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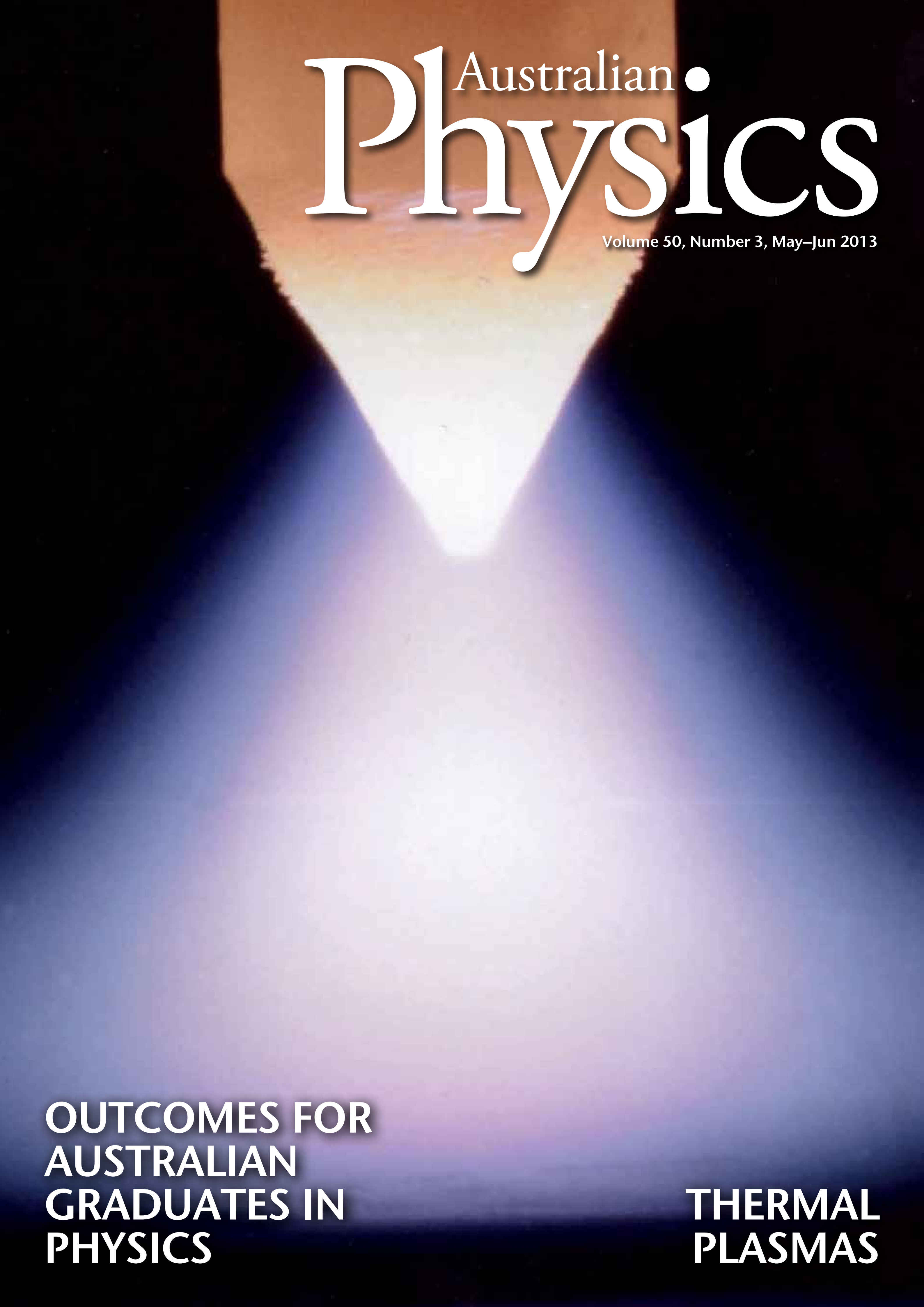

OUTCOMES FOR AUSTRALIAN GRADUATES IN PHYSICS

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& Optoelectronic Accessories

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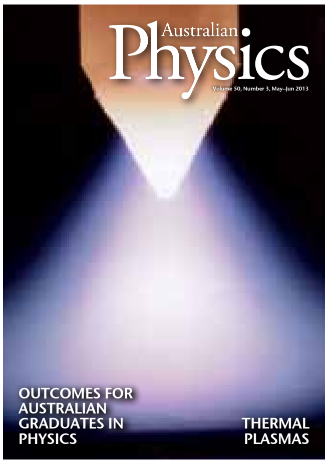

Cover

An arc in a mixture of helium and argon; the helium, which appears pink, becomes concentrated in the centre due to demixing. © 1999 IEEE. Reprinted, with permission, from A. B. Murphy, Color separation in an argon–helium arc due to radiative properties and demixing, *IEEE Trans. Plasma Sci.*, **27**, 31, 1999.

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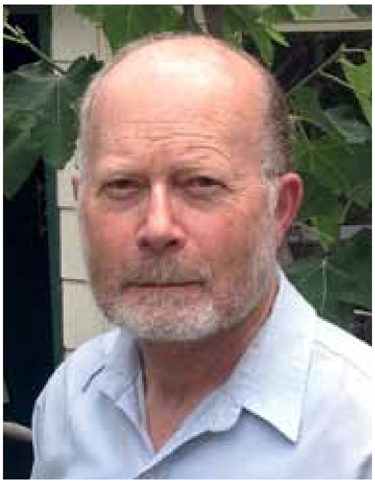
EDITORIAL

Vale Tony Farmer



It is with great sadness that I take on the role of acting editor following the recent death of Tony Farmer in a helicopter accident. Tony had just completed editing his second issue of Australian Physics at the time of his death. When invited to consider becoming editor, Tony accepted with great enthusiasm and was anticipating a tenure of several years, during which he expected to oversee evolution of the journal to include a greater online presence. I will miss very much Tony's enthusiasm and attention to detail. Also killed in the accident, along with John Dunlop and Gerry Haddad, was Don Price, who for many years selected items for the Samplings section.

The first article in this issue is by Tony Murphy, CSIRO Materials Science and Engineering, who was awarded the 2012 Harrie Massey Medal by the Australian Institute of Physics and the Institute of Physics for his "outstanding research in the field of thermal plasmas, in particular his work on computational modelling and measurement techniques and their application to the development of industrial processes". The award is made every two years for contributions to physics or its applications by an Australian physicist. In the article, which expands upon a talk he gave at the 20th AIP National Congress in December 2012, Tony shows how the scientific effort of developing realistic models has been rewarded by outstanding achievements in industrial applications in Australia and overseas.

In the second article, Margaret Wegener, University of Queensland, describes the development of Threshold Learning Outcomes for Australian graduates in physics. This follows a wider project to establish Learning and Teaching Academic Standards for Science degrees in Australia, which was completed in 2011 by a committee that included representation from the AIP. It triggered projects to establish more specific standards for the various discipline areas. The development of the physics standards was carried out by widely representative goup of tertiary physics educators, under Margaret's leadership. The standards specify what graduates will know and be able to do upon completion of a major in physics. Such standards, developed by the disciline, have a crtical role to play in compliance frameworks and professional accreditation. At the same time they provide a reference for evaluating existing physics degree programs, and guidance for future curriculum development.

Brian James

Tough times: Mourning the loss of friends and preparing for the September Federal Election

Recent weeks have been tinged with sadness with the loss of four CSIRO physics colleagues, including Tony Farmer the editor of this magazine, in a tragic helicopter accident on Thursday 21st March at Bulli Tops, just south of Sydney. Tony Farmer had worked with CSIRO from 1973 and since his retirement in 2010 was involved as a Fellow at Lindfield. Gerry Haddad was with CSIRO from 1982 until 2007 and his partner Jacqui De Battista also worked at CMSE as Communication Manager and is now retired. Don Price started at CSIRO in 1982 and retired in 2009, but continued as an honorary Fellow. Don was the son of Sir James Robert (Jerry) Price who was a member of the executive from 1966-1970 and Chair of CSIRO 1970-77. Between Don and Jerry they had nearly 70 years in CSIRO. John Dunlop worked with CSIRO from 1976 until 2008 and his partner of 15 years was Vivian Cateaux, former personal assistant to Gerry Haddad.

And then, on the Monday of the following week, another CSIRO physics colleague, Steve Wilkins, died unexpectedly of a heart attack while lecturing at Monash University. Many will know Steve from his major contributions in optics and X-rays, and more broadly to physics and crystallography. He was a key player at the Australian Synchrotron. Indeed one of Steve's last invited talks was as a keynote speaker at the meeting "Taking X-ray phase contrast imaging into mainstream applications", which was held at The Royal Society in London in February, 2013.

For myself, I had treasured Steve's wise and cogent advice, over the last three years, on the new neutron-imaging facility which is nearing completion at Lucas Heights, as part of the Government's Super-Science Initiative, through his involvement in the Beam Instruments Advisory Group. And John Dunlop had served on the same committee in a similar capacity towards the end of the initial instrument build at the OPAL Reactor. And of course, John and Don had been active and regular participants at the annual Wagga-Wagga condensed-matter physics meetings. We will miss all of them.

Changing subjects, as the Federal Budget comes closer, it is becoming clearer that the coming year is going to be much tougher for research in Australia. On 14th April, the Federal Government announced $2.3 billion in cuts to the university sector. The AIP is a major player within the umbrella organisation Science and Technology Australia (STA, and formerly known as FASTS) and its president, Professor Michael Holland, promptly put out the following media statement:

"We represent 68,000 people working in science and technology across Australia. Dr Emerson's announcement that $2.3 billion will be slashed from Universities to contribute to school reforms, is profoundly disappointing. The cuts will have a direct effect on the day-to-day work of Australia's Science and Technology workforce, who fuel national productivity and innovation. Cutting universities to fund schools just doesn't make sense. It is counterproductive, short-term policy making at its worst. It is difficult to predict how universities will extract the savings from already stretched budgets, but one thing is certain, the cuts will damage the quality of education and research they can provide. This will hurt students and the nation. Australian Universities are already struggling to keep pace with international competitors - this will leave them falling further behind. This is a shameful waste of national talent, and simply not good enough for a nation that is supposed to be undertaking an education revolution. While this is an attack on the public sector, it is bound to have knock-on effects for the private sector, at the very least limiting the kind of collaborative work that is critical to solving the big issues facing the nation and the world. Australia's scientists call on the Government to reconsider the cuts as a matter of urgency. We also call on the Coalition to reject the cuts, and commit to reversing them should they win office in the Federal Election".

As I mentioned in last month's column, I would urge all of our members to contact the candidates for the upcoming Federal election, and discuss the issues related to science, and physics in particular, with them.

Rob Robinson

New CEO for Science & Technology Australia

Catriona Jackson has become the new CEO of Science & Technology Australia, the nation's peak body for science and technology. Ms Jackson brings a 25-year background in politics at the senior level in the federal arena (in government and opposition), in tertiary education and in print and radio journalism. Most recently she led the Communication and External Liaison Office at The Australian National University and prior to that was a senior staff member for Minister Senator Kim Carr.

Ms Jackson replaces Anna-Maria Arabia, who has served as CEO of Science & Technology Australia for the past 3 years and has now taken up a senior position at Questacon. In welcoming Ms Jackson to Science & Technology Australia president, Professor Michael Holland noted that "Ms Jackson will be a forceful and intelligent advocate for the sector and we welcome her to this challenging role as we enter a critical election year."

Woman of the Year award to Dr Cathy Foley

Dr Cathy Foley, Chief of the CSIRO's Materials Science and Engineering Division, has been awarded one of two NSW Premier's Awards for Woman of the Year for 2013.

For the last 28 years, Cathy has been actively promoting the role of women in physics and science. Her determination to see women excel in the field has seen her form numerous groups including the AIP Women in Physics Group, Women in Superconductivity and Women in Science Enquiry Network. She was the keynote speaker at the first Women in Science and Engineering Symposium held at Parliament House in Canberra in 2007. Cathy was President of the Australian Institute of Physics (2007-8) and Science and Technology Australia (2009-11). She has served on several boards and advisory groups, including the Prime Minister's Science, Engineering and Innovation Council.

Dr Foley's scientific achievements include LANDTEM, a system for mineral exploration that has contributed to the detection of more than $6 billion worth of mineral deposits worldwide. Her enthusiasm, professionalism, resourcefulness and pragmatism have made her an ideal role model for young women around Australia, especially in science where there are still relatively few women at the highest levels.

ANSTO: 60 years of nuclear innovation

Sixty years ago, in 1953, Federal Parliament passed the Atomic Energy Act establishing the Australian Atomic Energy Commission (AAEC). In 1981 parts of the Commission were split off to join the CSIRO. The remainder continued until 1987, when it was replaced by the Australian Nuclear Science and Technology Organisation (ANSTO). Having long since moved on from nuclear power research, ANSTO today is a state-of-the-art scientific campus: home of the $460 million OPAL research reactor and the workplace for 1000 scientists, engineers and experts working in fields as diverse as medical and environmental research.

ANSTO's Chief Executive Officer, Dr Adi Paterson, said that perhaps ANSTO's most vital role is its contribution to the Australian medical system – creating and distributing 10,000 doses of nuclear medicine to 250 hospitals and medical centres a week.

"Today ANSTO enables environmental scientists, biologists, geneticists, material scientists and many others to use nuclear techniques to inform their research and deliver new insights that are helping to address some of the big issues of our time, particularly surrounding health and climate change.

"ANSTO is much more than a research facility: we use nuclear technologies to support local industry, to produce 85 per cent of Australian nuclear medicines and serve the microelectronics and minerals industries globally.

"That medical role will be enhanced in coming years, thanks to the Federal Government's recent announcement of $168 million to dramatically enhance Australia's nuclear medicine capacity by building a new nuclear medicine manufacturing facility at ANSTO."

A photograph gallery highlighting some of the history of ANSTO is available at **http://www.ansto.gov.au/AboutANSTO/60thanniversary/photogallery/index.htm**

Prime Minister Robert Menzies officially opening the HIFAR reactor in 1958, in the presence of AAEC Chief Scientist Charles Watson-Munro.

NMI Award for 2013

The National Measurement Institute (NMI) has awarded the NMI Prize for 2013 to Dr Daniel Creedon of the University of Western Australia for his contributions to research in measurement techniques.

Dr Creedon made measurements on a Whispering Gallery Maser Oscillator (WGMO) which demonstrated the nature of the processes limiting its performance, thus pointing the way to further improvements for the WGMO as a next generation ultra-stable frequency standard. He improved the stability of the WGMO and developed an improved measurement system that allowed characterisation of the WGMO without adding noise.

Dr Creedon characterised crystal sapphire oscillators at very low temperatures, thus discovering a new operational range with the potential for even better frequency stability. With precise characterisation, he also discovered non-linear effects which have potential application to a number of quantum technologies and to the generation of microwave frequency combs.

The NMI Prize is an annual award that acknowledges and celebrates outstanding achievement in measurement research and/or excellence in practical measurements by a young individual working in academia, research or industry in Australia. It is one of two annual awards (the other being the Barry Inglis Medal) made by NMI In recognition of World Metrology Day, an international annual event that marks the signing of the Metre Convention on 20 May 1875.

Branch News
New South Wales

On Tuesday 26 March 2013, the NSW Branch held its March meeting and featured Professor Deb Kane on the topic of "To PhD or not to PhD: that is the question". Prof Deb Kane's areas of research activity have grown and evolved. 30 years on, she shared reflections on what doing a PhD did for society and for herself. Prof Kane made suggestions on how to approach decisions on whether to do a PhD, what to do it on, where to do it, with whom as a supervisor, and how to go about it to try to optimise "downstream" benefits. The talk was aimed to be of interest to all in physics, and particularly to students of physics contemplating a PhD, and any science "PhDs-to-be". The NSW Branch of the Australian Institute of Physics thoroughly thanks Professor Deb Kane for her outstanding lecture!

From left to right, Dr Fred Osman, Prof Deb Kane, Dr Keith Suter and Jane Phelan

Computational modelling of thermal plasmas – from scientific resource to industrial tool

Anthony B. Murphy*

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There have been remarkable advances in the computational modelling of thermal plasma processes, such as arc welding, over the past 20 years. Once limited to explaining experimental results, modelling is now used to develop and design industrial processes. Much of this progress has been based on improved scientific understanding of thermal plasmas and their interaction with materials. Some of the important thermal plasma research that has been carried out at CSIRO, and its contribution to the development of thermal plasma modelling, is presented in this article. Particular examples of the successful applications of computational modelling, to arc welding and the treatment of hazardous gases, are discussed.

Thermal plasmas

Thermal plasmas are an everyday phenomenon - anyone who has seen a lightning strike, observed the intense light produced by arc welding or used a data projector has experienced a thermal plasma. What is less appreciated is how many everyday products and processes are dependent on thermal plasmas. For example, arc welding is used to join metal components in a huge range of industries and products, such as motor vehicles, trains, power stations, pipelines and construction. Plasma cutting is used to cut thick sheets of metal rapidly and reproducibly. Plasma spraying deposits wear-resistant and thermal barrier coatings, for example on jet engine turbine blades, biocompatible coatings on artificial joints (for example, a CSIRO-developed process to deposit hydroxyapatite on artificial hips), and so on. Electric arc furnaces are used in steel production and many other metallurgical applications. Plasma waste treatment is used to destroy hazardous chemicals, and convert household and industrial waste into useful products such as syngas. Nanoparticle production, arc lighting, spheroidisation of particles, circuit interruption and thin-film deposition are all processes that commonly utilise thermal plasmas.

Plasmas are, of course, ionised gases. They form the vast majority of the visible universe, making up stars and the interstellar medium. Life on earth is dependent on the energy liberated by thermonuclear fusion reactions in the solar plasma. A huge amount of research funding has been devoted to developing controlled thermonuclear fusion as an energy source; the most-promising approach is based on the confinement of a high-temperature plasma by strong magnetic fields.

Here, we are concerned with industrial applications of plasmas. The relevant plasmas can be conveniently divided into three classes: low-pressure, atmospheric-pressure non-equilibrium, and thermal plasmas. In the first two classes, the electrons are at high temperature (typically a few eV; 1 eV ~ 11 000 K), while the heavy species (molecules, atoms and ions) are at or close to room temperature. In thermal plasmas, in contrast, all the species are at 1–3 eV.

"… how many everyday products and processes are dependent on thermal plasma"

Why are thermal plasmas hot? It is simply a consequence of the high collision rate between the particles, allowing energy to be transferred from electrons to heavy species. The high collision rate is in turn because of the high pressure, usually 1 atm, and in the range from 0.1 to 1000 atm. In low-pressure plasmas, the collision rate is much lower, while in atmospheric-pressure non-equilibrium plasmas, the individual discharges are very short-lived, so there is insufficient time for substantial energy transfer.

Thermal plasmas are useful for three main reasons: their capacity to transfer very high power densities in a controlled manner, the strong radiation they emit, and their ability to produce high fluxes of active species, such as radicals. The high power densities are vital in many applications including arc welding, plasma cutting and steel production. Arc lamps, and some metallurgical applica-

*** Tony Murphy was awarded the 2012 Harrie Massey Medal by the Australian Institute of Physics and the Institute of Physics for his research in the field of thermal plasmas.**

tions, make use of the strong radiative emission, while the high fluxes of active species are important in nanoparticle production and thermal plasma deposition.

Computational modelling of thermal plasmas

Computational modelling of thermal plasmas was, until fairly recently, limited to developing a better physical understanding of established processes; a scientific resource rather than an industrial tool. Models were at most two-dimensional, and thus limited to axisymmetric geometries; the complex geometries often present in industrial processes could not be considered. Models were restricted to a single gas, even though most industrial processes involve mixtures of gases. Only the plasma region was taken into account, with the electrodes included as boundary conditions, so the effects of the plasma on the electrodes could not be predicted; this is a particularly important problem when, as is commonly the case, the electrode is

"Thermal plasmas are fluids and can be treated using the methods of computational fluid dynamics."

the material being processed.

Today, computational modelling is an established industrial tool. At CSIRO, we have secured funding for development of models of arc welding of aluminium components from General Motors and the CRC for Advanced Automotive Technology, and the influence of lightning strikes on aircraft materials from Boeing. Modelling played an essential role in the successful application of the 'PLASCON' waste treatment process, developed by CSIRO and SRL Plasma, to ozone-depleting substances [1, 2]. The design of plasma-cutting torches is heavily reliant on computational models; the major manufacturers of plasma cutting systems, such as Hypertherm, Tanaka, Cebora and Farley, all either use in-house or contract modelling expertise. The scale-up of particle spheroidisation and nanoparticle production processes is unthinkable without the assistance of modelling, and indeed companies such as Canada's Tekna Plasma Systems employ many scientists with computational modelling expertise.

This article examines some of the advances that have allowed computational models to progress from a scientific resource to an industrial tool. While I highlight work performed at CSIRO, there of course has been, and continues to be, a large amount of related research and development performed at institutions around the world.

Equations and computational approaches

Thermal plasmas are fluids, and can be treated using the methods of computational fluid dynamics. This entails solving a series of coupled partial differential equations with appropriate boundary conditions. The applicable equations are in most cases those for viscous compressible flow. Those required in all cases are conservation of mass (mass continuity), conservation of momentum, conservation of energy, and since plasmas conduct electricity, conservation of charge (current continuity) and some of Maxwell's equations. Additional terms, specific to plasmas, appear in some equations; for example, a radiative cooling term in the conservation of energy equation. The equations are given in Ref. [3], for example.

The equations can be solved using finite volume or finite element methods. The most widely-used approach is the finite-volume method [4], implemented either in 'self-written' codes or increasingly in commercial packages. The rapidly increasing power of computers has allowed three-dimensional models to become feasible, so that complex geometries can now be treated. The mesh-generation routines supplied in commercial codes are an advantage for such geometries, but adapting the capabilities of such codes to treat thermal plasma processes can cause difficulties, in particular in dealing with the interactions between plasmas and electrodes.

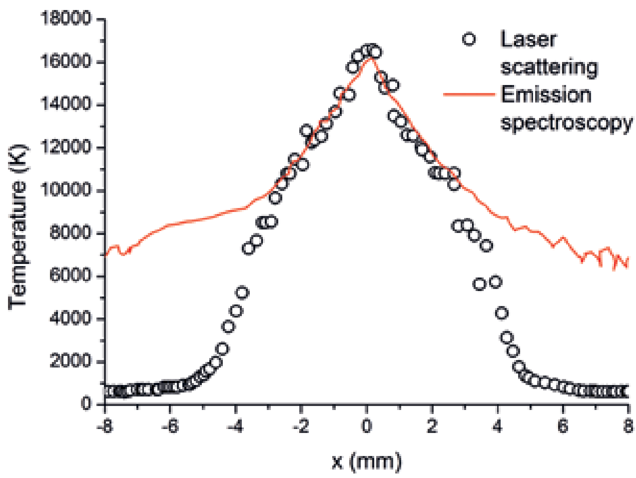

Figure 1. Radial dependence of temperature in an argon arc plasma, with arc current 100 A and length 5 mm, at a vertical position 2 mm below the upper electrode. The line shows temperatures obtained using emission spectroscopy, and the points show temperatures obtained using laser scattering.

Local thermodynamic equilibrium

An important simplifying concept in thermal plasma modelling is the assumption of local thermodynamic equilibrium (LTE). Essentially, this means temperatures

of all species at a given point in the plasma are the same: the kinetic temperatures of each species, the excitation temperatures of atoms, ions and molecules, and the temperatures of dissociation and ionisation reactions. If LTE can be assumed, only one energy conservation equation is required. If not, at least two such equations, one for electrons and one for the heavy species, are needed.

CSIRO researchers performed important work that established the validity of LTE in most regions of thermal plasmas. The most common method for measuring temperature of thermal plasmas is emission spectroscopy, typically based on the intensity of line radiation emitted by the plasma. Spectroscopic measurements of argon arc plasmas typical of those used in welding are, however, problematic; they indicate that high-temperature region extends many millimetres into the fringes of the arc, as shown in Figure 1, which is in strong disagreement with theoretical considerations.

The discrepancy was resolved by the application of laser-scattering techniques. In these experiments, a continuous-wave laser beam was directed through the plasma, and the fraction of the light scattered by the atoms, ions and electrons in the plasma was measured. The measurements were highly challenging, since the intensity of the scattered light was typically less than 10^{-9} of that of the radiation emitted by the plasma; a combination of filters to select scattering at the laser wavelength, and phase-sensitive detection, were required to obtain an adequate signal-to-noise ratio. The measurements demonstrated that the temperature in the fringes of the arc plasma was low, as shown in Figure 1, in agreement with theory [5, 6], thus establishing the accuracy of theoretical predictions assuming LTE.

Subsequent measurements of thermal plasmas performed using high-power pulsed lasers indicated that the electron temperature was several thousand kelvin higher than the heavy-species temperature, in direct contradiction to the LTE assumption. A careful theoretical investigation indicated that the heating of the electrons by absorption of the laser light had not been properly accounted for in the interpretation of the measurements [7], and the validity of LTE was once again confirmed.

Thermodynamic and transport properties

A critical requirement in modelling is accurate values of the thermophysical properties of the plasma; mass density, specific enthalpy and specific heat (thermodynamic properties), and viscosity, thermal conductivity and electrical conductivity (transport coefficients). These depend strongly on temperature, pressure and the type of gas used to form the plasma.

Calculation of these properties is a complicated task, requiring partition functions for all the species, and collision cross-sections for interaction between each pair of species. CSIRO has made two major contributions in this area. The first is the calculation of benchmark values for the thermodynamic and transport properties for all the major plasma gases. For example, Figure 2 shows the composition of an argon–nitrogen plasma, and thermal and electrical conductivity of argon, nitrogen and argon–nitrogen plasmas [8]. The thermal conductivity has peaks associated with the dissociation of nitrogen molecules, and the ionisation of argon and nitrogen atoms, while the electrical conductivity depends strongly on the electron density.

These data have been shared with academic and industrial researchers around the world, aiding progress and leading to many collaborations in thermal plasma modelling.

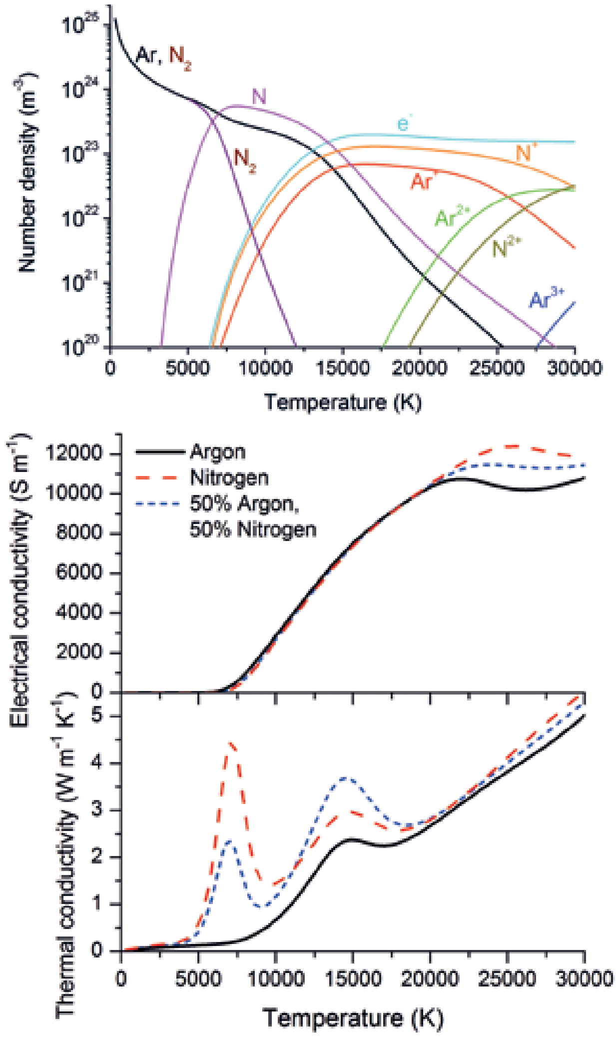

Figure 2. Temperature dependence of the composition of a thermal plasma in a mixture of 50 vol% argon and 50 vol% nitrogen at 1 atm, and electrical and thermal conductivity of this mixture, pure argon and pure nitrogen.

Combined diffusion coefficients

The second of CSIRO's main contributions to plasma property calculation is the development of the combined diffusion coefficient method [9]. Treating diffusion in mixtures containing multiple species is a difficult problem, since a separate conservation equation has to be solved for each species, and diffusion coefficients have to be calculated for each pair of species. A thermal plasma in a mixture of nitrogen and argon contains significant concentrations of N_2, N_2^+, N, N^+, N^{2+}, N^{3+}, Ar, Ar^+, Ar^{2+}, Ar^{3+} and electrons, requiring solution of 10 conservation equations and the calculation of over 50 diffusion coefficients (each of which is a function of temperature, pressure and the concentration of every species). The combined diffusion coefficient method allows the combination of species into their parent gases, so the nitrogen–argon plasma, for example, can be treated using just one conservation equation and two diffusion coefficients, without loss of accuracy. This places diffusion coefficients on the same level as other transport coefficients such as thermal conductivity, and for the first time permitted reliable theoretical characterisation of thermal plasmas in gas mixtures. The method has been very widely adopted internationally, and has been shown to be markedly superior to other approaches [10].

Demixing

The development of the combined diffusion coefficient method allowed the phenomenon of demixing to be accurately modelled. Demixing is a process, driven by diffusion, that leads to the separation of the different gases present in a plasma. It can lead to large changes in the composition of a plasma, and as a consequence, significant alterations in important properties such as voltages, and heat fluxes to surfaces.

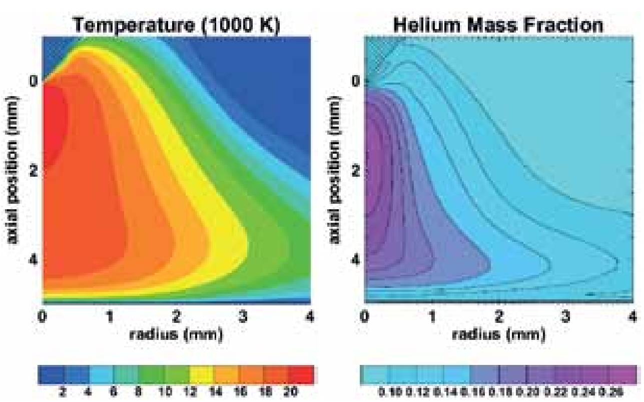

Figure 3. Calculated distributions of temperature and helium mass fraction in a 100 A arc in a mixture of 10 wt% He and 90 wt% Ar.

Figure 3 shows the calculated temperature and composition of an argon–helium arc, indicating the strong concentration of helium in the central high-temperature regions due to demixing. The predicted effects of demixing have been found to be in good agreement with experimental results [11].

Chemical reactions

In many thermal plasma processes, chemical reactions are important. For example, the development of the PLASCON process for destruction of hazardous liquids and gases required a detailed understanding of the chemical reactions that take place. By incorporating chemical kinetics into a model of the thermal plasma, it was possible to determine the important chemical reactions and where they occurred. Modelling was vital in the successful modification of the process to allow the destruction of ozone-depleting substances (ODSs), such as chlorofluorocarbons and halons. Initial experiments showed that while the process successfully destroyed the input ODS, recombination reactions led to the formation of other ODSs [1].

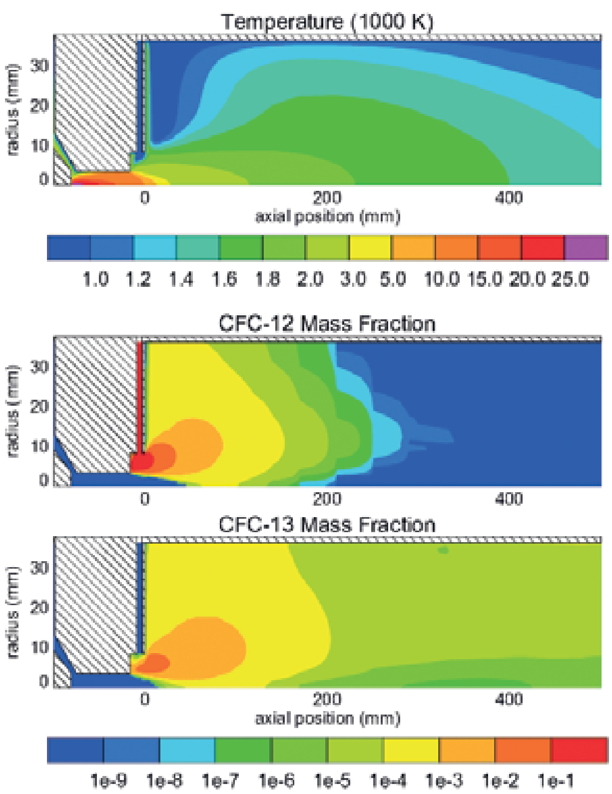

Figure 4. Calculated distribution of temperature, mass fraction of CFC-12 (CF2Cl2) and CFC-13 (CF3Cl), for typical conditions in a research-scale PLASCON reactor. The plasma torch, which produces an argon plasma jet, is at axial positions z < 0. CFC-12, mixed with oxygen, is injected from the radial edge at z ~ 0. The rapid destruction of the CFC-12, and the accompanying production of CFC-13, are clearly apparent.

An understanding of the chemistry developed through modelling allowed this problem, illustrated in Figure 4, to be addressed by the introduction of steam into the plasma. The hydrogen produced by dissociation of the water molecules rapidly combines with free halogens to form HF, HCl and HBr, preventing the unwanted recombination reactions [2].

PLASCON plants now operate around the world, destroying the waste products of agricultural chemical manufacture (Australia), polychlorinated biphenyls (Australia and Japan), ozone-depleting substances (Australia, USA and previously UK; practically all of Australia's stockpile of these substances, over 1500 t, has been destroyed using PLASCON), and the major greenhouse gas trifluoromethane (USA and Mexico; each plant continuously destroys greenhouse gases equivalent to the CO_2 released by a 400 MW coal-fired power plant).

Inclusion of electrodes

Accurate and reliable modelling of thermal plasmas requires the electrodes to be included in the computational domain. In many applications, such as arc welding, the material being processed is an electrode, so the temperature of the electrode is a vital process parameter. Further, the electrode temperature plays an important role in determining the current density in the plasma, which can strongly influence the plasma temperature and the arc voltage. The interactions between plasmas and electrodes are extremely complex; CSIRO researchers have concentrated on developing approaches that combine a reasonable level of accuracy with an acceptably low level of computational overhead.

A complicating factor in developing treatments of electrodes is that different phenomena must be considered for different electrode polarities and materials. For example, cathodes composed of refractory materials such as tungsten, hafnium and graphite can reach the temperatures of over 3000 K that are required to emit large electron current densities by thermionic emission [12]. Other materials, such as copper, aluminium and steel, vaporise before reaching such temperatures; the mechanism of electron emission is more controversial in this case [13]. A particular problem in treating the anode arises because the plasma temperature close to the anode is typically only 3000 K, and at such low temperatures, a plasma in LTE does not conduct electricity (as can be seen in Figure 2). Methods have been developed to address this problem by taking into account deviations from LTE [14], or by an appropriate choice of computational mesh [15].

Electrode melting

An additional degree of complexity arises when the melting of the electrodes occurs. This is of particular importance in gas–metal arc welding, the most widely-used form of arc welding in industry, shown schematically in Figure 5. In this process, the upper electrode is a metal wire, which melts to form droplets. The droplets pass through the arc and into the weld pool (the molten region of the lower electrode).

Calculation of the shape of the molten regions is a difficult problem. CSIRO pioneered the application of the volume-of-fluids (VOF) method to the modelling of the formation of the molten droplet at the tip of the metal wire [16]. In the VOF method, the location of the liquid–plasma boundary is calculated taking into account the liquid flow velocity. While the VOF method has many advantages, it is difficult to implement, and highly computationally intensive. As a consequence, simpler approaches are preferred in industrial models. The influence of the droplets has been treated using a new method, in which the mass, momentum and energy transferred between the molten droplets and the arc plasma and weld pool are calculated on a time-averaged basis [17]. The surface profile of the weld pool is determined by balancing the pressure exerted by the arc and droplets against the liquid surface tension [18].

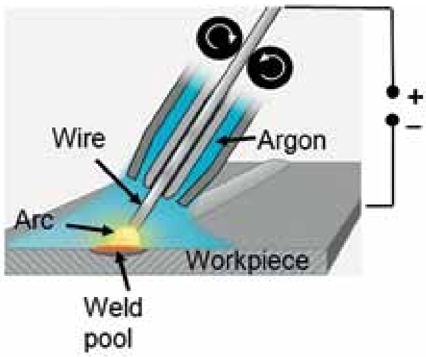

Figure 5. Schematic of gas–metal arc welding.

Metal vapour

In arc welding, and other applications of thermal plasmas, the molten metal electrodes release large quantities of metal vapour. In the last 5 years, spectroscopic measurements and computational modelling have both indicated that the metal vapour can have a major influence on the properties of the plasma, and as a consequence on the heat transfer to the electrodes [19]. For example, in gas–metal arc welding, metal vapour concentrations usually reach at least 50% below the upper electrode. Since metal atoms and ions radiate much more strongly than those of the

usual welding gases such as argon and oxygen, radiative cooling of the plasma is greatly increased, reducing the plasma temperature by a factor as large as two. Figure 6 shows the strong reduction in the temperature in the arc plasma and in the weld pool when metal vapour is considered [20].

The combined diffusion coefficient method is ideally suited to treating of the transport of metal vapour in the arc plasma. Computational models that use this method have shown good agreement with experiments, and have given detailed physical insights into the influence of metal vapour in arc welding plasmas [20, 21].

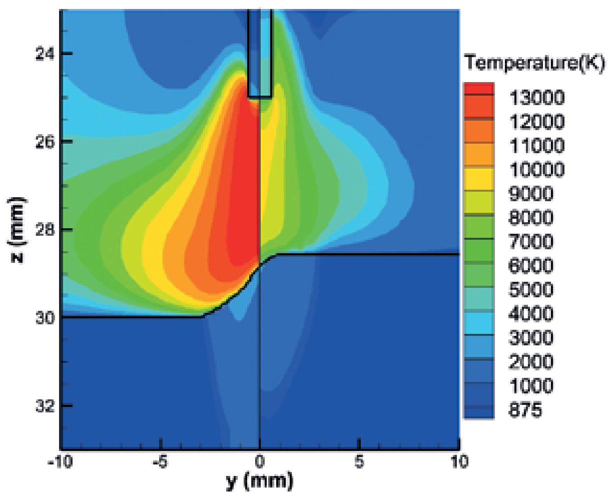

Figure 6. Temperature in a vertical cross-section through the arc and electrodes, for a 95 A argon arc and aluminium electrodes. The arc is moving to the left; the change in height of the lower electrode is due to the addition of metal droplets to the weld pool. The temperatures on the left-hand side are calculated neglecting the influence of metal vapour, and those on the right-hand side considering the influence of metal vapour. From [20].

Conclusion

Research performed at CSIRO has played an important role in the transformation of computational modelling of thermal plasmas from a scientific resource to an industrial tool. Perhaps the earliest case in which modelling led experiment was in the adaptation of the PLASCON waste treatment process to ozone-depleting substances, which was discussed above. An excellent recent example of the progress in modelling is the development of a gas–metal arc welding model for General Motors and the CRC for Advanced Automotive Engineering. The model uses many of the techniques described above; it is based on the assumption of LTE, and uses thermodynamic and transport properties calculated for mixtures of argon and aluminium vapour, with the combined diffusion coefficient method applied to treat the mixing of the vapour with argon. Electrodes are taken into account, the shape of weld pool surface is determined and the influence of the droplets is calculated using the methods referred to above. The model is able to predict the depth and shape of the weld for a range of welding parameters; an example is shown in Figure 7. General Motors are planning to use the model to help determine the optimum parameters for the many welds required in assembling motor vehicles.

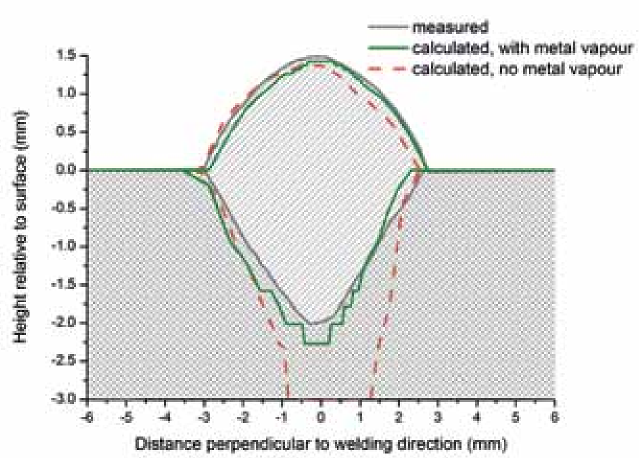

Figure 7. Comparison of measured weld cross section for gas–metal arc welding of a 3 mm sheet of aluminium, with calculated cross-sections obtained including and neglecting the influence of metal vapour on the arc. From [20].

Acknowledgements

The research presented here has been the effort of a large group of colleagues and collaborators, including John Lowke, Jawad Haidar, Trevor McAllister, Dick Morrow, Tony Farmer and Gerry Haddad of CSIRO, Manabu Tanaka of Osaka University, and Michael Schnick of Technical University Dresden.

The support provided for some of the work reported here by General Motors, General Motors Holden, and the Commonwealth of Australia, through the Cooperative Research Centre for Advanced Automotive Technology, is gratefully acknowledged.

This article is dedicated to the memory of Tony Farmer and Gerry Haddad, two of the pioneers of thermal plasma research at CSIRO, who died in a helicopter accident in March this year.

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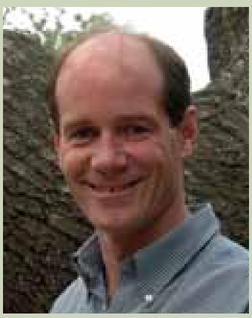

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Tony Murphy joined CSIRO in 1989, following a postdoc at Max Planck Institute for Plasma Physics in Germany and a PhD in physics at University of Sydney. He is currently a Chief Research Scientist and leads the Plasma and High-Temperature Processes Research Group. His research is directed towards the application of thermal and other atmospheric-pressure plasmas.

Tony is a member of the Editorial Boards of Journal of Physics D: Applied Physics, Plasma Chemistry & Plasma Processing and Scientific Reports. As well as the 2012 Harrie Massey Medal, he has been awarded the 2008 Alan Walsh Medal, 2000 Pawsey Medal and 1995 Edgeworth David Medal.

Development of Threshold Learning Outcomes for Australian Graduates in Physics

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University of Adelaide	Judith Pollard, Peter Veitch, Chris Chantler, Lloyd Hollenberg
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University of Queensland	Michael Drinkwater, Tim McIntyre, Anton Rayner, Margaret Wegener
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Academic standards for physics across Australian universities have been collaboratively developed, to aid with emerging regulatory requirements, and to foster good practice in higher education in physics.

This paper describes the process, and presents the results to date, of a community effort to develop agreed minimum academic standards for students graduating with a physics major from an Australian university. These standards describe what graduates will know and be able to do upon completion of a major in physics, at Bachelor level.

"…what graduates will know and be able to do upon completion of a major in Physics"

The aim is to develop truly representative and useful standards. This development of learning standards for physics is taking place in an environment of increasing emphasis on quality assurance and monitoring of standards in higher education, eg: the Australian Quality Framework and TEQSA. Agreed standards have a role to play in compliance frameworks and professional accreditation. Developed threshold learning outcomes (TLOs)for physics will provide a means for evaluation of existing physics degree programs, and be a design tool for future curriculum development. The intent is to aid genuine improvement in the quality of our programs.

Development of the standards has been an iterative and collaborative process. Standards have been expressed succinctly as TLOs. The outcomes cover knowledge,

Table 1: Bachelor Level Threshold Learning Outcomes for Physics

	Upon completion of a Major in physics, graduates will:
Understanding science	1. *Demonstrate a coherent understanding of the nature of physics by:* 1.1 Articulating how physics uses observations of relationships between measurable quantities to create conceptual frameworks which can be used to explain, interpret and predict other observations. 1.2 Identifying the role of fundamental physics concepts (such as laws of conservation) in a variety of different contexts. 1.3 Acknowledging that there are physical reasoning processes characteristic of the discipline 1.4 Explaining the role and relevance of physics in society.
Scientific knowledge	2. *Exhibit depth and breadth of scientific knowledge by:* 2.1 Demonstrating well-developed knowledge in the subject areas of the physics discipline. 2.2 Demonstrating knowledge in the related disciplinary area of mathematics.
Inquiry and problem solving	3. *Critically analyse physical situations by:* 3.1 Gathering, documenting, organising, synthesising and critically evaluating information from a range of sources. 3.2 Designing, planning, carrying out and refining a physics experiment or investigation. 3.3 Selecting and critically evaluating practical, computational and/or theoretical techniques or tools in order to conduct an investigation. 3.4 Applying appropriate physics concepts to the interpretation of experimental or observational data and the drawing of conclusions from that data.
Communication	4. *Be effective communicators of physics by:* 4.1 Communicating physics data, results and analysis, to a range of audiences, for a range of purposes, and using a variety of modes. 4.2 Understanding and interpreting arguments or opinions based on physics, presented by others.
Personal and professional responsibility	5. *Be accountable for their own learning and scientific work by:* 5.1 Being independent and self-directed learners. 5.2 Working effectively, responsibly and safely in an individual or team context. 5.3 Exhibiting intellectual integrity and practising ethical conduct.

skills, and values that govern professional work practices. Comprehensive guidance on how to interpret the TLOs, providing a framework for applying the standards, is also provided. The latest version of the physics TLOs appears in Table 1. Also, an excerpt from the accompanying explanatory notes, relating to the process of inquiry and problem solving, is included as Insert 1. Known contributors to the document are acknowledged above. It is envisioned that the full, final document will be published on the AIP website.

Insert 1: Explanatory notes for TLO 3: Inquiry and problem solving.

Inquiry and problem-solving
Approach: Graduates will be able to use critical thinking skills and a quantitative approach to analyse physical situations and solve complex problems.
Domain: Graduates will be able to apply physical principles in a range of contexts. They will have the skills to solve problems that lie within the domain of traditional physics, as well as tackle more open-ended research questions.

TLO 3.1

Gathering, documenting, organising and synthesising information: Physics graduates will be able to identify, access, record in appropriate format, collate and integrate information.

Critically evaluating information: Physics graduates will be able to assess the soundness of the information that they gather against the criteria of their knowledge and understanding of physics.

Range of sources: It is recognised that information about the physical world is available from a variety of sources, such as books, refereed and non-refereed journal articles, conference presentations, seminars, lectures, peers and the internet. Information processing also deals with data generated as a consequence of experimentation or observation, or the analysis of existing data.

TLO 3.2

Designing, planning and problem-solving: Physics graduates will be able to devise a sequence of data acquisition and analysis using methods based on accepted physical principles. They will be able to form hypotheses and then design activities or experiments to test these hypotheses. Physics graduates will use a systematic approach to problem-solving using the laws of physics. In addition, physics graduates will have an appreciation of how to frame a problem so that it might be solved in a creative or innovative way.

Refining: Physics graduates will be able to review the effectiveness of the methods they have used so as to improve their approaches and to acquire qualitatively and quantitatively superior data.

TLO 3.3

Techniques and tools: Physics graduates will be able to use a range of the tools of physics, including instruments, apparatus, mathematical and statistical approaches, including modelling, and information and communication technologies. They will be able to use a range of measurement and data analysis tools to collect data with appropriate precision. Through their undergraduate learning experiences, physics graduates will be knowledgeable of techniques used to solve different types of problems. Physics graduates will be able to use appropriate (combinations of) practical, theoretical and computational tools to solve problems in their discipline, and will have an appreciation of the techniques used in other areas of science.

TLO 3.4

Applying appropriate physics concepts: Physics graduates will be able to identify the physical concepts that apply to a particular situation or phenomenon being investigated. They will recognise the limits and boundaries of models.

Interpretation of experimental or observational data: Physics graduates will be able to analyse data to yield justifiable conclusions. They will evaluate quantitative evidence, to judge the quality of data and results, using one or more of the techniques of measurement uncertainty, reproducibility, precision, or statistical analysis.

Drawing conclusions Physics graduates will have the capacity to develop defensible arguments based on evidence and draw valid conclusions based on their interpretation of data. They will be able to explain the influence of theoretical or empirical models and measurement uncertainties when drawing conclusions from experimental, simulated or observational data.

As a first step in the development of agreed standards, a Draft Statement of Learning and Teaching Academic Standards for Physics was prepared by a small group of physics academics from around Australia. "Learning and Teaching Academic Standards: Science Standards Statement" [1] was the starting point for discussion of learning outcomes for physics graduates. This document had emerged from a large-scale, pan-Australian project with extensive consultation. Use was also made of work that had been done to translate the generic science standards to chemistry [2], a discipline closely-related to physics via its experimental nature. Because the physics draft was adapted from the general science standards and the standards mapped to chemistry, there can be confidence that the physics statement is well-suited to express both what a person trained in physics has in common with graduates of the other sciences, and what makes the physics-trained graduate distinct from other disciplines.

"The next stage was consultation with the dedicated physics education community"

The next stage was consultation with the dedicated physics education community. An invitation to provide feedback on the Draft TLOs via email was sent to a group self-identified as interested in physics education. The Physics Education Group, a special interest group of the AIP, has over the last decade or so fostered a growing

awareness of good practice through collaborative projects, workshops and research of individual members. The Australia-wide network of physics educators that has grown up is a way to communicate ideas and to share resources on teaching development.

Members of the Physics Education Group had the opportunity to refine ideas about physics learning outcomes at a national workshop. Participants were asked to brain-storm what makes a physics graduate special. They then classified their responses according to the general Science TLOs, and the TLOs and the Notes about implementing them were discussed from the specific points of view of teaching and assessing them in physics. During this analysis the overwhelming importance of inquiry/problem-solving skills for physics became obvious. Also, it was decided to specify the particular related disciplinary area of mathematics as expected knowledge in Scientific knowledge TLO 2.2. After this discussion, the document was substantially revised.

"… learning outcomes can help define the voice of Physics amongst the other sciences, and in the national education setting"

Consultation with the broad membership of the physics community then occurred. Input was requested from each university via Heads of Departments. It was suggested that Heads or their nominees prompt discussion within institutions. At the time of invitation, Heads were advised that agreement with the TLOs would be assumed if they did not notify otherwise by a deadline date, and that a consensus document would be presented publicly at the AIP National Congress 2012. The document was again revised to incorporate feedback. A Keynote address in the Education stream of AIP Congress included significant time for discussion by delegates.

The iterative process used to engage the community with the TLOs – working in stages towards larger numbers of people being involved – has strengths because it aids workability, helps refine ideas, and means that the end-product should be genuinely representative. Strategies used here are similar to the "Define Your Discipline stakeholder consultation process" based on the Modified Delphi Technique, used recently to define graduate outcomes in engineering [3].

During the stage of broad consultation with physics academics, a realisation emerged that TLO 1: Understanding science is really about the *nature* of the discipline – a cultural kind of aim. Note that the purpose of the TLOs (and the AIP Accreditation criteria) is not a listing of mandated topics. The current AIP Accreditation document lists criteria in terms of "competencies for a graduate physicist:

1. Demonstrate knowledge of fundamental physics concepts and principles;
2. Evaluate the role of theoretical models and empirical studies in the past and in the current development of physics knowledge;
3. Apply physics principles to understand the causes of problems, devise strategies to solve them and test the possible solutions.
4. Use a range of measurement and data analysis tools to collect data with appropriate precision and carry out subsequent analysis with due regard to the uncertainties.
5. Use the tools, methodologies, language and conventions of physics to test and communicate ideas and explanations;
6. Work effectively and ethically in a multi-faceted scientific environment; and
7. Be responsible, critically reflective, self-directed and motivated learners." [4].

These do not quite have one-to-one correspondence with the statements of the TLOs.

Early draft statements of the TLOs were presented to the AIP Executive Council and AIP Accreditation Panel, and further involvement sought from these arms of the professional body. Discussions with leaders of AIP Accreditation Panel resulted in in-principle agreement that alignment of AIP criteria for accreditation and TLOs (for other quality assurance purposes) would be useful. Throughout consultation, it's been clear that academics involved with accreditation (especially those with high-level management experience) see the idea of TLOs as valuable. The latest version of the Statement of Learning and Teaching Academic Standards for Physics was presented at the AIP Executive Council Meeting, 2013. Council asked members of the Accreditation Panel to form a Working Party to deliver unification of physics TLOs and AIP Accreditation criteria. The Working Group includes Stephen Collins (Chair of AIP Accreditation Panel), Judith Pollard and Margaret Wegener. If you have comments about the TLOs and accreditation, please contact a member of the group.

By stating what we stand for, learning outcomes can help define the voice of physics amongst the other sciences, and in the national education setting. Recent events have

lifted the importance of this aspect. The Australian Council of Deans of Science has committed to support some education development activities with cohesion across the sciences, and various science disciplines have gained funding for networks to facilitate communication amongst their educators. Representatives of a variety of disciplines in science and mathematics met at the Australian Council of Deans of Science National Workshop - Advancing Science TLO's, in February, 2013, to discuss and compare progress in interpreting TLOs for individual disciplines.

There were relatively few differences between what has been developed so far by different disciplines. The modification by physics of the Science Communication TLOs to incorporate the two-way nature of communication (the Science TLOs mention only the outward-bound process) was acknowledged generally as useful. Alignment of our discipline with maths, sharing strong theoretical and computational aspects, was apparent. Physics has emphasised ethics that relate to intellectual integrity in the Personal and professional responsibility TLO. This can relate to experimental, observational and theoretical endeavours. For some other disciplines regulatory frameworks were seen as the most important aspect of professional responsibility. The feature of the physics TLOs of having to cater for various sub-disciplinary branches (such as theory vs experiment) was matched in some other disciplines by comparable disciplinary divisions. It is expected that the expressions of TLOs that are common to different disciplines will evolve to be the same.

Important next steps for physics will relate to themes that have already emerged from discussion, such as assessment of outcomes, and higher standards (rather than just minimum outcomes). A group funding application has been submitted to support a Physics Education Network, with one of the main aims being development of staff and resources to implement physics TLOs.

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AUTHOR BIO

Margaret Wegener is a lecturer at The University of Queensland. She has just completed four years as leader of the AIP's Physics Education Group, and is now its Deputy Convenor. She is involved in physics education via teaching, professional service, and research. She teaches aspiring physicists and physics service courses in Engineering and the life sciences. Major themes of her work are the creation of environments for learning physics, via inquiry-based lab learning, contextualisation, and technology-enabled resources, and the effect of student attitudes on learning. She is deeply interested in the interrelationships between science and the arts.

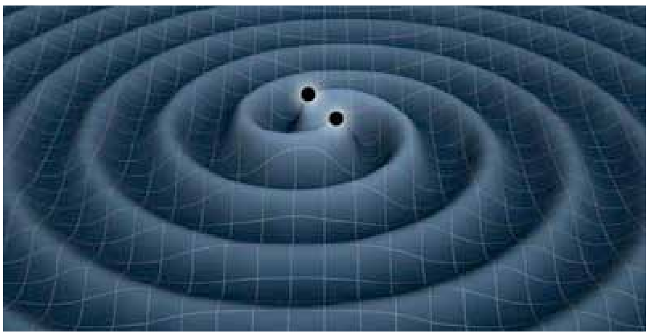
Interfering atoms could help detect gravitational waves

Scientists in California have proposed a new type of gravitational-wave detector that is immune to laser noise – a problem that adds to the expense of current detector designs. The researchers believe that their proposal – a modified form of an atom interferometer – would be cheaper and easier to implement in space than current laser interferometers.

The conventional way to try to detect gravitational waves involves a long-baseline laser interferometer. A passing gravitational wave should cause the pathlengths of the two beams to change slightly, causing a shift in the interference fringes when the beams are recombined. None of these detectors have yet succeeded in detecting a gravitational wave; so to increase sensitivity, astronomers need to put detectors in space. The proposed Laser Interferometer Space Antenna (LISA) project, originally scheduled for launch in 2015, has been revised because of its high cost.

Atom interferometers were proposed in the late 1980s and first built in the early 1990s by physicists including Mark Kasevich and Steven Chu at Stanford University. Instead of measuring the difference in phase between two beams of light, an atom interferometer measures the change in the phase of a matter wave made of atoms in a superposition of quantum states. An atom interferometer can be created by repeatedly exciting and de-exciting one half of the wavefunction using a laser while holding the other half in the ground state. The wavelength of an atom shortens when the atom is in its excited state, creating a phase shift between the two halves of the wavefunction that depends on how long the first half has spent in the excited state.

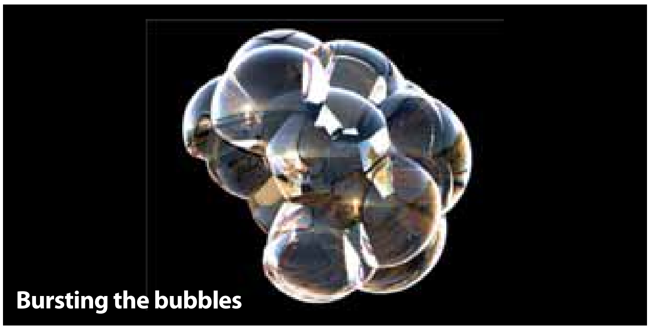
In this latest work, Kasevich and colleagues propose placing two atom interferometers a long distance apart and using the same pulsed lasers – one originating at one interferometer, one at the other – to excite and de-excite the atoms in both interferometers. [*Phys. Rev. Lett.* **110**, 171102 (2013)]



Gravitational waves: is atom interferometry the way forward?

Getting to the bottom of foamy physics

Researchers in the US have created a new mathematical model to describe the complex evolution of foamy bubbles – something that has proved fiendishly difficult to model thanks to the hugely varying length and time scales involved. Their computed results closely match theoretical models as well as lab-based observations of foamy bubbles. The team hopes the underlying equations could have a variety of applications, including helping to make better metal and plastic foams, developing lightweight crash-absorbent materials and also to model a number of biological processes such as the growth of cell clusters.



Bursting the bubbles

Foams are all around us: from the froth on a cappuccino or beer to the soapy suds in a bubble bath. However, scientists have found it difficult to describe exactly how such clusters of bubbles coalesce, grow and change shape over time – before they ultimately go pop. Now, James Sethian and Robert Saye of the University of California, Berkeley have separated the various processes that determine a foam's evolution according to the different length and time scales at which they occur – and have created a model for bulk foam dynamics. The researchers say that the model accurately describes how fluid moves within a bubble and how the individual cells form and how their junctions (or borders) are rearranged as individual bubbles within the foam.

While a large part of the aim of this work was to develop a fundamental model, the researchers claim that it could have other applications. When it comes to biological modelling, Sethian says the equations could help to understand highly complex systems, such as cell cluster growth, that may go from being organized to unorganized systems. According to him, the models might help "to better understand how cells group together and aggregate... and to study the kind of physical forces involved – such as adhesion between cell boundaries, fluid dynamics, etc – as well as the mechanisms involved in how cell clusters grow from clusters of 5 to 10 cells to those of hundreds to thousands of cells". [*Science* 10 May 2013: **340** no. 6133 pp. 720-724]

New insights into what triggers lightning

Cosmic rays interacting with water droplets within thunderclouds could play an important role in initiating lightning strikes. That is the claim of researchers in Russia, who have studied the radio signals emitted during thousands of lightning strikes. The work could provide new insights into how and why lightning occurs in the first place.

There are three basic types of lightning: lightning that occurs within a single cloud; lightning that occurs between two clouds; and lightning that occurs between a cloud and the Earth's surface. In a typical cloud-to-ground lightning strike, scientists know that an electrically-conducting plasma channel forms between the cloud and the ground, which allows the discharge to occur. However, the factors that cause the initial charging of the cloud and its subsequent discharge are not clearly understood.

Now, Aleksandr Gurevich of the Lebedev Physical Institute in Moscow and Anatoly Karashtin of the Radiophysical Research Institute in Nizhny Novgorod have suggested a new model that includes two crucial factors that could help explain the process: the behaviour of water or ice particles inside clouds, dubbed "hydrometeors"; and showers of electrons that might be created by cosmic rays. The theory that cosmic rays may cause the ionized showers that initiate lightning was first put forward by Gurevich more than 20 years ago. Known as "runaway breakdown", Gurevich suggested that the ionized particles create free electrons within thunderclouds that are then accelerated to extremely high energies by electric fields within the clouds. These electrons collide with other atoms in the air to cause an "avalanche" of high-energy particles within the cloud – and this provides the seed for the onset of lightning. While the theory was widely discussed, Gurevich was not able to find proof that cosmic rays do indeed trigger the avalanche. In a bid to gather more evidence, Gurevich and Karashtin have now done a new analysis using a radio interferometer of radio pulses emitted at the onset of 3800 lightning strikes across Russia and Kazakhstan. A long series of these short yet strong pulses is emitted just before lightning strikes and, according the researchers, the pulse data match Gurevich's model of electrical breakdown. [*Phys. Rev. Lett.* **110**, 185005 (2013)]

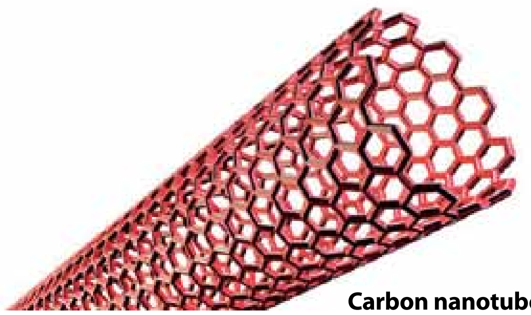
What initiates a lightning strike?

How nanocrystals squeeze through nanotubes

Researchers in the US have made a remarkable discovery about how an iron nanocrystal moves through a carbon nanotube that does not have a uniform diameter. They found that if the crystal meets a constriction in the tube, the crystal reforms, atom by atom, to fit through the constriction, without undergoing any melting or compression. According to the researchers, this behaviour could have many applications in nanomechanics and could possibly be used to synthesize small nanoparticles.

Scientists already knew that metallic nanocrystals can be made to travel through carbon nanotubes (CNTs) if a current is applied to the tube. The crystal moves in the direction of the electron flow and can easily be made to move back and forth by switching the polarity of the current, while the speed of the movement depends on the current magnitude. Indeed, this has been tested with numerous metallic nanocrystals including copper, tungsten and gallium. This is of particular interest to those developing nanoscale actuators or memory devices, and for the removal of minute impurities from within the metal crystal. Previously, most of the CNTs used to study this "electromigration" were smooth and had a constant inner-diameter hollow core. But if for some reason the CNT narrowed down at some point, such that the nanocrystal was now bigger than the tube itself, it was assumed that the crystal would block the tube until it melts and flows through as a liquid.

Surprisingly, what Sinisa Coh and colleagues from the University of California, Berkeley, and Lawrence Berkeley National Laboratory found was very different. The metallic nanocrystals, while remaining solid and crystalline, somehow managed to slip through the narrow passage while not being deformed. Rather, the researchers found the crystal deconstructing and reforming within the narrow passage, at the atomic scale. The team watched the movement of iron nanocrystals with a high-resolution electron microscope. Electron diffraction measurements verified that the crystals did not melt or experience compression. [*Phys. Rev. Lett.* **110**, 185901 (2013)]

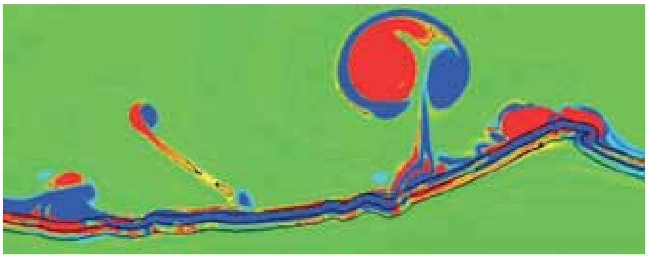


Carbon nanotube

Atmosphere agitated by breaking waves

Ocean waves breaking far from shore impart a greater portion of their energy to the air than they do to the surrounding water. That is the claim of scientists in Italy and Australia who are the first to model the dynamics of the air directly over breaking waves. Although it has not been verified experimentally, the result challenges the previously held belief that most of a breaking wave's energy remains in the water. If verified, the finding could have important implications for our understanding of cloud formation, climate modelling, oceanic circulation, and wave and weather forecasting.

The simulations showed that right before a wave breaks, it accelerates and its crest becomes sharp. As it breaks, the airflow on top of the wave suddenly separates from the crest and forms a vortex behind it – much like the vortices that form behind a spoon pulled through a cup of coffee. When the vortex makes contact with the water surface, it kicks up a second vortex of opposite sign, and the two tangle together in a capsule of counter-rotating air known as a dipole, and get thrown upwards into the atmosphere.



Throwing a dipole

Alex Babanin, an oceanographer at Swinburne University of Technology and co-author of the study, says "The implications for air–sea interactions, including weather and climate modelling, are significant but the large-scale models don't simulate waves at all." Instead, wind speed is used as a proxy for air–sea fluxes, but this can introduce errors of "hundreds of per cent" in the case of breakers resulting from modulation instability.

Although the team's results are not immediately applicable in today's climate models, a combination of scaling up the newly recognized contribution from breaking waves and improving the resolution of climate models should see a much more accurate picture of the interplay unfold. Babanin says "We now have a joint project with the Australian Bureau of Meteorology to do exactly that." [*Phys. Rev. Lett.* **110**, 184504 (2013)].

How fat is Schrödinger's cat?

In recent years physicists have been placing ever-larger objects into states of quantum superposition – the curious state that Schrödinger's cat finds itself in. While superposition is a regular feature of the microscopic world, it is never seen in our everyday lives. Some physicists think that this conundrum is resolved by quantum mechanics simply breaking down above a certain size scale. Others believe instead that the transition is more gradual, with it becoming increasingly difficult for larger quantum objects to remain in a superposition. This is because the effect of environmental noise on a quantum state is essentially the same as making a measurement.

To find out exactly how and where the quantum world ends and the classical one begins, physicists have been placing bigger and bigger objects into quantum superpositions. However, there had been no unambiguous figure of merit that physicists can use to compare the size or "macroscopicity" of different experiments.

Now Stefan Nimmrichter and Klaus Hornberger of the University of Duisburg-Essen have defined macroscopicity in terms of the experiment used to realize a certain quantum state rather than as a property of the state itself. They devised a general mathematical expression to describe the minimum modification that would need to be made to the dynamics of Schrödinger's equation in order to destroy a certain quantum state. The macroscopicity of a given experimental result is then determined by the number of such modifications that the result has ruled out, with a more macroscopic result ruling out more modifications. But an object's mass is also important, with a more massive molecule, for example, ruling out a larger class of modifications than a lighter one would for a given coherence time. These two parameters, together with a third related to the scale of the superposition, yield a single number, μ, on a logarithmic scale, such that the superposition state of the object has the same macroscopicity as that of a single electron existing in a superposition for 10^{μ} seconds. Nimmrichter and Hornberger find that the most macroscopic superposition to date was done using a molecule of 356 atoms. Carried out in 2010 by a University of Vienna-led collaboration, of which they were part, this experiment produced a μ of 12. [*Phys. Rev. Lett.* **110**, 160403 (2013)]

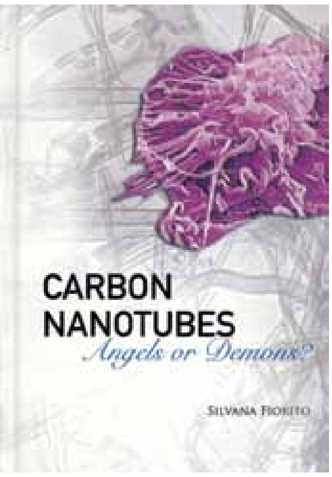
Schrödinger's cat has a macroscopicity of 57

BOOK REVIEWS

Carbon Nanotubes: Angels or Demons?

By Silvana Fiorito
Pan Stanford Publishing, 2008, pp 147 (hardcover)
ISBN 13-978-981-4241-014

Reviewed by Lee Weissel
Trinity Anglican College, Albury



The work, Carbon Nanotubes: Angels or demons? is an attempt at an exhaustive overview of current fields in which techniques and applications of these carbon nanotubes are being used. The editor and one of the authors, Silvana Fiorito (professor of internal medicine and immunology at the University 'La Sapienza' Rome), provocatively utilises the sub title to draw an analogy to the popular fiction book by American author Dan Brown. In contemporary debates on the potential functionality and use of Carbon nanotubes in a wide range of applications, the issues of toxicity and biocompatibility to human tissue have left an overshadowing presence in the field.

Nanotechnology disasters have long been a staple of science fiction and Fiorito comments in her introduction that much research is hindered by public misunderstanding. Therefore, the first two sections explain the history and construction of nanotubes. The other articles cover important applications ranging from everyday use to the exotic. Fiorito rightly points out that nanotechnology is not new but has been happening for centuries on a cellular level and we are only now catching up.

This work adds helpfully to the debate by reinforcing some of the known applications as well as introducing new ones. Each section of the book describes examples of how carbon nanotubes are utilised, followed by succinct arguments as to the advantages and possible issues that are raised by their use.

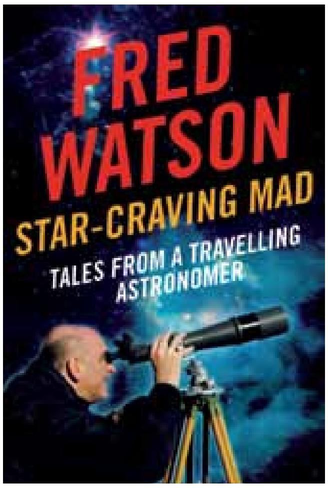
The range of applications is indeed impressive with mechanical applications utilising the strength and flexibility of the nanotube. The characteristics of the particular hybridizations available to the structure enable self-correction to any deformity in use. The mechanical application is further reinforced by electrical application, providing enhanced density, and has demonstrated self-assembled behaviour at the nano scale. The various authors of the sections have included experimental results to reinforce the ideas and potential avenues of inquiry put forward.

Other issues include drug and gene delivery, cellular and muscular reconstruction and tissue receptivity for artificial joint replacement parts. In a time when longevity in populations is an issue, this work does seem readily appropriate. The work as a whole is very ably written and presented and provides an eye-opening introduction into potentially marvellous new areas in the nano-technology field.

Star-craving mad

by Fred Watson.
ALLEN & UNWIN, Australia. 348pp
ISBN:9781742373768

Reviewed by Joanne Harrison, DSTO
Publication Date:2013.



In its own words, this book is "supposed to be about the science of the stars". It certainly includes some excellent writing along those lines. Some examples that I thought noteworthy are discussions on: the chemistry of stars (chapter 6); the principle of equivalence (chapter 8); the sustainability of space science (chapter 9); dark energy and dark matter (chapter 10); astrobiology (chapter 11). Also peppered throughout are tidbits of information that I (as a non-astronomer) found interesting – the way that astronomers define "metallic", for instance.

Described as a "sub-plot" of the book is the author's experience as a tour-guide for "astronomy tourists". That is, groups travelling the world to visit places with some link to astronomy. After the first 5 chapters, you would be forgiven for thinking that the entire book is nothing more than an excuse for the author to publish some of his favourite anecdotes from these tours (and from his life in general). There's a difference between stories that make good dinner party conversation, and stories that cry out to be immortalised in print. The distinction is subjective, so as an example – the author once met a guy who was taught at school by the guy who married the woman who, as a girl, was responsible for the former-planet Pluto getting the name Pluto...and the students nicknamed him

(the teacher, that is) "Foxy Phair". This story is labelled a "marvellous scrap of trivia for the Pluto archive". If you agree, then you might also find the many other personal reminiscences throughout the book appealing.

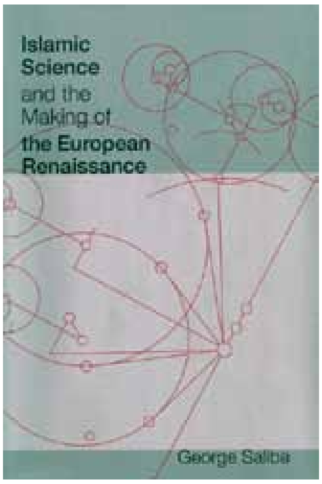
If I had to describe what this book is about, I would say that it's an attempt to combine popular science writing with travel writing, comedy writing, and autobiographical writing. The popular science writing, which takes up perhaps 25 to 50 percent of the book, is very good in parts. This is no less than you'd expect from an author who has spent decades honing his skills as a science writer.

If I had to describe who this book might appeal to, I would say that for the book taken as a whole: friends, family, and fans of the author. For anyone not in those categories: if you're interested in some of the historical (including archaeological) aspects of astronomy you might get some value out of the early chapters; if you're interested in modern astronomy (experiments, theory, instrumentation) you might like chapters 6 to 10.

Islamic Science and the Making of European Renaissance

By George Saliba
The MIT Press
ISBN-13:987-0-262-19557-7

Reviewed by by Jason Dicker, Launceston College.



This book was picked up in passing while perusing a local bookshop in the hopes of this reviewer gaining more knowledge of Islamic Science throughout the mediaeval period. What I had bought was a detailed look at Islamic theoretical astronomy from the collapse of the Roman Empire to the late Renaissance.

This is a fascinating book especially right towards its finish when Saliba shows how Islamic Astronomy not only influenced Western knowledge but directly contributes to Copernicus's work through diagrams and ideas, albeit not the fundamental concept of heliocentricity. That is clearly Copernicus's idea.

Its reading is difficult as it covers some 1000 years of Islamic astronomers of various countries and backgrounds as they wrestle with Ptolemy's Almagest and come to realise their strengths and weaknesses. The book also describes why the rising Islamic nations required mathematics, geometry and astronomy for its economy and Saliba contrasts this with the decaying Christian Byzantine Empire that regarded ancient Greek knowledge as pagan and to be disregarded. How fascinating that fundamentalists of the present day Islamic societies should be so similar to the early fundamentalist Christians!

As it works through the eras, it shows how astronomy was confined at any one time to relatively small groups who used their knowledge to attain positions in courts as administrators. By 1400, criticism of Ptolemy was deep but alternative ideas to his were strictly geocentric. Debate had slowed in the light of a lack of new ideas but the technology of astrolabes was very much alive.

Saliba also points out the various routes by which Islamic knowledge permeated the West in mediaeval times, not just through the south through Spain and Sicily but also through Central Asia and Russia possibly reaching Copernicus by the latter route.

In his comments on the decline of Islamic Science, he points out that the invasion by the Mongols was not the cause of collapse-indeed, discussion of astronomy was just as strong after Baghdad's sacking as before-rather, Islamic astronomy was simply overwhelmed by the developments of the West after Kepler and Galileo's work led to the rapid rise in science.

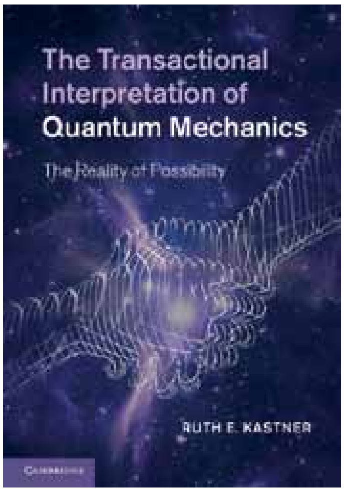
This is a very valuable work for any person interested in science history. It gives an insight to the "otherside". While I truly enjoyed the focus on astronomy, I failed to get what I had hoped when I picked this up: an overview of all of Islamic science for the period.

The Transactional Interpretation of Quantum Mechanics - The Reality of Possibility

by Ruth E. Kastner
Cambridge University Press, Cambridge 2013
ISBN-13: 9780521764155 (hardcover), viii, 224 pp.

Reviewed by David Miller, Centre for Time, University of Sydney.

The book begins with some questions, including why does quantum mechanics work? We know the answer to that type of question elsewhere in physics because there is consensus on interpretation in other areas. There is no consensus on the interpretation of quantum mechanics. It is argued that the central interpretational issue of quantum mechanics is "why the theory has the mathematical Hilbert space structure that it does" (p. 23).



The author poses and defends an extension of the transactional interpretation (TI) of quantum mechanics which the author calls the possibilist transactional interpretation (PTI). TI was proposed by John Cramer in the 1980s. It carries over many of the ideas of the Wheeler-Feynman (WF) absorber theory of electromagnetism into non-relativistic quantum mechanics. In TI the normal quantum state is characterised as an offer wave (OW) due to an emitter. The complex conjugate of the state, involved in the Born rule, is called the confirmation wave (CW) and is due to an "absorber". It is explained in the book why an absorber has to be a macroscopic object and this is important to PTI's solutions to the preferred basis and measurement problems. The components of the OW and CW give rise to incipient transactions and only one of these becomes actualised by a process akin to spontaneous symmetry breaking. Unlike the original TI formalism, PTI acknowledges that OWs, CWs and incipient transactions are "too big" to fit into spacetime (p.106). They inhabit a realm described by Hilbert space which is viewed as a genuine physical realm. The spacetime which we inhabit consists of the actualised transactions.

A fascinating part of this book is the linking of physical and philosophical ideas (mainly in Chapters 2, 7 and 8) in new and specific ways. Most importantly, PTI proposes that Hilbert space refers to an existing realm analogous to the noumenal realm of Kant (and other philosophical concepts discussed in the book) and that spacetime, made from the actualised transactions, is both real and "physical" and is analogous to Kant's phenomena.

Apart from the OWs and CWs existing in Hilbert space rather than spacetime, another significant advance of PTI is that it is expressed in quantum field theory (QFT) terms (mainly, Chapter 6) relying to some extent on Paul Davies' extension of WF absorber theory. A significant point is explaining the amplitude for generation of the CW in terms of the field coupling amplitudes in QFT.

Chapter 5 deals with challenges to TI and also explains how PTI deals with many of the well known counterintuitive "puzzles" of quantum mechanics. The book is up to date with recent developments in the field, including the new theorem of Pusey et al announced late last year. Unfortunately the index is very brief and not very usable.

Some (perhaps the best) undergraduates are disturbed by quantum mechanics and are dissatisfied with an admonishment to "Shut up and calculate". They could well be steered to the explanatory chapters (1, 2, 7 and 8) of this book. Physicists generally will find the book, including the more technical chapters, stimulating and perhaps persuasive.

Conferences 2013-14

14-19 July 2013
12th Asia Pacific Physics Conference (APPC12) in conjunction with the 3rd Asia-Europe Physics Summit. International Conference Hall, Makuhari Messe, Chiba, Japan.
http://www.jps.or.jp/APPC12/index.html

25-26 July 2013
Nuclear Energy for Australia. Powerhouse Museum, Sydney
http://www.atse.org.au/atse/events/nuclear_energy/content/events/nuclear_energy_content/nuclear_energy_conference.aspx

4-9 August 2013
21st International Symposium on Plasma Chemistry (ISPC 21). Cairns Convention Centre, Qld
http://www.ispc21.com/

29 Sep-3 Oct 2013
4th World Conference on Science and Technology Education (WorldSTE2013). Sarawak Malaysia
http://worldste2013.org/

13-16 Oct 2013
NEW Australasian Radiation Protection Society (ARPS) Conference. Cairns, Qld
http://www.arps.org.au/?q=content/conferences

8-11 December 2013
ANZ Conference on Optics & Photonics – Perth
http://optics.org.au/conferences

2-6 Feb 2014, Adelaide, SA
23rd Australian Conference on Microscopy and Microanalysis (ACMM23) and the International Conference on Nanoscience and Nanotechnology (ICONN 2014)
http://www.aomevents.com/ACMMICONN

21-26 Sep 2014
Joint International Conference on Hyperfine Interactions and Symposium on Nuclear Quadrupole Interactions 2014, Academy of Sciences, Canberra
http://www.hfinqi.consec.com.au/

7-11 December 2014
21st Australian Institute of Physics Congress. ANU, Canberra, ACT

PRODUCT NEWS

COHERENT

Fianium Introduce World's Highest Power White Light Laser - Again!

Fianium's Whitelase SC450 series has until recently been the industry's most powerful commercially available supercontinuum laser, producing over 8W of total output power in a continuous spectrum from 450nm to over 2microns. Fianium have now broken their own record with the introduction of the SC480-10 which produces over 10W power from 480nm to 2 microns.

For users requiring shorter wavelengths Fianium offer the Whitelase SC390 laser with output extending below 390nm. And for those who do not need such high powers Fianium offers the compact and highly affordable Whitelase micro.

A variety of plug-and-play filtering devices is available for all Fianium lasers, allowing narrow wavelength regions to be selected from the supercontinuum. The lasers are ideal for applications requiring tunable visible light such as fluorescence imaging, spectroscopy and lifetime studies.

Verdi G Now Available up to 20W at 532nm

Coherent's Verdi G-Series now adds 20W 532nm CW power to the lineup with the release of the new Verdi G20. Based on Coherent's optically-pumped semiconductor laser (OPSL) technology, the entire G-series offers the traditional Verdi low-noise performance, simple 'knob and key' operation, and is now available at exceptional new prices for the entire 2-20W range. Power-invariant beam parameters and the inherent lack of 'green noise' makes the Verdi ideal for Ti:sapphire pumping and a wide range of additional applications.

Mephisto Range of Single-Frequency Lasers Joins the Coherent Family

With Coherent's acquisition of Innolight, we are very pleased to bring the Mephisto laser product range to Australia and New Zealand, fully backed by Coherent Scientific's local support. Mephisto is based on Innolight's unique non-planar ring oscillator design and features:

- Sub-kHz linewidths
- 30GHz tuning range
- Powers up to 55W
- Wavelengths of 532nm, 1064nm and 1319nm

Direct applications include interferometry, quantum optics, atom cooling, gravimetry and more. Please contact Dale Otten, our advanced laser specialist, to discuss how Mephisto can be applied in your research.

Ultrafast Fibre Lasers from Calmar

Coherent Scientific now offers the Calmar range of ultrafast fibre lasers, to complement our existing range of Ti:sapphire ultrafast oscillators and amplifiers.

Calmar fibre lasers generate clean optical pulses less than 100fs, with repetition rates from kHz to 640GHz, average power up to 10Watts, and single pulse energies up to 20μJ. Fibre lasers are available at several wavelengths from 532nm to 1600nm.

All Calmar products are exceptionally compact and easy to use, requiring no alignment or other maintenance. Applications include amplifier seeding, optical communications, non-linear optics, biomedicine and materials processing and more.

For further information please contact Coherent Scientific at sales@coherent.com.au

Coherent Scientific
116 Sir Donald Bradman Drive
Hilton SA 5033
Ph: (08) 8150 5200 Fax: (08) 8352 2020
www.coherent.com.

LASTEK

QExtra - Quantum Efficiency Enhancing CCD Technology from HORIBA

HORIBA Scientific introduces QExtra Technology, an anti-reflective multi-layer coating to significantly improve quantum efficiency of back illuminated CCDs (BIDDs) over a broad spectral range while suppressing undesirable etaloning effects.

QExtra Technology provides outstanding low light detection capabilities from 300 nm to 1000 nm with quantum efficiency higher than 90%, predominantly advantageous for spectroscopy experiments where UV and NIR

region are of importance. Additionally, QExtra technology significantly suppresses etaloning effects noticeable in the NIR region above 750 nm in back thinned silicon scientific cameras.

The improvement in quantum efficiency offered by QExtra Technology over basic back-illuminated deep depleted cameras is significant, 50% at 400 nm. The increase in sensitivity offered by QExtra technology makes HORIBA Scientific BIDDs the ideal scientific cameras for luminescence, fluorescence and Raman spectroscopy measurements.

The new QEXTRA Technology is available with Horiba's state-of-the-art, low-noise, liquid- nitrogen-cooled (down to −130°C) Symphony® II CCD cameras and our thermoelectrically cooled (−95°C) Synapse® CCD cameras.

High Finesse - A New World of Accuracy, Stability and Speed

High Finesse and their partner company Angstrom is the leading supplier of high precision wavelength meters and research electronics, also with capabilities in high stability reference laser sources and continuous wave Ti:Sa systems.

Sensitive and compact wavelength meters are on offer from High Finesse, exhibiting wide spectral response, high speed measurement and a range of add-ons to provide unrivaled accuracy in laser measurement. The various WS series wavelength meters have accuracy up to 2 MHz and spectral response from the deep UV (192 nm) all the way out to 11 um. In conjunction with optional extras, the systems can resolve laser linewidth, measure CW and pulsed lasers, provide spectrum analysis and monitor up to 8 lasers simultaneously with PID control.

If a stable reference source is required for your wavelength measurement, the SLR products from High Finesse cover many wavelengths in the optical spectrum, such as 633, 895 and 1532 nm. Accuracy of the SLR lasers is better than 2 MHz and are provided in simple 'plug and play' compact packaged, complete with fibre coupling for ease of delivery to the WS wavelength meters.

The TS:Precise, continuous wave Ti:Sa laser system, has proved successful in quantum optical applications in the last decade. The Precise provides near perfect beam quality, in a robust, compact, modular design. Using unique 'slides' technology it allows easy wavelength tuning over the 670 - 1100 nm range with up to 2 W of optical output power. Pump sources can be provided by High Finesse/Lastek for the Precise system, or any existing pump laser can be utilised.

The first ever USB 3.0 Beam Profiling Camera from Gentec-EO

Gentec Electro-Optics and Lastek, are proud to launch the Beamage 3.0, the very first USB 3.0 camera dedicated to Laser Beam Profiling. This new CMOS-based camera comes with a completely redesigned software that features both a highly intuitive user interface and powerful data analysis tools. The USB 3.0 interface of the new Beamage 3.0 camera features a data transfer rate up to 10X faster than any USB 2.0 system. This incredible speed allows for much faster data transfer rates, up to 10 fps at 1 MPixels. USB 3.0 also features an improved communication architecture that reduces both data transmission latency and power consumption.

Thanks to its unique combination of high pixel density (2.2 MPixels) and large sensor size (11.3 x 6.0 mm), the Beamage 3.0 has the double advantage of accurately characterising both very small beams of only a few tens of microns to larger beams of several mm in width, thus effectively covering most of the applications in one device.

The completely redesigned software takes full advantage of today's best development tools. The simple interface is highly intuitive and yet comprises many useful functions, like Background Subtraction, Animation Tool, Signal Normalization, Filtering and Averaging Functions, External Triggering, Active Area Definition, Gaussian Fit and more.

If these points don't make the Beamage 3.0 attractive enough, it comes with an even more attractive price!

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

Lastek Pty Ld
Adelaide University - Thebarton Campus
10 Reid St, Thebarton, South Australia
Toll Free: Australia 1800 882 215 ; NZ 0800 441 005
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email: sales@lastek.com.au
web: www.lastek.com.au

WARSASH SCIENTIFIC
UV-visible-NIR, Fluorescence and Raman Microspectroscopy With the New 20/30 PV™ from CRAIC Technologies

CRAIC Technologies, the worlds leading innovator of UV-visible-NIR microanalysis solutions, is proud to introduce the 20/30 PV™ microspectrophotometer. Available exclusively in Australia and New Zealand through Warsash Scientific Pty Ltd, the new flagship product for CRAIC Technologies, 20/30 PV™ microspectrophotometer is designed to non-destructively analyse many types of microscopic samples from the deep ultraviolet to the near infrared by several different techniques. Analysis of samples can be done by absorbance, reflectance, Raman, luminescence and fluorescence with unparalleled speed and accuracy and all with the same instrument. The system can also be configured to image microscopic samples in the UV and NIR regions in addition to colour imaging.

Applications are numerous and include materials science research, forensic analysis of trace evidence and documents, spectral analysis of minerals, measurement of protein crystals, contamination analysis on hard drives and thin film measurement on patterned semiconductors. Combined with CRAIC Technologies Traceable Standards, specifically designed for use with microspectrophotometers and calibrated using Standard Reference Materials from NIST, the 20/30 PV™ microspectrophotometer™ is the cutting-edge micro-analysis tool for any laboratory or manufacturing facility.

The 20/30 PV™ microspectrophotometer integrates advanced spectrophotometers with a sophisticated UV-visible-NIR range microscope and powerful, easy-to-use software. This flexible instrument is designed to acquire data from microscopic samples by absorbance, reflectance, luminescence or even Raman spectroscopy. By including high-resolution digital imaging, the user is also able to use the instrument as a ultraviolet or infrared microscope. Touch screen controls, sophisticated software, calibrated variable apertures and other innovations all point to a new level of sophistication for microanalysis. With high sensitivity, durable design, ease-of-use, multiple imaging and spectroscopic techniques, automation and the support of CRAIC Technologies, the 20/30 PV™ is more than just a scientific instrument…it is the solution to your analytical challenges.

PIFOC® Objective Scanner with High Dynamics

Warsash Scientific is pleased to announce the release of the P-725KHDS PIFOC® Objective Scanner with High Dynamics from PI (Physik Instrumente). The P-725KHDS offers travel up to 400µm with a resonant frequency of 120Hz and a step and settle of 20ms with a 400g load. Featuring an integrated capacitive sensor the systems offers closed-loop resolution of 2.5nm and 0.06% linearity.

With the capability to handle thread sizes up to M32 and high dynamics at high loads, the P-725KHDS features properties that make it ideal for applications in multiphoton microscopy. Other applications include confocal microscopy, 3D imaging, screening, autofocus systems and surface analysis.

PICMA® multilayer piezo actuators are the driving force of the P-725 PIFOC® Objective Scanners. They have an all-ceramic encapsulation that makes them extremely robust and durable.

Well-known for the high quality of its products, PI (Physik Instrumente) is the global leader in piezo nanopositioning systems. PI's product range is available from Warsash Scientific in Australia and New Zealand, a longtime distributor, and reliable technology partner and consultant.

THE 2014 BRAGG GOLD MEDAL

FOR EXCELLENCE IN PHYSICS

PHYSICS DEPARTMENTS ARE NOW INVITED TO NOMINATE CANDIDATES FOR THE AWARD OF THE BRAGG MEDAL

Aim

The purpose of the prize is to recognise the work done by a Ph.D. student in Australia that is considered to be of outstanding quality.

Background to the Award

The Bragg gold medal was established in 1992 as an initiative of the South Australian Branch, to commemorate Sir Lawrence Bragg (whose picture is inscribed on the medal) and his father Sir William Bragg.

Conditions of the Award

The medal is awarded annually to the student who is judged to have completed the most outstanding Ph.D. thesis under the auspices of an Australian university, whose degree has been approved, but not necessarily conferred, in the thirteen months prior to the closing date for applications to the State Branch (i. e., from the 1 June 2012 to the 1 July 2013). No candidate may be nominated more than once.

Nominations and Time Line

Each Australian university may nominate one candidate. These nominations must be submitted to Secretary of the local State Branch by 1 Jul 2013.

The selected nominations from the State Branches, with the accompanying documentation, should reach Olivia Samardzic, AIP Special Project Officer, 205 Labs, EWRD, DSTO, P.O. Box 1500, Edinburgh, SA 5111, by the 1 Sep 2013.

The announcement of the winner shall be made by the end of Jan 2014.

THE 2013 WALTER BOAS MEDAL

FOR EXCELLENCE IN PHYSICS RESEARCH

CALL FOR NOMINATIONS

Aim

The aims of the award are to promote excellence in research in Physics in Australia and to perpetuate the name of Walter Boas.

Background to the Award

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

Time Line:

Nominations should be sent to Olivia Samardzic, Special Project Officer, 1.E.16, 205 Labs, EWRD, DSTO, P.O. Box 1500, Edinburgh, SA 5111 or olivia.samardzic@dsto.defence.gov.au by the 1st August 2013.

Presentation of the Award

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

Further information about these awards can be found at http://www.aip.org.au/
or obtained by phone on 0410 575 855 or by email from Olivia.Samardzic@dsto.defence.gov.au.

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