including new results in spectroscopy (*3*) A team led by Henry Chapman, a University of Melbourne graduate and now the University of Hamburg Centre for Free Electron Laser Science Director has also produced key results in the area of high resolution imaging (*4*).

In 2009, a further important milestone was reached with the first X-ray laser action observed at the Linac Coherent Light Source (LCLS) at the SLAC laboratory in California. Experiments have now commenced at the LCLS. X-ray free electron lasers are also under construction in Japan, adjacent to the SPring8 synchrotron facility and in Hamburg through the European X-ray free-electron laser program. Additional soft X-ray free-electron lasers are planned in Italy and Switzerland, among others. Interestingly, the development of X-ray lasers is seeing a rapid convergence of the X-ray and ultrafast laser communities andworkshops at this very interesting interface are now being held. It is an exciting time to be working in the X-ray field.

One can anticipate that the development of X-ray laser systems will revolutionise X-ray science in a manner analogous to the revolution the visible laser created in optical physics. The advent of the X-ray laser, then, has set the researcher the challenge of thinking about X-ray science in new ways and to endeavour to use the new capabilities to uncover new things about nature in ways that have not yet been invented. That is, in essence, the mission CXS has set for itself. Our goal is to develop the applications of coherent X-ray science towards important scientific goals. In developing the idea for CXS, we agreed immediately that it had to address important science but that at that stage it could not rely on access to X-ray laser facilities. In particular, though the LCLS has now delivered ahead of schedule and exceeded its design specifications, CXS planned for the use of XFEL sources beyond the life of the centre. Consequently, CXS has sought to develop science on synchrotron sources and explore other areas in which coherent short wavelength photons are being produced, in particular the rapidly developing field of high-harmonic generation sources. We also saw that the area of coherent X-ray science has the potential to be enormous and so we elected to concentrate on the particular problem of enabling new forms of structural biology using coherent methods. In making these choices, we have aligned ourselves with a significant international research goal.

Structural biology is an important area of science and one of its most important pillars is X-ray crystallography. The principles of crystallography are known to all physicists and the analysis of crystallographic diffraction patterns is, to a biologist, now a routine matter largely performed using off-the-shelf computer packages. The key goal of the working protein crystallographer is to acquire a crystal of their protein of sufficient size and perfection that it diffracts out to a high enough angle so as to permit a sufficiently high resolution image of the protein of interest. Unfortunately, many of the most interesting proteins simply refuse to form crystals. About 10 years ago it was proposed that perhaps the X-rays from a free electron laser would be so coherent that it would be possible to focus them onto a single molecule and acquire a diffraction pattern that can be inverted to form an image of the molecule (*5*). This idea has now become the most high-profile goal of the international XFEL community. If it is possible, the impact would be revolutionary. However it is very hard indeed!

Third generation synchrotrons began operation around the mid-nineties. The third-generation synchrotron source is characterised by using what are know as "insertion devices". These are structures that produce a varying magnetic field along a straight section of the storage ring and which act to increase the source output. One important consequence is that some insertion devices can greatly enhance the coherent output. The very large third-generation sources very quickly reported unexpected coherent effects, particularly the development of X-ray phase contrast imaging (*6*). Shortly thereafter, after a long period of development particularly championed by X-ray

crystallography pioneer David Sayre, it was demonstrated that one could use coherent diffraction from a non-periodic object to recover an image of it (*7*). This result has triggered considerable work on the development of diffraction methods for high-resolution lens-less imaging, where the ultimate application is to single molecules using an XFEL source.

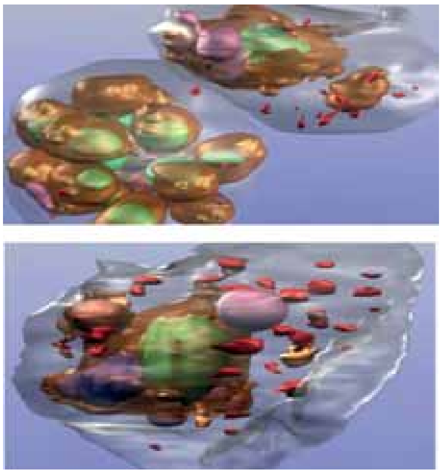

Fig. 3. Three-dimensional high-resolution (~80nm) resolution image of a malaria-infected red blood cell. Image processing has been applied to segment out various organelles in the sample. (Image courtesy of Eric Hanssen and Leann Tilley).

The theme of CXS is to develop coherent imaging for the biosciences and with the intent of positioning Australia to benefit from the development of X-ray lasers. We are determined to ensure that the development of our X-ray methods are relevant to the biosciences and so our goals are: to develop high resolution X-ray imaging methods; to apply these methods to high-profile problems in the biological sciences; to understand how intense coherent X-ray fields will interact with biological samples such as single molecules; and to work towards the development of smaller scale X-ray sources to use as a test-bed for our experimental methods and theoretical understanding. As such our first three years were structured around five programs:

The Experimental Methods Program

This program seeks to develop coherent X-ray imaging methods. We have developed new approaches (*8*) to high resolution imaging that are particularly robust and flexible. In order to develop these methods further we have constructed a unique and dedicated apparatus as part of an ongoing partnership with the Advanced Photon Source facility at the Argonne National Laboratory in the USA. CXS has guaranteed ongoing access to the facility and has staff placed in the USA for extended periods for the development of the facility and to enable its use by external users (Figures 1 and 2). CXS has led a collaboration with a number of other Australian universities to develop and upgrade our facility to enable very high resolution (~30 nm) X-ray fluorescence and transmission microscopy and this year will, we anticipate, see the first non-CXS Australian users there. This project is also partly funded by the Australian Synchrotron and we plan to move this facility to the Australian Synchrotron in a few years time.

It is now known that the radiation from an XFEL is not perfectly coherent (unlike a visible light laser, the XFEL does not have a cavity) and so the Experimental Methods Program has an active experimental program exploring the measurement and exploitation of partially coherent X-rays developing ideas that are of use for experiments on both XFEL and synchrotron sources. We also have an increasing role in the development of experiments at the new the Linac Coherent Light Source at Stanford with our participation in the first experiments late in 2009. The Experimental Methods Program is led by one of us (AGP).

The Biological Sciences Program

The philosophy of CXS is very much that important science will arise when groups of talented scientists with different perspectives get together to work on important problems of common interest. An example that we have taken to heart is the case of Watson (biologist) and Crick (physicist) coming together to solve a problem that turned out to be of revolutionary importance. It would be relatively easy for the physicists in CXS to have continued to work on the development of new methods in coherent X-ray science. However, we were anxious to ensure that we have an agreed set of goals that would ensure that we remain focused on what is both physically possible and biologically interesting. We are very fortunate to have found, in members of the Department of Biochemistry at La Trobe University, partners from the biological sciences who share this vision and Professor Leann Tilley is the CXS Deputy Director. Leann is an expert in the malaria parasite and is particularly interested in the development of new forms of microscopy to gain new insights into its structure and function (*9*). Consequently, our preliminary results have focused on this model. We have through a very close collaboration with the group of Professor Carolyn Larabell from the University of California San Francisco obtained excellent results in high-resolution X-ray tomography based at the Advanced Light Source at the Lawrence Berkeley National Laboratory in the USA (Figure 3). These results serve as a precursor to our high resolution methods, which are now beginning to bear fruit9. The biology program is led by A/Prof Mike Ryan from Biochemistry at La Trobe.

Short wavelength laser program:

A major area of development for the production of short-wavelength coherent light is the mechanism of high-harmonic generation. In this method, a very short but very intense laser pulse enters a medium which is driven so hard by the incident light that it responds in a non-linear manner and can produce very high-order harmonics of the incident frequency. These processes have been the subject of considerable development over the last decade or so and are seen to be a promising approach to the production of coherent short wavelength light. As yet, the mechanism has yet to deliver beams that are bright enough to offer really interesting uses. However we have chosen to invest in this area as there are, in our view, reasonable prospects for the sources to continue to develop. New ideas continue to emerge and, in any case, such a source offers a very useful test bed for the development of ideas and methods that may be later implemented on synchrotron and X-ray laser sources.

Fig. 4. Discussions at a poster session at the 2008 CXS "X-ray Biophotonics: Physicists & Biologists Working Together" interdisciplinary workshop

This program involves the Centre for Ultrafast Optics & Spectroscopy at Swinburne University of Technology and the School of Chemistry at the University of Melbourne and is led by Prof Lap Van Dao of Swinburne.

The Theory & Modelling Program

How does a large molecule behave in an intense coherent X-ray field? We certainly know that it

will explode due to the ionization processes taking place, but how fast does it explode? How short does an X-ray pulse need to be to ensure that the disintegration of the molecule has a negligible effect on the diffracted signal? These are some of the key questions to be addressed by the Theory & Modelling program. Interestingly, there are some fundamental similarities between the physics of intense X-ray laser fields and the physics of the interaction of intense short pulse lasers in the production of high-harmonic generation. This program has therefore evolved into a central activity of the centre with its ability to coordinate and synthesise many of the threads that make up the tapestry that is CXS. We also endeavour to lead cross-centre collaboration in this area and have organised two joint workshops with the ARC Centre of Excellence for Anti-matter Matter Studies.

An important aspect of the Theory & Modelling program has been its continued collaboration with the Experimental Methods Program on approaches to the analysis of experimental data. We have also brought in expertise in advanced diffraction data analysis through the hiring of Dr Ruben Dilanian. Ruben has been using his expertise to develop new approaches for the analysis of partially coherent diffraction data. He has also been working on the analysis of diffraction data obtained from haemozoin produced by the malaria parasite as part of a collaboration between the Biological Science Program and our collaborators in CSIRO. These methods will also play a critical role in our work with diffraction from free electron laser experiments. The program is led by Dr Harry Quiney of the University of Melbourne. The Beamline and Detectors Program: Complementing the work of the Experimental Methods Program, the Beamline and Detectors program has been instrumental in developing synchrotron beamline equipment and in elucidating the specifications for new detectors. As this aspect of the work has now largely been completed, this program, led by Dr Chris Hall at Monsah University, has wound up to allow the incorporation of a new program.

Fig. 5. Tess Kirkinis (Santa Maria College, Northcote), seated, and Dr Benedicta Arhatari (CXS – La Trobe) discussing the reconstruction of a tomographic image of a fossilized ant during a session of our Growing Tall Poppies outreach program.

The Attosecond Science Program

As a new initative arising from the strategic planning involved in the renewal of CXS we decided that it would be valuable to further develop our work on the underlying physics of the interaction of atoms with intense lasers. As such, we have recruited Dave Kielpinski and Robert Sang from Griffith University to work with us on experimentally probing the detailed dynamics of the interaction of fields with single atoms. It is our plan that this collaboration will match up with our work on short wavelength laser sources and the theoretical exploration of high-field physics to better enable us to understand how complex biomolecules might behave when subject to intense coherent X-ray fields. This program is led by A/Prof Dave Kielpinski at Griffith University.

Other CXS programs: At the outset, CXS saw itself as being closely aligned with Australian developments such as the establishment of the Australian Synchrotron. CSIRO also saw these developments as important and so we formed a strategic alliance with CSIRO in the area of coherent imaging science that can be performed with synchrotron sources. We therefore included two distinguished CSIRO scientists, Steve Wilkins and Jose Varghese, on our Executive committee to ensure that our efforts were well-aligned into the future. This has turned out to be a very productive relationship and we have managed to establish some new scientific collaborations, particularly in the area of structural biology.

Using funding from the University of Melbourne as part of the Nugent Federation Fellowship package, we have also established a program working on the development of new forms of coherent electron sources that is led by Rob Scholten. The methods we are developing with coherent X-rays may also find application using electrons. Indeed, the higher scattering cross-sections for electron scattering implies that this might emerge as an extremely important area of application10. In this program, which collaborates intensively with the University of Eindhoven, we use a laser-cooled cloud of atoms as a source of electrons with relatively high coherence with the aim of using them to study the scatter from samples such as biomolecules.

Beyond the Science

Outreach is an important part of the activities of an ARC Centre of Excellence. We have an extensive program that includes a series of workshops on interdisciplinary activities and an outstanding international workshop that we run at regular intervals called “X-ray biophotonics: Physicists & Biologists Working Together” (Figure 4). We have also tried experiments such as a “Talking Backwards” workshop in which we asked students with a physics background to explain biology, and vice versa, to a mixed audience. “Talking Backwards” turned out to be a great success and we plan to do it again.

The centre also runs professional development programs for researchers including seminars on commercialisation and intellectual property as well as setting policy on shared authorship and student funding. We have a strong Intellectual Property advisory committee and strong links to the Co-operative Research Centre for Biomedical Imaging Development. Part of the reason why our research and training workshop series run so smoothly is thanks to a small, but extremely talented pool of finance and administrative staff. The centre is not just multidisciplinary across the sciences – we value input from the administrative and business worlds!

We are also particularly pleased with the development of our Growing Tall Poppies program in which we take small groups of highly motivated Year 10 students and immerse them into a CXS activity for one week (Figure 5). We have chosen Year 10 girls as the target group as Year 10 is the time at which students are making important decisions concerning their further study of science. Enrolment numbers suggest that girls seem more motivated to study the biological sciences and are seriously under-represented in physics. CXS seemed like a perfect vehicle to show that physics is relevant and important to society in general and biology in particular. We were delighted that this partnership was awarded the inaugural Victorian State Impact Award from the new Schools First grant program operated by the National Australia Bank and that our teacher partner, Dr Eroia Barone-Nugent, was identified by the Melbourne Herald-Sun as one of Victoria’s ten most inspiring people.

CXS is turning out to be an interesting experiment. We have brought scientists from different disciplines together and we are all collaborating productively. There is no question that scientists from different areas see things differently and we are very fortunate that all members of the collaboration have a deep mutual respect and a real thirst to learn about the work of other members of the

centre. We have continued to publish high impact work and we are beginning experiments with the new X-ray laser sources. The current term of CXS runs until the end of 2013 so we have a few more years in which to use and savour the unusual environment that we have created.

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How does it work?

How do you recover the phase from a diffraction pattern? The basic idea has its origins in electron microscopy and the famous Gerchberg-Saxton algorithm. In this, one iterates between the plane at which the diffracted intensity is measured and the plane of the diffracting object about which it is assumed something is known *a priori*, such as its shape and size.

Propagation of a paraxial x-ray wave exiting a sample, ψ_s, to a detector can be described using the Fourier transform, $\Im$:

$$\psi_d = A\Im\left[B\psi_s\right],$$

where A is a constant and B is a parabolic phase term. If the detector is in the far field of the exit wave then $B \approx 1$. Under the projection and single scattering approximations the wave exiting the sample can be written as the product of a complex sample transmission function, T, and the incident wave. When the incident wave is planar then there is a Fourier transform relationship between the object transmission function and the wave at the detector, $\psi_d = A\Im\left[T\right]$. This wave is, in general complex, $\psi_d = \left|\psi_d\right| e^{i\phi}$, while the measurement is of the intensity, $I = \left|\psi_d\right|^2$. The resulting "phase problem" prevents us from being able to recover T by straightforward application of the Fourier transform to the measured data – a way needs to be found to obtain the phase of the wavefield.

It was pointed out by Sayre in 1952 that the diffraction pattern should itself provide enough information to obtain a solution. It took 30 years and some algorithmic magic to turn this information theory-based argument into a viable technique. It then took another 17 before the first demonstration of the method in x-rays was made. The simplest variant of the reconstruction algorithm is known as Error Reduction. ER proceeds by applying knowledge of the solution in both the detector and sample planes. A guess for the phase of the solution is used as a starting point and propagation is performed between the sample and detector planes using the Fourier transform. In the detector plane the current iteration of the solution is updated by replacing its amplitude with the measured amplitude. This can be described in operator notation as:

$$\psi_d^{k+1} = \hat{\pi}_m \psi_d^k = \frac{\psi_d^k}{\left|\psi_d^k\right|}\sqrt{I},$$

where k represents the iteration number and $\hat{\pi}_m$ is the detector space modulus constraint operator. Adequate sampling of the diffraction pattern, as proposed by Sayre, is possible for a given detector when the sample is isolated within a given region. This is taken as a priori knowledge and can be enforced using a "support constraint" operator, π_s, such that T^k is set to zero outside the support region and is unchanged inside. A cycle of the iterative loop is then defined:

$$T^{k+1} = \pi_s \pi_m T^k,$$

where $\pi_m = \Im^{-1}\hat{\pi}_m\Im$, the modulus constraint, includes the propagation steps. The convergence of the iteration is normally assessed by calculating an error metric comparing the current iterate for the amplitude at the detector with that actually measured.

Tunable lasers for atomic vapor laser isotope separation

The Australia's Contribution

by Frank J. Duarte

Introduction

In a previous article Pryor (*1*) described the contribution of Australian physicists to advanced uranium isotope enrichment. His article centers on two approaches: a phase transition transformation of UF6 known as the Ward process and molecular laser dissociation using CO_2 lasers. The first approach was a theoretical idea that was not demonstrated in practice but the molecular laser dissociation approach yielded many publications in international journals (*1*). In the same account Pryor writes "The AAEC considered an AVLIS program. Professor Jim Piper, from his university, would have been very happy to develop the copper-vapour pump and the tuned dye lasers. But the cautious hand refrained." Here, the development of efficient narrow-linewidth tunable laser oscillators for AVLIS applications, at Macquarie University, is described from a historical perspective. Also the influence of this oscillator physics, and architecture, program on various laser research efforts around the world are outlined as well as a stealth attempt to have an AVLIS effort adopted by the Australian Federal Government *circa* 1982.

Early laser resonators

In 1978, following my Honours year at the former School of Mathematics and Physics of Macquarie University, I embarked on a doctoral research project to develop an optically-pumped molecular laser under the supervision of J. A. Piper. The pump laser of choice was the copper-vapour-laser (CVL) which was one of the research areas that Piper had specialized in while working with C. E. Webb at The Clarendon Laboratory in Oxford. However, prior to performing these experiments we realized that we needed high-performance tunable lasers to replicate the emission lines of the copper laser at 510.554 nm and 578.213 nm and study the spectroscopy of the molecular gain medium. Thus, I built a nitrogen-laser-pumped tunable dye laser based on the telescopic design of Hänsch (*2*). Due to its relatively long cavity length and its two-dimensional intracavity beam expansion, illuminating the diffraction grating, this laser proved rather sensitive to thermal variations. The need for more compact, stable, and rugged alternatives became painfully clear. As possible alternatives, Jim Piper brought a paper by Hanna *et al.* (*3*), on a single-prism beam expander, and a couple of papers on grazing-incidence designs (*4*, *5*). It didn't take me long to implement these designs and to enjoy the benefits of compactness. However, the price to pay was either very low conversion efficiencies or high levels of amplified spontaneous emission (ASE) at the output. High ASE levels originated from coupling the output emission from either the reflection losses at the prism or the reflection losses at the grazing-incidence grating. Since low conversion efficiencies were unacceptable, and ASE is the equivalent of broadband optical noise, something had to be done. The drive towards efficient low-ASE narrow-linewidth tunable laser emission led to the independent development of closed-cavity multiple-prism grating dye lasers (*6*) and shortly afterwards to the introduction of the prism pre-expanded near-grazing-incidence tunable lasers (*7*).

Copper-vapour-laser-pumped narrow-linewidth tunable dye lasers

Soon the main focus of my research became the development of efficient high-power narrow-linewidth tunable dye lasers. In 1982, while partially funded by the AAEC, I began a series of experiments on closed-cavity CVL-pumped multiple-prism grating tunable laser oscillators. At first we employed a low repetition rate TE CVL as the excitation laser (*8*). My knowledge on the TE CVL grew, at the practical level, from my observation of the work of Milan Brandt who was completing his doctoral research on the subject (*9*). These low pulsed-repetition-frequency (prf) experiments were followed by a series of experiments using a high prf (~8kHz) CVL laser as the pump (10, 11). Two of the closed-cavity oscillators developed in these experiments are depicted in Figures 1 and 2. Basic emission parameters include tuning in the nm range, laser linewidths of $\Delta\nu$ ~ 650MHz (or $\Delta\lambda$~0.0007nm at $\Delta\lambda$~575nm) for a 4-5% conversion efficiency. The peak power of this narrow-linewidth emission was ~1kW.

Generalized multiple-prism dispersion theory

The systematic development of multiple-prism grating laser oscillators required the theoretical characterization of the laser linewidth which in turn depends on the overall intracavity dispersion of the multiple-prism grating configuration. However, at the time there was no comprehensive theory and no multiple-prism dispersion equations. In regard to the multiple-prism dispersion Jim Piper suggested that I should "look it up in a book." So I did, and the more that I looked the more I realized that it wasn't out there. At the time I was doing a postdoc with Brian Orr, at the University of New South Wales, and for a while I would spend the evenings working on this problem. Eventually, I worked out the generalized single- and double-pass multiple-prism-grating dispersion equations thus allowing us to characterize the double-pass linewidth equation (*12*). A following paper extended the treatment to a multiple return-pass analysis (*11*) and a subsequent paper included generalized higher derivatives applicable to pulse compression in femtosecond lasers (*13*) which recently has been extended to a mathematical framework, derived using a Newtonian iterative approach, that provides higher derivatives, in analytical form, at will (*14*). As a footnote I should add that Newton had pictorially, and qualitatively, discussed the first order dispersion of multiple-prism arrays in his book *Opticks* (*15*). Our equations can be nicely used to quantify the dispersion in Newton's prismatic configurations. Besides the use of these equations in laser cavity design (*16*), and pulse compression calculations (*17*), researchers have also applied them in the design of femtosecond laser microscopy systems (*18*, *19*).

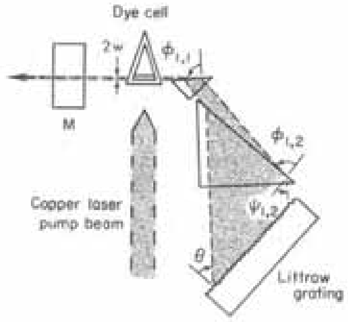

Fig. 1. CVL-pumped narrow-linewidth multiple-prism grating tunable laser oscillator. In this closed-cavity dispersive oscillator configuration the beam waist at the gain medium (w) is reduced to achieve single-transverse-mode emission. The resulting beam dimension (2w) is then expanded to completely illuminate the diffraction grating. For this particular oscillator the beam magnification factors is (from (*10*)).

Advocacy for an AVLIS effort in Australia

Due to my involvement in the Macquarie science reform movement (*20*) I had developed several contacts among noted Australian politicians and also within the Australian Federal Government at the time. In particular, I was acquainted with the federal minister for education (1975–1979) Senator John L. Carrick whom subsequently became the minister for national development and energy (1979–1983). By then I had studied several reports on AVLIS for uranium and I was very keen to continue the work on the physics and architecture of narrow-linewidth tunable laser oscillators. Thus, on my own initiative, I directly proposed to Sir John the introduction of an AVLIS facility in Australia. Correspondence was interchanged and in one of his letters Sir John Carrick wrote "The Uranium Enrichment Group of Australia (UEGA) assessed a number of competing technologies… and concluded that centrifuge technology would be best suited for an Australian plant… I am assured that UEGA has taken into account the recent advances in laser isotope separation… UEGA was not, however, prepared to commit to a technology still at the R&D stage" (*21*). From his letter it was clear that Carrick took advice from the UEGA group and that a decision had already been taken not to invest in AVLIS or alternative laser isotope separation

schemes. Albeit he politely suggested a meeting with some senior public servants it was obvious that the decision was final. As Pryor insightfully said in his writings… "the cautious hand refrained."

AVLIS efforts in the open literature

The popular literature often associates AVLIS with the American effort at the Lawrence Livermore Laboratory which is best summarized by Bass *et al.* (*22*). The truth is, however, that AVLIS is a far more widespread research and development approach to isotope enrichment. As our papers were published I began to receive numerous postcards with reprint requests from the USA, all over Europe, Israel, and Asia. Among these requests were postcards from the now well-known Bhabha Atomic Research Centre (BARC), in India.

Years after sending their reprint requests the Bhabha laser group published several papers describing the use of multiple-prism pre-expanded near-grazing-incidence tunable lasers (see Figure 2) for the efficient generation of low-noise narrow-linewidth tunable laser radiation in the $564 < \lambda < 602$ nm portion of the spectrum (*23*). Japanese laser researchers working in the nuclear field also adopted multiple-prism grating oscillator designs in their CVL-pumped tunable laser systems (*24*).

In 1998, when the underground nuclear tests were conducted in India, questions were asked to attempt to elucidate if the researchers at BARC had the capability to achieve laser isotope separation. The answer was in the open literature.

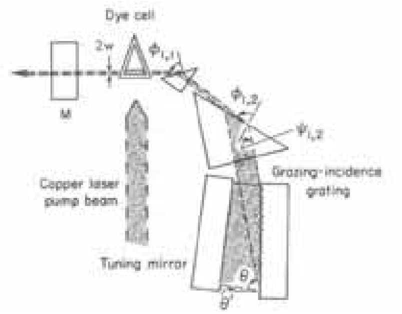

Fig. 1. CVL-pumped narrow-linewidth multiple-prism pre-expanded near grazing-incidence grating tunable laser oscillator. In this closed-cavity dispersive oscillator configuration the diffraction grating is deployed at a higher angle of incidence so that the required intracavity beam expansion is reduced to lasing at a MHz linewidth corresponds to single-longitudinal-mode emission (from (*10*)).

American laser sequel

Around 1982-1983 academic positions in lasers, or optics, were scarce in Australia. Although I was offered a very nice position with the Australian Department of Defense, I decided to accept an assistant professorship at the University of Alabama with funding to do research in infrared lasers. There I demonstrated the use of multiple-prism grating cavities, using ZnSe prisms, to achieve tunable narrow-linewidth emission in high-power TEA CO_2 lasers (*25*). Then, one late morning and out of the blue, I got a phone call from R. W. Conrad, a top physicist with the US Army Missile Command (MICOM), asking me what I knew about narrow-linewidth high-energy dye lasers. That was a long phone conversation that led to an even longer collaboration (1985-2002) on the development of narrow-linewidth high-energy tunable lasers. The pride and joy of this effort was a highly-stable single-longitudinal-mode long-pulse oscillator engineered in an all-invar structure (*26*). This elegantly ruggedized oscillator was successfully tested on a moving vehicle over a rough terrain but, due to the end of Cold War funding, was not integrated to its matching kW-class amplifier stage.

The work I did on multiple-prism grating CO_2 lasers, plus the work of other researchers, proved that these oscillator configurations were universally applicable to tunable lasers. In 1992 Paul Zorabedian, working at Hewlett Packard, successfully applied our multiple-prism grating configurations to semiconductor lasers (*27*).

The experiments at MICOM also led to research into solid-state dye lasers. Paradoxically, using highly purified dye-doped polymers developed in the former Soviet Union I was able to demonstrate, for the first time, tunable narrow-linewidth emission from solid-state dye laser oscillators (Duarte, 1994). Subsequently, this work led to the development of very compact optimized multiple-prism grating oscillators, tunable in the $550 < \lambda < 603$nm range, yielding high-power single-longitudinal-mode laser emission at a linewidth $\Delta\upsilon$~350MHz, for pulses Δt~3ns (FWHM) (*28*). The emission of these laser oscillators is at the limit allowed by Heisenberg's uncertainty principle.

AVLIS status

Despite opposition from participating scientists, the Lawrence Livermore uranium AVLIS effort was brought to an end shortly after it was transferred to a commercial entity in 1999.

Although the approach was a scientific and technological success apparently this success was not enough to ensure timely commercial viability. At present it is undetermined how many laboratories around the world are engaged in this type of research. The interest is not just on uranium but also on various other atomic species including lithium (see, for example, *29*). A Russian perspective on AVLIS is given by Bokhan *et al.* (*29*).

"Then, one late morning and out of the blue, I got a phone call from R. W. Conrad, a top physicist with the US Army Missile Command (MICOM), asking me what I knew about narrow-linewidth high-energy dye lasers..."

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Samplings

Locks and keys build tiny structures

http://physicsworld.com/cws/article/news/42091

Researchers in the US have invented a "lock and key" technique that causes small particles to assemble themselves into a variety of tiny structures. The method could offer a simple way to create technologically useful materials on the micrometre and nanometre length scales.

Many functional materials can be created by directing the assembly of colloidal particles into a predetermined structure. Control over particle assembly usually involves tagging them with molecules such as DNA that can recognize and bind each other. Now, Stefano Sacanna and colleagues at New York University show that shape complementarity — the construction of colloids using a lock-and-key recognition mechanism — offers a simple and effective alternative control mechanism (http://www.nature.com/nature/journal/v464/n7288/full/nature08906.html). The keys are colloidal spheres, and monodisperse colloidal particles with a spherical cavity are the locks. The two will spontaneously and reversibly bind via the depletion interaction if their sizes match. This procedure yields complex colloidal structures held together by flexible bonds, and offers a simple yet general means to program and direct colloidal self-assembly.

Sacanna and colleagues now plan to make "smart" particles and push their self-assembly to the limit where well-defined structured clusters of particles can self-replicate.

See also this Nature commentary: http://www.nature.com/nature/journal/v464/n7288/full/464496a.html.

New twist to electron beam

http://physicsworld.com/cws/article/news/42232

Physicists in Japan have for the first time generated beams of electrons displaying the fundamental physical property of orbital angular momentum. Like light beams before, these electron beams have had their wavefronts distorted so that they spiral through space and create a "phase singularity" at the centre of the beam, a type of vortex where the intensity of the wave is zero and its phase is undefined.

In addition to the angular momentum carried by a photon's spin (represented by its polarization), light beams can also be engineered to carry orbital angular momentum. Such beams find a variety of uses, for example, as optical 'spanners' — essentially a 'twisted' variant of the more familiar optical tweezers. Now Masaya Uchida and Akira Tonomura of the RIKEN Institute, writing in Nature (http://www.nature.com/nature/journal/v464/n7289/full/nature08904.html), show that it is possible in principle to engineer similar behaviour into an electron beam, which could find use in a variety of spectroscopy and microscopy techniques.

Tiny water desalination device help aid efforts

http://physicsworld.com/cws/article/news/42231

Each year, two million people – mostly children – die from water-borne diseases, such as diarrhoea and cholera, according to the United Nations. The particularly vulnerable include those people trapped in disaster-stricken areas, such as victims of the recent earthquake in Haiti, who struggled to get clean water after damage to water resources. However, a technique that produces drinking water from seawater, using just small amounts of energy, could lead to a portable technology that could help to address this dire situation.

The technique, developed by researchers in the US and Korea, manages to desalinate water using a simple electronic system on a tiny chip (see article in Nature Nanotechnology http://www.nature.com/nnano/journal/vaop/ncurrent/full/nnano.2010.34.html). The process starts by passing water along a tiny channel on a polymer chip – with a width of just 500 μm – until it reaches a junction, which then splits off into two separate tubes. By applying an electric potential along one of these tubes, salt ions are dragged towards this channel in the form of brine, while desalinated water flows down the second channel under the force of gravity.

To demonstrate the technique, the researchers created one chip that successfully converted seawater, with a salinity of 30,000 mg/L, into fresh water with a salinity of less than 600 mg/L, which meets the international standards for water purity.

The technique, dubbed ion concentration polarization (ICP), compares favourably with established methods of water desalination in terms of energy consumption, requiring less than 3.5 Wh/L. Reverse osmosis, for example, which works by forcing seawater through a membrane at high pressures to capture the salt, requires 10–15 Wh/L. And electrodialysis, which works by transporting salt ions from one solution to another by means of ion-exchange membranes, requires 5 Wh/L.

In addition to removing salts, ICP can also remove potentially harmful larger molecules such as cells, viruses and bacteria. Unlike reverse osmosis and electrodialysis it does not utilise membranes that can become heavily clogged by these particles.

Samplings

Physicists watch entropy in action

http://physicsworld.com/cws/article/news/41645
http://www.sciencemag.org/cgi/content/full/327/5965/560

Physicists at Harvard University have gained important insights into the process of crystallization by studying how tiny plastic balls spontaneously form clusters. They found that highly symmetric clusters are created much less often than those with lower symmetry, which could shed light on how clusters of atoms or molecules form just before a liquid solidifies into a crystalline solid.

Observation of the role of entropy during crystallization is difficult because clusters of atoms are too small and appear and vanish much too quickly to be seen. But by using clusters of much larger particles, which can be observed in real-time with an optical microscope, Vinothan Manoharan and colleagues at Harvard University in the US have been able to gain new insight into the role of entropy in the "nucleation" process.
See also http://www.sciencemag.org/cgi/content/full/327/5965/535

Colliding in the cold

http://physicsworld.com/cws/article/news/41707
http://www.sciencemag.org/cgi/content/full/327/5967/788
http://www.sciencemag.org/cgi/content/full/327/5967/853

Chemical reactions occur through molecular collisions, which, in turn, are governed by the distributions of energy in each colliding partner. Although quantum mechanics lies at the heart of every chemical reaction, it is not easy to work out how the initial quantum states of the reactants affect the rate of reaction. This is because most of what we know about chemistry is based on observations at tens or hundreds of kelvin, where thermal fluctuations cause atoms and molecules to enter reactions in a wide range of initial quantum states. What happens when molecules are cooled so that they no longer have sufficient energy to collide?

Ospelkaus et al. at the University of Colorado explored this question by preparing a laser-cooled sample of potassium rubidium (KRb) diatomic molecules with barely any residual energy in any form (translational, rotational, vibrational, or electronic). By monitoring heat release over time, evidence was gathered for exothermic atom exchange reactivity through quantum mechanical tunneling. As predicted by theory, these reactions were exquisitely sensitive to the quantum states of the molecules, with rates changing by orders of magnitude on varying minor factors such as nuclear spin orientation.

Plasmonic reviews

http://www.nature.com/nmat/journal/v9/n3/full/nmat2630.html
http://www.nature.com/nmat/journal/v9/n3/full/nmat2629.html

The current issue of Nature Materials contains two interesting review articles about the emerging area of plasmonics that may be of interest: one about the ability of plasmonic nanostructures to concentrate and manipulate light; and the other about the use of plasmonic structures for improving the performance of photovoltaics.

Clocking on to relativity

http://physicsworld.com/cws/article/news/41740
http://www.nature.com/news/2010/100217/full/463862a.html
http://www.nature.com/nature/journal/v463/n7283/abs/nature08776.html

A central prediction of general relativity states that a gravitational field slows the running of a clock. Previous measurements of this effect, known as gravitational redshift, have involved clocks at different heights, and until now this has been the least accurately determined of the parameters supporting curved space-time theories. Now this prediction has been confirmed to unprecedented accuracy using the results of lab experiments performed more than 10 years ago in a study of the acceleration of free fall (of caesium atoms over ~0.1 mm). Analysis of the data — on quantum interference of single caesium atoms bobbing up and down in an atomic fountain — provides a measurement based on matter-wave interference that improves accuracy by a factor of 10,000.

See also the development of a new optical clock of unprecedented accuracy, by David Wineland's group at NIST, Boulder (http://physicsworld.com/cws/article/news/41696). The clock is based on laser-cooled aluminium ions, and uses a technique known as quantum logic spectroscopy to provide a precision of 2.3×10^{-17}, or about 1 second in 3.7 billion years.

Cutting it fine

Appl. Phys. Lett. 96, 053107 (2010).

Atomically thin sheets of carbon called graphene are revered for their unusual electrical properties. Now graphene has competition: Alexander Balandin and his colleagues at the University of California, Riverside, have found another material that can form atomically thin flakes, bismuth telluride (Bi_2Te_3).

Unlike graphene, which consists of layers just one atom thick, Bi_2Te_3 has five closely packed atomic sheets bound by weak forces. The researchers created flakes of five sheets or fewer by rubbing them off a larger crystal mechanically, a method similar to that used to isolate graphene. The flakes had different electrical properties depending on the number of atomic sheets they contained, which might allow Bi_2Te_3 sheets to be 'tuned' for different uses. Moreover, Bi_2Te_3 is thermoelectric – it can turn a heat gradient into an electrical current. This conversion, the authors suggest, might be more efficient in the graphene-like Bi_2Te_3 sheets than in their bulk crystal counterparts.

Small, strong and supple

http://www.nature.com/nmat/journal/v9/n3/full/nmat2622.html

Strong materials, such as ceramics, are often brittle and prone to snapping — but those that deform gracefully under tension, such as metals, are weaker.

Now, Dongchan Jang and Julia Greer from the California Institute of Technology in Pasadena have overcome this trade-off with zirconium-based metallic glasses — alloys that are formed of disordered metal atoms and that can be moulded when heated. They show that when the material is reduced in size to pillars measuring 100 nanometres in diameter, it assumes both a metal-like ductility and a ceramic-like strength. The authors suggest that internal flaws in the glass — which would shear the alloy apart in bulk form — find it much harder to propagate through the nanometre-scale structure.

Ferroelectricity goes organic

http://www.nature.com/nature/journal/v463/n7282/full/nature08731.html

Ferroelectric compounds have a range of properties useful in practical applications, including polarity reversal in electric fields, temperature sensitivity and the ability to convert mechanical stress into electricity. It is generally assumed that ferroelectricity is rare and mostly poor in organic compounds, but Horiuchi et al. now report the discovery of above-room-temperature ferroelectricity with relatively high polarization in the organic crystal croconic acid, a component of black dyes. These properties are not readily apparent in the crystalline form of this simple molecule, but they emerge on application of a modest electric field that induces a molecular-topological keto-enol conversion. This finding raises the prospect that organic ferroelectrics might be much more abundant that previously thought.

Evanescent waves bring new window into nanoworld

http://physicsworld.com/cws/article/news/41277
http://www.nature.com/nature/journal/v462/n7275/full/nature08662.html

Optical near-field microscopes can beat the optical diffraction limit when probing electromagnetic fields in the vicinity of microscopic objects, but cannot match the atomic-scale resolution of an electron microscope. Barwick et al. at Caltech have now developed an ingenious blend of these two imaging modalities — they show how the enhanced electron–photon interactions mediated by these evanescent electromagnetic fields can be detected using an ultrafast electron microscope, generating images of these fields that are well resolved in space and time. This work demonstrates the potential of photon-induced imaging in general and for nanoscale studies of fields at interfaces in particular. See also: http://www.nature.com/nature/journal/v462/n7275/full/462861a.html

Colloids as models

http://www.sciencemag.org/cgi/content/full/327/5964/445

Colloids are often used as analogs for atoms in order to study crystallization kinetics or glassy dynamics using particles that are much easier to observe and that move on much slower time scales. Ganapathy *et al.* of Cornell University

consider whether the analogous behavior extends to the growth of epitaxial films, a technique that is used in manufacturing. Controlling the rate of addition of the colloidal particles allowed the mapping of diffusional pathways during film nucleation and growth on a patterned substrate. The same relationships used to describe atomistic growth could be applied to the colloidal systems, but certain growth barriers such as those found at step edges and corners were controlled by diffusion rather than energetics. See also:
http://www.sciencemag.org/cgi/content/full/327/5964/423

The minutiae of friction

http://www.nature.com/nature/journal/v463/n7277/full/nature08676.html

The behaviour of systems as diverse as earthquakes and hard drives is influenced by frictional motion and its strength. What at first glance appears to be a continuous sliding process between touching surfaces is in fact a product of a series of 'slip' and 'stick' events on the microscopic scale. The mechanism of evolution of frictional strength at this level, though, is still unclear. Ben-David et al. have studied the evolution of the local contact area between two sliding bodies (PMMA plastic blocks) and the motion of their interface, and find that it involves four distinct phases. Within microseconds, all the contact area reduction has occurred. This is followed by a rapid slip phase, then a sharp transition to much slower slippage culminating in a 'stick' phase when motion is arrested. After several hundred microseconds the contact area begins to increase again. These results provide a basis for a better understanding of this kind of motion in many technologically important contexts.

Superconducting quantum optics

http://www.sciencemag.org/cgi/content/full/327/5967/840

The coherence properties of superconducting circuits enable them to be developed as qubits in quantum information processing applications. Astafiev et al. now show that these macroscopic superconducting devices also behave as artificial atoms and can exhibit quantum optical effects. The ability to fabricate and integrate these superconducting devices in electronic circuitry may help toward developing a fully controlled quantum optics system on a chip.

The biomechanics of barefoot running

http://www.nature.com/nature/journal/v463/n7280/full/nature08723.html

Before the introduction of modern padded running shoes in the 1970s, and for most of human evolutionary history, humans ran either barefoot or in minimal shoes. A comparison by Daniel Lieberman and colleagues of the biomechanics of habitually shod versus habitually barefoot runners now suggests that the collision-free way that barefoot runners typically land is not only comfortable but may also help avoid some impact-related repetitive stress injuries. Kinematic and kinetic analyses show that modern shoes allow runners to land on the heel, as they do when they walk. Runners who don't wear shoes land more often on the ball of the foot or with a flat foot. This means that they often flex their ankles as they strike the ground and generate smaller impact forces than shod, rear-foot, strikers — compare the impact generated by landing from a jump on your heel versus your toes. This research will also prompt fresh studies of running injuries. See also:
http://www.nature.com/nature/journal/v463/n7280/full/463433a.html

Spiders' super-strong silk relies on its crystals

http://physicsworld.com/cws/article/news/42056

Spider's silk may seem a bit flimsy but it has a tensile strength that exceeds high grade steel, and the more you pull, the more it extends – but it will not snap. Now, a group of researchers in the US and Korea are able to explain, numerically, how spider silk combines strength with extreme ductility.

A spider's silk is made from basic proteins, including some that form thin, planar crystals called beta sheets. These sheets are connected to each other by hydrogen bonds, which are among the weakest types of chemical bond: far weaker, for example, than the covalent bonds found in most organic molecules. However, by stacking multiple beta sheets, a spider's silk manages to fail gracefully, with hydrogen bonds breaking one by one under external force.

Markus Beuhler and his colleagues at Massachusetts Institute of Technology, working with researchers at Pohang University of Science and Technology, have studied this silk failure in the finest detail to date. Using a series of computer simulations they found that the strength of spider silk depends on a critical size of crystal within the beta sheets of around 3 nm. Once the crystals are allowed to grow beyond 5 nm, however, the silk suddenly becomes weak and brittle. Further details in Nature Materials:
http://www.nature.com/nmat/journal/vaop/ncurrent/full/nmat2704.html

3D invisibility cloak unveiled

http://physicsworld.com/cws/article/news/42043

The first device to hide an object in three dimensions has been unveiled by a group of scientists in the UK and Germany. While the design only cloaks micro-scale objects from near-infrared wavelengths, the researchers claim that there is nothing in principle to prevent their design from being scaled up to hide much larger artefacts from visible light.

The origins of this design date back to 2006, when David Smith and colleagues at Duke University in North Carolina created a cloak that could bend microwaves around an object, like water flowing around a smooth stone. This early cloak was made using a metamaterial – an artificially constructed material with unusual electromagnetic or other properties – which consisted of a cylinder built up from concentric rings of copper split-ring resonators. This first cloak, however, only worked in two dimensions – in other words, looking at the cylinder from above revealed the presence of the shielded object.

Now Tolga Ergin and colleagues at Karlsruhe Institute of Technology in Germany, together with John Pendry of Imperial College in London, have overcome this problem by creating a "carpet cloak". Proposed in 2008 by Pendry and Jensen Li, this involves hiding an object underneath a bump on the surface of an otherwise smooth material – just as something might be hidden under a carpet – and then smoothing out the resulting bump. This is achieved by creating a bump on a flat mirror and then placing onto the mirror a layer of metamaterial with optical properties such that light appears to reflect off the mirror as if the bump were not there. The work has been published on-line in Science Express at:
http://www.sciencemag.org/cgi/content/abstract/science.1186351.

Taming turbulence

http://www.sciencemag.org/cgi/content/full/327/5972/1491?ijkey=8b8ea82537bedf81edda9393ee82a598ff3dda3f

When fluid flows through a pipe, if the inertial forces are increased or the viscosity is decreased, the flow will become increasing noisy and will shift from being laminar to turbulent. Turbulence can be triggered by roughness in the pipe or other irregularities, which cause local eddies that grow into full-scale disruption of the otherwise smooth flow. Hof *et al.* show that a continuous turbulent eddy, downstream, eliminates the growth of upstream disturbances and can prevent the overall flow from becoming turbulent. Unlike many other control methods, the energy cost for implementing this strategy is less than the benefit gained by maintaining a laminar flow. See also a Perspective article in Science:
http://www.sciencemag.org/cgi/content/full/327/5972/1462

Quantum effect observed in a macroscopic object

http://physicsworld.com/cws/article/news/42019

Physicists in California have observed true quantum behaviour in a macroscopic object big enough to be seen with the naked eye. This is the first time this feat has been achieved and it could shed light on the mysterious boundaries between the classical and quantum worlds.

One of the fundamental principles of quantum mechanics is that objects can be in two states at the same time. This means that an electron can, for instance, be in two places at once. However, these "superposition" states are never seen in classical, macroscopic objects (one example being Schrödinger's famous cat, who clearly could not be both dead and alive) because thermal vibrations mask or destroy quantum effects. Until now, such states have only been observed in atomic-scale objects and some larger molecules, such as a "buckyball", which is made up of 60 carbon atoms.

Andrew Cleland and colleagues of the University of California, Santa

Barbara, have now achieved this for a substantially larger object than in previously experiments – a mechanical resonator made of aluminium and aluminium nitride, measuring about 40 μm in length and consisting of around a trillion atoms. It is a thin disc, which resonates at about six billion vibrations per second.

In the experiment, Cleland's team reduce the amplitude of the vibrations in the resonator by cooling it down to below 0.1 K, and measured the quantum state of the resonator by connecting it electrically to a superconducting quantum bit or "qubit". The qubit acts, in fact, like a "quantum thermometer" that can identify just one quantum thermal excitation, or phonon. The qubit can then be used to excite a single phonon in the resonator, and to transfer this excitation to and from the resonator many times. In this way the researchers created a superposition state of the resonator where they simultaneously had an excitation in the resonator and no excitation in the resonator, such that when they measured it, the resonator has to "choose" which state it is in. Further details in Nature:
http://www.nature.com/nature/journal/vaop/ncurrent/full/nature08967.html.

See also a report of a long quantum walk by an ultracold calcium ion in an ion trap (http://physicsworld.com/cws/article/news/41992) reported in Phys. Rev. Lett. **104**, 100503 (2010).

Enter the 'thermopower wave'

http://physicsworld.com/cws/article/news/41978

Researchers in the US and Korea have discovered that igniting a carbon nanotube, coated in chemically flammable material, can trigger a high-speed wave to race along the tube at 10,000× the speed of the spreading chemical reaction. The new phenomenon, dubbed a "thermopower wave", could lead to a new way of generating electricity and may enable micro power sources to drive nanoscale devices.

These self-propagating waves, which are related to combustion waves, had previously been predicted by the same researchers in earlier papers. In their experiment, Michael Strano and his colleagues at MIT coated multi-walled nanotubes (MWNTs) with a chemical fuel known as cyclotrimethylene trinitramine (CNT). They then fire the system with a low-power laser, which ignites the fuel to initiate a reaction in the chemical, which spreads along the nanotube. However, the burning fuel also triggers a thermopower wave, which also propagates along the nanotube at 1–10 metres each second – 10^4× faster than the reaction itself.

The high speed thermal waves energize electrons before, effectively, "pushing" them through the nanotube – establishing an electric current. It is observed here in carbon nanotubes because the low heat capacity enables a feedback system where heat escaping from the nanotube ignites more fuel and increases the speed of chemical reaction. The resulting electrical pulses can lead to a specific power as high as 7 kW/kg, which is 10× the value associated with standard lithium batteries.

More in Nature Materials: http://www.nature.com/nmat/journal/vaop/ncurrent/full/nmat2714.html.

Harvesting heat

http://pubs.acs.org/doi/full/10.1021/nl903267n?cookieSet=1

Waste heat from vehicle exhaust pipes and industrial waste streams could offer a sustainable energy source, but current technologies for harvesting thermal energy are costly and inefficient.

Ray Baughman at the University of Texas at Dallas and his colleagues (including Gordon Wallace from Wollongong University) have created a 'thermocell' that can be wrapped around pipes. Made of carbon nanotube electrodes, the device is three times as efficient as conventional platinum-based thermocells. The difference in temperature between the two electrodes creates an electrochemical potential difference, which the thermocell uses to generate electricity. One of the team's prototypes can be attached to hot nuclear-reactor pipes. The work is reported in Nano Letters.

Spectroscopy: Expanding the versatility of SERS

http://www.nature.com/nature/journal/v464/n7287/full/nature08907.html

Placing molecules on properly nanostructured substrates is a crucial part of the working principle of surface-enhanced Raman spectroscopy (SERS), a technique that is widely used to characterize the chemical composition of a sample. This approach has been shown to boost the intensity of the molecules' vibrational Raman spectrum by factors exceeding one million, and has allowed a single molecule to be detected under favourable circumstances. One drawback of SERS is that the Raman signal, obtained by scattering laser light from the sample, is sufficiently strong only for molecules residing on gold or silver (or hard-to-handle metals such as lithium or sodium) substrates that have roughened surfaces or consist of arrangements of metallic nanoscale features. Now, Li *et al.* describe an innovative approach to SERS, termed shell-isolated nanoparticle-enhanced Raman spectroscopy (SHINERS), that expands the versatility of SERS.

Li and colleagues' SHINERS technique relies on coating nanoparticles with a very thin layer of an oxide, such as silica or alumina, and then spreading these nanoparticles onto a sample. The nanoparticles provide Raman signal amplification, and the coating keeps them separate from each other and from the probed substance. The new technique is demonstrated by probing pesticide residues on the surfaces of yeast cells and citrus fruits. It could be useful in materials science and the life sciences, as well as for the inspection of food safety, drugs, explosives and environmental pollutants. See also this commentary in Nature:
http://www.nature.com/nature/journal/v464/n7287/full/464357a.html

Mysterious 'dark flow' at the edge of the Universe

http://physicsworld.com/cws/article/news/41984

Astronomers have found that whole clusters of galaxies are moving in convoy towards a single point in the sky. This unexpected motion appears to be separate from the expansion of the universe and the researchers even suggest that a force beyond the visible universe is the culprit. The discovery has been named "dark flow".

Cosmologists have already observed two distinct effects caused by invisible entities in the universe: dark matter is known to affect the rotation of galaxies and dark energy seems to be causing the expansion of the universe to accelerate. Dark flow is the latest addition to this shadowy family.

A new study led by Sasha Kashlinsky, of the Goddard Space Flight Center in the US, reports the discovery after analysing small fluctuations in the cosmic microwave background (CMB). The CMB is the afterglow of the Big Bang and shows that the temperature of the universe is the same wherever you look in the sky, 2.7° above absolute zero. However, surveys by NASA's Wilkinson Microwave Anisotropy Probe (WMAP) have previously revealed small-scale variations to this uniform temperature of about one ten thousandth of a degree. Kashlinsky's work shows that these temperature fluctuations are shifted in the direction of a number of galaxy clusters. This implies that the clusters are moving with reference to the rest of the universe, a motion that is therefore independent of its expansion.

See also the report "Galaxy study backs general relativity" (http://physicsworld.com/cws/article/news/41948) and the discussion it produced, and a Nature commentary:
http://www.nature.com/nature/journal/v464/n7286/full/464172a.html.

Obituary

Sir Ian Axford

02/01/1933 - 13/03/2010

by Professor Brian Fraser

Sir Ian Axford died on 13 March 2010. Born in Dannevirke, on the North Island of New Zealand, Ian was educated at Napier Boys High School where he was dux in his final year. The following years were spent at Canterbury University where he graduated with a double degree in science and engineering followed by a double Masters in Science with first class honours and in engineering with distinction. As a member of the Royal New Zealand Air Force's Defence Science Corps he was sent to the University of Manchester to study aerodynamics, but his PhD in 1960 ended up researching the properties of interstellar gases; so-called plasmas. It was there that Ian was inspired by Patrick Moore's television program "The Sky at Night". After a year at Cambridge he joined the Defence Research Science Board of Canada where he published, in collaboration with Colin Hines, his most cited paper "A unifying theory of high latitude geophysical phenomena and geomagnetic storms" in the Canadian Journal of Physics in 1961. This paper for the first time introduced the concept of viscous interaction between the solar wind plasma impinging on the Earth with the protective cavity created by the geomagnetic field in the magnetosphere to explain the current systems seen in the high latitude ionosphere during geomagnetic storms. This classic paper remains the basis for present day studies of magnetospheric dynamics and substorm processes.

From 1963 to 1974 Ian taught astronomy and physics at Cornell University where he became a full professor at the age of 33, and later at the University of California, San Diego. This was the time of the explosion of interest and activity in space exploration and Ian became closely involved in the Pioneer mission to Venus and the Voyager 1 and 2 missions to Jupiter, Saturn, Uranus and Neptune.

After 14 years in the United States and at the age of 41 Ian was appointed scientific member and director of the Max Planck Institute for Aeronomy, later to become the Max Planck Institute for Solar System Research, a position he held until 2001, but interrupted for three years (1982-1985) by tenure as Vice Chancellor of the Victoria University of Wellington in New Zealand. Ian significantly increased the profile of the Max Planck Institute through attracting numerous guest scientists, many of them New Zealanders, and participating in important international space missions. Major contributions were made to the Giotto mission (a rendezvous with Comet Halley) and the Ulysses and SOHO solar probes.

Ian published more than 250 scientific papers over a wide variety of topics. In addition to studying the basic structure of the Earth's magnetosphere, which he applied across the planets, he also advanced our knowledge of the solar wind and cosmic rays.

In his services to scientific communities Ian was a true leader. He was deeply involved in establishing the European Geophysical Society and served as president over 1990-1992. Pursuing his interests in widening the sphere of scientific collaboration he was a founding member of the Asia Oceania Geosciences Society (AOGS) established in 2003 and based in Singapore. He was also the first elected president (1986-1988) of the International Committee on Space Research (COSPAR), a body established in the cold war era with leadership until then provided by the USA and the USSR.

Ian was the recipient of numerous awards including the John Adam Fleming Medal from the American Geophysical Union in 1972, the Tsiolkovsky Medal from the Kosmonautical Federation USSR in 1987 and the Chapman Medal from the Royal Astronomical Society and the Rutherford Medal, New Zealand's top honour, in 1994. The following year he was named New Zealander of the Year and in 1996 was knighted. At that time he was the only New Zealander to accomplish the triple honour of being Fellow of the Royal Society London, a Foreign Associate of the US National Academy of Sciences and a member of the Academia Europaea. On his 60th birthday one of his favourite honours was bestowed, the naming of Asteroid 5097 after him.

Ian considered manned space flight to costly and risky and instead was a strong supporter of unmanned space probes. He also showed interest in global warming in his later years and was of the belief that the large populated countries of the world would need to exploit the nuclear option to avoid extreme climate change.

Ian was patron of the Ian Axford Fellowships in Public Policy, a program to host mid-career US professionals in New Zealand. He was a strong supporter of the arts, particularly music. He was quietly spoken but always helpful and cheerful and a very good administrator and communicator. Ian was always a New Zealander at heart and when meeting up with fellow countrymen the conversation would inevitably end up on cricket or rugby.

He is survived by his wife, Joy and their four children.

Branch News

South Australia

The SA branch has had a busy 12 months, with many events since our last report. The first was a public lecture in May by Prof. Geraint Lewis on "A Universe made for me? The anthropic principle in Astronomy". We thank the Astronomical Society of Australia and the national executive for arranging this as part of the ASA International Year of Astronomy lecture series. In June the branch held a discussion meeting on the "Future of Physics in Australia", organised by A/Prof. Murray Hamilton. This was part of the project undertaken by the National Committee for Physics (Australian Academy of Science), led by Prof. Michelle Simmons, UNSW, to produce a snapshot of Physics around Australia, along with an indication of where the discipline is going, or wants to go.

Fig. 1. SA branch chair, Dr Pina Dall'Armi-Stoks with students who were presented with Bronze Bragg merit certificates.

In July the branch held its inaugural mid-year dinner. This was partly a social event, but included presentation of some of the branch's awards. These included the Silver Bragg medals, awarded to the best 3rd-year Physics student at each SA University. This year the recipients were Kieran Clancy of Flinders University and Sophie Underwood of the University of Adelaide. Delayed presentations from previous years were also made to Emma Lawrance of Flinders University and Mark Argent of the University of South Australia. Sophie Underwood's DSTO Honours Scholarship was also acknowledged. The inaugural AIP-SA branch's "Outstanding contribution award" was presented to Dr Laurence Campbell.

In August the branch held a Student-Industry Night, this being a reception at the National Wine Centre. Invitations were sent to relevant employers, and to Physics academics and students. The event was organized by Dr Scott Foster and sponsored by DSTO (major sponsor) plus NewSpec, LASTEK, the University of Adelaide, Flinders University and the University of South Australia. Universities nominated particular postgraduate students to present posters about their work. Dr Jackie Craig of DSTO gave an address on Physics careers.

In September, the branch, in conjunction with the Women-In-Physics group and as part of the AIP 2009 Women in Physics Lecture Tour, hosted a public lecture by A/Prof. Christine Charles on "To planets or just to the shops, Plasmas pave the path". Christine presented Claire Corani awards (for the best second-year female Physics students at each university) to Lilian Ellis-Gibbings of Flinders University and Emma Langhans of the University of Adelaide. The lecture included practical demonstrations, as shown in the photograph. Christine also met with groups of female students at the University of Adelaide and Flinders University and gave a lecture to about 250 school students. We thank Emma Heading for organizing the SA portion of the tour. During National Science Week the education subcommittee hosted the annual Super Science Quiz, for upper-high-school students. We thank Doug Medwell for taking the lead in organizing the event, St. Peter's College for providing a venue, Dr Olivia Samardzic for being MC and undergraduate Physics students for their help.

A unique event, organised by Dr Maria Parappilly as part of the International Year of Astronomy, was the "Astrofest", a one-day event for 150 year-9 students. This event consisted of a plenary lecture "The Milky Way in Different Light" by Dr Gavin Rowell, followed by a number of parallel activity sessions on astronomy/space-related topics: "The Universe: How Big is it?", "A mission to Mars: Can we do it?" and "Patterns in the Sky". We thank University of Adelaide staff and students Prof. Bruce Dawson, Dr Gavin Rowell, Dr Paddy McGee, Nigel Maxted and Vanessa Holmes for giving talks at this event and Flinders and Adelaide Universities for sponsorship.

Fig. 2. A demonstration of plasma as part of the WIP lecture by A/Prof Christine Charles. certificates.

At the annual dinner following the branch's AGM, the after-dinner speaker Professor Barry Brook spoke on "Sustainable energy solutions for successful climate change mitigation", with an emphasis on nuclear energy. The first event for 2010 was a public lecture on April 15th by A/Prof. Craig Savage on "Through Einstein's Eyes". Craig presented Bragg certificates to students (see picture) who received 20/20 for year-12 Physics in 2009, then gave a fascinating lecture using computational techniques linked with advanced graphics to show how things would appear if you could travel at near the speed of light.

New South Wales

The March meeting of the NSW branch of the AIP was held at the University of Sydney on Tuesday 23 March 2010 and featured two unique topics in physics to launch the branches first double meeting of the year. Our first speaker Dr Jesse Shore from Prismatic Sciences has over 26 years experience as a science communicator. Currently he works through his business, Prismatic Sciences, to develop science based programs for various audiences and media. He enjoys making science meaningful to a variety of audiences and likes to have a bit of fun in how he presents his content. Jesse is President of the Australian Science Communicators. Jesse made excellent use of his experience and skills as a science communicator by giving an enlightening, back to basics public talk; about the enormous affects light has our everyday life.

He opened his talk with the somewhat amusing statement: light is good; no light is bad. He explained how the various frequencies that make up light (colours) may travel at different speeds within matter, leading to rainbows, and how the often-puzzling phenomena of multiple rainbows are formed. These ideas can be extended to explain many things from the fantastic colours in diamonds to how one can be successful at spear fishing. Jesse then went on to describe how the Danish Astronomer Roemer (1676) was the first person to measure the speed of light by observing the moons of Jupiter. Roemer's speed of light calculation, 200 000 km/s, was surprising accurate given the limitations of the technique and the technology of the period. Other areas Jesse gave us an insight into included cooking with light (microwave ovens); colloids, making light (hot incandescence bulbs and cold LEDs), controlling light and using light for data storage (2D – current CD/DVD, 3D – multilayer DVD, 4D DVD using colour and 5D DVD using polarisation). Jesse concluded his talk by mentioning the Bose Einstein Condensate, Cerenkov radiation and firing our imaginations on possible future applications and technologies such as cloaking devices. The talk was very well

Fig. 3. Year-9 students at the plenary lecture by Dr Gavin Rowell at the Astrofest.

structured, informative and descriptive from start to finish and well received by the audience.

The second talk of the night featured Dr Duldig, a Senior Principal Research Scientist with the Australian Antarctic Division where he manages the atmospheric component of the Division's climate program as well as the cosmic ray observatories. Being a world leader in Cosmic Ray modulation research and responsible for cosmic ray observatories in Australia and Antarctica, he was in an excellent position to provide a talk that successfully gave a unique insight into cosmic ray astronomy. Marc began the talk by explaining that cosmic rays consist mainly of protons (90%) with heavier nuclei such as alphas making up the rest. This composition actually mirrors the matter distribution in the universe and is galactic in origin. The cosmic ray spectrum is not like the EM spectrum but it does have a similar energy range from maximum to minimum. Marc then went on to talk about the history of cosmic ray research with Victor Hess (1911-13) showing the radiation initially decreased with altitude but then increased proving it was celestial in origin. Anti matter was also detected in cosmic rays. Cecil Powell (1939–45) developed emulsion photographic plates with Raymond Davis Jr using CCl4 to detect neutrinos from the sun. This count turned out to be only half of what was predicted, proving theory wrong and resulting, eventually, in a Nobel Prize.

Fig. 1. From left to right, Dr Graeme Melville (AIP Branch Chair) and Dr Jesse Shore.

Marc went on to talk about cosmic ray detections methods, explaining that the most energetic rays (≥10^{12} eV) hit the top of the atmosphere creating a cascade of particles and pair production. Lower energy particles (10^9 – 10^{12} eV) only cause ionization so they reach the surface of the earth. Low energy particles (below 10^9 eV) scatter with atmospheric nuclei, giving a lot of neutrons at the ground. High altitude detectors such as those on high mountains, use multiple light detection detectors to view the nitrogen fluorescence caused by the cascade, which give direction as well as intensity data. Neutrons can be detected by their nuclear reaction with Boron. The highest energy cosmic rays are cosmologically local in origin (within our galactic supercluster) and have a cutoff at 10^{20} eV, because of their interaction with the microwave background. Marc explained how there is a connection between solar activity (as seen for example by increased sunspot numbers) and cosmic ray flux on the earth. When the sun is active, actually less cosmic rays reach the earth. This process is generally understood to be due to the sun extended magnetic field carried out beyond the solar system by the solar wind but many details remain unexplained. Marc finished the talk by explaining that the sun can give off Coronal Mass Ejections (CMEs), more commonly around its activity maximum but possible at any time in the solar cycle, which can lead to a number of local problems ranging from computer upsets and memory failures to electricity grid and telecommunications disruption, satellite damage and astronaut and airline passenger radiation safety concerns. The combination of Dr Marc Duldig's deep inside knowledge into these areas and sense of humour meant the talk was highly entertaining from start to finish and well received by the audience. The Australian Institute of Physics thanks both Dr Shore and Dr Duldig for there outstanding lectures!

Fig. 2. From left to right, Dr Marc Duldig and Dr Fred Osman, (AIP Branch Secretary).

Ultrathin fibres heat up

The inaugural event of the National Humboldt Lecture Series took place in Townsville at James Cook University in April. Dubbed the Great Global Climate Debate it involved Prof David Karoly from the University of Melbourne and Prof Peter Ridd of James Cook University. The evening was chaired and mediated by JCU Prof Robert Robson, President of the Australian Association of von Humboldt Fellows.

Prof Karoly opened with his talk titled "Climate Change: an Update on the Science." Using much of the data presented in the IPCC Report 2007, Prof Karoly gave on overview of the broad evidence supporting its conclusions that the climate has warmed over the past 50 years, mostly as a result of human activity. He looked at the low impact of water vapour in initiating climate change, highlighted the difficulty of using experimental techniques to verify if CO_2 is affecting the Earth's temperature, and detailed how computer modelling may not be very good at predicting the weather on your next birthday, but has been very good at simulating climate observations since 1990. Prof Peter Ridd took an interesting tack in his approach to the debate; he chose to advance his arguments against human activity causing climate change as though CO_2 were on trial and then proceeded to make his case. Prof Ridd asked the audience to consider that the physics and mathematics of climate modelling is far

Australian Association of von Humboldt Fellows

more important than the environmental science. He outlined the problem with instabilities in the air mass, and the use of imprecise parameters, significantly affecting the efficacy of climate modelling. Prof Ridd also raised questions about the process of funding scientists and in the IPCC itself. He ended on a humorous note stating that "CO_2 should be released on bail until we can organise a retrial. "The event was attended by over 200 members of the public, many of whom had pointed questions in the follow up session afterwards. The lecture was sponsored by James Cook University and the Australian Association of von Humboldt Fellows www.humboldtaustralia.org.au

Tasmania

The Tasmanian Branch has had an excellent start to the year's activities. Already we have held four public lectures. The series opened on 11th February, when Dr Alan R. Whitney from the MIT Haystack Observatory in Massachusetts discussed "Creating a Radio Telescope the Diameter of the Earth". A seemingly ambitious undertaking, but as one looks at the steady progression over several decades in antenna design, electronics and signal processing, from the pioneering single telescopes of the 1930's using vacuum tubes (remember them?) to the wired antenna fields of the 1950s and early 1960s and then to current levels of technology, the target now seems to be an inevitable outcome. A large aperture allows better resolution, making widespread but connected antennae a requirement for many aspects of radio-astronomy. The first successful demonstration of linked telescopes occurred in 1967. Since then, the practice of Very Long Baseline Interferometry (or 'VLBI', as it has become to be known) has progressed to include Earth-size telescope arrays doing amazing work, such as making the most detailed images of some of the most distant objects in the universe, determining the positions of distant extragalactic radio objects to extraordinary precision, determining the size of the black hole at the centre of our galaxy, directly measuring continental drift, and exquisitely measuring the wiggles and wobbles of the Earth as it moves through space. The talk explores the world of VLBI and its many aspects, including a pre-view of exciting instruments planned to be built in Australia and elsewhere.

Fig. 4. Dr Paulo de Souza after his talk at UTAS.

On March 3rd, about 60 people heard Prof Hans Bachor gave an interesting talk "100 years of photons, 50 years of Lasers and much more in the future" to about 60 people. He started from the beginning of modern optics, more than 100 years ago, talked about the history of quantum mechanics, going back to Planck, Einstein, de Broglie and Schroedinger, before moving on to the laser. It can be hard to realise that 50 years ago this now all-pervasive device was only just becoming known outside a small band of scientists and engineers. Hans showed us the bold concepts and diverse group of people who created this marvellous technology. His audience had many questions.

On 16th April Dr Paulo de Souza, the new editor of Australian Physics, gave a lunchtime talk at Launceston College on "The Quest for Life on Mars". The 35 attendees were mainly students, plus a few staff and public. His fascinating material contained animations and real-time photography, collated from the Spirit and Opportunity Mars Rover expeditions. Factual content was excellent: challenging ideas about the existence of water on Mars (long time ago) and speculating about possible life forms. The speaker exhorted the student audience to follow up a career in this field. The level was well chosen for a lunchtime audience and several interesting questions were raised and discussed.

Five days later 80 Hobartians heard Paulo discuss "Roving the Red Planet: Spirit, Opportunity and the Exploration of Mars". Starting from the 'canals' postulated by Schiaparelli in 1887 the talk moved rapidly to present understanding. Excellent photographs and animations gave the audience a good understanding of the difficulties involved in keeping the two Rovers, Spirit and Opportunity, going, now for six years even though the original expectation was for just a few months of observations. Martian dust storms have sufficient energy to keep the Rovers' solar panels clean but all movement has to be tailored to the amount of energy available. Techniques for overcoming jammed wheels and extracting the rovers from awkward locations were clearly presented. Questions at the end showed that the audience greatly appreciated both the presentation and its content.

Awards

The 2011 Bragg Gold Medal for Excellence in Physics

Closing date: 1th July 2010

The purpose of the prize is to recognize the work done by a Ph.D. student in Australia that is considered to be of outstanding quality. The Bragg gold medal for the best Ph.D. thesis by a student from an Australian university was established in 1992 as an initiative of the South Australian Branch, to commemorate Sir Lawrence Bragg (whose picture is inscribed on the medal) and his father Sir William Bragg.

Conditions of the Award

The medal is awarded annually to the student who is judged to have completed the most outstanding Ph.D. thesis under the auspices of an Australian university, whose degree has been approved, but not necessarily conferred, in the thirteen months prior to the closing date for applications to the State Branch (*i.e.*, from the 1st June 2009 to the 1st July 2010). No candidate may be nominated more than once. Only one medal shall be awarded; there is no possibility of a dual award. If the selection committee considers that none of the theses submitted reaches an appropriate standard, no award will be made.

Physics Departments are now invited to nominate candidates for the award of the Bragg Medal.

Nominations

Each Australian university may nominate one candidate. These nominations are submitted to the State Branch committee The committee selects the best thesis from their State (two for NSW and Vic), and three copies of the selected thesis are then forwarded to Dr Olivia Samardzic, AIP Special Project Officer.

Time Line

Nominations from the universities should reach the Secretary of theclosing date. The selected nominations from the State Branches, accompanied by three copies of the thesis, the citation and referees' reports, should reach the Dr Olivia Samardzic by the 1st Sep 2010. The announcement of the winner shall be made by the end of Jan 2011.

Presentation of the Award

The medal will be presented to the chosen candidate at the AIP Congress in even numbered years, and in odd numbered years at a function to be arranged by the AIP Branch of the State of the candidate's university. The medal will not be awarded in absentia; the candidate must be available for the presentation at a time which is mutually convenient. Reasonable expenses in attending the presentation will be met by the Council of the AIP.

Previous Winners

2008 Dr Frank Ruess, University of NSW

2009 Dr Christian Rosberg, Australian National University

2010 Dr Clancy James, Adelaide University

Further Information

Further information about these awards can be obtained by email from the AIP Special Projects Officer at:

olivia.samardzic@dsto.defence.gov.au

or by phone on (08) 8259 5035.

All applications and nominations should be sent by email attachment to the above address or by mail to:

Dr Olivia Samardzic
Special Projects Officer
205 Labs, EWRD
DSTO
P.O. Box 1500
Edinburgh, South Australia 5111.

Awards

The AIP Prize for Excellence in Physics Education
Closing date: 16th July 2010

The purpose of the prize is to emphasize the importance of all aspects of physics education in Australia. The award was proposed as an initiative of the Physics Education Group at the 2000 AIP Congress in Adelaide.

General Conditions

The prize is awarded to any member of the AIP who is judged to have made a significant contribution to physics education in Australia. In determining the recipient of the award, the quality of the work, the significance to physics education, and the creativity displayed will be taken into account.

Presentation of the Award

The prize is presented every second year at the AIP Congress. It will not be awarded *in absentia*. The recipient is expected to present a paper at the Congress on some aspect of their work.

Nominations

State Branches or individuals may nominate any qualified person.

Previous Winners

2005 Prof M. Zadnik, Curtin University of Technology
2008 Dr Judith Pollard, Adelaide University

2010 AIP Harrie Massey Medal
Closing date: 16th July 2010

The purpose of this award is to recognize contributions to physics made either by an Australian physicist or by work carried out in Australia. The Massey Medal was established in 1990 as a continuing gift of the IOP to mark the 25th anniversary of the founding of the AIP as an autonomous body in 1963.

Sir Harrie Massey, Hon. FInstP., FRS was born in 1908 about 50 miles from Melbourne, in what was then bush country. By the age of 21 he had gained a joint honours BSc in physics and chemistry and a BA in maths. A distinguished and wide-ranging career followed at Cambridge, Queen's University Belfast and University College London with Massey's publication (with Edward Bullard) of the first experimental evidence for electron diffraction in gases in 1931, setting the cornerstone for his work on atomic collision theory.

His interest in atomic and molecular processes in the upper atmosphere made him one of the first to see the potential of using direct rocket probes of the atmosphere layers and he devoted boundless energy to initiating rocket exploration. As chair of the British National Committee for Space Research, he guided the entire UK space program and from 1960-64 he was President of the European Preparatory Commission for Space Research. He was knighted in 1960.

Massey was President of the Physical Society 1954-56 and was elected Honorary Fellow of the Institute of Physics in 1976. He died in 1983.

General Conditions

The prize is awarded for contributions to physics or its applications made by an Australian physicist working anywhere in the world, or by a non-Australian resident in, and for work carried out in, Australia.

Presentation of the Award

The award is presented at the biennial Congress by the president of the AIP. The next presentation will be made at the 2010 Congress in Melbourne. The recipient is expected to present a talk at the Congress on their work.

Previous Winners

2005 Prof Peter Drummond, University of Queensland.
2006 Prof Bruce McKellar, University of Melbourne.
2008 Prof David Cockayne, Oxford University.

2010 Award for Outstanding Service to Physics in Australia
Closing date: 16th July 2010

The Australian Institute of Physics has several awards for excellence in some aspect of Physics. They are usually based on the research contributions of the individual or group concerned.

There are many individuals within the AIP who give great amounts of time and effort to the furtherance of Physics as a discipline. While some of these would also be contenders for one or other of the more research oriented awards, others would not. They tend to be quiet achievers, sometimes more devoted to teaching and its development than to research. The AIP inaugurated an award for Outstanding Service to Physics in Australia in 1996.

Eligibility and Procedure

The award will be open to members of the AIP. Nominations may be made by a Branch Committee or by three members of the AIP. There will be no more than three awards nationwide in any one year and the Selection Committee, which will be appointed by the Executive, will reserve the right to make no awards in any one year.

The AIP Award for Outstanding Service to Physics will recognise an exceptional contribution on the part of an individual. Nominations should be accompanied by a clear one or two page citation describing the outstanding service given by the nominee. The results of the decision of the judging panel will be announced in November of each year.

Previous winners

2003 Prof J. Prescott (for many years of service, particularly in employment surveys and physics job advertisements)
2007 Prof Colin Kaye (for his contributions as editor for all versions of the publication of the AIP for many years)
2009 Prof John O'Connor (for the development of the Science and Engineering Challenge and services to the AIP and FASTS)
2009 Prof Hans Bachor (for many years of service, his research achievements and his contribution to teaching)

The Walsh Medal
Closing date: 16th July 2010

The award recognizes significant contributions by a practising physicist to industry in Australia. The Walsh Medal for Service to Industry was inaugurated in 2002 by the AIP. It is named for the late Sir Alan Walsh, who was the originator and developer of Atomic Absorption spectroscopy (AAS) and pioneered its applications as a tool in chemical analysis.

General Conditions

The award consists of a medal and is open for competition among persons resident in Australia for at least 5 of the 7 years preceding the closing date for applications. The award will be given for physics research and/or development that has led to patents, processes or inventions which, in the opinion of the judging panel, have led to significant industrial and/or commercial outcomes, such as devices that are being manufactured or have influenced a major industrial process.

Presentation of the Award

The medal will be presented at the AIP Congress in Melbourne in December 2010, at which the medallist will present a lecture on the subject of the award.

Nominations

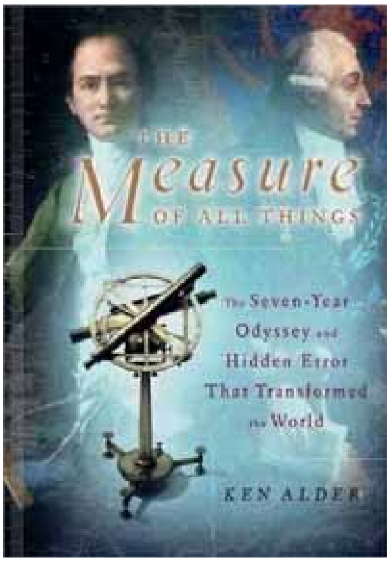
Any member may nominate any qualified person.

Previous Winners

2005 Dr Brian Sowerby and Dr James Tickner, CSIRO
2006 Prof Andrew Blakers and Dr Klaus Weber, ANU
2008 Dr Tony Farmer, Dr Tony Murphy, and Dr Trevor McAllister

Continued on page 54.

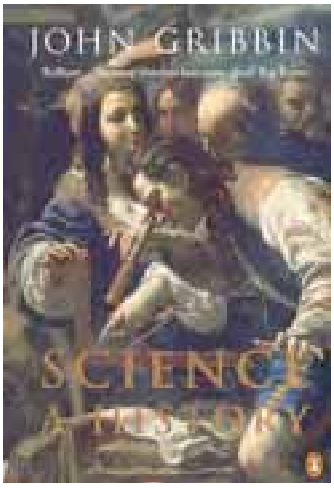
Book Reviews



"The Measure of All Things: The seven-year Odyssey that Transformed the World" by Ken Alder, Little, Brown.
ISBN: 0 316 85989 3

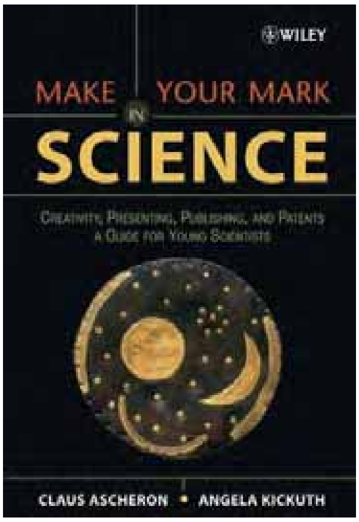
This book presents the revolutionary adventures of two French scientists in the late eighteenth century whose expedition to measure the shape of the world inaugurated the metric system. This is an interesting text that describes their efforts to measure the meridian in order to establish the meter as the standard measure which could be used for everyone at anytime. The author explains why it was so necessary from the economical, social and political points of view to fulfill this mission.

The venture of Jean-Baptiste-Joseph Delambre and Pierre-Francois-Andre Mechain is an exciting history of how they changed the way we look at the world.



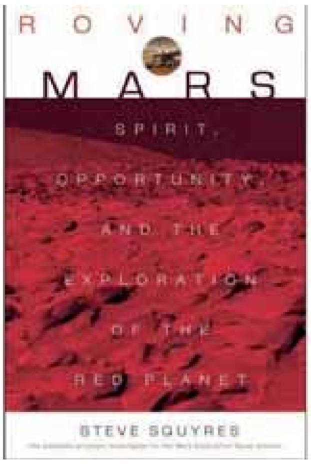
"Science: A History" by John Bribbin, Pengin Books.
ISBN: 978 0 140 29741 6

A remarkable book describing in rich detail the story of scientists who changed the way we see the world. From the perspective that development of technology is more important that human genius, the author demonstrates that the start of the scientific revolution 'coincides' with the development of the microscope and the telescope. Starting from 1643 the text takes us on a journey from the Renaissance men, through our first scientists until modern times where we measure distances of stars, background radiation and our venture into the inknow. Essential reading with future editions to be written by our generation.



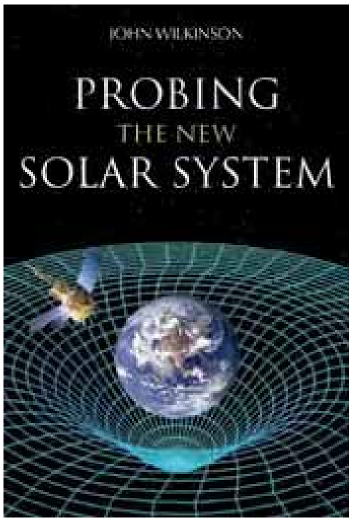
"Make your Mar in Science" by Claus Ascheron and Angela Kickuth, Wiley.
ISBN: 0 471 65733 6

This book gives the young scientist the guidance and support much needed during the early years of his or her career. The text covers daily-life aspects of a scientist: effective communication of scientific results, scientific publishing, patents. It is an essential book for students, young scientists, as well as for experienced scientists who need to improve their communication skills.



"Roving Mars: Spirit, Opportunity and the Exploration of the Red Planet" by Steven W. Squyres by Hyperion Books.
ISBN: 1 4013 0851 1

Written by the Principal Investigator of the Mars Exploration Rover missions, this book shares the challenge of two rovers, Spirit and Opportunity, that were expected to operate for only a few weeks, but are still operating almost seven years later. The book was written a year and a half after landing on Mars. Their development was plagued with problems, and shortly before the launch of *Spirit*, it looked like the missions might be scrubbed; the giant landing airbags had failed in test after test. Spirit has endured a communications breakdown and a troublesome rear wheel, but *Opportunity* quickly found geological evidence for the existence of water millions of years ago. Squyres relates the toll that monitoring the rovers took on his colleagues: longer Martian days resetting scientists and engineers watches and their internal clocks to work, eat and sleep like Martians. Squyres communicates the excitement and the anxieties involved in a project of this magnitude, steering clear of technical jargon, though more casual science buffs might want to fast-forward occasionally in early chapters packed with detail on the ins and outs of NASA's approval process for proposals and institutional politicking.



"Probing the New Solar System" by John Wilkinson, La Trobe University.
ISBN: 9780643095755

Exploration by space probes has revealed many fascinating details about Earth's planetary neighbours. Today we stand on the threshold of the next phase of planetary exploration and knowledge, with several space probe missions currently underway and others being planned. Probing the New Solar System discusses the latest findings that have contributed to a changed understanding of the solar system – and how the revised definition of a planet in 2006 by the International Astronomical Union affected this understanding. Each chapter includes some historical information, interesting facts, and images of objects in the solar system showing newly discovered features of the planets, their moons and of dwarf planets. This is an up-to-date record of the many recent discoveries made about our solar system and other planetary systems using ground-based and space probe technology.

Superconductivity at CSIRO (Sydney) 1969-2009

Four Decates of Australian Research in Superconductivity

by John MacFarlane

Introduction

This brief and highly subjective essay is based on the writer's personal memories of 40 years working in superconductivity at CSIRO Division of Applied Physics (Sydney), which for most of the period, comprised the National Standards or National Measurement Laboratory. To set it in perspective, a few historical milestones in the development of superconductivity are first summarised. Much work and many individual contributions will have been unavoidably overlooked or misrepresented in such an arbitrary and personalized selection of material. All such errors and omissions are entirely the author's responsibility.

Hystorical Milestones

IHeike Kamerlingh-Onnes found to his astonishment in 1911 that a sample of mercury attained a state of zero electrical resistance at the temperature of liquid helium. What had started out as a methodical, if unexciting, endeavour to catalogue the low-temperature electrical properties of various metals, opened a door to a totally new, and anomalous, aspect of Nature. It would be a further 20 years before theory even began to glimpse a possible explanation for this behaviour. The enlightenment

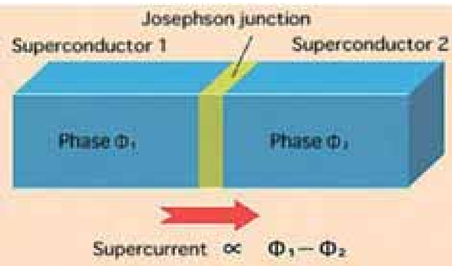


Fig. 1. Idealised sketch of a Josephson junction.

was arguably triggered by the discovery in 1933 by Meissner and Ochsenfeld of an equally surprising effect: perfect diamagnetism, accompanied by the expulsion of magnetic flux from a solid as it makes the transition into a superconducting state. A phenomenological theory based on the two-fluid model, consisting of normal and superconducting electrons co-existing side by side, was introduced by Gorter and Casimir in 1934. Then in 1935, F. and H. London proposed two equations which govern the motion of the superconducting "fluid", while the normal fluid obeys only Maxwell's Equations. This approach led to the notion of the London Penetration length for magnetic fields at the surface of the sample. Not all superconductors however behaved in the same way--in some, it appeared that superconductivity persisted even when magnetic fields penetrated large distances. Type I and Type II superconductors were thus recognised. Abrikosov in 1957 explained

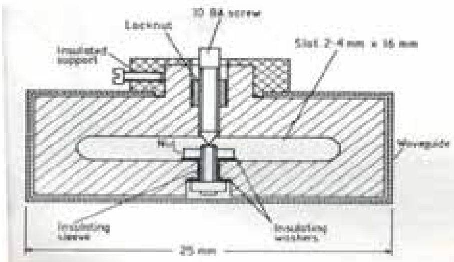


Fig. 2. A prototype Nb point-contact Josephson junction.

the magnetic penetration of Type II materials by conceiving the existence of vortices arranged in a periodic lattice. Each vortex consisted of one flux quantum Φ_0, equal to h/2e. A great leap forward in 1950 by Ginzburg and Landau produced a phenomenological theory which embodied the ideas of a wave function and an order parameter, confirmed the expression for the London penetration length, and introduced a second characteristic dimension called the coherence length. The G-L Theory explained the magnetic behaviour and many other experimental observations on the basis of this "hydro-dynamic" model . Independently, following an entirely different microscopic approach to the problem, H. Frohlich proposed that superconductivity occurs because of an interaction between the electrons and the ions of the crystalline lattice mediated by phonons. He suggested that pairs of electrons were in some way able to attract each other, despite their Coulomb repulsion, to form charged Bosons. Moreover, as electrons "condensed" into the superconducting state, an energy gap opened up, which was later confirmed both by thermal and electrical measurements. Experimental evidence in support of Frohlich's hypothesis was soon established by Bardeen. The microscopic approach, based on a weak electron-phonon interaction as formulated by Bardeen, Cooper and Schrieffer, quickly gained acceptance as a vital part of the mechanism, and the BCS Theory was shown to be consistent with all then- known phenomena of "conventional" superconductors. But more was to come: still more intriguing aspects of superconductivity were, as yet, unknown to the authors of the G-L and BCS theories. The "elephant in the room" was introduced in 1962 by B. D. Josephson, a Ph.D. student at Cambridge. Despite sceptical comments of Bardeen, Josephson proposed that quantum mechanical tunnelling of Cooper pairs could occur across thin insulating barriers, to the accompaniment of phenomena just as remarkable as any yet seen since Onnes' serendipitous observations. A schematic sketch of a Josephson junction is shown in Fig. 1. The Josephson effects and their applications will occupy much of the rest of this review, as they were responsible for this author's entry into and subsequent 40-year journey through the fields of cryogenics and superconducting technology from 1969 to the present. Only the discovery by Bednorz and Muller of high-temperature superconductors in 1986 was to have an even more career-determining impact.

Low-temperature capabilities at CSIRO National Standards Laboratory, Sydney

The CSIRO work in superconductivity that I am about to describe would undoubtedly have been hindered, had there not already been a well-established on-site effort in cryogenics. Its origins can be traced back to a Cabinet decision in 1938 to set up a National Standards Laboratory, and to appoint as Officers in Charge: Norman Esserman (Metrology), George Briggs (Physics), and David Myers (Electrotechnology). These men, together with 5 or 6 later appointees, went to the National Physical Laboratory, Teddington, UK, in 1939 to gain relevant experience.

The War intervened, but after 1946 Briggs was probably instrumental in setting up a cryogenics facility in Sydney, drawing on his experience at

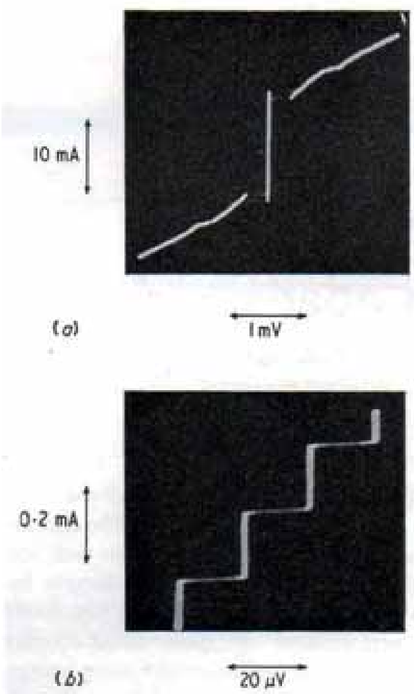


Fig. 3. Graphs of the current-voltage characteristic of a Josephson junction (a) without and (b) with microwave radiation, showing Shapiro constant-voltage steps.

Cambridge where Kapitsa developed an expansion engine helium liquefier in the early 1930s, and subsequently in New York when Sam Collins and Howard MacMahon at MIT co-operated with Arthur D. Little Inc to produce the first commercial "Collins" liquefier.

Back at the National Standards Laboratory (NSL) of the CSIRO, which was situated in the premises now known as the Madsen Building

in Sydney University grounds, Alan Harper and Ron (WRG) Kemp took up the challenge to make a copy of the Collins machine, with the help of working drawings kindly donated by Collins and MacMahon.

Three Sydney graduates, Guy White, Paul Klemens and John Rayne were sent on CSIRO overseas studentships to gain relevant experience at Oxford and Chicago. White returned in 1950, and when Kemp and Bill Smythe succeeded in producing the first liquid helium in the Southern Hemisphere, he initiated a research program concentrating on thermal properties of gold, silver, copper at temperatures between liquid helium and liquid oxygen, ie 2K to 100K. Klemens joined the group in 1953, and began to compare the theory of the electron-lattice interaction developed in the 1930s by Peierls, Bardeen, Makinson et al. with the experimental data. An early superconducting magnet was wound from NbZr wire in 1961.

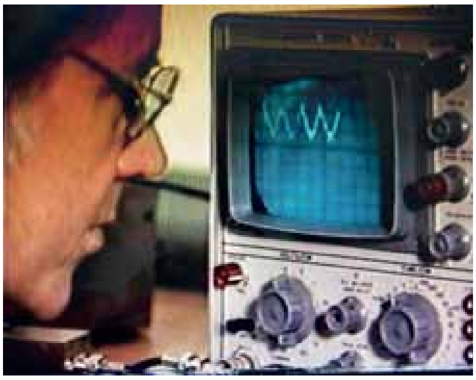


Fig. 4. Ian Harvey observes the triangular voltage vs. flux characteristic of a SQUID pattern.

Superconductivity at the National Standards Laboratory, Sydney.

The cryogenics research initiated by Guy White and colleagues was carried out in what was then the Physics Division of NSL (under the overall direction of R. G. Giovanelli). Electrical metrology (maintenance of the standards of time, frequency, voltage, resistance, etc) was located in the Division of Applied Physics, and was directed, in succession, by F. J. Lehany, J. J. Lowke, W. R. Blevin, and J. G. Collins.

Early in 1967, a paper by a group at University of Pennsylvania appeared in Physical Review Letters:

"Using the ac Josephson effect, we have determined that 2e/h = 483.5912±0.0030 MHz/microvolt. The implications of this measurement for quantum electrodynamics are discussed as well as its effect on our knowledge of the fundamental physical constants." (Parker, Taylor, and Langenberg, PRL, 18, 1967).

It came to the attention of Mel Thompson, who was well advanced at NSL in establishing the calculable capacitor as an absolute method for realizing the Ohm, and Ian Harvey, who was working with Len Hibbard on the construction of a hydrogen maser frequency standard. Harvey grasped the significance of the Parker, Taylor, and Langenberg paper, which showed that Josephson's ac effect could in principle, provide a quantum-mechanical route for the definition of a voltage in terms of the frequency of an electromagnetic oscillation, and

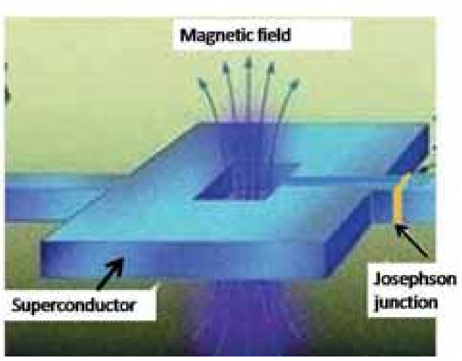


Fig. 5. Idealised diagram of a SQUID.

depended only on the fundamental constants h and e: f=(2e/h)V. Because a frequency could be measured, with reference to an atomic frequency standard such as the hydrogen maser to an accuracy of a few parts in 10^{10}, there was an obvious incentive to embark on this new route for the realization of the volt.

The adoption of cryogenic technology and superconductivity was a major revolution in the electrical standards section of NSL. In retrospect, I have no recollection of any committee meetings, policy decisions or work-time allocations taking place. Ian Harvey and I, neither of us having any previous relevant experience, simply walked upstairs to Guy White's office in the Division of Physics, and explained the breakthrough in fundamental metrology that was foreshadowed by Josephson's theoretical paper and the Pennsylvania work. Within a few days, with help initially from John Birch who gave us a beginner's crash course in practical cryogenics, we had a working cryostat and enough liquid helium to get started. Not many weeks later, following an overseas trip, Ian devised and constructed a simple point-contact Josephson junction from niobium wire, and mounted it inside a helium-cooled X-band waveguide. A prototype point-contact junction is sketched in Fig. 2. With microwave radiation applied from a borrowed Klystron source, the predicted Josephson/Shapiro constant-voltage steps were clearly displayed on the screen of an oscilloscope (Fig. 3). (I later prepared some thin-film PbIn and Sn tunnel junctions, which were shown to agree with the Nb point-contact result within the available precision of 2 in 10^7.)

For the work to be internationally accepted , the reliability of the existing working standard of voltage had to be ascertained. The immediate priority then at NSL, was to deploy the ac Josephson effect in a long- term, week-by-week monitoring of the in-house voltage working standard, which consisted of a group of electrochemical cells that had been carefully maintained at 20.00 °C in a constant-temperature oil bath over several decades. In fact some of the cells were part of the original 1940s bequest from NPL, Teddington. This monitoring routine was carried out by Ian Harvey, Bob Frenkel and myself, with technical assistance from Norm Ancher, Harry Collins and others.

A major effort was required to compare the voltage output of about 1 millivolt from the Josephson junction, at the temperature of liquid helium, with the standard cell voltage of 1.018… volts at room temperature. With traceability of our resistors to the Thompson-Lampard absolute resistance standard, and by means of regular calibrations using a series-parallel "Hamon" resistive ratio divider, the 1:1000 voltage ratio was reliably maintained with a precision of 2 in 10^7. The later invention by Ian Harvey of the superconducting current comparator established a new principle in electrical metrology, based on the Meissner effect and the quantization of magnetic flux, and enabled a ratio of currents to be established to a few parts in 10^{10}. The absolute value of 2e/h was at that time known to an accuracy of only several parts per million, and the challenge was opened for a series of intercomparisons by several independent national laboratories of 2e/h to the highest possible precision. The NSL result was published in 1970 :

"A value for 2e/h has been determined by the ac Josephson effect using niobium point-contact junctions. The value with respect to the international voltage standard as maintained at the Bureau International des Poids et Mesures, Sèvres (VBIP

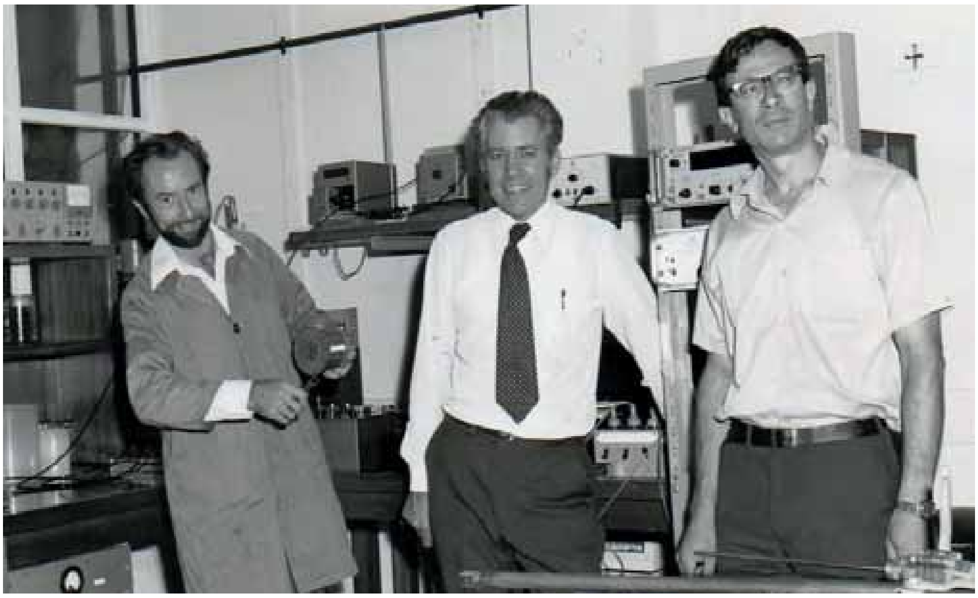


Fig. 6. The Josephson Volt team preparing to move some of the equipment to the new Lindfield laboratories in 1977. (L to R) John Macfarlane, Ian Harvey, Bob Frenkel.

M 69), is 2e/h=483.59384±0.00010 MHz/μV." (Harvey, Macfarlane and Frenkel. Phys. Rev. Lett. **25** (1970) 853.

The Josephson junction and the Superconducting Quantum Interference Device (SQUID)

The basic geometry of a Josephson junction formed between two superconductors is illustrated in Fig. 1. The state of each superconductor is determined by a quantum-mechanical wave-function with a phase parameter, ϕ, which is uniform throughout the superconductor. If the two pieces of superconductor are separated by a very thin barrier (~ 1 nm thick) their wave-functions can interact by quantum-mechanical tunnelling through the barrier. By this interaction, supercurrents can tunnel, without any voltage drop, across the barrier, provided the current does not exceed a value called the critical current. This value can range from a few micro-amps to several milli-amps depending on temperature, and other parameters. When the applied current exceeds the critical value, a voltage difference V appears (Fig. 3) and the quantum mechanical wave-functions in the two superconducting electrodes experience phase slippage, such that an alternating current with frequency f=2eV/h is set up. This equation is the basis of the Josephson volt.

Fig. 7. The author discusses an atomic model of YBCO with Bob Driver ca. 1987.

When a Josephson junction is inserted into a superconducting ring, the structure displays the unique property of Superconducting Quantum Interference. In this configuration, illustrated in Fig. 5, the critical current of the Josephson junction undergoes a periodic modulation as a function of the magnetic flux threading the ring (Fig 4). The period of the field corresponds to a change of one magnetic flux quantum Φ_0 in the ring, where $\Phi_0 = 2 \times 10^{-15}$ Wb. The sensitivity of the SQUID as a magnetometer depends primarily on designing an electronic read-out which can resolve flux changes in the order of $10^{-6}\ \Phi_0$. The original SQUID was designed with a single junction, and was necessarily sensed by a radio-frequency technique. Later devices, when junction fabrication techniques had become more reliable, used two junctions, and were read out by a low-frequency or dc method.

The Move to the National Measurement Laboratory, Lindfield.

Shortly after the successful realization of the Josephson volt, all staff and equipment at NSL (by now re-named the National Measurement Laboratory (NML)), were re-located to a new, purpose built laboratory complex in West Lindfield, some 20 km north of Sydney University.

A major effort over a 6-month period was required to ensure the safe dismantling, transportation, and re-establishment of a vast array of complex, sensitive apparatus in its new destination (Fig 6). In the case of the voltage standard, the crucial components were the standard cells and their constant-temperature bath; the 1000:1 resistive ratio divider; and various irreplaceable galvanometers. All due care was taken to avoid exposing the gear to shocks such as excessive vibration and extreme temperature changes. We were by now confident, however, that in a worst case scenario we could always re-establish the volt in terms of the atomic constants by means of the Josephson technique; a task which would have been impossible just a few years earlier.

After everything had settled down in the new, temperature-controlled, electromagnetically-screened labs in mid-1978 we resumed our weekly calibrations of the standard-cell group against the Josephson voltage. It became clear that, despite all the precautions, something had changed! The slow, uniform drift of about 0.04 microvolts per annum in the mean emf of the group, which had been continuously monitored from the inception of the Josephson experiment in 1969, underwent an abrupt upward shift of about 1 microvolt. A convincing explanation was never found, and after some months, the readings gradually resumed their original long-term trend line. Without the benefit of the Josephson experiment, and its intrinsic traceability to the fundamental constants, this excursion and eventual recovery in the voltage of traditionally-maintained standard cells would not have been reliably detected.

At about the same time, also at NML, the quest for an absolute voltage standard by an entirely different, non-Josephson, route was under way in the work of Keith Clothier, Graeme Sloggett and others. An immensely difficult and multi-disciplinary experiment, it relied on state-of-the-art optical interferometry, measurements of the gravitational acceleration, g, mercury- liquid densitometry, and vibration isolation, as well as high- precision electrical metrology, this work finally in 1983 yielded an absolute value for the volt with a precision of 3 parts in 10^7. Moreover, the new value differed by a relatively enormous 8 parts in 10^6 from the then internationally-agreed figure.

"An absolute liquid electrometer for high-accuracy determination of the volt has been developed and a number of determinations made. Provisional results, still subject to possible small systematic corrections, are encouraging and indicate a substantial error in the BIPM recommended unit of voltage." G. J. Sloggett *et al.*, 1985.

This determination, together with results from Josephson-volt experiments which by now had been set up and internationally verified in a number of standards institutes around the world, made a vital contribution to a revised definition of 2e/h which was internationally agreed in 1990. The endeavours of many CSIRO scientists and technicians, working individually on several quite independent, highly challenging experiments over a period of decades, thus converged within a year or two to produce a world-class contribution to the knowledge of the fundamental physical constants, thereby confirming the place of Australian metrology at that time amongst the top 2 or 3 electrical-standards labs in the world.

Towards Higher Frequencies

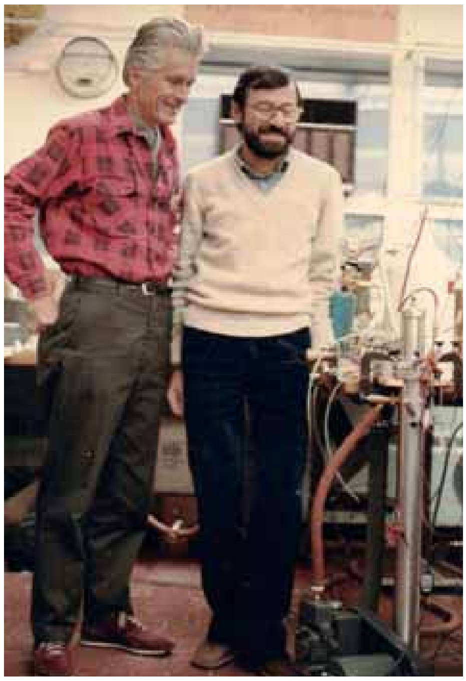


Fig. 8. Jim Zimmermann (L) inventor of the SQUID, and Richard Kautz, at the US National Bureau of Standards.

The Josephson effect experiment not only established a link between dc voltages and high-frequency electromagnetic radiation, it also catalysed a transition in the careers of those involved in its development. The high-frequency, broadband capabilities of Josephson junctions were becoming recognized for demanding applications, including radio astronomy, where low noise, ultra-sensitive

"The Josephson effect experiment not only established a link between dc voltages and high-frequency electromagnetic radiation, it also catalysed a transition in the careers of those involved in its development."

detectors were in demand. A collaborative project, initiated around 1982 with the Division of Radiophysics, Marsfield, enabled a dynamic researcher, Lew Whitbourn, to be recruited from ANU to activate this work. Involving the manufacture and testing of prototype SIS (superconductor-insulator-superconductor) diodes operating at 40 GHz in liquid helium, preliminary results were published in 1986 in the Australian Journal of Physics. Lew then, in collaboration with Brian James and colleagues at Sydney University, went on to greatly extend the scope of the project by designing and building an optically-pumped far-infrared laser, with which we carried out a number of innovative quasi-optical experiments at wavelengths around 400 microns, equivalent to a frequency of 750 GHz.; in Lew's words, we were now covering the electromagnetic spectrum "from dc to daylight".

Fig. 8. Some of the CSIRO Superconductivity group, ca. 1992: clockwise from left: Ian Harvey, Graeme Sloggett, Warren Wright, Lew Whitbourn, Tony Collings, Cathy Foley (Back to camera), Nikki Scheepers (back to camera).

Towards Higher Temperatures

While this lively laser work was in progress, the High-Temperature Superconductivity breakthrough announced in 1986 by Bednorz and Muller in Zurich triggered the next surge of activity at CSIRO/NML. Driven initially by the understandable desire to extend the Josephson work up to liquid nitrogen temperatures, we quickly realized that it would be essential to have in-house access to the new and strange rare-earth oxide materials that were just being reported, particularly by Paul Chu at the University of Houston. As soon as the relevant formula, $YBa_2Cu_3O_{7-x}$ was published in Applied Physics Letters, I took the reprint round to Bob Driver, one of the few "chemists" then working at NML (Fig 7). By chance, Bob had done some of his PhD work on oxides closely related to this compound. He seemed instinctively to know the process, including the critical firing and annealing in an oxygen atmosphere, that would be required. Within a few weeks, we were testing samples of this black ceramic, and when we achieved superconductivity at a temperature of 90 K, a front-page article appeared in the Sydney Morning Herald- such was the public interest at that time.

Rapid progress was achieved in the years 1986-91. Our ready access to the in-house expertise and facilities for reliable electrical and magnetic measurements, together with insightful calculations by Karl-Heinz Muller, contributed to a series of papers which made fundamental advances in understanding the response of the superconductor to magnetic fields. Valuable experimental support by Harold Welch, Steve Collocott, Ron Roberts, Chris Andrikidis, Cathy Foley, Corinna Horrigan and others, added to the effort. Theoretical contributions were also made by John Bell and David Eagles.

Immediately after we learned how to make and measure the HTS materials, the possible applications envisaged for Josephson devices such as SQUIDs multiplied overnight. The first HTS SQUID in Australia was demonstrated at CSIRO by Ian Harvey, and subsequent improvements made over the next 10 years have been summarised by Graeme Sloggett et al and by Cathy Foley et al. Early doubts about the feasibility of unskilled operators using liquid nitrogen and deploying relatively unproven equipment in field situations, were largely overcome by the ingenious adaptation of low-cost, ruggedized Dewar flasks as described by Keith Leslie, Rex Binks *et al.*. Although the original principle of the SQUID as applied to magnetometry was conceived by Silver and Zimmermann in the 1960s (Fig 8), its use had been restricted for many years to the laboratory, due to the necessity of operating the original devices at liquid-helium temperatures. Now the easy availability and relatively low cost of liquid nitrogen caused an explosive growth around the world in superconductivity research.

It was realised in the late 1980s that the then-new HTS materials required a great deal of specialist knowledge and "green-fingers" techniques in order to yield reproducible performance. Towards achieving this requirement, Nick Savvides at CSIRO developed an unbalanced magnetron sputtering process which was used to fabricate high quality a-b aligned c-axis oriented $YBa_2Cu_3O_{7-x}$ thin films. Parallel work was done by Steven Filipczuk on an ion-beam sputtering method. Although the preferred method to form Josephson junctions in HTS materials is to use bicrystal substrates, we opted instead to develop step-edge junctions on single-crystal MgO (001) substrates. These substrates were relatively cheap, and had the advantage that the junctions could be placed at arbitrary positions. Later refinements allowed control of the junction critical current over four orders of magnitude by variation of the step angle.

Collaborations

From 1986 until 1992, our "Superconducting Devices Group" grew in size to well over a dozen. The spirit of enthusiastic co-operation that emerged between people working on theory, materials, measurement standards, cryogenics, XRD and scanning electron microscopy, was truly magnificent. It was a privilege to work with those people (Fig 9) and to be, for a time, their Project Leader. The opportunity of more widespread collaboration emerged during a workshop meeting at Warburton, Victoria, in 1987 where I met Dr John Watson, then the Research Director at BHP Melbourne Laboratories. More or less over dinner, we sketched out a research program which in due course, brought CSIRO, BHP, and AWA together in a successful application for Commonwealth government funding. The outcome of this and successive collaborations, (described in the next paragraph) proved that cryogenic techniques can be successfully deployed in real-world field situations. Other collaborations were set up, for instance, with Metal Manufactures and the University of Wollongong. Meanwhile, in 1992, I moved to the University of Strathclyde and the National Physical Laboratory, UK, but maintained my links both personal and scientific with CSIRO, where I have recently, with Dr Jia Du, resumed work on the radio-frequency and THz properties of HTS Josephson devices.

"While this lively laser work was in progress, the High-Temperature Superconductivity breakthrough announced in 1986 by Bednorz and Muller in Zurich triggered the next surge of activity at CSIRO/NML."

Superconductivity in Geo-exploration

It is impossible to expand here on all the projects that grew from the work on superconducting devices. The titles of some current or recent

Fig. 10. Keith Leslie and Cathy Foley, at the Applied Superconductivity Conference, Boston, USA ca. 2006.

Acknowledgement

Some of the photographs (Figs 4, 6, 7) were taken by staff of the then-existing Divisional Photolab. I am grateful to Dr Guy White for providing background notes on the development of cryogenics at NSL/NML/CSIRO; to Gordon Donaldson and Colin Pegrum, University of Strathclyde; to John Gallop and Ling Hao, NPL Teddington; and indeed to all my colleagues, past and present, for their inspiration and support.

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The Author:

Dr John MacFaelane worked for 40 years with superconductivity at CSIRO Division of Applied Physics in Sydney, which for most of the period, comprised the National Standards or National Measurement Laboratory.

Awards

2010 Walter Boas Medal
Closing date: 16th July 2010

The aims of the award are to promote excellence in research in Physics in Australia and to perpetuate the name of Walter Boas. The Medal was established in 1984 to promote excellence in research in Physics and to perpetuate the name of Walter Boas (University of Melbourne 1938-47, CSIRO 1947-69). The award is for physics research carried out in the five years prior to the date of the award, as demonstrated by both published papers and unpublished papers prepared for publication, a list of which should accompany the nomination. Any AIP member may make nominations or may self nominate for the award.

Eligibility and Procedure

Nominees should be members of the AIP and Australian citizens and should have been residents of Australia for at least five of the seven years preceding the closing date for nominations. The Medal shall not be awarded more than once to any person. The award shall be given for original research making, in the opinion of the examiners, the most important contribution to physics. This will be judged in papers published during the four years immediately preceding the date on which entries for the award close, supported where appropriate by unpublished papers or reports on work carried out during that period. If a candidate considers that knowledge of work carried out prior to the four year period is necessary for the correct evaluation of the record of work submitted for the award, reference may be made to the work where published, or an unpublished account of such previous work may be submitted.

Supporting Information

Candidates for the award should provide::

- A brief curriculum vitae covering personal details, academic and professional qualifications, outline professional career history, and honours and distinguished awards. A full CV is not necessary.
- A short account of the research achievements of the candidate (or candidates if there is a joint submission) setting out the achievements on which the application rests and drawing attention to those articles that are important.
- A list of relevant publications, patents and reports by descriptive title and reference related to the achievements on which the application is based. Where heavy reliance is placed upon material not reasonably available, a copy of this material may also be submitted.

Candidates are invited to provide the names of up to three internationally known referees who have the appropriate expertise to offer a critical appraisal of the candidate's achievements.

Presentation of the Award

The award is conditional on the recipient delivering a seminar on the subject of the award at a meeting of the Victorian Branch of the AIP in November. The recipient is also expected to provide a manuscript based on the seminar for publication in Australian Physics.

Previous winners

2005 Prof Yuri Kivshar, ANU
2006 Prof Michael Tobar, University of WA
2007 Prof Derek Leinweber, University of Adelaide,
2008 Prof Peter Drummond, University of Queensland
2009 Prof Victor Flambaum, University of NSW

Samplings

Locks and keys build tiny structures

http://physicsworld.com/cws/article/news/42091

Researchers in the US have invented a "lock and key" technique that causes small particles to assemble themselves into a variety of tiny structures. The method could offer a simple way to create technologically useful materials on the micrometre and nanometre length scales.

Many functional materials can be created by directing the assembly of colloidal particles into a predetermined structure. Control over particle assembly usually involves tagging them with molecules such as DNA that can recognize and bind each other. Now, Stefano Sacanna and colleagues at New York University show that shape complementarity — the construction of colloids using a lock-and-key recognition mechanism — offers a simple and effective alternative control mechanism (http://www.nature.com/nature/journal/v464/n7288/full/nature08906.html). The keys are colloidal spheres, and monodisperse colloidal particles with a spherical cavity are the locks. The two will spontaneously and reversibly bind via the depletion interaction if their sizes match. This procedure yields complex colloidal structures held together by flexible bonds, and offers a simple yet general means to program and direct colloidal self-assembly.

Sacanna and colleagues now plan to make "smart" particles and push their self-assembly to the limit where well-defined structured clusters of particles can self-replicate. See also this Nature commentary:
http://www.nature.com/nature/journal/v464/n7288/full/464496a.html.

New twist to electron beam

http://physicsworld.com/cws/article/news/42232

Physicists in Japan have for the first time generated beams of electrons displaying the fundamental physical property of orbital angular momentum. Like light beams before, these electron beams have had their wavefronts distorted so that they spiral through space and create a "phase singularity" at the centre of the beam, a type of vortex where the intensity of the wave is zero and its phase is undefined.

In addition to the angular momentum carried by a photon's spin (represented by its polarization), light beams can also be engineered to carry orbital angular momentum. Such beams find a variety of uses, for example, as optical 'spanners' — essentially a 'twisted' variant of the more familiar optical tweezers. Now Masaya Uchida and Akira Tonomura of the RIKEN Institute, writing in Nature (http://www.nature.com/nature/journal/v464/n7289/full/nature08904.html), show that it is possible in principle to engineer similar behaviour into an electron beam, which could find use in a variety of spectroscopy and microscopy techniques.

Tiny water desalination device help aid efforts

http://physicsworld.com/cws/article/news/42231

Each year, two million people – mostly children – die from water-borne diseases, such as diarrhoea and cholera, according to the United Nations. The particularly vulnerable include those people trapped in disaster-stricken areas, such as victims of the recent earthquake in Haiti, who struggled to get clean water after damage to water resources. However, a technique that produces drinking water from seawater, using just small amounts of energy, could lead to a portable technology that could help to address this dire situation.

The technique, developed by researchers in the US and Korea, manages to desalinate water using a simple electronic system on a tiny chip (see article in Nature Nanotechnology http://www.nature.com/nnano/journal/vaop/ncurrent/full/nnano.2010.34.html). The process starts by passing water along a tiny channel on a polymer chip – with a width of just 500 µm – until it reaches a junction, which then splits off into two separate tubes. By applying an electric potential along one of these tubes, salt ions are dragged towards this channel in the form of brine, while desalinated water flows down the second channel under the force of gravity.

To demonstrate the technique, the researchers created one chip that successfully converted seawater, with a salinity of 30,000 mg/L, into fresh water with a salinity of less than 600 mg/L, which meets the international standards for water purity.

The technique, dubbed ion concentration polarization (ICP), compares favourably with established methods of water desalination in terms of energy consumption, requiring less than 3.5 Wh/L. Reverse osmosis, for example, which works by forcing seawater through a membrane at high pressures to capture the salt, requires 10–15 Wh/L. And electrodialysis, which works by transporting salt ions from one solution to another by means of ion-exchange membranes, requires 5 Wh/L.

In addition to removing salts, ICP can also remove potentially harmful larger molecules such as cells, viruses and bacteria. Unlike reverse osmosis and electrodialysis it does not utilise membranes that can become heavily clogged by these particles.

Elemental mapping atom-by-atom

http://www.nature.com/nature/journal/v464/n7288/full/nature08879.html

An imaging technique able to resolve and identify all individual atoms in non-periodic solids would be a very useful tool for materials analysis. Annular dark-field (ADF) imaging in an aberration-corrected scanning transmission electron microscope optimized for low voltage operation allows such an analysis, as shown by Ondrej Krivanek and co-workers. The technique was used to examine a monolayer of boron nitride, in which it revealed individual atomic substitutions involving carbon and oxygen impurity atoms. Careful analysis of the data enables the construction of a detailed map of the atomic structure, with all the atoms of the four species resolved and identified.

Why twist to electron beam

A main impediment to the development and commercialization of micro- and nano-electromechanical systems has been the difficulty in effectively lubricating the small-scale moving parts. Greasing the sliding interfaces in the usual way, with liquids, fails because they are readily squeezed out of the contact region. The resulting friction and wear have catastrophic consequences for the functionality of the device. To keep the lubricant within the contact region, molecules can be functionalized so that they self-assemble into a protective and strongly adhering coating on the surface. But problems still remain, primarily insufficient antiwear performance and the difficulty of scaling up the coating process to the size of a wafer. An alternative strategy based on solid lubricants such as graphite or layered MoS2 is already being used for macroscopic systems, but thickness becomes a variable in ways that would not be seen with liquid lubricants. Now, Lee *et al.* (http://www.sciencemag.org/cgi/content/full/328/5974/76) unravel a systematic trend of friction with the thickness of the solid lubricant that, surprisingly, is a general effect independent of the material.

Looking beyond silicon

http://www.sciencemag.org/cgi/content/full/327/5973/1595

Silicon-based electronics have been the mainstay of the industry for several decades, a veritable powerhouse of the economy, driving technological breakthroughs that affect virtually all aspects of everyday life. Devices have become smaller, faster, more efficient, more powerful, and cheaper. However, the size of transistors—the building blocks of electronics—is approaching the limits of what can be done on a large-scale industrial basis. Has the time come when a replacement for silicon can no longer be avoided? If we look beyond raw processing power, might there be a future for silicon if it is given new capabilities? There are a number of articles in this Special Issue of Science that consider materials for electronics.

Product News

Lastek

High speed nanopositioning for 3D particle tracking from Mad City Labs

The Nano-LPQ is an ultra-low profile, high speed, three axis nanopositioning system with 75 µm of travel in XY and 50 µm in Z. Designed to minimize the moving mass, lightweight sample holders are integrated into the stage and represent the only moving component.

This unusual design allows the three axes of motion to have matched resonant frequencies and step response times. Equal 3-axis speed is particularly useful for applications like 3D particle tracking. The Nano-LPQ uses internal position sensors utilizing proprietary PicoQ™ technology to provide absolute, repeatable position measurement with sub-nanometer resolution under closed loop control.

Features:
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The most compact, fully integrated THz Time Domain Spectrometer, weighing in at less than 5 lbs with true turn-key operation. Produces and measures pulsed terahertz waves from 0.1 to 4.0 THz using time domain spectroscopy techniques in both transmission and reflection geometries with a waveform measurement of up to 20 Hz.

Flexible enough for laboratory use and prototyping THz applications, but also designed to be integrated into larger systems requiring THz capabilities.

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XR-Series Miniature Fiber Optics Spectrometers from Ocean Optics

The XR-Series of Extended Range Spectrometers from Ocean Optics are responsive across a wide spectral range, providing an optical resolution of ~2.0 nm (FWHM) and the convenience of a single, monolithic spectrometer to cover all wavelengths from ~200-1050 nm.

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Hiden

Transient Mass Spectrometer provides for Fast Event Gas Analysis Studies

Hiden Analytical introduce their Transient MS system specifically designed for the analysis of fast transient gas events at pressures near atmosphere.

The compact benchtop system is founded on the Hiden HPR-20 QIC series gas analysers and features a purpose-designed fast response capillary inlet and the HAL/3F

PIC mass spectrometer with pulse ion counting detector. The combination enables inlet system response times of less the 150 msec with measurement speeds of up to 500 data points per second over an entire 7 decade dynamic range. The system monitors species with molecular weights to 300 amu, with higher mass ranges available for specialist applications.

The MASsoft control and data acquisition program provides ease of operation with integral calibration routines together with user-programmable template files for automatic operation of routine analyses. Multiple I/O's permit integration of external parameters such as temperature or flow rates, and control of external equipment with species-specific pressure level sensors. Application areas include pulsed gas experiments for catalyst characterisation, surface reaction and reduction studies, respiratory analysis and, with high-speed rotating multiport valve, spacial gas distribution measurement as demonstrated in the award-winning (R&D 100 Awards) Hiden Spaci-MS system.

For information on this or other Hiden products contact:
Hiden Analytical
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SciTech

iXonEM Blue EMCCD Camera

iXonEM Blue EMCCD camera is the latest addition to Andor's award-winning performance EMCCD range, offering > 20% extra response in the blue. It represents the new benchmark for ultrasensitive imaging of blue photons. Compared to the 'standard' back-illuminated EMCCD, iXonEM Blue offers enhanced QE between 300nm to 470nm.

Until now, back-illuminated EMCCD cameras have been available only with a 'mid-band' anti-reflection coating, resulting in a Quantum Efficiency curve optimized for the green/red wavelength range. However, some applications specifically require superior sensitivity performance in a region below 450nm for which iXonEM Blue is specifically optimized.

Whether probing ultracool calcium ions or imaging blue emitting fluorophores under reduced phototoxicity, iXonEM Blue provides a valuable sensitivity boost. This blue-enhanced single photon sensitive camera will be put to good use across a number of specific applications, including ultra-cold ion imaging, luminescence detection and calcium signalling.

High Speed Camera System

SciTech is proud to announce the new pco.dimax, 4-megapixel digital high speed CMOS camera system with a 12-bit dynamic range. It provides 2012 x 2012- pixel resolution at a rate of 1100 fps with lower resolutions at rates as fast as 56,300 fps. The 31.4-mm-diagonal CMOS image sensor features 11 micron pixels and a quantum efficiency greater than 44%. The camera is available in colour and monochrome.

The system features a variety of trigger options to cover all offboard applications that have been required by

High Speed Camera System

the automotive industry. The image data are transferred via GigE Vision or USB2.0 interfaces and there is a 32GB imaging memory.

For preview purposes a DVI interface is integrated. The pco.dimax has a smart battery control, which allows a full operation for 1 h and a data backup for 6 h. This digital CMOS camera system is perfectly suited for high speed camera applications such as material testing, offboard crash or impact tests or super slow motion movie clips.

12 bit ultra speed intensified imaging

Having a single optical input, this ultra speed camera system comprises an image splitter unit, four intensified CCD camera modules with fast switchable MCP image intensifiers and high resolution CCD image sensors. Each module with its 12 bit dynamic range and a high resolution CCD image sensor (SVGA) features an excellent signal-to-noise-ratio and the ability of single photon detection.

Four high speed serial fiber optic data links connect the system to the PC. It can be triggered externally by light or electrical input. This ultra high speed camera system is perfectly suited for the imaging of extremely fast events, like hypervelocity impacts, short time physics, ballistics or combustion imaging.

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Coherent

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With the new Legend Elite CEP, Coherent Inc expands its family of Carrier-Envelope Phase stabilised ultrafast lasers.

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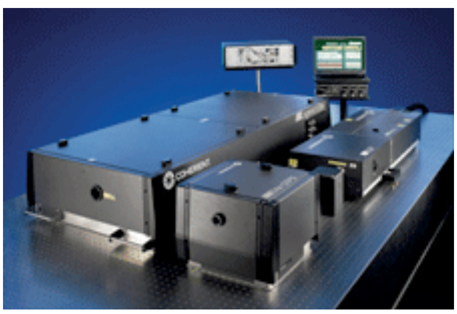

Legend Elite platform, this new ultrafast regenerative amplifier includes an active feedback control to lock the phase velocity of the oscillating light field to the group velocity of the phase envelope. Thus, for ultra short pulses consisting of only a few optical cycles, the peak of the oscillating electrical field can be maximised under the phase envelope.

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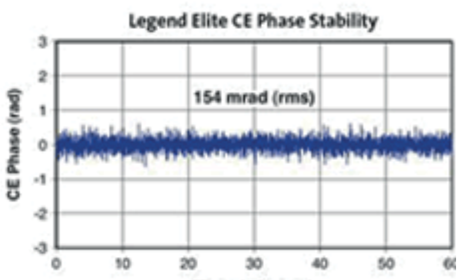
The Legend Elite CEP is currently available with an average power of up to 4W, pulse energy up to 4mJ and pulse duration of less than 35fs. Additional configurations are under testing and will be released in the near future.



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EMCCD camera now available with custom kinetics option

Kinetics mode is included as standard on all later model CCD and ICCD cameras from Princeton Instruments. Kinetics mode allows the vertical shifting of the camera to be directly controlled so that multiple images may be rapidly acquired and "stacked" on the CCD prior to readout.

The ProEM camera from Princeton Instruments is now available with a special masking option to further increase the camera's flexibility when operating in kinetics mode.

The new option includes an adjustable slit mask that allows the height of the kinetics sub-image to be varied in accordance with the experimental conditions. A further fixed mask is applied directly to the CCD, leaving the last two rows exposed for ultra high-speed kinetics acquisition.

For more information on the ProEM camera and on the new kinetics option please contact Paul Wardill (paul.wardill@coherent.com.au)

Warsash

Lightweight Benchtop Vibration Isolation

Warsash Scientific is pleased to announce a new lightweight benchtop vibration isolation system from Kinetic Systems, Inc. Specifically designed for portability, the ELpF can be easily repositioned on the benchtop, even with a load and in float. Its unique, self-contained design provides this without causing damage to the vibration isolators.

An economical alternative to heavyweight models, the Ergonomic Low-Profile-Format platform provides vibration isolation for sensitive devices. It features a load capacity of 100 or 300 lbs. in a lightweight, ergonomic system.

The platform has a low profile (only 3" high), uses a small tabletop (16" x 19" standard), and weighs 40 lbs., making it very portable. Ergonomic features include gauges tilted upward for easier viewing and recessed handles for easy carrying.

Designed for use in laboratories and Class 100 cleanrooms, the ELpF platform is ideal for supporting atomic force microscopes, microhardness testers, analytical balances, profilometers, and audio equipment.

Self-leveling and active-air isolation give the platform low natural frequencies (1.75 Hz vertical, 2.0 Hz horizontal) and typical isolation efficiencies of 95% (vertical) and 92% (horizontal) at 10 Hz.

Other tabletop sizes can be customized per specifications. The top, which can be ordered with or without mounting holes, can be aluminum plate, ferromagnetic stainless steel, plastic laminate, or anti-static laminate.

For more details on this or other vibration isolation equipment, contact sales@warsash.com.au

Real-Time Operating System for Systems Integration

PI (Physik Instrumente), the leading manufacturer of piezoceramic drives and positioning systems, offers a real-time module as an upgrade option for the host PC and also the connection of the GCS (PI General Command Set) software drivers. The module is based on Knoppix-Linux in conjunction with a pre-configured Linux real-time extension (RTAI).

The use of real-time operating systems on the host PC allows it to communicate with other system components, e.g. a vision system, without time delays with discrete temporal behavior and high system clock rate.
A library which is 100% compatible with all other PI GCS libraries is used for the communication with the real-time system. All PI GCS host software available for Linux can be run on this system.

Real-Time Operating System for Systems Integration by Physik Instrumente

The real-time system running in the real-time kernel can be used to integrate PI interfaces and additional data acquisition boards for control. Open functions to enable you to implement your own control algorithms are provided. Data, such as positions and voltages, is recorded in real time, and pre-defined tables, with positions, for example, are output in real time to the PI interface and to additional data acquisition boards.

You can program your own real-time functions in C/C++, MATLAB/SIMULINK and SCILAB.

The system includes a PI GCS server, which allows the system to be operated as a blackbox using TCP/IP, via a Windows computer, for example.
Product News continued over page...

The system can be installed on a PC or booted directly as a live version from the data carrier. A free demo version with restricted functionality is available.

For more information on the real time operating software or other PI positioning equipment, contact sales@warsash.com.au

E-618: 3.2 kW Peak Power for New Piezo Amplifier
Available from Warsash Scientific is the new PI

(Physik Instrumente) E-618 high power amplifier for ultra-high dynamics operation of PICMA® piezo actuators.

The amplifier can output and sink a peak current of 20A in the voltage range between -30 and +130V. The high bandwidth of over 15kHz makes it possible to exploit the dynamics of the PICMA® actuators. This type of performance is required in active vibration cancellation and fast valve actuation applications.
The E-618 also comes with a temperature sensor input to shut down the amplifier if the maximum allowed temperature of the piezo ceramics has been exceeded. This is a valuable safety feature given the extremely high power output.

The E-618 is available in several open-loop and closed-loop versions with analogue and digital interfaces.

For more information on these and the range of other PI products, contact sales@warsash.com.au

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New Sensors Improve Precision of S-340 Tip/Tilt Mirror
Warsash Scientific is pleased to announce the release of the new S-340 piezo tip/tilt mirror platform from PI (Physik Instrumente), equipped with new high-resolution strain gauge sensors.

The S-340 now achieves a resolution of 20nrad at angles of 2mrad about both orthogonal axes.

This large mirror platform is used for optics with diameters of up to 100 mm (4 inches) and achieves a resonant frequency of 900Hz for a mirror of 50 mm diameter.

The S-340 can be operated by the new, low-cost E-616 controller. Together, they form a compact, high-performance solution for beam control and image stabilization as employed in astronomy, laser machining or optical metrology, for example.

For more information on the S-340 Tip/Tilt Mirror platform or other Positioning equipment from PI, contact sales@warsash.com.au

New Sensors Improve Precision of S-340 Tip/Tilt Mirror

Conferences

July 4 - 10
18th International Conference on Composites or Nano Engineering
Anchorage, Alaska, USA
http://www.uno.edu/~engr/composite

July 5 - July 8
Astronomical Society of Australia Annual Science Meeting
Hobart, Tasmania
http://www-ra.phys.utas.edu.au/ASA2010

July 11 - 16
9th International Conference on Excitonic and Photonic Processes in Condensed and Nano Materials (EXCON'10)
Brisbane, Queensland
http://www.cdu.edu.au/excon10/

July 12 - 16
The 7th Vigier Symposium: The Search for Fundamental Theory
London, UK
http://www.mindspring.com/~quantum.computing/ index7.html

July 19 - 23
10th International Conference on Quantum Communication, Measurement and Computing
Brisbane, Queensland
http://qcmc2010.org

July 19 - 23
STATPHYS 24: The XXIV International Conference on Statistical Physics of IUPAP
Cairns, Queensland
http://www.statphys.org.au/

July 25 - 30
22nd Int. Conference on Atomic Physics CAP2010
Cairns, Queensland
http://www.swin.edu.au/icap2010/

July 28 - 31
3rd Conference on Nonlinear Science and Complexity
Ankara, Turkey
http://nsc10.cankaya.edu.tr/

August 2 - 10
Quo Vadis Bose-Einstein-Condensation?
Dresden, Germany
http://www.mpipks-dresden.mpg.de/pages/veranstaltungen/frames_veranst_en.html

August 23 - 27
20th International Congress on Acoustics (ICA 2010)
Sydney, New South Wales
http://www.ica2010sydney.org/

August 30 - September 3
9th Quark Confinement and Hadron Spectrum
Madrid, Spain
http://teorica.fis.ucm.es/Confinement9

September 13 - 18
4th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics
Karlsruhe, Germany
http://congress2010.metamorphose-vi.org/

November 10 - 12
International Conference on Earth and Space Sciences and Engineering (ICESSE 2010)
Sydney, New South Wales
http://www.waset.org/conferences/2010/sydney/icesse/index.php

November 14 - 18
55th Conference on Magnetism and Magnetic Materials
Atlanta, USA
http://www.magnetism.org

December 6 - 10
2010 AIP Congress
Melbourne, Victoria
http://www.aip2010.org.au/

December 13 - 16
International Conference on Nano materials and Nanotechnology (NANO 2010)
Nammakkal, India
http://ksrct.ac.in

December 16 - 17
3rd International Conference on Science & Technology : Applications in Industry and Education (ICSTIE 2010)
Penang, Malaysia
http://www.icstie.com

April 4 - 8, 2011
Greenhouse 2011
Cairns Convention Centre, Queensland
http://www.greenhouse2011.com

June 28 - July, 2011
IUGG Earth on the Edge: Science for a Sustainable Planet
Melbourne, Victoria
http://www.iugg2011.com