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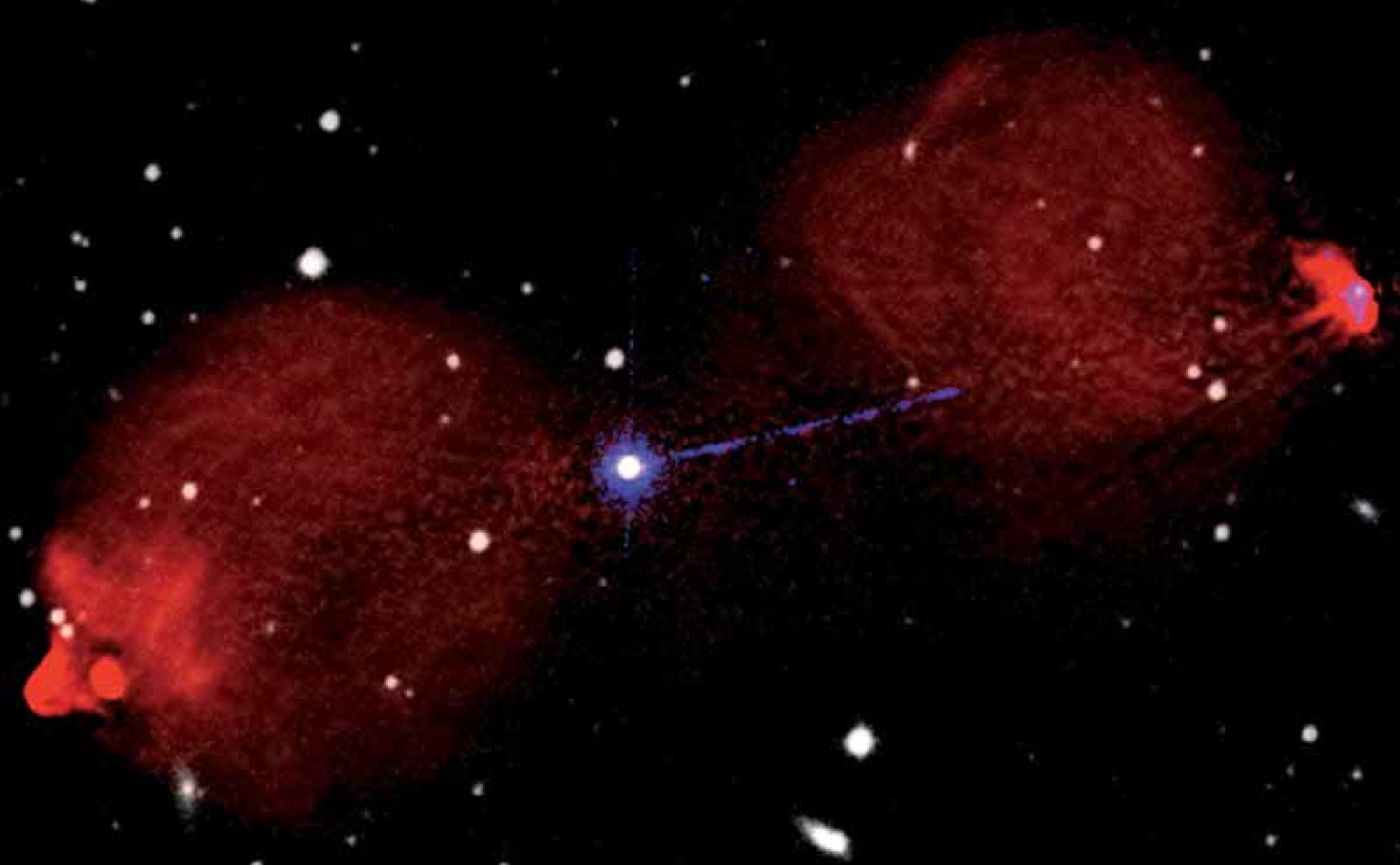

Harrie Massey Medal for 2010 awarded to Hans Bachor

Alan Walsh Medal for 2010 – Commercialising Laboratory Lasers

Walter Boas Medal for 2010 – Plasma Nanoscience

Bonsai Black Hole in Our Backyard

A Publication of the Australian Institute of Physics

Promoting the role of physics in research, education, industry and the community.

Submission Guidelines

Articles for submission to *Australian Physics* should be sent in electronicaly. Word or rich text format are preferred. Images should not be embedded in the document, but should be sent as high resolution attachments in eps, tiff or jpg format. Authors should also send a short bio and a recent photo. The Editor reserves the right to edit articles based on space requirements and editorial content. Contributions should be sent to the Editor.

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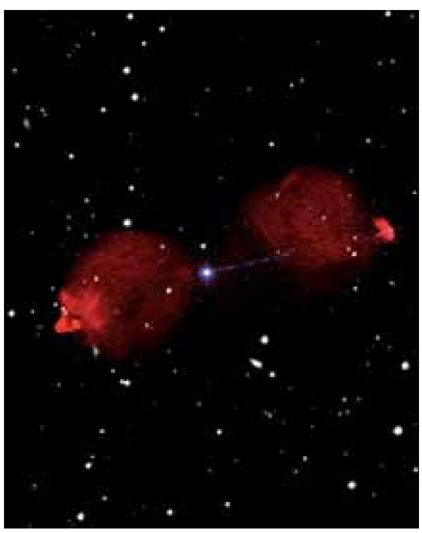

Cover

A composite multi-band image of Pictor A, a close and powerful Fanaroff–Riley class II radio source. The host appears as a non-descript point at the centre of the background optical image (European Southern Observatory DSS-2 R-band image in grey). An X-ray jet is seen emanating from the centre of the galaxy extending across 360,000 light-years toward a brilliant hotspot (Chandra X-ray image in blue). Two nearly circular lobes, normally reminiscent of a 'dying' radio source, are seen at radio wavelengths (6 cm Australia Telescope Compact Array image in red), but the presence of hot spots seen at the lobe extremities suggests that the jet may have been recently re-activated. A similar object known as Fornax A is featured in Robert Soria's article on p. 111. [Courtesy: Emil Lenc, Australia Telescope National Facility, Sydney]

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Editorial

Challenges Ahead

It is an honour to be asked to be the next editor of *Australian Physics*, a magazine I've been reading for over thirty years. Some of you may remember me as the editor of the *Australian Journal of Physics*, formerly published by CSIRO and the Australian Academy of Science. During my time as editor (1980 to 2001), I looked on *Australian Physics* as the 'sister' to *Aust. J. Phys.* and there was always a close relationship between the two publications.

Publishing a magazine though is quite different to a research journal and so I'll be on a steep learning curve over the next few months. As you know, the magazine is running over six months late and so the major challenge will be to get the publication schedule back on track. This can only happen if we have a stream of quality material coming our way. So I strongly encourage you to think about preparing a feature article on your research or any other area of physics that interests you. If you have an idea for an article, contact me and we can discuss how to develop the idea.

At the highly successful Congress in Melbourne last December the AIP awarded a number of prizes and medals. In this issue we bring you two articles based on these presentations: the award of the Sir Alan Walsh Medal to Robert Scholten (University of Melbourne) for his commercialisation of a laboratory laser and the award of the Walter Boas Medal to Kostya (Ken) Ostrikov (CSIRO) for his work on plasma nanoscience.

We also have a profile on Hans Bachor (Australian National University) who was awarded the Harrie Massey Medal by the AIP and the UK IOP for his research in quantum optics. An article by Hans describing the development of quantum optics in Australia will appear in our next issue. Similarly, we plan to publish an article by Joe Wolfe (University of NSW) who was awarded the AIP Education Medal during the Congress.

Lastly, I can mention that we have formed a very talented editorial team and over the next few issues I will be introducing them to you. The team will be working hard this year to help get *Australian Physics* back on schedule.

Peter Robertson

Letter

Dear Editor,
The wide publicity given to possible nuclear radiation levels arising from the recent reactor disaster in Japan has prompted me to revise my knowledge of the units currently in use. I grew up with, and became familiar with, the rad and the rem, but have not caught up with the Gray and the Sievert. So the publicised estimates in microsieverts or millisieverts left me in the dark. I suggest an authoritative discussion by an expert in the field around the units of exposed dose (Grays) and absorbed dose (Sieverts), relative to the current recommended maximum levels, might form a suitable subject for a future article in *Australian Physics*.

Sincerely,
John Macfarlane

President's column

Scientific Volunteerism

While thinking about what I should write for my first President's column I became very aware of the honour of being elected, and slightly daunted by the role I have taken on. I see the Presidency as a welcome challenge to try and have an impact. There is much that is great about our Institute, but there are also many improvements that can be made, and I intend to work with the rest of the executive to put some of the necessary improvements into place.

You will see we now have a new editor, and a plan to catch up on the publication of the magazine so that the cover date and the publication date are once again aligned. This relies on you as members to provide articles that highlight the range and excellence of physics carried out across Australia and to tell your fellow physicists about it. We will only catch up if we have a steady supply of articles so please let's hear about your exciting work.

This actually forms a nice introduction to the main theme of my first President's column which is the role and importance of volunteerism to science and its societies. Cathy Foley, in a previous President's column some years ago, discussed volunteering from the perspective of it forming one of the underlying structures that support the scientific method. The role of peer review – be it for journal articles, project or funding proposals, fellowships and promotions – is part of the scientific process and its success. Without voluntary refereeing the whole system would simply fail. As such, it is important that we all play our part in the process and equally that as supervisors or managers of staff we also recognise this contribution in performance assessment and promotion considerations.

However, there is another aspect to scientific volunteerism that I also see as of high importance and that appears to be under even greater stress than the peer review system – the role of representation on scientific societies. It is becoming more and more difficult to fill branch, group and national positions in the Institute, and it is not entirely clear why this situation has developed.

In the past such representation was a valuable addition to one's CV, and I would hope that this is still the case. Because one of the most valuable ways for any person to advance their career is through the professional networks they develop. These are gateways to opportunity, because with networking comes information. Information about new developments, jobs, committees that will influence the direction your chosen field takes that could eventually benefit you through enhancement of your field.

The people you get to know through volunteer committees in societies are one of the richest sources of networking you will find. They are invariably from a far wider range of areas than your direct experience, they will include the movers and shakers of tomorrow and they will expose you to ways of thinking and political awareness that will always serve you well. There are few better enhancements to your professional skill set than your networks.

I have heard it said that some supervisors, managers or department heads have opposed junior staff 'wasting their valuable time' on society committees when they should be concentrating on their teaching or research. I disagree with that view entirely. I think that such service, in appropriate amounts relative to the stage of their career, is invaluable and I ask all leaders to promote rather than discourage involvement for the reasons I have mentioned above and to recognise these contributions positively when assessing staff.

Finally, I still believe that all of us who have made a career out of our chosen scientific field have a responsibility to put something back into a system that has looked after us. This is particularly true for mid and late career people who should be able to find some time for just such activities.

I would welcome comment, criticism and discussion on this column and hope that members will send a 'Letter to the Editor' for inclusion in the next issue. Feel free to send in letters on other topics as well because it is good to have open discourse through these pages.

Marc Duldig

Professor Tanya Monro (University of Adelaide) is South Australian of the Year for 2011.

Tanya Monro named South Australian of the Year for 2011

Physicist Tanya Monro has been named South Australia's 'Australian of the Year' for 2011. Tanya, who is the Director of the Institute for Photonics and Advanced Sensing (IPAS) within the School of Chemistry & Physics at the University of Adelaide, was presented with her award by the Governor of South Australia, Kevin Scarce, at a ceremony last November.

Tanya became the inaugural professor in photonics at the University of Adelaide in 2005. Her PhD research focused on developing new classes of optical fibres, for which she received the Bragg Gold Medal for the best physics PhD in Australia. From 1998 to 2004 Tanya worked at the University of Southampton in the UK.

In 2006 Tanya was named as one of the top 10 brightest young minds in Australia by science magazine *Cosmos*. In 2008 she was awarded the Prime Minister's Prize for Physical Scientist of the Year. She is currently an ARC Federation Fellow.

Tanya has been recognised for her work in the field of photonics – technology that

allows the generation and control of light using glass optical fibres. This enables the creation of new tools for scientific research and solutions for problems in areas such as information processing, surgery, health monitoring, military technology, agriculture and environmental monitoring. She has published over 300 papers in journals and refereed conference proceedings.

The vision of the Institute for Photonics and Advanced Sensing is to bring together researchers in physics, chemistry and biology to pursue a trans-disciplinary approach to science for applications in defence, preventative health, environmental monitoring and food and wine. In late 2008, IPAS was awarded $29 million from the federal government's HEEF (EIF) scheme towards the construction of a new building for IPAS on the North Terrace campus of the University of Adelaide. This project is also receiving support from the South Australian state government and the Defence Science & Technology Organisation.

As winner of the SA 'Australian of the Year' award, Tanya joined recipients from other States and Territories as a finalist in the national awards which were announced in Canberra on Australia Day on 26 January 2011.

Minister Kim Carr during an official visit to CERN in March this year, with Director-General Rolf-Dieter Heuer (centre) and Professor Geoff Taylor (University of Melbourne) [credit: CERN].

CERN Director-General announces New Australian Centre

The Director-General of CERN in Switzerland, Professor Rolf-Dieter Heuer, announced a new $25 million Australian Research Council Centre to explore the origins of the universe during the Australian Institute of Physics Congress last December. Heuer was also appointed as the chair of the International Advisory Committee of the ARC Centre.

Led by the University of Melbourne, the ARC Centre of Excellence for Experimental Particle Physics at the Terascale will explore particle physics at terascale energies through the ATLAS experiment, a giant particle detector which is an essential part of the Large Hadron Collider (LHC) at CERN.

Director of the ARC Centre, Professor Geoff Taylor at Melbourne's School of Physics said that by probing fundamental particle interactions at higher energies, more would be discovered about the early stages of the evolution of the universe after the Big Bang: "Exciting new physics such as the existence of extra dimensions of space, microscopic black holes, and an extension of relativity called supersymmetry, are possible discoveries motivated by plausible extensions of the standard model of particle physics."

More particularly, CERN physicists are desperately hoping to discover the elusive Higgs boson, predicted in 1964 by UK's Peter Higgs and others, which explains how particles of matter achieve the property we know as mass.

As Geoff Taylor notes: "The Centre will greatly expand Australia's role in the largest pure science enterprise on the planet, the LHC. Our collective scientific effort will leave a legacy of enhanced national capability at the forefront of this intellectual endeavour."

The Centre brings together scientists from the University of Melbourne, the University of Adelaide, Monash University, the University of Sydney and international collaborators including Cambridge University, the University of Pennsylvania, Freiburg University, the University of Geneva, Duke University and INFN Milano.

The involvement of CERN director Professor Heuer in the ARC Centre has reinforced the international standing of the particle physics expertise in Australia. According to Taylor: "We are very excited to announce the start of a new era of Australian collaborative scientific research in the field of particle physics and understanding the beginnings of the universe".

Australian Synchrotron announces Senior Appointments

The Australian Synchrotron (AS) has announced a number of new senior appointments, as well as a major re-organisation of responsibilities for senior staff.

Professor Keith Nugent will be the new Director of the Australian Synchrotron, a part-time position. He replaces Dr George Borg who was appointed Acting Director after the controversial departure of the inaugural director, Professor Robert Lamb, in 2009.

Currently, Nugent is Research Director of the ARC Centre of Excellence for Coherent X-ray Science and Laureate Professor of Physics at the University of Melbourne. He will combine the position with his existing responsibilities. The ap-

New appointments at the Australian Synchrotron: part-time Director, Professor Keith Nugent (left) and Head of Science, Professor Andrew Peele.

pointment follows an extensive international search.

Nugent will focus on and be responsible for scientific leadership and strategic development. He is currently a member of the AS Board of Directors, but will step down from the Board to take on his new role. The AS Board said it was delighted to be able to appoint a distinguished and respected scientist such as Professor Nugent.

A second senior appointment is Dr Andrew Peele who took up the new position of Head of Science late in 2010. Peele who is an Associate Professor at La Trobe University and head of its X-ray Science Group joins the AS on full-time secondment.

As an investigator on grants totalling more than $25 million, Peele has significant experience in team management and science administration, having previously been the chair of the AIP Victorian Branch and co-chair of the organising committee of the AIP Congress last December. He also has extensive experience in synchrotron science having published over 80 refereed articles.

According to Peele, by synchrotron standards the science facility was still very young and its credentials and performance, first class. “In its short life, the Australian Synchrotron has attracted some of the best minds in synchrotron science and, in addition to supporting the research needs of over 2000 domestic and international scientists since its opening in 2007, it continues to run its existing beamlines at better than 99% per cent reliability.”

“The Australian Synchrotron has realised its aims in establishing its first suite of beamlines covering research techniques ranging from imaging and medical therapy to powder diffraction, but it must grow so as to continue to provide Australian and international researchers with access to a world-class science and research facility”, Peele said.

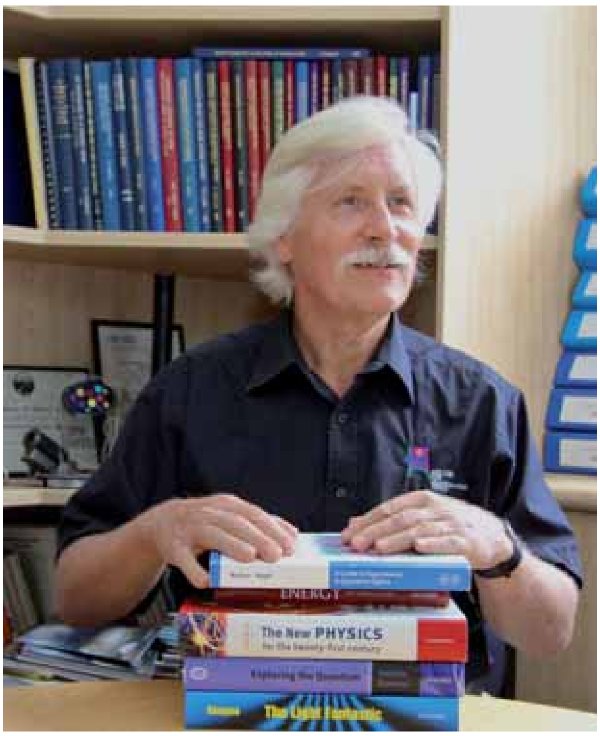
The Board said the re-organisation aimed to further enhance the Australian Synchrotron focus on producing great science, while ensuring that its administration maintained high standards of effectiveness, accountability and compliance.

Harrie Massey Medal for 2010 awarded to Hans Bachor

Ben Villani

How do you pop a small purple balloon that is blown up inside a large clear balloon? With a green laser of course! The energy in green light passes through clear rubber and is then absorbed by the purple balloon – which heats up and bursts.

Professor Hans Bachor used this surprising phenomenon to show how lasers can be used in eye surgery. The demonstration was one of many he performed at an event held last November at Questacon – the National



Professor Hans Bachor at the ANU's ARC Centre of Excellence for Quantum-Atom Optics [courtesy: Damien Hughes].

Science and Technology Centre to mark the 50th anniversary of the laser's invention. The performance is an excellent example of Bachor's efforts to engage the public with physics.

He has recently received awards for his contributions to scientific outreach as well as his outstanding achievements in research, teaching and mentoring of students, all done at the Australian National University (ANU).

In December 2010 Hans Bachor was awarded the Harrie Massey Medal of the Australian Institute of Physics (AIP) and the UK Institute of Physics (IOP) and the Beattie Steel Medal of the Australian Optical Society. These were presented to him during the AIP Congress held in Melbourne. Together with the AIP Award for Outstanding Services to Physics in 2009, the decorations represent a rare 'trifecta' of recognition which very few scientists have received.

Bachor began studying lasers and plasma physics during his PhD in Germany. In 1981 he came to Australia looking for adventure and performed post-doctoral work at the ANU. Here he enjoyed the freedom to study something novel and he initiated quantum optics experiments in Australia. Currently, Bachor is Director of the internationally recognised ARC Centre of Excellence for Quantum-Atom Optics (ACQAO). He and his team are researching the strange behaviour of light and matter on the quantum scale. They do this by designing experiments that manipulate only a very small number of atoms or photons.

"Our aim is to test what is possible! For 25 years we have been scrutinising many of the untested predictions of quantum mechanics." Bachor's extensive research contribution has been published in over 150 journal articles. The work conducted with ACQAO and others will have many practical applications and has the potential to revolutionise communications, computing, cryptography and ultra precise measurements of time, space and gravity.

As well as scientific research and public engagement, Bachor is known for his passionate commitment to teaching and the inspiring lectures delivered at the ANU and internationally. He has guided and supervised 28 PhD graduates, and says "They have all worked very hard and found their way as professionals. I'm proud about the fact that I have helped them with one important step."

"Our aim is to test what is possible! For 25 years we have been scrutinising many of the untested predictions of quantum mechanics."

At the same time Bachor acknowledges he could not have achieved success by working alone. "You can't do physics all by yourself. I've been very fortunate over the years to work with many teams. And while I've played in these teams, I've got into the sin bin occasionally, but I've also won some premierships. I became a trainer, a coach and now a mentor. That's how you progress. I've always enjoyed the fact, that really, doing science is very much a team activity."

And today, as director of ACQAO, Bachor compares his job to that of an orchestra conductor. He says it's like working with amazing and creative solo artists, but the most incredible sounds happen when everyone plays together. "Working together is an essential feature in science because everybody contributes something different. Everybody thinks slightly different – theoretically, mathematically, or like an engineer – and all of these styles are necessary."

Ben Villani moved recently from Questacon to the ANU where he is a science communicator.

Alan Walsh Medal

From Lab to MOGLabs: Commercialising Laboratory Lasers

Robert E. Scholten

The interactions between atoms and coherent lightfields have enabled a vast assortment of fascinating research advances and technological applications, including laser cooling of atoms, Bose-Einstein condensation, magnetic imaging of hyper-polarised gas, and quantum squeezing. Experiments in these areas rely on tuneable narrow linewidth lasers, particularly external cavity diode lasers. While today we can choose from several good commercially available lasers, it was not long ago that researchers had little choice but to build their own. This is the story of how a rat-nest tangle of wires in a university laboratory became the foundation of a company that exports to labs all over the world.

Sir Alan Walsh

Everyone has seen the yellow glow of sodium when salt is thrown in a fire, and for anyone with even a primary school concept of atomic structure, it is not too hard to imagine identifying material constituents from emission spectra. Until the early 1950s, emission was the basis of spectrographic atomic analysis, until Sir Alan Walsh invented and developed the atomic absorption spectrometer, which revolutionised chemical analysis in the 1950s through three key contributions [1].

The first was his understanding that even in a flame or discharge, only a small fraction of constituent atoms will be excited and therefore emit, whereas the much larger ground state fraction will readily absorb resonant radiation. Absorption was commonly used for molecular analysis but the flames and discharges necessary to atomise a sample inherently produced strong emission which swamped the absorption measurements. Walsh realised that the two could be separated by modulating the light source which was being absorbed combined with synchronous detection; that is, with a lock-in amplifier. Finally, he used spectral line lamps, rather than a broad continuous spectrum white light source. Much higher signal-to-noise ratios were possible since no light was wasted in areas of the spectrum not absorbed by atomic constituents of interest.

Fig. 1. Sir Alan Walsh with an early atomic absorption spectrometer [courtesy: Science Image, CSIRO].

The atomic absorption spectrometer (AAS) provides fast, simple, accurate and highly sensitive measurements of atomic constituents, with applications in medicine, agriculture, mineral exploration, metallurgy, food analysis, biochemistry, environmental monitoring, and probably many more. In 1968 the AAS was described by Sir Ian Wark, Chief of the CSIRO Division of Industrial Chemistry, as "the most significant advance in chemical analysis this century" [1].

The invention and development of the AAS occurred just as a booming global mining industry needed accurate and reliable chemical analysis. After a slow start with a UK scientific instrument maker, Walsh helped some local electronics, glass blowing and machining companies put together do-it-yourself AAS kits, and they eventually became Varian Australia, with a staff of 400 and a similar number at external contractors.

Tuneable lasers

The story of MOGLabs, named after the Melbourne Optics Group, is also based on the interactions of light with atoms, in this case the need for better lasers to do experiments in atom optics. The development of tuneable lasers in the 1970s and 80s enabled an explosion of new science, including laser cooling of atoms to micro- and nano-Kelvin temperatures, Bose-Einstein condensation, quantum optical squeezing, atomic clocks, exquisite gravity gradiometers, the GPS system, new tests of the equivalence principle, and slow light, with new examples arising almost daily. Many rely on lasers that can be tuned precisely to an atomic transition, with optical frequencies of order 10^{15} Hz and linewidths of 10^5 Hz or better: an uncertainty better than one part in 10^{10}.

As an example, my lab has developed a source of ultracold electrons, based on photoionisation of laser cooled atoms, for applications in diffractive imaging at the

nanoscale. Fig. 2 shows a schematic of the experiment. Rubidium atoms effuse from a thermal reservoir at speeds of 300 m/s. They are slowed by counter-propagating laser beams, and cooled and trapped by additional lasers in a magneto-optic trap. A cloud of 10^8 atoms is then excited (by a laser) and those excited atoms are ionised (by a laser) to produce a cold plasma. The electrons (or ions) are extracted with an electrostatic field to produce a highly coherent beam of electron bunches (see Fig. 3).

Semiconductor lasers have made modern laser cooling experiments feasible. They are tuneable, narrow in linewidth, compact, and reliable. But in the early days, commercial products were expensive and most labs found they could do just as well by making their own. My lab developed a popular design [2], and also designed and built some crude electronics to drive the lasers (see Fig. 4). The electronics were functional, but frustrating. A rat-nest of wires was time consuming to build, a nightmare to debug, and underwhelming in performance.

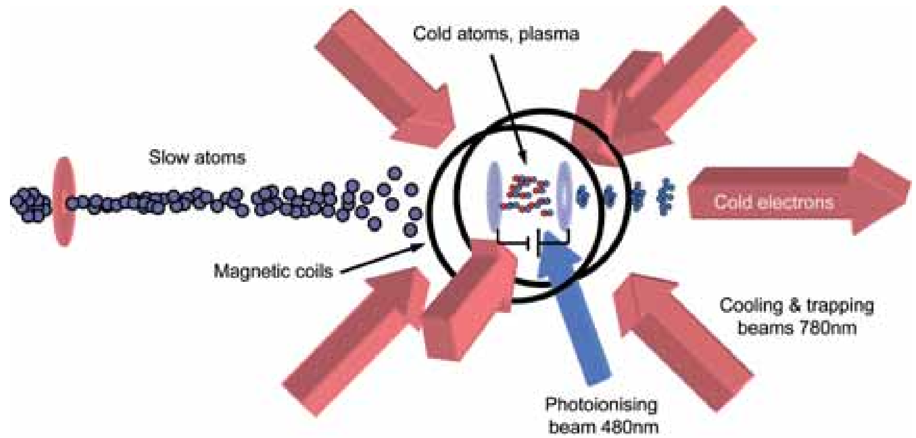


Fig. 2. Atoms are cooled and trapped using narrow linewidth tuneable diode lasers, and then photoionised to produce a very cold electron bunch.

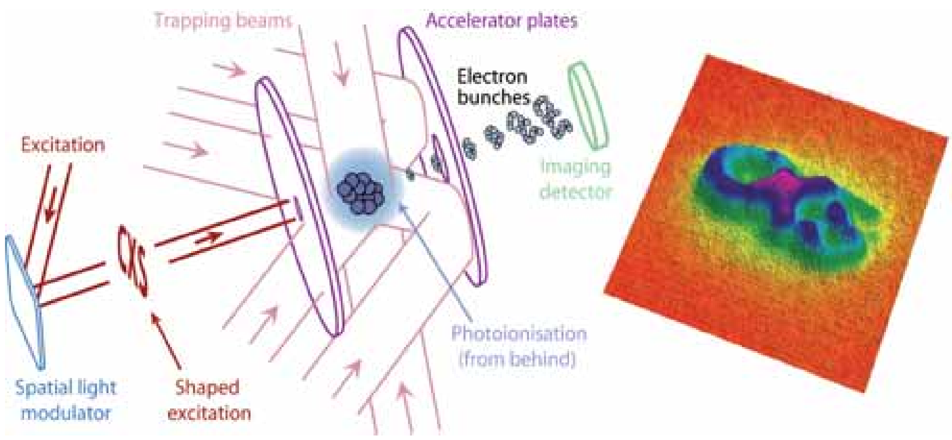


Fig. 3. Electron bunches can be arbitrarily shaped by exciting and photoionising only some of the cold atoms, for example in the letters CXS. Because the electrons are very cold, the pattern is retained when the electron bunch propagates.

Two pivotal opportunities

Two critical events occurred at almost the same time. The first was my sabbatical in 2002 at the Technical University of Eindhoven (TU/e), in The Netherlands. Some of my students accompanied me, including Lincoln Turner. Our colleagues at TU/e also had problems with their laser electronics, and so Lincoln and some Dutch PhD students decided they needed to understand electronic control theory. The books were large and obtuse, but fortunately their brains were even larger, and through their work, our understanding grew beyond simple PID concepts.

We were then fortunate in being able to employ an outstanding electronics engineer, Alex Slavec, at The University of Melbourne, just when we thought we knew what electronics was needed to drive our lasers. Alex was accustomed to designing incredibly complex circuit boards for cutting-edge technology in fibre communications, so it was like hitting a nail with a jackhammer. The rat-nest of wires became an elegant six-layer circuit board with almost 1000 surface-mount components,

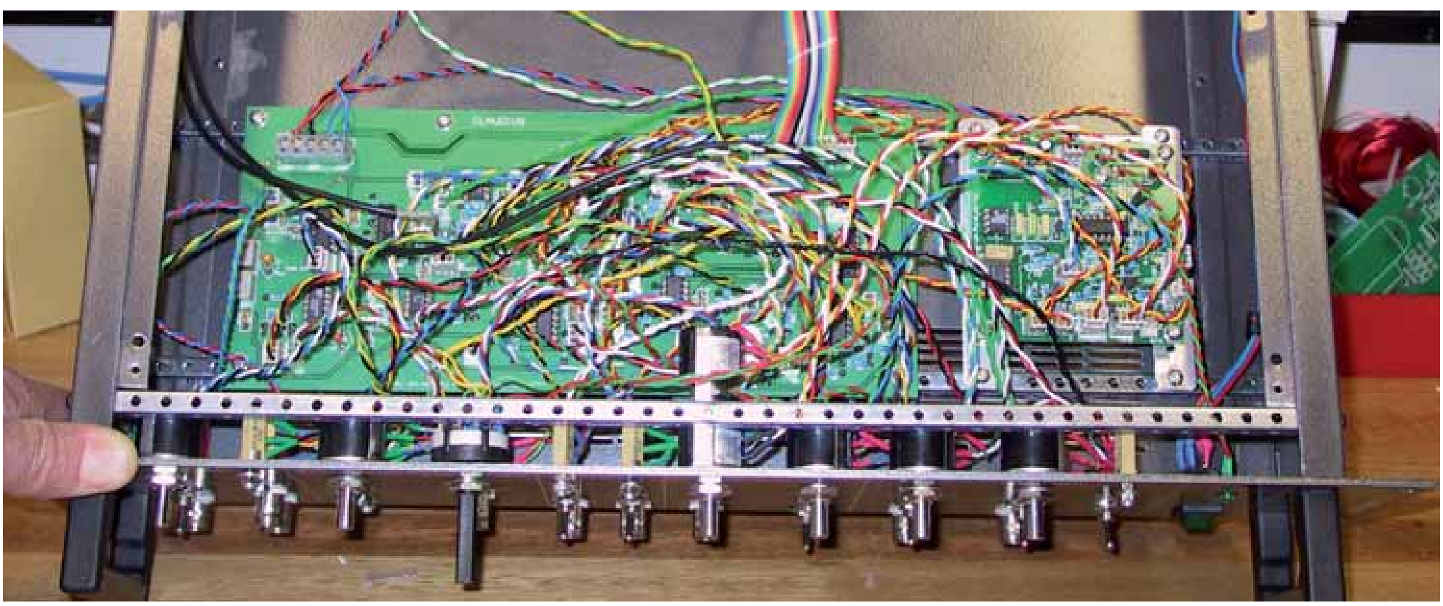


Fig. 4. Lab-built electronics: a rat-nest of wires.

Fig. 5. Iconic sculpture at the gates of the Technical University of Eindhoven in The Netherlands.

code-named *Augustus* ('the revered one').

Alex simulated every stage of the design, before laying out the circuit board, and hand-soldering the thousand tiny surface mount components to the board. And contrary to all our prior experience in designing apparatus for physics experiments, his worked.

No returns

We wanted eight for the lab, but the incremental cost per unit was relatively small, so we built a few extra – twelve in total. We sent a few to friends for their suggestions and feedback – but they didn't return them. To quote: "… please, please, please can we buy it?", and eventually we (the University) sold all but two of the twelve (see Fig. 7).

Why? What is so good about a MOG? The answer is a combination of ergonomics and performance. The ergonomics is important: compared to the Teutonic style and user-interface of the main competition, a MOGLabs controller ('MOGbox') is easy to use, with accessible knobs and switches, convenient selection of signals to monitor on an oscilloscope, and most importantly, everything needed for running a laser and locking it to an atomic transition. To run the laser, the MOGbox includes a current supply for the diode, a temperature controller, frequency sweep ramp, and high voltage outputs to control piezo-electric transducers. For locking, it includes a low-noise differential photodetector, and everything needed for synchronous detection, as used by Sir Alan in his atomic absorption spectrometer. That is, a sine generator to drive an external modulator, a demodulator (lock-in amplifier), and feedback servo shaping based on the control theory learned in Eindhoven.

The performance is defined primarily by low noise [3]. The frequency of light from a laser diode is extremely sensitive to current, about 3 MHz/μA. To achieve the 100 kHz linewidths desired for laser cooling of atoms, the current noise must be lower than 30 nA, for a 200 mA DC supply. The MOGbox design is steadfastly analogue, with no digital clock signals. The power supplies are all linear, rather than switchmode. The transformer is toroidal to minimise external AC magnetic fields through the PCB, with an additional layer of magnetic shielding to be sure. The DC voltage supplies are each filtered and regulated, then filtered and regulated again. Sensitive signals on the PCB are run along inner layers with Faraday shielding copper on other layers around them. The result is very nearly too small to measure: -150 dBm/√Hz, i.e. 1 attowatt/√Hz (10^{-18} W/√Hz), or in current terms, below 100 pA/√Hz. No other laser diode driver has demonstrated such low noise, and using a MOGbox, a laser linewidth of 35 kHz (rms) is readily achievable [4].

Corporate commercialisation

There are hundreds, if not thousands, of laser cooling labs around the world, nearly all using external cavity diode lasers. ECDL products are also used in chemistry labs, environmental monitoring research, astrophysics (e.g. investigating guide stars based on alkali vapours), metrology labs, fibre communications research, and many other areas. In 2007, a US manufacturer advertised that they had sold over 5000 ECDLs. With several enthusiastic users of our first batch of controllers, we contacted the commercialisation arm of our university, Melbourne Ventures, to discuss the possibility of licensing the design to an existing manufacturer.

Melbourne Ventures investigated possible buyers, including existing manufacturers of ECDLs and other laser manufacturers that did not yet have these products. They estimated a total market of around 700 units over five years, with an

Fig. 6. From rat-nest to six-layer PCB and surface-mount components.

end-user value of something like $1 million per annum. Contemplating the inventor's share of the royalties, we started looking at holiday homes in the exclusive Victorian beach resort of Sorrento…

DIY commercialisation

Meanwhile, back in the lab… actually *outside* the lab, in Alex's home: the dot-com industry had begun to recover and Alex moved back to the fibre communications industry at the end of 2003, and continued his work on the MOGbox in his own time. Only one of the prototypes was finished; he completed the second unit, and then the first batch of 12 units, after changing jobs. Even while negotiating with Melbourne Ventures, we continued to improve the design, and after some months they suggested we start our own company to build and sell the product. In other words: "We don't know how to sell this, so why don't you?"

We *were* a little passionate about it, fuelled by positive comments from users. And so, indeed it seemed like a good idea at the time. We registered MOG Laboratories as a proper business (i.e. Pty Ltd), a partnership between myself and Alex, and signed a three-year licensing agreement with Melbourne Ventures.

One of the first steps was to improve the appearance of the MOGbox, to better reflect the high quality of the electronics inside. The units worked well, but looked very homemade. It was clear that we needed to increase the price if the company was to be viable, but it was critical that customers should appreciate the quality they were paying for. We contracted a Sydney company known as Konstruktdesign to design a better enclosure – money well spent, but money our business did not have. The only readily accessible finance was that tied to the family mortgages. And so our families had to take a leap of faith, a faith that faltered a little when we decided to buy the MOGbox components in batches of 25 to get the costs down. And faltered a little more when the time came to pay for a batch of 25 assembled PCBs: sufficient funds to buy each of our families a new car – instead sent by wire to a company in Silicon Valley.

"We don't know how to sell this, so why don't you?"

Fortunately, Konstruktdesign and the PCB manufacturer did a fantastic job, and the controllers worked well and looked the part. They have been sold to all corners of the globe, from South Africa to the United Arab Emirates, the USA to China. A single customer now has 14. Even the strongest competitors to MOGLabs have bought them, and it is gratifying – and somewhat annoying – to see some familiar features in their latest products. The company has moved from home dining-room to a business incubator, and hopes to move again to larger premises soon. So far there is only one part-time employee; most of the work is contracted to over 100 suppliers from Melbourne and Sydney to San Jose.

Fig. 7. One of the twelve units which were sold to other labs in Australia, the US, The Netherlands and to a notable German manufacturer of external cavity diode lasers.

Fig. 8. Current model of the MOGLabs controller, laser and photodetector. More than 100 controllers have been sold around the world.

The Future

Why do it? Why take an idea, or an instrument design, from the lab, and try to sell it around the world? It is another adventure; physics is only a small part of making the business work, which means that there have been a lot of new things to learn. Of course it is satisfying to see that other people care about your work, enough to pay for it, and to be manufacturing high-tech equipment in Australia. It has brought new connections to similar researchers around the globe, and better instrumentation in my own lab. The rewards are intangible: it has never been about making money – but at the same time, we want to develop new products, and employ more staff, and move into larger premises, so the concern for financial matters is never far away.

'Contemplating the inventor's share of the royalties, we started looking at holiday homes in the exclusive Victorian beach resort of Sorrento…'

MOGLabs is now five years old. It has grown without advertising, without government assistance, without private investment and without venture capital. Organic growth has allowed steady improvements to the flagship product, and even to research and develop, in house, the obvious extension – a MOGLabs external cavity diode laser. But we have many more ideas for new products, and see a promising future in following Sir Alan Walsh's lead, in designing and manufacturing scientific instrumentation in Australia.

Acknowledgements

Many people, knowing and unknowing, have contributed to the research and development of the external cavity diode lasers and electronics at MOG Laboratories. Special thanks to Keith Nugent, Leo Holberg, Jamie White, Anton Barty and Jolanda van de Ven and to former students Lincoln Turner, Karl Weber, Colin Hawthorn, Sebastian Saliba, Mirek Walkiewicz, Chris Vale and Phil Fox. Most of all my thanks go to Alex Slavec, an engineer with legendary insight and expertise in electronics, and remarkable patience with a physicist's concept of a commercial-ready design.

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Bio

Robert Scholten is an Associate Professor and Reader in Physics at The University of Melbourne, where he leads the Ultracold Plasma high-brightness electron source Programme of the ARC Centre of Excellence in Coherent X-ray Science. His research career began with studying electron collisions from laser-excited atoms, where the laser polarisation controlled the quantum state of the target atoms. His interest in the laser-atom interactions formed the basis of his further research, for example using atom-optics techniques for nanofabrication as a Fulbright Postdoctoral Research Fellow at NIST in the USA. He has also developed novel approaches to optical imaging of cold atoms, is currently working on quantum sensing using colour centres in diamond, and has created a high-tech start-up company (MOGLabs) based on lasers and laser electronics.

A Bonsai Black Hole in Our Own Backyard

Robert Soria

The discovery of powerful jets from a nearby black hole reveals new clues about the behaviour of massive quasars in the early universe.

Black holes are popularly portrayed as a place of darkness and gloom, but to astronomers they are the cleanest and most efficient source of energy in the universe. The recent discovery of a very large glowing bubble of ionised gas inflated and heated by a black hole in the nearby galaxy NGC 7793 helps us to understand their role as cosmic powerhouses.

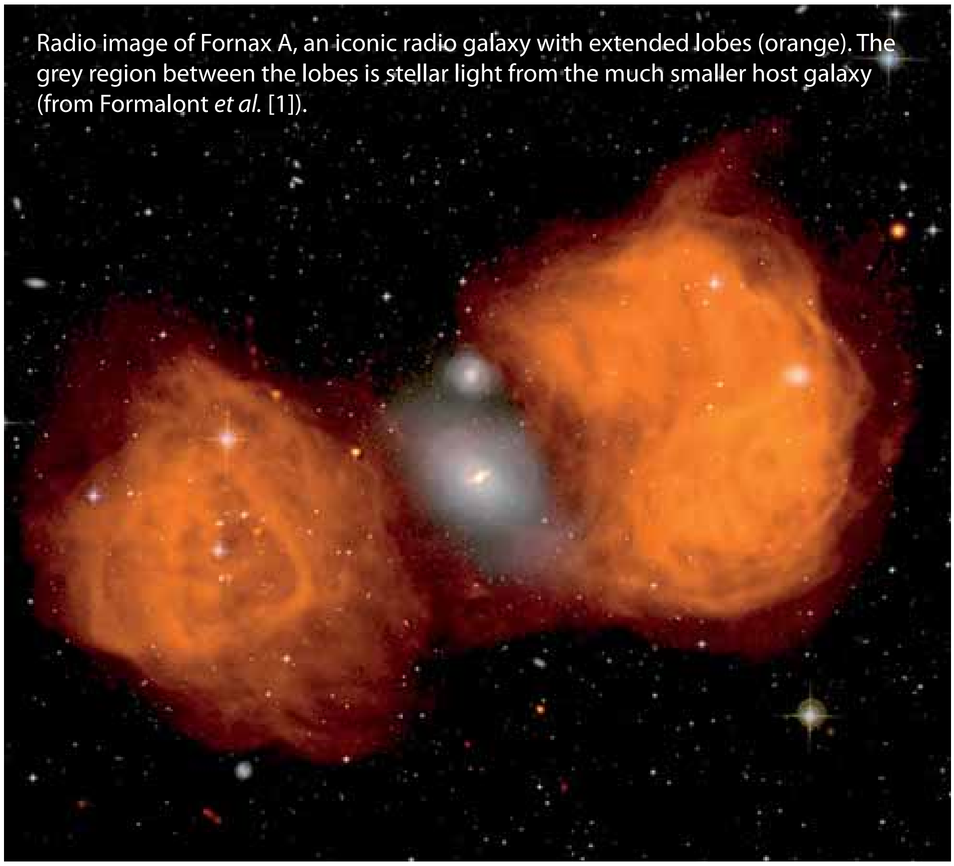
While stars use nuclear fusion to extract energy from their gas, black holes extract gravitational energy from the infalling matter before it disappears into the hole – a process known as accretion. Indeed hydrogen bombs and hydro power plants are based on the same physical principles as stars and black holes, respectively.

Hydro power may seem less efficient than nuclear fusion. While it takes a lot of falling water to produce the same energy as we would get from nuclear fusion, this is only because the gravitational field of the Earth is so weak. But gravity near a black hole is much stronger, and accretion power can be up to 50 times more efficient than nuclear fusion.

This is why black holes – or, more exactly, the gas in the region immediately outside the black-hole horizon – can be the most luminous and powerful objects in the universe when enough matter is falling towards them. The end result is that black holes get bigger over time as long as there is matter to fuel them.

The general energetics of black-hole accretion is known from fundamental physical principles, but there are still many important things we do not know about how that energy is released. The two main channels are radiation of photons and the kinetic energy of a jet.

The photons are emitted from the surface of an accretion disk that is formed by gas that is slowly spiralling towards the event horizon – and is getting very hot in the process. When photon output dominates, a black hole appears as a very luminous source, especially in the X-ray and ultraviolet bands. A supermassive black hole in the centre of a galaxy, with a mass that is many millions of times the mass of the Sun, can be more luminous than all the stars in that galaxy put together.



Radio image of Fornax A, an iconic radio galaxy with extended lobes (orange). The grey region between the lobes is stellar light from the much smaller host galaxy (from Formalont *et al.* [1]).

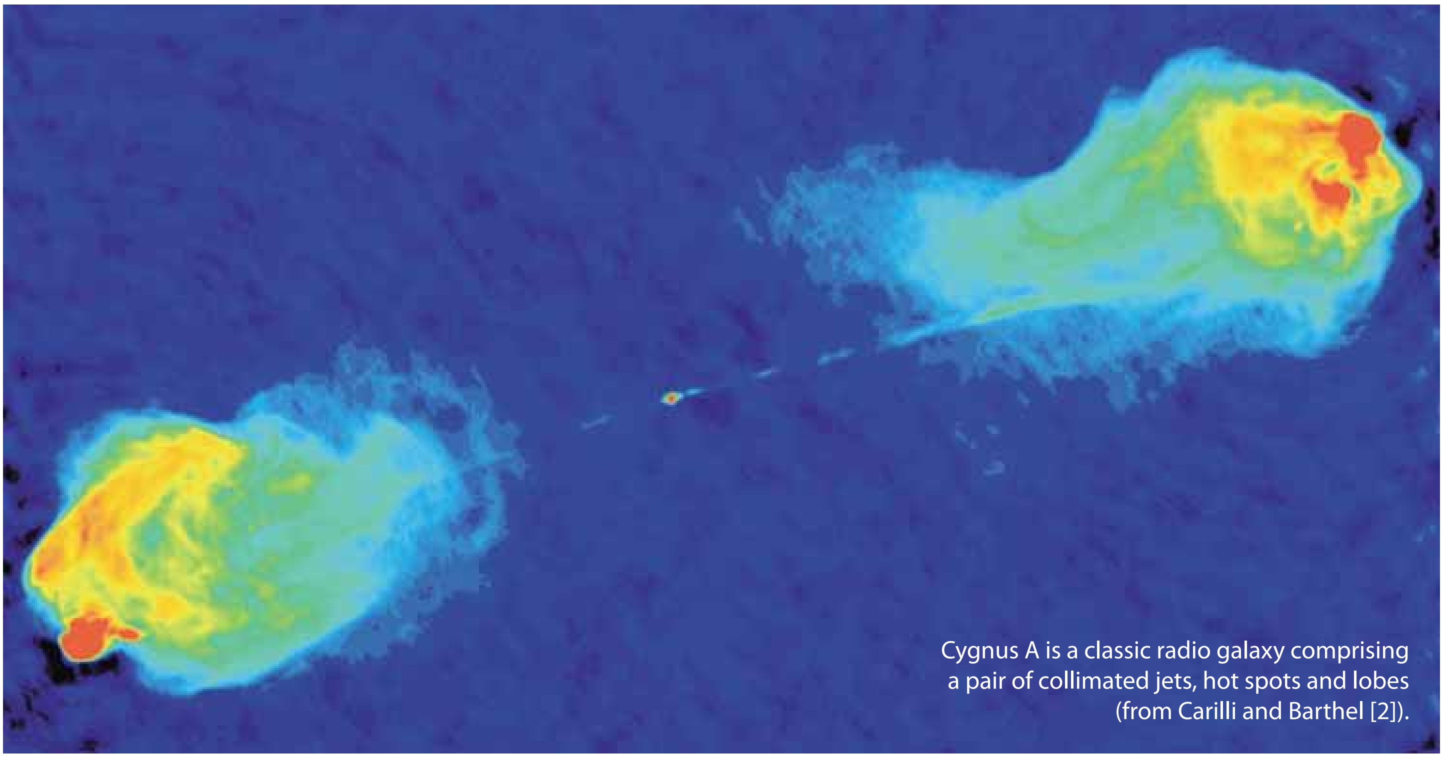
Alternatively, accretion power can be carried out by a collimated jet of charged particles – either electrons and positrons, or electrons and protons – moving at almost the speed of light.

A third ingredient may also be present, especially in the most active black holes: a dense wind launched from the surface of the accretion disk can carry away mass, energy and angular momentum.

How does a black hole decide whether to release its accretion power via photons, jets or winds? What switches the jet on and off? These are still unsolved mysteries of black-hole astrophysics, but this is where our recent discovery of the most powerful stellar-mass black hole jet 12 million light years away in NGC 7793 will help to provide some answers.

Radio galaxies and microquasars

One of the best things about black holes is that their fundamental physical properties are the same at all scales. Supermassive black holes in distant quasars work just like stellar-mass black holes in our galaxy, apart from a simple rescaling in the equations. What changes is the environment around them, such as whether their fuel comes from galaxy-scale gas inflows or a companion star.


Cygnus A is a classic radio galaxy comprising a pair of collimated jets, hot spots and lobes (from Carilli and Barthel [2]).

From an astronomer's point of view, a crucial advantage of nearby stellar-mass black holes over their more distant and massive cousins is that they evolve over shorter timescales and can switch between jet, disk and wind states within the timescale of a university research grant. Supermassive black holes may be bigger and brighter, but they switch states over tens of millions of years.

Over the past two decades, much work has been done to understand the connections between astrophysical objects that once seemed totally unrelated but are all powered by active black holes. Radio galaxies and microquasars are among the most spectacular examples.

'Radio galaxy' is, in fact, a poorly chosen name. The 'radio' label comes from their initial discovery from radio observations in the 1950s: it was not known at the time that the radio emission is produced by relativistic electrons in a jet. And the 'galaxy' label is misleading: it is not the galaxy that produces the jet, it is the supermassive black hole in its centre. Today, we have independent evidence of black holes with jets from infrared, optical and X-ray studies, but radio observations still provide the best spatial resolution and are not affected by interstellar absorption.

Powerful black-hole jets share a common structure. They drill through the surrounding gas until they lose enough energy or hit denser interstellar material. A shock front forms at the slowly-advancing head of the jet and is often visible as a bright 'hot spot' in several energy bands. When the relativistic jet particles reach the shock front, their orderly bulk motion is converted into random motion and the collimation of the jet stream is lost.

"From an astronomer's point of view, a crucial advantage of nearby stellar-mass black holes over their more distant and massive cousins is that they evolve over… the timescale of a university research grant."

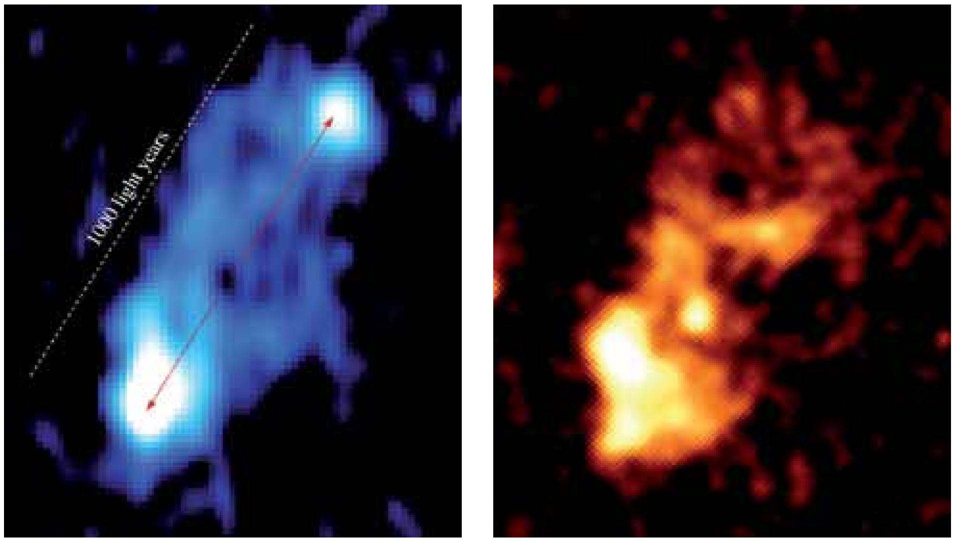
After going through the shock front, electrons backflow and disperse into a large, fluffy lobe around the end of the jet, and sometimes form a full cocoon around the black hole. As they swirl around magnetic field lines, the electrons emit synchrotron radiation – mostly in the radio bands but sometimes extending also to the optical and X-ray band. The rest of the jet power is transferred to the ambient gas as thermal energy and used to inflate the hot cocoon.

Microquasars are the stellar-mass equivalent of radio galaxies. They are powered by a black hole formed from the collapse of a massive star. They contain a pair of relativistic jets that interact with the interstellar gas and may produce bright hot spots, radio lobes and an expanding cocoon or cavity.

Radio observations of the inner jet and outer lobes have been a crucial tool for discovering and studying radio galaxies and microquasars, but calculating the total jet power from its radio emission is not simple. The swirling cloud of radio-emitting electrons carries only a small and poorly-known fraction of the total power. The rest is transferred from the jet to the surrounding gas, which is heated and swept out, forming a hotter, lower-density bubble around the black hole. This is what determines the full impact of the black hole's activity on the surrounding gas, but it is difficult to observe this effect directly.

The most powerful microquasar

This is why an object such as the recently discovered black hole S26 in NGC 7793 is so important. Our team, led by Dr Manfred Pakull at the University of Strasbourg, used optical and X-ray observations to reveal the hot spots at the end of the symmetric jets, and the hot bubble of gas around the system. The bubble is expanding at a



Left: radio image at 3-cm wavelength of the newly discovered microquasar S26 in NGC 7793. The red arrows mark the trajectory of the two jets, travelling in opposite directions from the black hole. The brighter regions (hot spots) at the end of the jets are where the fast jet particles hit the surrounding interstellar gas and dissipate their energy. Right: the emission from ionised Helium reveals the location of hot gas (heated by the jets) in the same system (from Soria *et al.* [3] and Pakull *et al.* [4])

speed of 250 km/s. The jets are driving the expansion of the bubble, pushing its shell as they slam against the denser and cooler interstellar medium. Strong radio emissions from the jet lobes and the cocoon were discovered from our observations in 2009 and 2010 at the Australia Telescope Compact Array at Narrabri in NSW.

This object contains the largest bubble and the longest jets ever seen from a stellar black hole, with a total length of about 1000 light years. Furthermore, they are emitted from a black hole that is at most a few hundred kilometres in diameter.

We estimate that the active phase of this black hole started around 200,000 years ago – the blink of an eye in the history of the universe. During this short period of time, the black hole has swallowed as much gas as there is in the Sun, and has produced 300 times more energy than will be emitted by our star over its entire lifetime.

Having measured both the radio emission from the relativistic electrons and the heating effect on the surrounding gas, we could then estimate the total jet power. It is a few hundred times the power carried by the radio-emitting electrons alone.

This is more than previously thought. It makes S26 one of the most powerful stellar black holes – including both jets and photon output – by an order of magnitude. It also means that we may have underestimated the total jet power of many other black holes, especially in the distant universe, if we only measured their luminous output.

It was previously thought that radio jets were only associated with moderately weak black holes, while jets could not be launched by black holes that are growing very fast (i.e. when a lot of gas is falling into them). In other words, at low accretion rates, black holes would produce jets, while at high accretion rates they would have a luminous disk.

The discovery of S26 – and similar recent discoveries of a few jet-dominated, powerful quasars in the distant universe – have challenged this scenario. It seems now that at least some of the most powerful black holes can have strong jets.

Black-hole spin and jets

But a fundamental problem remains unsolved: why do some of the most powerful black holes – both in the stellar-mass and supermassive class – have jets while others do not, even if they are accreting at the same rate and have the same total power? How do black holes switch from one state to the other?

One suggestion is that black-hole spin determines the jet power. Rapidly spinning black holes would more likely produce stronger jets or retain their jets at high accretion rates, all other conditions being the same. This is at least in qualitative agreement with what is seen in other astrophysical objects (e.g. protostars, neutron stars), where jets are more often launched by fast-spinning bodies.

Spin is the most elusive property of a black hole, and is even more difficult to measure than its mass. If we could measure both the mass and the spin of an active black hole we could test crucial predictions of general relativity and learn more about black-hole formation and growth. Different formation channels predict different spin values, so it would be extremely interesting if the jet power of black holes is indeed an indicator of their spin.

Regardless of the mechanisms for jet formation, the observed existence of very powerful black-hole jets has profound implications for the early history of the universe. During the first billion years or so the cosmos was dominated by quasars, which are the most powerful state of supermassive black holes in the nuclei of galaxies. However, the quasar phase ended after most of their gas supply was exhausted.

S26 is a bonsai quasar in our own backyard. It is heating and sweeping the gas around it, much like quasars did on a grander scale billions of years ago. If some quasars can output a significant fraction of their power through jets – instead of, or in addition to, photons – they would be more efficient at heating the ambient gas and would have a stronger effect on the evolution of their host galaxies.

Modelling the interaction between black-hole growth and galaxy evolution will be a key science goal of the Australian Square-Kilometre-Array Pathfinder (ASKAP) radio telescope being built near Geraldton, WA, in synergy with infrared and X-ray studies.

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Walter Boas Medal for 2010

Plasma Nanoscience: From Controlled Complexity to Practical Simplicity

Kostya (Ken) Ostrikov

Physicists are often asked to explain the significance, novelty, and most important scientific points of their research work. More precisely, they are commonly expected to clarify the 'excitement created by the scientific novelty and approach' and the 'significance and outcomes' of their work.

These simple points set the framework to structure, perform, and communicate scientific reseach in a way that generates new knowledge and scientific excitement on one one hand and leads to some practically meaningful outcomes on the other. Put simply, one could pose the question *"what is new in what you do and why it is useful?"* This needs to be clearly answered to satisfy our curiosity and to maintain the interest and excitement of all the categories of listeners and readers, ranging from professional colleagues to the general public and school students.

What is Plasma Nanoscience?

Plasma Nanoscience is a multidisciplinary research field which aims to elucidate the specific roles, purposes, and benefits of the ionised gas (plasma) environment in assembling and processing nanoscale objects in natural, laboratory and technological situations and to find the most effective ways to ultimately bring these plasma-based processes to the deterministic level [1]. The concept of the deterministic plasma-based nanoscale synthesis and processing is based on finding the most optimum plasma process parameters to minimise the number of experimental trials one needs to undertake to achieve nanostructures and nanomaterials with the desired properties, which in turn determine their performance in practical applications.

What do we do in Plasma Nanoscience?

In an attempt to provide a relatively simple and concise answer to this question, it would be fair to state that myself and many of my colleagues and collaborators do research in the field of Plasma Nanoscience to find new plasma-specific mechanisms to control complex organisations of atomic matter at sub-nanometre to microscopic scales to develop new materials, devices, and processes for energy conversion, electronics/IT, health care, environmental and other applications that are critical for a sustainable future. Even more concisely, we are trying to *control the plasma-related complexity to eventually achieve the practical simplicity in applications,* which is also reflected in the title of this article. Our research also aims at explaining some natural phenomena that are affected by the plasma- and nanoparticle-related effects.

Without trying to exhaustively cover even a small subset of relevant physical phenomena and practical applications, here we will only highlight a few typical examples and consider one of these examples in more detail using the framework of *"what is new in what you do and why it is useful?"*

Our research simultaneously involves low-temperature plasmas, nanoscale objects, or mesoscopic objects with nanometre features. Situations where the plasma meets small solid or liquid objects are numerous and can be found in many natural, laboratory and technological environments. For example, interstellar dust nucleates in the relatively cold envelopes of red giant stars, where the gas temperature and the ionisation degree are suitable for condensation of carbon atoms that are produced and ejected by the stars. At this stage, nanoparticles of solid matter are created; this process is affected by the plasma environment. Relevant plasma-specific phenomena include ion-induced nucleation, turbulent flows, vapour supersaturation, among others.

As another example, low-temperature plasmas are used for microstructuring semiconductor wafers in microelectronics, deposition of functional coatings, films and interlayers, surface hardening and modification, etc. Fabrication of tiny features in semiconductor wafers involves many plasma-specific effects such as surface charging, reactive ion etching, ion bombardment, production of reactive radicals by electron-impact processes, just to mention a few.

As a third example, which will be considered in greater detail below, carbon nanotube nucleation and growth benefits from microscopic electric fields near the surface, electron- and ion-assisted production of carbon atoms from hydrocarbon precursors, plasma-specific localised heating, and some other effects. These and many other effects make low-temperature plasmas truly unique environments for nanoscale synthesis and processing. Not surprisingly, in many applications, plasma-based nanotools have shown superior performance compared with techniques primarily based on neutral gas chemistry, such as thermal chemical vapour deposition (CVD).

Why make things more complicated?

Compared to neutral gas-based routes, in low-temperature weakly-ionised plasmas there is another level of complexity related to the necessity of creating and sustaining a suitable degree of ionization and a much larger number of species generated in the gas phase [1]. Furthermore, in many cases it is very challenging to control the generation, delivery and deposition of a very large number of radical and ionic species. This is further complicated by intense physical (physisorption, sputtering, etc.) and chem-

ical (chemisorption, bond passivation, reactive ion/radical etching) plasma–surface interactions. This higher level of complexity leads to a number of practical difficulties in operating and controlling plasma-based processes and provokes an obvious question: "*Why do we need more complex, plasma-based systems if it is possible to produce nanoparticles using wet chemistry or other relatively simpler means?*"

Years of research in the Plasma Nanoscience field has provided many convincing examples where an investment into producing a more complex, ionised gas environment has led to significant advantages in terms of energy efficiency, quality, reproducibility, and safety of the fabrication processes, on one hand, and superior nanomaterial structure, properties, and performance on the other. It is not surprising that the discovery of carbon nanotubes, the most common basic building blocks in present-day nanotechnology, was made using thermal plasmas of arc discharges [2].

Other non-exhaustive examples relate to significantly reduced process temperatures, control over species production and dynamics in the gas phase and solid surfaces, very high energy efficiency, charge- and magnetic field-related driving forces for self-organisation, possibility of commercial-scale nanoparticle production, unique vertical alignment of one-dimensional nanostructures, effective control of nanomaterial properties by the process parameters, unique plasma-enabled nanostructures and growth regimes impossible otherwise, dry ultra-fine precision etching and writing of virtually any nanoscale features including very high aspect ratio and straight trenches for nanoelectronics, finely conformal coatings of micro- and nanoscale features with any required thickness down to a single monolayer or even sub-monolayer coverage, property-transforming (e.g. conducting to semiconducting) surface functionalisations of various nanostructures including single-walled carbon nanotubes (SWCNTs) and graphene, production of thermodynamically unfavourable metastable structures and nanophases, intricate self-organised nanopatterns on a variety of substrates ranging from metals, ceramics, and semiconductors to flexible and temperature-sensitive surfaces, the as recently elusive possibility to control the 'uncontrollable' chirality of SWCNTs, formation of graphene nanoribbons by cutting and unzipping carbon nanotubes, synthesis of nanomaterials with exotic superstructures, porosity, nanocrystalline inclusions, surface topology, reactivity, to mention just a few [3].

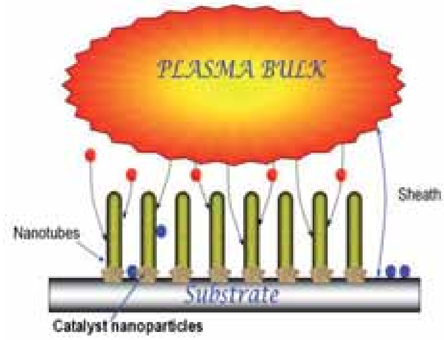

Fig. 1. A typical plasma–solid system used in the growth of single-walled carbon nanotubes (SWCNT), showing the plasma–surface interactions.

How to grow nanotubes and where are the challenges?

Let now consider an example of plasma-based growth of single-walled carbon nanotubes in more detail (see Fig. 1). First of all, SWCNTs have generated a lot of excitement in the last decade owing to their unique structural, electronic, mechanical, optical and other properties. The unprecedented toughness and electron conductivity make SWCNTs perhaps the most structurally stable one-dimensional superconducting nanomaterial of the future.

"It is not surprising that the discovery of carbon nanotubes… was made using thermal plasmas of arc discharges"

Nanotubes are commonly synthesised using metal or metal alloy catalyst nanoparticles (e.g. Fe, Co, Ni, Au and alloys such as Fe–Ni) with a suitable lattice spacing, carbon solubility, and melting temperature. In thermal CVD processes, hydrocarbon precursors (methane, acetylene, etc.) are decomposed to produce carbon atoms on the hot surface of a substrate material such as Si. This process requires a very significant external heating, up to 900–1000°C and even higher. This heat is used to produce carbon atoms and give sufficient energy to a fraction of them to overcome quite significant potential barriers (of the order of ~1–2 eV depending on the nanotube size and catalyst material) to diffuse through the catalyst nanoparticles and then to be incorporated into the developing tubular structure. It is believed that the nanoparticle size determines the thickness of the SWCNT.

The thinner the nanotubes, the stronger is the quantum confinement of electrons and more unique size-dependent quantum effects can emerge. However, it is more challenging to grow very thin nanotubes. Indeed, nanoparticles of smaller radii tend to produce stronger internal tension which effectively pushes the incoming carbon atoms back to the substrate. This phenomenon is known as the Gibbs-Thompson effect, which strongly affects the nucleation and growth or a broad range of inorganic one-dimensional nanostructures.

Consequently, as the catalyst nanoparticles get smaller, the barriers that carbon atoms need to overcome increase. As a result, the substrate temperatures required to supply this energy need to be increased even further. Such higher surface temperatures are not only well above the presently tolerable process temperatures in microelectronics (and some other areas), but also lead to the strong diffusion of the catalyst material into the substrate. In some cases this diffusion consumes the whole catalyst nanoparticle even before the nanotubes start growing. To prevent this, thin interlayers such as SiO_2 are used. However, SiO_2 is a dielectric material and represents an obvious obstacle to achieve ohmic loss-free direct integration of carbon nanotubes into the presently dominant silicon-based nanodevice platform. Moreover, thermally grown SWCNTs often feature structural defects, are twisted and tangled and, as well, are very randomly oriented on the substrate. Furthermore, it is not presently known how to control the chirality, which is the angle of twist of a wrapped graphene sheet that makes up the nanotube.

Therefore, the major scientific challenges in this direction are to: (1) drastically reduce the growth temperatures; (2) minimise the amount of building material and

energy used to achieve the desired growth rates; (3) prevent catalyst diffusion into the substrate without using intervening layers; (4) vertically align the nanotubes on the substrate and eventually achieve regular three-dimensional nanoarrays; (5) achieve energy-efficient nucleation and growth of very thin nanotubes; (6) enable chirality control of SWCNTs; and, if possible, (7) eliminate the need to use any catalyst at all.

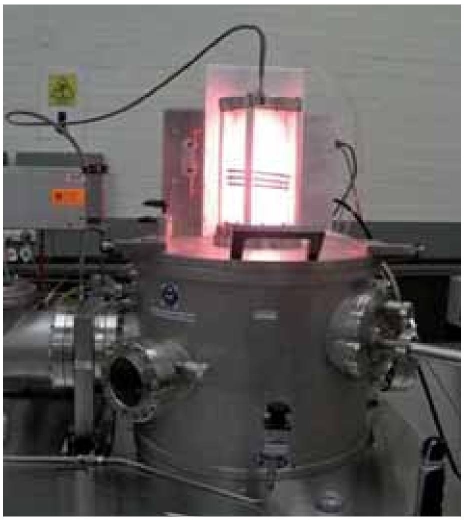

Fig. 2. The remote plasma reactor at the Plasma Nanoscience Centre, CSIRO Materials Science and Engineering, at Lindfield, NSW. The reactor is used for plasma-assisted growth of delicate nanoscale objects such as carbon nanotubes, graphene, silicon quantum dots and inorganic nanowires.

Can we help you? Yes we can!

This is where various Plasma Nanoscience approaches based on the unique properties of low-temperature plasma–solid systems (Fig. 1) are used to solve the above scientific challenges. However, reasonable care should always be exercised in the plasma-based growth of single-walled carbon nanotubes. For instance, to minimise any possible damage to the delicate single-walled structure of the nanotubes through bombardment by energetic ions, remote plasma systems are used for this purpose (see Fig. 2). In this case, the plasma is separated from the substrate and only a small amount of material is delivered to the growth surface. This arrangement also reduces the effect of burying the catalyst particles or the short nanotubes at the early growth stages by amorphous (carbon in this case) material. This is a common problem in the catalysed growth of a large number of one-dimensional nanostructures such as nanotubes, nanowires, nanotips, etc.

As shown in Fig. 1, the plasma bulk is separated from the surface by the area of uncompensated space charge termed the plasma sheath. In low-temperature non-equilibrium plasmas, the electrons have much higher energy than the ion or neutral species. Thus, many reactive species can be created in the ionised gas phase by electron-impact reactions. In the carbon nanotube growth, carbon atoms need to be produced from hydrocarbon precursors such as CH_4, C_2H_2, and some other gases and gas mixtures. In thermal CVD, these processes mostly take place on the surface; thus, very high surface temperatures that are sufficient for the effective hydrocarbon dissociation are required. The strong thermal non-equilibrium of the plasma makes it possible to generate the needed atomic and radical species in the plasma bulk and therefore substantially (e.g. several hundred Kelvin) reduce the surface temperatures needed for nanostructure growth. This in turn dramatically reduces the rates of metal catalyst diffusion into the substrate.

Furthermore, due to a very high mobility of electrons, the surfaces are at a negative potential compared to the plasma bulk. Therefore, there are non-uniform electric fields within the plasma sheath; the electric field lines start in the plasma bulk and converge to the sharp tips of the developing one-dimensional nanostructures. This leads to strong ion focusing by the nanostructures. Depending on the energy, ions can deposit in different sections of the nanotubes and on the substrate surface between the nanostructures. Since the ion energy is determined by the potential drop across the plasma sheath, selective ion deposition can be effectively controlled by the plasma parameters and the substrate bias.

This leads to the unique possibility to selectively deposit ion fluxes in the specified areas, with nanometre (and possibly even higher) precision. In the SWCNT case considered, it is desirable to deposit the ions onto (or as close as possible) the catalyst nanoparticle, which is located at the nanotube base. This will lead not only to the faster delivery of carbon species to the catalyst, but also to stronger and faster *localised* heating of the catalyst nanoparticles. This localised heating reduces even further the minimum external substrate heating (and hence the substrate temperatures) required for the nucleation and growth. In addition, several ion-assisted processes facilitate the production of carbon atoms directly on the SWCNT surface (see Fig. 3). The carbon atoms produced in this way can diffuse along the nanotube surface and also be incorporated into the growing tubular structure through the catalyst nanoparticle. The carbon atoms and other radicals can also easily detach/evaporate from the nanotube and the substrate surfaces. Therefore, lower surface temperatures in the plasma-based SWCNT growth also substantially reduce the rates of material losses thereby *increasing the matter and energy efficiency* in the nanoscale synthesis process.

Fig. 3 shows many other elementary interactions between the plasma-generated species and the single-walled carbon nanotube. The number of elementary reactions that lead to the nanoscale transfer of energy and matter on the surface of the nanotubes is very large and is usually larger than in neutral gas-based processes. In particular, a

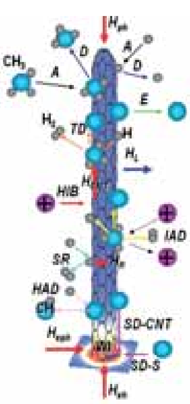

Fig. 3. The complexity of subnano- and nanoscale interactions of low-temperature plasmas with a single-walled carbon nanotube, showing the principal processes of energy and matter transfer [4]: *A* – adsorption; *D* – desorption; *E* – evaporation; *TD* – thermal dissociation; *IAD* – ion-assisted dissociation; *SR* – surface recombination; *HAD* – hydrogen-assisted desorption; *SD-CNT* – surface diffusion on the carbon nanotube surface; *SD-S* – surface diffusion on the substrate surface; and *WI* – incorporation of carbon atoms in the nanotube walls. The following processes are related to nanoscale transfer of energy: H_{ph} – energy transfer from the plasma to the SWCNT; H_L – energy transfer from the SWCNT to the plasma (energy loss); H_{sh} – energy transfer to the SWCNT due to external substrate heating; H_{sph} – energy transfer to SWCNT due to the surface heating by the plasma; H_{IB} – energy transfer to the SWCNT due to plasma ion bombardment; and finally H_R – energy transfer to the SWCNT due to exothermic SR.

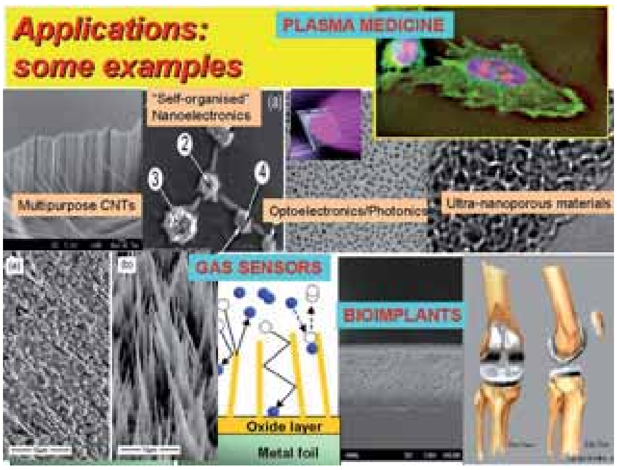

Fig. 4. Some applications of plasma-made nanomaterials and microscopic plasma–surface interactions.

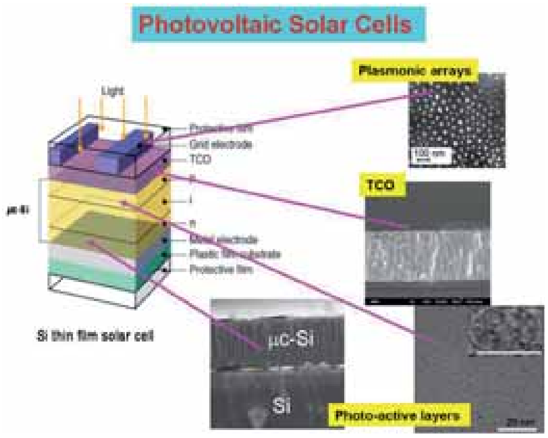

Fig. 5. Photovoltaic solar cell technology for renewable energy generation relies heavily on plasma-based nanoscale processes. Quantum-dot enhanced photoactive *nc*-Si functional layers, nanostructured ZnO transparent conducting oxide layers, and plasmonic arrays of Au nanoparticles are advanced features of the next-generation solar energy conversion devices.

very large number of electron- and ion-assisted processes, not common to neutral gas-based thermal processes, are involved. Therefore, the complexity of the plasma–surface interactions at the nanoscales is higher compared to neutral gas-based processes.

Nevertheless, this complexity leads to the better energy- and matter-efficiency of the plasma-based nanoscale synthesis processes. It is important to stress that the above features make it possible to also achieve much higher rates of the nanostructure nucleation and growth compared with many other nanofabrication processes. Moreover, localised nanoparticle heating effects lead to the possibility of nucleation of much thinner one-dimensional nanostructures, thus mediating the adverse Gibbs-Thompson effect mentioned above.

In many cases plasma-based processes lead to a superior quality of the nanostructures produced. For example, the level of structural defects in SWCNTs produced in arc discharge plasmas is usually lower compared with many wet chemical and neutral gas thermal processes. In addition, charging and polarization of the nanotubes substantially improve their alignment, most prominently in the direction of the electric field within the plasma sheath. Since this electric field is normal to the substrate surface, the nanotubes also align in the same direction. This is why this effect is usually referred to as the vertical alignment of one-dimensional nanostructures. The electric field alignment effects appear to be stronger for the multi-walled CNTs and substantial efforts are still required to obtain very regular arrays of vertically aligned SWCNTs.

The two issues of control of SWCNT chirality and complete elimination of the catalyst remain among the greatest scientific challenges for the coming years. Plasma-produced Fe–Ni metal alloy catalyst nanoparticles [5] as well as the application of external magnetic fields lead to substantial improvements in the SWCNT chirality distributions. On the other hand, our experiments suggest that the exposure of small features directly written on a Si wafer to high-density plasmas enables a completely catalyst-free growth of multi-walled carbon nanotubes. This possibility, without any (e.g. metal or oxide) catalysts or artificially carbon-enriched layers, still awaits its realisation for SWCNTs.

It is noteworthy that plasma-based approaches bring many other new and exciting features into nanoscale synthesis and processing. This is why we hope that the above discussion answers the first part of the question: *"what is new in what you do?"*

Why is it useful?

Let us now try to answer the second part of the question, namely *"why is it useful?"* The carbon nanotubes discussed above show a truly outstanding potential for a very large number of applications. Indeed, having very high conductivity, metallic SWCNTs can serve as inter-level (and other) conducting connections in nanoelectronics; appropriately (e.g. selected-area) doped semiconducting SWCNTs can be used as tiny p–n junctions for photovoltaic energy conversion; interconnected SWCNT networks offer tantalising prospects to achieve unprecedented nanoscale connectivity in new-generation, non-silicon-based nanodevices; unique hydrophobic properties make plasma-processed carbon nanotube arrays ideal candidates for the advanced drug/gene/protein delivery systems; and carbon nanotube arrays have been demonstrated as the darkest matter that can absorb almost 100% of the incident light. These are just a few examples among the many reported applications that benefit from the unique nanotube properties arising from their size, dimensionality and structure. The plasma-based synthesis offers many possibilities not only to improve the nanotube quality and the energy-, matter-, and cost-efficiency of the synthesis processes, but also to uniquely post-process (e.g. coat, functionalise, etc.) the nanotube surfaces to enable additional controls of their electronic, optical, bio-compatibility, and other properties.

Figs 4 and 5 show further examples of the applications of plasma-made nanomaterials and microscopic plasma processing. In addition to the multipurpose CNT arrays discussed above, these non-exhaustive examples include carbon nanowire connections between Ag nanoparticles for the 'self-organised' electronics of the future; regular arrays of highly-luminescent quantum dot arrays for the energy-efficient, ultra-bright solid-state light emitting sources; ultra-nanoporous metal-oxide nanowires for photochemical hydrogen production and nanofluidics; ultra-sensitive environmental sensors based on plasma-produced iron oxide and other inorganic nanowires; nanostructured hydroxyapatite coatings of hip and joint implants for reconstructive surgery; as well as cellular control via microscopic plasma–cell interactions for the improved bacterial sterilisation, biofilm removal, wound healing, blood coagulation, and even highly-selective treatment of malignant (e.g. melanoma) cells in cancer therapies.

Fig. 5 shows the structure of a photovoltaic solar cell of the next generation

based on plasma-made functional layers. The main photo-conversion layer is made of nanocrystalline Si (*nc*-Si). Such layers, recently produced in reactive low-temperature plasmas, contain fairly regular three-dimensional arrays of tiny Si nanocrystals with a reasonably uniform size distribution, which is very difficult to achieve otherwise. Transparent conducting oxide (TCO) layers made of the plasma-produced ZnO offer excellent light transparency and very high electrical conductivity; the latter can be effectively controlled using plasma-assisted doping. The arrays of Au nanoparticles in turn further enhance light capture via the surface plasmon-related forward scattering effect. Plasma-assisted magnetron sputtering is a very effective tool not only to produce such two-dimensional arrays, but also to control the size- and position-distribution of the nanoparticles within the arrays.

"… the next-generation solar cells are expected to significantly enhance the efficiency and reduce the cost of photovoltaic renewable energy generation"

These features of the next-generation solar cells are expected to significantly enhance the efficiency and reduce the cost of photovoltaic renewable energy generation. This is expected to be achieved by the effective use of photons from the entire solar spectrum, minimising energy losses of the photo-generated carriers, enabling multiple exciton generation (MEG) by a single energetic photon, and other exciting physical effects. Importantly, these physical effects represent a significant scientific challenge and are expected to generate exciting multidisciplinary research in the coming years.

Where there is a will there is a way

An important point to stress is that by doing fertile research in the Plasma Nanoscience field we are trying to learn how to control complex plasma-based processes, during nanoscale synthesis and processing, to produce new nanomaterials that in turn enable new functionalities in new-generation nanodevices. Most importantly, these materials and devices should be reliable, effective, energy- and cost-efficient, as well as reasonably simple in the practical applications envisaged. This is why I particularly want to emphasise the need to ultimately aim to achieve the *practical simplicity* (a 'will') by learning how to control complex physical phenomena (*controlled complexity* – a 'way') at the atomic and nanometre scales (e.g. nanoscale control of energy and matter by using the plasma-specific effects).

It is also imperative to emphasise that plasma-based nanotechnology is among the safest nanotechnologies and offers a safe nanofabrication environment with much reduced nanoparticle toxicity risks and lower exposure to hazardous gases and chemicals.

Finally, I believe that the non-exhaustive arguments in this article suggest that doing research in Plasma Nanoscience is indeed something new, exciting, challenging, useful, and also safe. I also hope that these arguments have shed some light on the question *"what is new in what you do and why is it useful?"* and will generate interest among researchers irrespective of their field, academic rank or background and will also urge them to direct their research efforts in their own fields *from controlled complexity to practical simplicity*.

Moreover, everyone is welcome to engage in this exciting and rapidly emerging research field and collaborate with us and colleagues from our large international network. I take this opportunity to thank all my coauthors and collaborators, as well as the international Plasma Nanoscience research community for their contributions and support.

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Bio

Kostya (Ken) Ostrikov is a CEO Science Leader, ARC Future Fellow, and a founding leader of the Plasma Nanoscience Centre Australia at CSIRO Materials Science and Engineering at Lindfield, NSW. His achievements include the Pawsey Medal awarded by the Australian Academy in 2008, eight prestigious fellowships in six countries, three monographs and more than 280 refereed journal papers and 80 plenary, keynote and invited talks at international conferences. His research on nanoscale control of energy and matter in plasma–surface interactions contributes to the solution of the grand and as-yet unresolved challenge of directing energy and matter at the nanoscale, a challenge that is critical for the development of renewable energy and energy-efficient technologies for a sustainable future. He can be contacted at kostya.ostrikov@csiro.au.

How Much Free Will Do We Have?

Quantum mechanics may be even spookier than we thought, as Tim Wetherall reports

In a Bell inequality scenario, a measurement made on one such entangled particle causes both it and its twin to instantly condense into a single real state, even if the two are separated by vast distance.

Quantum mechanics is inherently statistical in that it can tell you the probability of something like a nucleus emitting an alpha particle in a given time, but it can't tell you exactly when or how. In the early days of quantum mechanics this caused great consternation for many scientists, including Einstein whose dislike of this apparent randomness prompted him to protest "God does not play dice!"

Einstein and others, proposed what's now known as hidden variable theory, to get some causality back into the quantum world. In essence this says that there are mechanisms within the nucleus that lead to the emission of the alpha particle in a deterministic way, but we can't see them so they appear random to us. However in 1964, the physicist John Bell published a famous paper in which he argued that no hidden variable theory can reproduce all of the observed quantum phenomena.

A well-known and intriguing aspect of Bell's work are known as Bell inequalities. Bell proposed a situation in which something like the decay of a nucleus emits two particles simultaneously that move in opposite directions.

One of the key features of quantum mechanics is that each such emitted particle exists in a superposition of every possible state until a measurement is made, at which point they condense into a single real state. In this way, it is the actual process of making measurements that in effect 'creates' reality – strange but true.

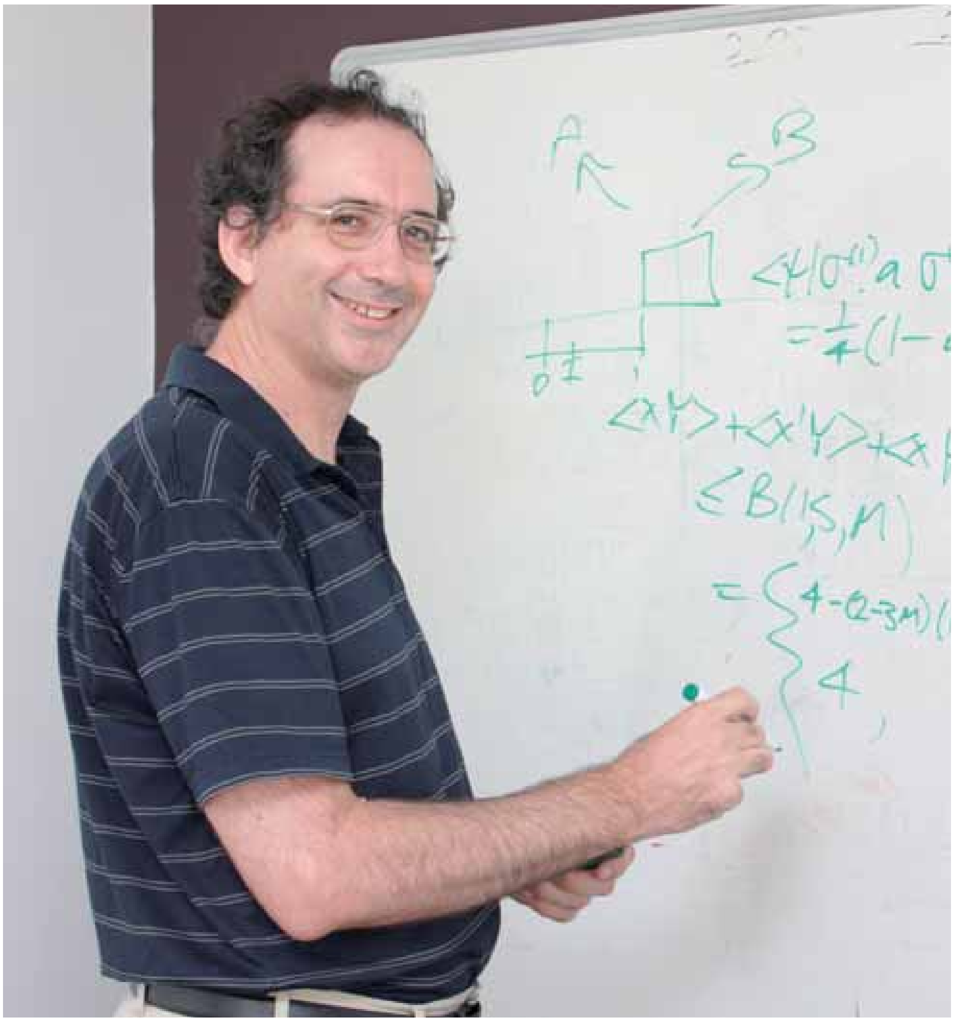
Conservation rules also dictate that if the spin of one such emitted particle is up, then that of its twin must be down. But of course until a measurement is actually made, each particle has both spin up and down at the same time. Physicists call this quantum entanglement – two particles whose states depend on each other but where both particles still exist in all possible states because no measurement has yet been made on them.

In a Bell inequality scenario, a measurement made on one such entangled particle causes both it and its twin to instantly condense into a single real state, even if the two are separated by vast distance. This notion was also intensely disliked by Einstein, who termed it "spooky interaction at a distance".

However, Bell showed Einstein could not have his cake and eat it too. His 'Bell inequality' paper proved that any hidden variable theory for quantum systems, in which observers had free will to choose what they measured, was forced to have such spooky interactions!

Of course people immediately began to ask whether a Bell inequality scenario, or something like it, could be used to create faster than light communication. The basic idea being that a pair of quantum entangled particles are sent in opposite directions from a location midway between two distant observers. If a measurement is made on one, perhaps by an alien civilisation in a distant galaxy, that would instantly affect the state of its twin here on Earth so surely that's faster than light communication right?

Unfortunately the universe doesn't work that way. The problem is, that although the effect may be instant, if we measure the spin of our particle as up, we don't know if the aliens caused that by measuring theirs as down, or if it was our own measurement that condensed the state. There are exactly as many ups as downs, so there is no way to tell. To find out you would have to send a message to the aliens and ask them what



Dr Michael Hall is patent examiner at IP Australia in Canberra. In his spare time he is a visiting fellow at the ANU Department of Theoretical Physics.

they did and of course that would have to be at sub-light speed. It would seem therefore that no faster than light signalling or information transfer is possible. However that's not to say that the physics of Bell inequalities is not interesting.

One scientist looking into the interpretation of quantum mechanics and what might or might not be possible within Bell inequalities is Dr Michael Hall, a visiting fellow at the ANU Department of Theoretical Physics. According to Hall: "It's been shown that you can't have no-signalling, determinism and experimental free will all together in a world described by quantum mechanics. You have to give up some or all of at least one. But how much of each one is a really interesting question."

"I comfort myself with the thought that, while I'm not as good a physicist as Einstein, I'm a better patent examiner!"

Dr Hall has recently published a paper [1] in the prestigious journal *Physical Review Letters* suggesting that if you give up just a little experimental free will you can accurately model a Bell inequality using the kind of deterministic hidden variable physics Einstein might have loved.

"I'm looking at what's known as a relaxed Bell inequality, that is one in which the need for absolute free will is relaxed slightly. Do that, and you can make it work deterministically without evoking faster than light signalling."

If this is indeed how the universe operates, the very strange implication would be that the apparent randomness in the spin orientation of entangled particles may be weakly coupled to the apparent randomness with which an experimenter chooses when and where to measure. In other words your free will might not be as free as you think!

"My model sidesteps Bell's theorem, by allowing the same underlying variable that predetermines the measurement outcomes to have a small statistical influence on the choices of measurement made for each particle. This influence – known as 'measurement dependence' – is not directly observable but leads to the correct quantum correlations."

Of course that slight statistical shift in the 'free' choices made by the measurer are not limited to human experimenters. If a random number generator were used, there may also be a shift in its choices though statistically the numbers it created would appear perfectly random.

How could this still appear random? Well imagine tossing a coin four times. Heads, heads, tails, tails is statistically as probable as heads, tails, heads, tails. The first might be influenced by measurement dependence the second not – how would you know?

Such an effect may have implications for quantum cryptography which relies on entanglement to send secure signals. If someone taps into the system, the entanglement is lost and the eavesdropper is sprung.

"Quantum cryptography is basically sound from a physics point of view, but our work opens up the question of the sending and receiving devices being tampered with. If someone has 'monkeyed' with your equipment, you may be exposed to data leaks hidden within the seemingly random statistics, without that being at all obvious."

In a strange coincidence, Hall and Einstein have more in common than an interest in hidden variable theories. In addition to his visiting fellowship at the ANU, Hall is also currently working as a patent examiner. "I comfort myself with the thought that, while I'm not as good a physicist as Einstein, I'm a better patent examiner!", he says.

Tim Wetherall is editor of ScienceWise magazine, published by the ANU College of Physical Sciences

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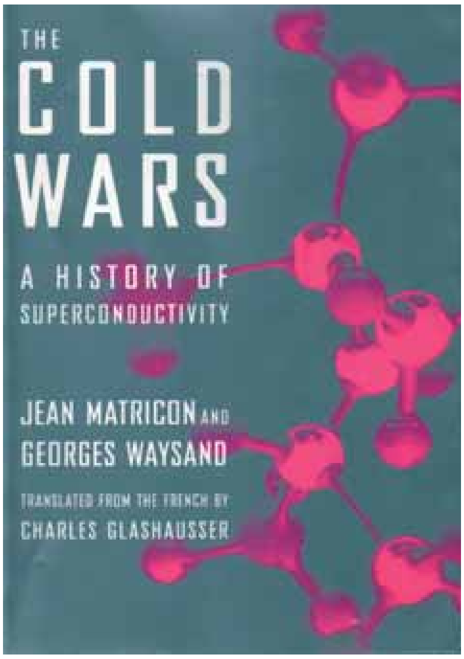
Book Reviews



The Cold Wars: A History of Superconductivity

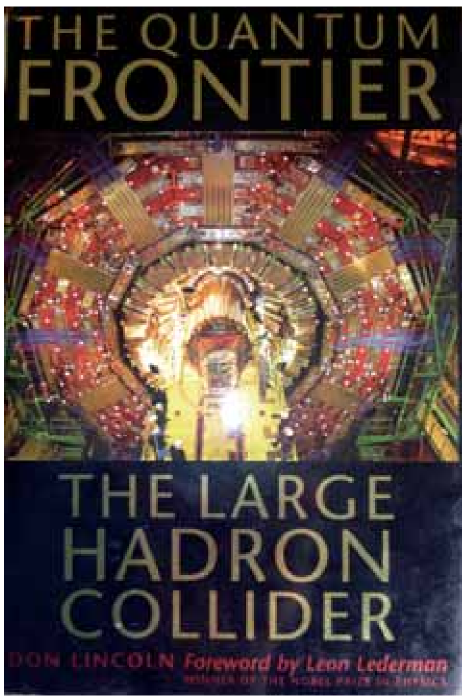
By Jean Matricon and Georges Waysand
Rutgers University Press, 271 pp., $US25
Translated from the French by Charles Glashausser
Reviewed by John Macfarlane, CSIRO Lindfield

This is an eminently readable book, although a couple of years out of date by now, with which to celebrate the Centenary Year of Superconductivity. Originally published as a French-language text in 2003, the recent translation by Glashausser brings a fascinating history to a deservedly-wider audience. Starting with a brief outline of earlier nineteenth century milestones in the production of low temperatures by pioneers such as Faraday, Joule, Kelvin and Dewar, the human aspects of the development of superconductivity research that was triggered in 1911 by Kamerlingh Onnes are brought to life. We learn, for example, that Onnes gave insufficient credit to the contribution of an assistant, Gilles Holst, who had actually carried out the crucial electrical measurements.

The 'Cold Wars' of the title is appropriate also to the political scene of the times, with an account of how Kapitza was encouraged by Rutherford to leave the Soviet Union to establish the Mond Laboratory in 1933 at the University of Cambridge, England. Stalin subsequently ordered Kapiza back to Moscow, along with much of his Cambridge equipment. Kapitza was nevertheless instrumental in securing the release of Landau, who derived a theory of superfluidity, from prison in 1940.

The works of Meissner, Ginzburg, Landau, F. and H. London, Bardeen, Cooper and Schrieffer are woven into a vivid journey leading towards our, as yet, imperfect understanding of the superconductivity phenomenon. Brilliant highlights including the Josephson effect, and the discovery of the 'high-temperature superconducting' rare-earth oxides, occupy several chapters. The main text is supplemented by no less than 20 pages of detailed Notes, and a comprehensive Index.

Whether as a serious history, or as an enjoyable weekend read, this book provides excellent value for content, entertainment, and quality. The air of disillusionment which has set in over superconducting applications in recent years is honestly conveyed, and does not in any way diminish the excitement of earlier chapters. *The Cold Wars* is highly recommended to interested laymen, teachers and students alike.



The Quantum Frontier: The Large Hadron Collider

By Don Lincoln
Johns Hopkins Press, $25
ISBN 978-0-8018-9144-1
Reviewed by Lee Weissel, Wagga Christian College

This book takes on the daunting task of seeking to explain the existence and purpose of that magnificent scientific machine known as the Large Hadron Collider (LHC). The author Don Lincoln is himself a scientist with the Fermi National Accelerator Laboratory and also author of a previous book, *Understanding the Universe: From Quarks to the Cosmos*.

What is immediately apparent in reading this book is the author's passion and knowledge for this subject. The fervour with which he writes, particularly in chapter five regarding the possible new directions and exciting new understanding of reality that may be obtained from the LHC, is infectious almost as though through the LHC we will drink from the Holy Grail itself.

The work, which is divided into five chapters, plays out as having the reader enter into the science surrounding the LHC. The audience for which the book is written seems to be the non-expert in particle physics and begins with a general appeal to the reader who has an interest in the current directions of science. Some knowledge of the periodic table, atoms, their components and indeed the standard model of matter would be beneficial, although not essential.

The book then moves into the startling revelation that there is a deep uncertainty as to what the LHC will discover. Discussion on topics such as the Higgs boson, supersymmetry and what is the smallest particle in the universe is both stimulating and contextualising in understanding the purpose of the LHC.

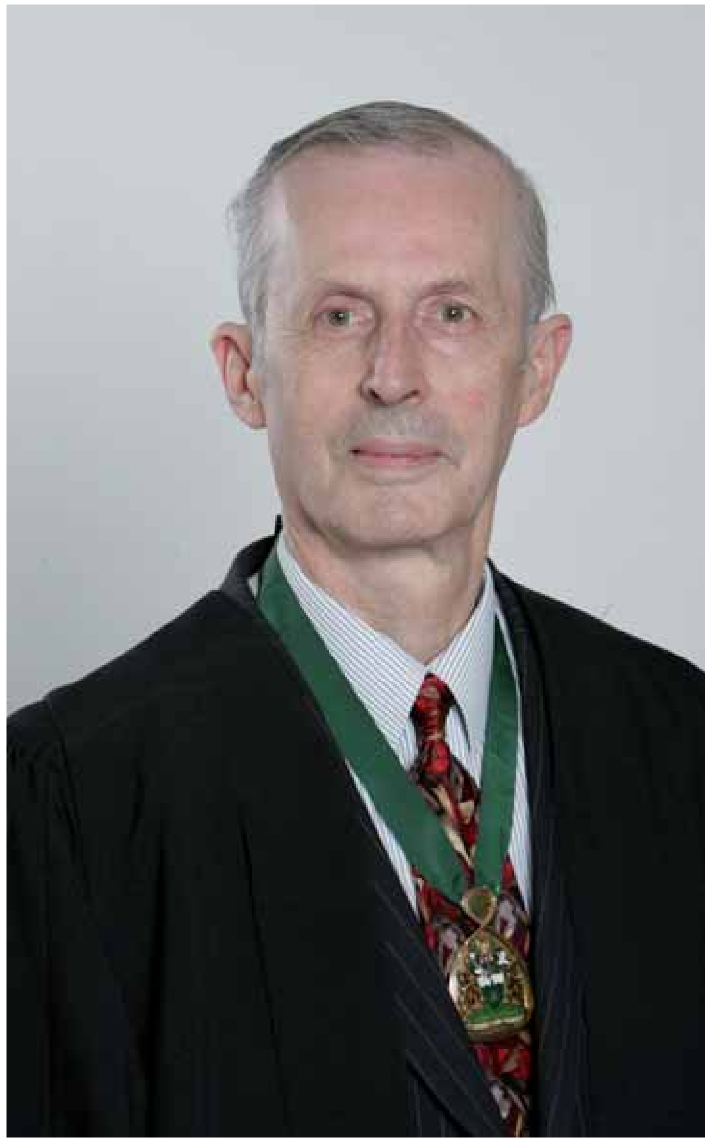
The book moves into the practical side of how this will be achieved by explaining how accelerators work, and what makes the LHC different from those that have gone before. It is in chapter four, particularly the second half of the chapter, where the detail of the book while interesting for the technical aspects presented may swamp the non-physicist reader who only seeks to understand the general concepts that the creators of the machine wish to use it for. The work closes with a discussion on much broader issues that scientists are currently tackling. The strength of the work lies within the striking detail and understanding that the author is able to bring to bear in discussing this area of interest.

My criticism of the book is its uneven emphasis on the various aspects the author wishes to cover. It is as though you wade into the work only to discover that later on you perhaps should have brought more resources with you, as it can seem to suddenly become deep. Overall though, *The Quantum Frontier* can be thoroughly recommended for an introduction to the LHC and to the contemporary frontiers of science. It is a work to whet the appetite of those enthusiasts in physics that a paradigm changing discovery could be just around the corner.

Obituary

Marshall Stoneham 1940–2011

Hamish Johnston



The theoretical condensed-matter physicist Marshall Stoneham died on 18 February 2011 at the age of 70. Stoneham, who was a fellow of the Royal Society, spent much of his career studying the effects of defects in solids and published several books on the topic. In October 2010 he took over as president of the Institute of Physics, which publishes *Physics World*. His duties for the Institute will for the moment be taken over by the Institute's immediate past-president Jocelyn Bell Burnell.

Stoneham was born in Barrow-in-Furness on 18 May 1940. He completed a PhD in physics at the University of Bristol in 1965 and spent much of his career at the UK Atomic Energy Research Establishment (AERE) in Harwell, Oxfordshire, where he led the solid-state and quantum-physics group of the theoretical division between 1974 and 1989. The following year he was appointed director of research at AEA Industrial Technology and later took up the position of chief scientist of AEA Technology.

In 1995 Stoneham moved to University College London, where he became director of the university's interdepartmental Centre for Materials Research. With his wife Doreen, who is also a physicist, Stoneham founded Oxford Authentication Ltd in 1997 and remained a director at the time of his death. The small firm uses thermoluminescence techniques to establish the provenance of earthenware, stoneware, porcelain and the casting cores of bronzes.

Stoneham also served as vice-president of IOP Publishing, the publishing arm of the Institute, and was editor-in-chief of the Institute's *Journal of Physics: Condensed Matter*. In his spare time, Stoneham was an enthusiastic French horn player and even published two books in this area. He is survived by his wife Doreen and two daughters. In a statement, the Institute said that "he will be greatly missed by the physics community, and by all of us in the Institute".

Stoneham had a wide range of research interests, including the electronic structure of defects, the properties of surfaces and interfaces, the true nature of scanning-probe microscopy and diamond films. However, in recent years he had taken a growing interest in quantum-information technology and hoped to create solid-state quantum gates that are compatible with silicon and could operate at room temperature. Stoneham was also involved in various projects linking physics and medicine, including one that sought to understand how humans can discriminate between different scents and whether left- and right-handed versions of chiral molecules should smell the same or not.

Hamish Johnston is an editor of physicsworld.com.

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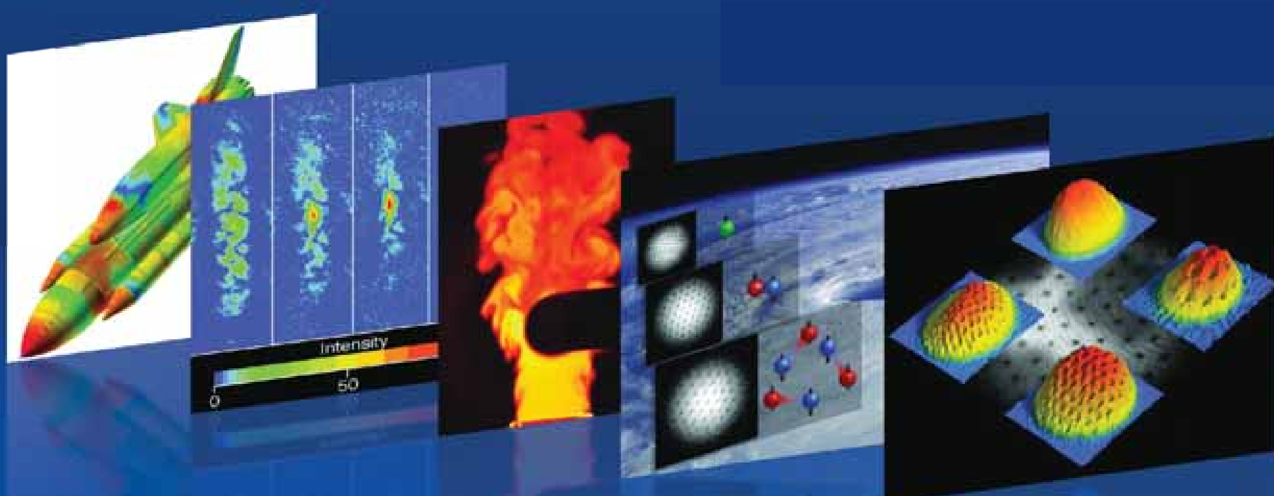

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Product News

Lastek

Lowest Profile 3-axis Nanopositioners from Mad City Lab

The Nano-LPQ is the lowest profile high speed XYZ nanopositioner available and offers 75 x 75 x 50μm travel with picometer position noise under closed loop control. The Nano-LPQ features equal millisecond

response times in XYZ, an integrated sample holder, analog and digital control with added scan synchronization features, and compatibility with major image and automation software.

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.

The Nano-LPQ is LabView™ and C++ compatible and is supplied with Mad City Labs' Nano-Route™3D software, for ease of use.

Features:

- Low profile, high speed, XYZ motion
- Built-in sample holders
- Equal speeds on all three axes
- Closed loop control

Typical Applications:

- Optical microscopy, easy to retrofit
- Optical trapping experiments
- Fluorescence imaging
- Particle tracking
- Single molecule spectroscopy

The Nano-LPS Series is the lowest profile 3 axis piezo nanopositioning systems suitable for applications such as super resolution (SR) microscopy and force microscopy. The Nano-LPS series continues the innovative design approach originally introduced by Mad City Labs. At only 20mm tall and an 83mm wide center aperture, the Nano-LPS series is designed for practical microscopy users interested in nanoscale phenomena. The Nano-LPS series features up to 300 microns of motion per axis and picometer precision under closed loop control. The low height of the Nano-LPS Series allows it to be easily integrated into existing inverted optical microscopes. Like the related Nano-LP Series, the Nano-LPS Series is ideal for demanding microscopy applications which require long range travel, fast scan rates, and three axes of motion.

Mad City Labs proprietary PicoQ™ sensors enable picometer position noise with ultra high stability, which is important for demanding applications such as SR microscopy techniques.

Features:

- Lowest profile 3-axis nanopositioner available
- Large aperture for standard 3” slides
- 100 μm, 200 μm, and 300 μm ranges of motion (XYZ). Closed loop control

Typical Applications:

- Optical microscopy, easy to retrofit
- Optical trapping experiments
- Fluorescence imaging
- Alignment
- Single molecule spectroscopy

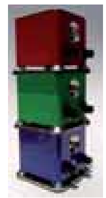
Ocean Optics acquires Sandhouse Design

Ocean Optics extended its product family after acquiring Sandhouse Design, LLC.

Sandhouse developed a unique line of high-powered LED light sources for research and spectroscopic applications.

These products have been widely used in biotechnology, process control and industrial applications.

LED Light Sources



These ergonomic and smartly designed fiber-coupled LED light sources are ideal for fluorescence, spectroscopy and general fiber illumination applications. The Ultra LED high-power light sources can be operated in continuous or external trigger modes. Available in UV, VIS and Infrared.

SIR Scanning Spectrometers

The SIR Scanning Spectrometer Series from Ocean Optics provides you a range of fiber-based spectral data collection in a detection instrument that is built to last and always reliable.

These SIR Scanning Spectrometers feature USB 2.0-compliant interfaces that provide fast data transfers. Plus, the included software can be used to control all of your SIR spectrometer's functions as well as analyse data.

The SIR spectrometer family includes:

- SIR-1700: 400-1700 nm
- SIR-2600: 0.9-2.6 μm
- SIR-3400: 1-3.4 μm
- SIR-5000: 2-5 μm
- SIR-6500: 3.0-6.5 μm

Deep UV LEDs

Sandhouse Deep UV LEDs are available in a wide range of wavelengths and package sizes. These devices are manufactured using AlGaN/GaN technology, which enables a new generation of high band-gap energy opto-electronics devices, able to perform down to 240 nm.

Latest News from Toptica Photonics

Multi-Colour Systems – Multi-Laser Engines and Tunable VISible Lasers

Three exciting new systems are now available from Toptica:

iChrome MLE-L

Multi Laser Engine with up to three diode lasers and one DPSS Laser fully integrated in one compact box.

- Multi-line laser with up to four laser lines
- Wavelengths diode lasers: 405, 445, 488 and 640 nm (375, 473, 660, 785 nm and others on request)
- Wavelengths DPSS laser: 532 and 561 nm (505, 515, 594 nm and others on request)

iChrome MLE-S

All-diode Multi Laser Engine with up to four diode lasers fully integrated in one compact box.

- Multi Line Laser with up to four diode laser lines
- Available wavelengths: 405, 445, 488 and 640 nm (375, 473, 660, 785 nm and others on request)
- High free-space and fibre coupled output power levels

Common to both MLE models

The individual lasers are efficiently combined and delivered free beam or via an all-in-one PM/ SM fibre output. The microprocessor controlled system enables flexible OEM integration. High speed analogue and digital modulations allow fast switching of laser wavelength and intensity.

TOPTICA's ingenious COOL^{AC} technology automatically aligns the system with a single push of a button. This feature ensures a constant optical output level even under strongly varying ambient conditions and completely eliminates the need for manual realignment - making the iChrome MLE the most advanced multi-line laser system on the market.

- Single mode, polarisation maintaining fibre output or free beam COOLAC technology for highest coupling efficiency, ultimate stability and drop-shipment capability
- Direct modulation and fast switching between wavelengths
- True one-box solution with integrated electronics
- Unique features: COOLAC, FINE and SKILL technology
- Most compact and cost effective solution for multicolour biophotonic applications

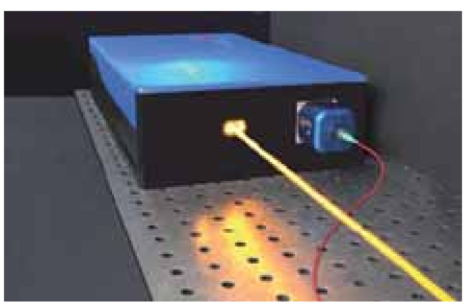
iChrome TVIS

Our ultrachrome picosecond laser is:

- Continuously tunable in the visible range of 488 – 640 nm
- Fibre coupled output (single-mode)
- Fully automated operation
- Pure colour, narrow emission bandwidth (< 3 nm)
- Perfectly suited for fluorescence lifetime imaging microscopy (FLIM) or optical testing of components

The iChrome TVIS laser system is a fibre laser with the flexibility to set automatically the laser output to any wavelength in the visible (488 – 640 nm). The coherent laser output ensures that the visible light exhibits the best intensity noise performance and the use of polarisation maintaining optical components a stable linear polarisation of the fibre coupled output beam is achieved. The entire laser system is extremely user friendly: No alignment procedures of any optical components distract the user from the main task – to produce results.

DL-RFA-SHG pro @ 589nm 2 Watt, single line for sodium cooling



The new DL RFA SHG pro is a narrow-band tunable continuous wave laser for sodium cooling. The system is based on a near-IR diode laser in the successful 'pro-design' (DL 100/pro design, 1178 nm), with a subsequent Raman fibre amplifier (RFA) and a resonant frequency doubling stage (SHG pro).

The DL RFA SHG pro features a spectral linewidth below 1 MHz and 20 GHz mode-hop free tuning. For system operation, no water cooling and no external pump is required. The power scalable approach of the DL RFA SHG pro also offers solutions for other high power applications such as sodium LIDAR, medical therapy or super resolution microscopy. Customised systems with higher output powers up to 10 W are available on request. Wavelengths between 560 and 620 nm will soon be available as customised solutions.

FemtoFiber pro – the product family is expanded

After the successful introduction of the FemtoFiber pro IR, NIR and SCIR models, TOPTICA is now taking the final step to also include the remaining system variants such as tunable visible (TVIS), tunable near-infrared (TNIR) and tunable ultra compressed pulse (UCP). Options such as variable repetition rate (VAR) and a phase-locked loop Laser Repetition rate Control (LRC) by TOPTICA's well-established PLL-electronics are rounding up the FemtoFiber pro product family.

The first and fastest of the new models, UCP, shows short pulses in the range down to 13 fs, the fastest available on the market from a turnkey SAM modelocked fibre laser system.

The TVIS expands the super-continuum generation (SCIR) by a tunable second harmonic generation and allows transferring femtosecond pulse generation into the visible wavelength range from 490 to 700 nm.

The TNIR variant finally adds a new feature to the FemtoFiber pro family. As opposed to the TVIS, it uses the high-band continuum (>1560 nm) for second harmonic generation. This continuum part is a solitonic pulse and therefore needs no pulse compression. The output wavelength can be tuned from 800 to 1100 nm. This variant was not previously available in the FFS product family.

For more information please contact Lastek at sales@lastek.com.au
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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.

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.

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
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Tel: +61 2 9319 0122
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www.warsash.com.au

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

Coherent

PI-MAX3 Intensified CCD Cameras

Princeton Instruments' PI-MAX series of intensified CCD cameras has set the standard for time-resolved imaging and spectroscopy for almost a decade. Now Princeton's PI-MAX3 takes ICCD performance to a new level with order of magnitude speed improvements and a host of new features to allow easier and more accurate time-resolved imaging.

PI-MAX3 is available in formats of 1024 x 1024 pixels for imaging and 1024 x 256 pixels for spectroscopy. Video frame rates can be achieved in the imaging format and spectral rates of thousands of spectra per second can be achieved. Most importantly, the camera allows sustained gating rates up to 1 MHz, a 20-fold improvement over previous designs.

The camera includes the improved SuperSynchro timing generator, SyncMaster clock output, a compact 'one-box' design, convenient GigE interface and much, much more.

For further information please contact Paul Wardill on sales@coherent.com.au:
Coherent Scientific
116 Sir Donald Bradman Drive, Hilton SA 5033
ph: (08) 8150 5200 ; fax: (08) 8352 2020
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Light-Field 64-bit Acquisition Software

From the world leaders in optical spectroscopy and CCD/EMCCD/ICCD technology comes LightFieldTM, an all-new 64-bit data acquisition platform for spectroscopy and imaging. LightFieldTM combines complete control over Princeton Instruments' cameras and spectrometers with easy-to-use tools for experimental setup, data acquisition and post-processing.

LightfieldTM ensures data integrity via automatic saving to disc, time stamping and retention of both raw and corrected data with full experimental details saved in each file. LightFieldTM works seamlessly in multi-user facilities, remembering each user's hardware and software configurations and tailoring options and features accordingly. The optional, patent-pending IntelliCal package is the highest-performance wavelength calibration software available, providing up to ten times greater accuracy across the entire focal plane than competing routines.

Features include:

- Immediate data acquisition upon launch
- Progressive disclosure - contextual menus ensure that only relevant options appear
- Graphical hardware configuration builder ensures that system elements work exactly as the end user expects
- Dark gray GUI reduces monitor brightness; monitor dims automatically during acquisition
- All experimental parameters are saved to data file headers - no more searching old notebooks for data acquisition settings
- Automatic light saturation warning with pseudocolour
- Multiple regions of interest can be defined in a single window
- Save and reload experimental settings and share between multiple users
- Configurable setting dock holds preferred commands
- Control multiple cameras via multiple instances of LightField
- Drag-n-drop data into Excel, Paint and Notebook or export to TIFF, FITS, CSV etc.
- Peak find function works with both narrow and broad lines
- IntelliCal provides up to ten times improved accuracy

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eXcelon…CCD and EMCCD sensitivity redefined

Princeton Instruments and Photometrics are pleased to announce the launch of new eXcelon back-illiminated charge-coupled device (CCD) and electron-multiplication CCD (EMCCD) detector technology that will revolutionise scientific imaging and spectroscopy.

New eXelon sensors provide excellent photon-detection capabilities across a wide spectrum, from 200 to 1100nm, and are particularly beneficial for applications requiring enhanced sensitivity in the blue and near-infrared (NIR) region, as illustrated below. In addition, eXcelon back-illuminated sensors significantly reduce etaloning (the problematic appearance of fringes).

When eXelcon technology is applied to EMCCD devices, the result is a detector with sub-electron read noise, superb sensitivity, low dark current, little (if any)

etaloning and high frame rates.

New eXcelon technology will be featured in Princeton Instruments' PIXIS and ProEM deep-cooled cameras and is available in several pixel-array formats:

- 1340 x 100 and 1340 x 400 CCD cameras for spectroscopy
- 512 x 512 and 2048 x 2048 for imaging

The technology is also available in 512 x 512 and 1024 x 1024 ProEM EMCCD cameras.

These new eXcelon-enabled cameras will target a wide variety of applications in both the life and physical sciences. Examples include astronomy, Raman spectroscopy, live-cell imaging confocal imaging, total internal reflection fluorescence microscopy (TIRFM), Forster resonance energy transfer (FRET), Bose-Einstein condensate (BEC) imaging, solar cell inspection, as well as super resolution techniques such as STORM and PALM.

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Physics Decadal Plan

The Australian Academy of Science is overseeing the development of a new Decadal Plan for Physics. The AIP has been charged with the responsibility of running the process of developing the plan. A similar process was last run in 1993 which produced the publication 'Physics: A Vision for the Future'. The Australian Research Council has granted funds to support the development of the new plan.

Michelle Simmons (UNSW), in her role as the Chair of the Academy of Science National Committee for Physics, has appointed David Jamieson (UMelbourne and past AIP president) to convene a Working Group to take the process to the next stage. The Working Group includes Hans Bachor (ANU), Cathy Foley (CSIRO), Ian McArthur (UWA), John O'Connor (UNewcastle), Halina Rubinsztein-Dunlop (UQueensland), Brian James (USydney and past AIP president).

The Working Group has been busy interviewing a large number of physicists in academia, CSIRO, DSTO, ANSTO, schools, industry, government, representative organisations and many other segments of the physics community. There was also a second interview process to establish the research resource requirements of the various physics sub-disciplines and their views on what the big opportunities for research are for the next 10 years. From these interviews the common issues affecting all will be identified and specific requirements for solutions will be developed.

The Decadal Plan consists of two broad components. The first is an inward looking component which will consist of a survey of Physics in Australia today to show how the discipline has evolved since 1993 and identify the significant areas of activity and expertise. The second is a forward looking component that aims to identify emerging opportunities that can be highlighted and developed. The Plan aims to have a broad audience and will serve to make the excitement and potential of Physics in the twenty-first century accessible to a wide audience.

Both components have called for comment and vision from the Physics community through a website, town hall meetings and the call for white papers. The deadline for submission of white papers was the beginning of April 2011. Most important has been the opportunity for delegates to the 2010 AIP Congress last December to present their views at dedicated sessions that were held during the Congress week.

A further six months of consultation and review will follow before the draft plan, provisionally titled 'Investing in the future of Physics' which will be presented to the Academy in July 2011.

Further information is available at http://www.physicsdecadalplan.org.au/home.

Conferences

29 May – 3 June 2011
Fourth International Conference on Chaotic Modelling, Simulation and Applications
Agios Nikolaos, Greece

28 June – 1 July 2011
Twenty-fifth International Union of Geodesy and Geophysics (IUGG) General Assembly: Earth on the Edge
Melbourne Convention & Exhibition Centre

1 – 3 July 2011
Astronomical Society of Australia's Harley Wood Winter School
Adare House, Victor Harbor, SA

4 – 8 July 2011
Astronomical Society of Australia's Annual Science Meeting
University of Adelaide, SA

4 – 8 July 2011
Fifteenth International Conference for Women Engineers and Scientists (ICWES15)
Adelaide Convention Centre, SA

19 – 22 July 2011
American Association of Physics Teachers (AAPT) 2011 Summer Meeting
Omaha, Nebraska

30 July – 3 August 2011
Twenty-second General Assembly and Congress of the International Union of Crystallography (IUCr)
Madrid

22 – 31 August 2011
URSI General Assembly and Scientific Symposium of International Union of Radio Science
Istanbul, Turkey

13 – 20 August 2011
IQEC/CLEO Pacific Rim 2011
Sydney

28 August – 1 September 2011
International Conference on Nanoscience & Technology, ChinaNANO 2011
Beijing

7 – 9 September 2011
Thirty-sixth Annual Condensed Matter & Materials Meeting
Charles Sturt University, Wagga Wagga

31 January – 3 February 2012
Queensland Astronomy Education Conference (QAEC)
Brisbane

25 February 2012
Thirty-sixth International Conference on High Energy Physics, ICHEP2012
Melbourne Convention and Exhibition Centre

4 – 11 July 2012
Nuclei in the Cosmos 2012
Cairns Convention Centre, Qld

5 – 10 August 2012
Fifteenth International Conference on Small-angle Scattering, SAS 2012
Sydney

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