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**Cover**

Instrumentation for spin-polarised electron beam analysis, School of Physics, University of Western Australia. See article on p197.

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For all information about the Australian Institute of Physics, visit: www.aip.org.au
Earlier this year I became a member of the Editorial Board of the Bulletin of the Association of Asia Pacific Physical Societies (AAPPS), replacing Rob Robinson. In October I attended a two-day Editorial Board meeting hosted by the Asia Pacific Center for Theoretical Physics (APCTP) in Pohang, Korea. Although the Board has monthly video meetings, there is an annual face-to-face meeting. Other members of the Board come from Japan, China, Taiwan, Korea and Singapore. The Bulletin is now largely distributed electronically and is freely available for download from http://aappsbulletin.org/. While the Bulletin has a strong circulation among the East Asian member societies of AAPPS, it has less penetration among South East Asian member societies (except Singapore) and members of the Australian and New Zealand Institutes of Physics. As a Board member I have to take my turn as a guest editor, in this case for the August 2017 issue. This will involve sourcing several feature articles from Australia and New Zealand. While I will be actively seek articles, I would be very happy to receive offers from members.

Now to the final issue of Australian Physics for 2016. The first article, *The historical evolution of plasmon studies at UWA* by JF Williams, SN Samarin, M Kostylev, N Kostylev, and I Maksymov, follows on from the article *Early History of the Electron Spectroscopy Project at the University of Western Australia: First Definitive Identification of Surface and Bulk Plasmons* by Cedric Powell (Aust. Phys., 53(3), 88 (2016)).

Over recent years we have published a number of articles in which the author describes how their career developed after completing undergraduate or postgraduate study in physics. The second article in this issue is one such: *Life after physics: a career in defence science* by Sandra Tavener, who progressed through various roles at DSTO (now DST Group) to her current position as a system analyst.

This being the last issue for the year, the inside back cover contains an index of articles for volume 53.

I look forward to the AIP Congress (jointly with the Asia Pacific Physics Conference) in Brisbane (4-8 December) and the opportunity to meet many acquaintances from the physics community (and maybe signing up a few authors for 2017 issues!) Best wishes to members for end of year celebrations and the New Year.

Brian James
It is that time of the year again when there is much excitement and interest surrounding the announcement of the Nobel Prize winners. Physics is no exception, with much speculation abounding as to who the winner(s) will be. This year, I am sure there were many of us who thought the Nobel Prize in Physics might go to the LIGO team for their very first detection of an astrophysical gravitational wave event – the merger of two black holes – which was announced on the 11th February this year. However, the announcement was not well timed relative to the annual Nobel Prize nomination cycle, where nominations need to be received in Stockholm by 31 January. I am sure their turn will come!

This year’s winners were in fact David Thouless from the University of Washington in Seattle, Duncan Haldane from Princeton University in New Jersey, and Michael Kosterlitz from Brown University in Providence, Rhode Island, “for theoretical discoveries of topological phase transitions and topological phases of matter”. Half of the Prize was awarded to Thouless, and Haldane and Kosterlitz shared the other half. It is interesting that all three of them were part of the 20th century British “brain drain” which saw many UK scientists lured to the US by the better laboratories and salaries there. It is also interesting that the prize this year has been awarded for theoretical work, and that work involved the application of a branch of mathematics, topology, to explain the unusual properties of matter in very cold or condensed states. As Nobel committee member Thors Hans Hansson described it when the prize was announced, “it has combined beautiful mathematics and profound physics insights, and achieved unexpected results that have been confirmed by experiments”. Aware of its esoteric nature, Hansson then went on to explain the basic concepts of the work, particularly topology, using a cinnamon bun, a bagel, and a pretzel!

The key element of topology that Thouless, Haldane and Kosterlitz (THK) used in their work is the “invariants”, such as holes, that can only exist in geometric shapes in discrete integer numbers. In this context, a bun has zero holes, a bagel has one hole, and a pretzel has two. Recognising that the paired vortices that occur in thin layers of material represented a “hole” that could be treated as a topological invariant, THK were able to explain how super-cold films of helium undergo a phase transition, and how these phase transitions then change their properties – particularly in terms of how conductive they are to electric currents and magnetic fields. This theoretical understanding has led to important practical applications in the development of new materials with novel properties, such as “topological insulators” that conduct electricity only on their surface. While these have not been commercialized yet, they are considered to have great potential for replacing copper components in computers, and in quantum computing applications.

While on the topic of Nobel Prize winners in Physics, we are now on the final countdown to the Joint 13th Asia-Pacific Physics Conference and AIP Congress, which will be held in Brisbane from 4-8 December. The co-winner of last year’s Nobel Prize in Physics, Taaki Kajita, will be one of the plenary speakers, talking about his prize-winning research on the discovery of neutrino oscillations. This will be one of many excellent plenary, keynote, invited, and contributed talks given at the meeting, with the program being one of the best we have had at an AIP Congress. It is still not too late to register, and join the 750 people (including over 200 from the Asia-Pacific region) who have done so already. I strongly urge all AIP members to attend, since this is your meeting and one that is overwhelmingly recognised by members as being the scientific and networking highlight on the AIP calendar.

Finally, to make brief mention of the Prime Minister’s Prizes for Science, the award ceremony for which I attended just a couple of nights ago. Both the Prime Minister and the Minister for Industry, Innovation and Science, Greg Hunt, gave long and quite impassioned speeches on the importance of science and innovation to Australia’s future and its economy, with the latter signalling the imminent release of what he called “the second wave of the National Innovation and Science Agenda (NISA)” which will have a very strong focus on providing incentives for private investment in science and research. This was the first year of the Prime Minister’s “New Innovator” Prize, and it was a thrill to see it awarded to Dr Colin Hall from UniSA, a physicist who played a leading role in the invention of South Australia’s highly successful plastic automotive mirror. You can read more about Colin and his work in the News Section in this issue.
NEWS & COMMENT

‘10 qubits in 5 years’: UNSW strikes deal to commercialise quantum computer tech.

UNSW has struck a $70 million deal to create a consortium to develop and commercialise technology that could lead to the world’s first quantum computer in silicon. The four-way agreement between UNSW, the researchers, business and the federal government will pave the way for the development of a prototype silicon quantum integrated circuit – the first step in building a functional quantum computer.

The UNSW team is the only research group in the world that can make atomically precise devices in silicon. The scientists and engineers, within the Australian Research Council Centre of Excellence for Quantum Computing and Communication Technology (CQC2T) led by UNSW Scientia Professor Michelle Simmons, hope to have built a 10-qubit circuit within five years. The CQC2T is a collaboration of six Australian universities; UNSW, the Australian National University, the University of Melbourne, the University of Queensland, Griffith University, the University of Sydney and 12 international university and industry partners.

In 1975 I was part of an official group (we had diplomatic green passports) led by Paul Wild who visited the Soviet Union to set up an exchange agreement in radio astronomy. There was a reception for us at the Academy of Science in Moscow. When it came to the formal welcome, the MC apologized (in English) for the absence of the President of the Academy (whose name I don’t recall) and said that Vice President Prokhorov would welcome us. The name meant nothing to any of us, and went in one ear and out the other. Prokhorov gave the welcome in English, with a strong Russian accent. I didn’t take much notice. It was Paul Wild who commented to us that Prokhorov’s English has an Australian accent in his vowels. (Not a surprise now that we know that he learnt his English in rural Queensland.) Paul made contact with Prokhorov while we were at the Academy, and discovered the Australian connection, that none of us had heard of. At that stage we did not learn that he was a Nobel Laureate. Unfortunately, I didn’t meet him, so that I have nothing personal to add.

Don Melrose
Emeritus Professor
School of Physics, University of Sydney

LETTER TO EDITOR

Earlier this year the one-hundredth birthday of Nobel Prize winner Alexander Prokhorov (who was born in 1916 in the Atherton Tablelands, attended school there and then returned with his parents to their Russian homeland) was celebrated in Far North Queensland. I have the following brief reminiscence of Prokhorov.

In funding already announced, the federal government has contributed $25 million over five years to the consortium through its National Innovation and Science Agenda, complementing $25 million from UNSW, and $10 million each from the Commonwealth Bank of Australia.
and Telstra. Other partners are expected to join the consortium to bring the founding investment to $100 million. The Australian Research Council recently extended funding to the CQC²T as a Centre of Excellence. This funding, comprising $34 million in government contributions and $103 million in cash and in-kind support from participating organisations, supports the Centre’s fundamental research over the next seven years.

Source: UNSW

2016 Eureka Prizes
The Eureka Prize winners for 2016 were announced on 31 August. Seventeen prizes were awarded, including two for school science. The following prize winners have a particular relevance to physicists.

**Eureka Prize for Innovative Use of Technology:** Ewa Goldys (Macquarie University) and Martin Gosnell (Quantitative Pty Ltd) for imaging technology that allows the colour of cells and tissues to be used as a non-invasive medical diagnostic tool.

**Eureka Prize for Emerging Leader in Science:** Sharath Sriram (RMIT) nanomaterial researcher.

**Eureka Prize for Leadership in Innovation and Science:** Gordon Wallace (University of Wollongong) nanomaterials and intelligent-polymer research leader.

**Eureka Prize for Innovation in Citizen Science**
The Fireballs in the Sky (Curtin University) team, for recruiting community help to understand the workings of the Solar System.

**Eureka Prize for Promoting Understanding of Australian Science Research:** Astronomer and communicator Lisa Harvey-Smith (CSIRO).

**Eureka Prize for Science Journalism:** Physicist and communicator Derek Muller for the TV series Uranium – Twisting the Dragon’s Tail.

Australian Synchrotron

In December last year the Australian Government announced a $520 million, ten-year investment in the ongoing operations of the Australian Synchrotron. Part of that announcement was the transfer of ownership of the Australian Synchrotron to the Australian Government, through the Australian Nuclear Science and Technology Organisation (ANSTO). On 1 July 2016, ownership of the Australian Synchrotron transferred to ANSTO and on 1 September 2016 staff formally become part of ANSTO.

The Synchrotron remains a user facility with a commitment to and capability to deliver on world-class outcomes. Discussions are taking place with governments and institutions across Australia and New Zealand in order to secure funding for a suite of new beamlines, each providing techniques not yet available in our region. This expansion will give Australian and New Zealand researchers access to the specialised tools and techniques needed for critical research in growth areas and areas of national priority: energy, resources, advanced manufacturing, food, health and medical research, materials and textile science and the environment. For further details see: [www.synchrotron.org.au/images/2015_AustralianSynchrotron_Bright.pdf](http://www.synchrotron.org.au/images/2015_AustralianSynchrotron_Bright.pdf)
2016 Nobel Prize for Physics

The Royal Swedish Academy of Sciences has awarded the 2016 Nobel Prize to three British-born physicists working in the US. One half of the Prize was awarded to David J. Thouless (University of Washington, Seattle, WA, USA) and F. Duncan M. Haldane (Princeton University, NJ, USA), and the other half to J. Michael Kosterlitz (Brown University, Providence, RI, USA) “for theoretical discoveries of topological phase transitions and topological phases of matter.”

They used advanced mathematical methods to explain strange phenomena in unusual phases (or states) of matter, such as superconductors, superfluids or thin magnetic films. Kosterlitz and Thouless have studied phenomena that arise on surfaces or inside extremely thin layers that can be considered two-dimensional, compared to the three dimensions with which reality is usually described. Haldane has studied matter that forms threads so thin they can be considered one-dimensional.

Source: www.nobelprize.org/nobel_prizes/physics/

Women in Physics lecturer 2017 – call for nominations

The Australian Institute of Physics Women in Physics Lecture Tour celebrates the contribution of women to advances in physics. Under this scheme, a woman who has made a significant contribution in a field of physics will be selected to present lectures in venues arranged by each participating state branch of the AIP. Nominations are currently sought for the AIP WIP Lecturer for 2017. We are seeking a woman working in Australia who:

• has made a significant contribution in a field of physics research
• has demonstrated public speaking ability
• is available in 2017 to visit Canberra and each of the six Australian State capital cities and surrounding regions.

Presentations will include school lectures, public lectures and research colloquia, subject to negotiation with the various AIP state branches and their contacts. School and public lectures are expected to be of interest to non-specialist physics audiences, and to increase awareness among students and their families of the possibilities offered by continuing to study physics. University lectures will be presented at a level suitable for the individual audience (professional or graduate). Air travel and accommodation will be provided.

2016 WIP lecturer, Dr Catalina Curceanu, Head Researcher at Italy’s National Institute of Nuclear Physics.

Nominations should be sent via mail or email to the AIP Special Projects Officer via the nomination form - for details see the AIP website. Self-nomination is welcomed, as are nominations from branches or employers/colleagues. The closing date is 30th November 2016.

Academy of Science Reports

The Australian Academy of Science has recently released two reports.

Discovery machines: Accelerators for science, technology, health and innovation explores the science of particle accelerators, the machines that supercharge our ability to discover the secrets of nature and have opened up new tools in medicine, energy, manufacturing, and the environment as well as in pure research.

Energy for Australia in the 21st Century: The central role of electricity outlines the challenges posed by Australia’s aging infrastructure when trying to respond to rapidly evolving technologies. Focusing on three key drivers—affordability, security and sustainability—the report examines the science and
technology that will drive and enable a transformation in Australia’s electricity system over the coming decades.

These and past reports are available for download from the Academy’s website: www.science.org.au/support/analysis/reports.

**PM’s New Innovator Prize for UniSA’s Dr Colin Hall**

At the Prime Minister’s Sciences Prize ceremony in October, the inaugural New Innovator Prize was awarded to Dr Colin Hall of the University of South Australia, for his contribution to creating a new manufacturing technology that will allow manufacturers to replace components made from traditional materials, like glass, in cars, aircraft, spacecraft, and even whitegoods—making them lighter and more efficient.

Their first commercial success is a plastic car wing-mirror, with more than 1.6 million mirror assemblies produced in Adelaide for Ford. The mirrors are made in Adelaide by SMR Automotive and have earned $160 million in exports to date. The innovation challenge for car mirror manufacturers was to overcome problems with coating adhesion to plastic, oxidation of any reflective mirror layer and coating stability in both sunlight and extreme temperatures.

A physicist by background, Dr Hall obtained his undergraduate and honours degrees in Applied Physics from UniSA. After almost a decade in the ophthalmic coatings industry he returned to UniSA where he completed a PhD in Minerals and Materials.

At the awards ceremony Dr Hall gave credit to colleagues at UniSA’s Future Industries Institute and the partnership with SMR Automotive.

**Conferences 2016**

4-8 December 2016
22nd AIP Congress - in association with the 13th Asia Pacific Physics Conference. Brisbane Convention Centre
aip-appc2016.org.au

12–14 December 2016
COMMAD 2016
13th International Conference on Optoelectronic and Microelectronic Materials and Devices
UNSW, Sydney, NSW
www.commad2016.org.au

31 January - 3 February, 2017
Wagga 2017 - The 41st Annual Condensed Matter and Materials Meeting
Charles Sturt University, Wagga Wagga, NSW
cmm-group.com.au

5-9 February 2017
Australian X-ray Analytical Association (AXAA) 2017 Conference and Exhibition

12–16 February 2017
8th International Conference on Advanced Materials and Nanotechnology
Queenstown, NZ
confer.co.nz/amm8/contact/

26 July - 1 August 2017
30th International Conference on Photonic, Electronic and Atomic Collisions (ICPEAC XXX)
Convention Centre, Cairns, Qld
icpeac30.edu.au
Nine new ARC Centres of Excellence have been awarded funding commencing in 2017. Of these the seven listed below are relevant to the discipline of physics. More details about the centres, including the list of participating institutions for each centre can be found at www.arc.gov.au/centres-excellence-2017-summary.

The ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (administering organisation: The Australian National University) will answer fundamental questions in astrophysics, including the origin of matter and the periodic table of elements, and the origin of ionisation in the Universe. The Centre, led by Professor Lisa Kewley, will capitalise on innovative Australian technology and instrumentation to propel Australia to the forefront of astronomical research.

The ARC Centre of Excellence for Climate Extremes (administering organisation: The University of New South Wales) will transform Australia’s capacity to predict future climate extremes through data modelling, research collaboration and researcher training programmes. Led by Professor Andrew Pitman, the Centre’s research is expected to make Australia more resilient to climate extremes and minimise risks from climate extremes to the Australian environment, society and economy.

The ARC Centre of Excellence for Engineered Quantum Systems (administering organisation: The University of Queensland) will harness the quantum world for the future health, economy, environment and security of Australian society. The Centre, led by Professor Andrew White, aims to solve the most challenging research problems at the interface of basic quantum physics and engineering by working with industry partners to translate research discoveries into practical applications and devices and training scientists in research, innovation, and entrepreneurship.

The ARC Centre of Excellence for Gravitational Wave Discovery (administering organisation: Swinburne University of Technology) will explore the extreme physics of black holes and warped spacetime, inspiring the next generation of Australian scientists and engineers. Researchers at this Centre, led by Professor Matthew Bailes, will build on decades of Australian investment in gravitational wave and pulsar science, coalescing research activities into a focused national program.

The ARC Centre of Excellence in Exciton Science (administering organisation: The University of Melbourne) will manipulate the way light energy is absorbed, transported and transformed in advanced molecular materials. Led by Professor Paul Mulvaney, the Centre’s research is expected to produce outcomes and benefits that include: new Australian technologies in solar energy conversion; energy-efficient lighting and displays; and security labelling and optical sensor platforms for defence.

The ARC Centre of Excellence in Future Low Energy Electronics Technologies (administering organisation: Monash University) will develop the scientific foundation and intellectual property for new electronics technologies. Decreasing energy use is a major societal challenge. This Centre, led by Professor Michael Fuhrer, aims to meet that challenge by realising fundamentally new types of electronic conduction, expected to form the basis of integrated electronics technology with ultra-low energy consumption.

The ARC Centre of Excellence for Quantum Computation and Communication Technology (administering organisation: The University of New South Wales) will develop new technology, expected to provide a strategic advantage in a world where information and security are increasingly important. The Centre, led by Professor Michelle Simmons, aims to implement quantum processors able to transfer information across networks with absolute security.
The historical evolution of plasmon studies at UWA.

JF Williams, SN Samarin, M Kostylev, N Kostylev, and I Maksymov
School of Physics, University of Western Australia, Crawley, Australia. 6009.

1Now at ARC Centre of Excellence for Nanoscale BioPhotonics, School of Science, RMIT University, Melbourne, Vic 3001

An historical view of the evolution of plasmon studies with UWA technology indicates how technological change underpins knowledge and its applications. Studies advance from traditional transmission and reflection Electron Energy Loss Spectroscopy from surfaces of formvar, aluminium and carbon 215 nm films to showing that the electron spin dependence of the excitation of plasmons in thin layered Ag/W(110) or Ag/Fe changes significantly with the interface. A link between an energy loss feature and an emission feature of the secondary emission spectrum of LiF film is shown. Optically active materials, engineered metal thin film nanostructures and studies of the magneto-optical activity of ferromagnetic metals enable control over the excitation of plasmons, their propagation, dispersion, confinement, and mode structure.

Introduction

The pre-1977 history of electron spectroscopy in the Physics Department at the University of Western Australia was described recently [1] with a personal account of the first definitive experimental identification of surface and bulk plasmons, i.e at UWA by Powell and Swan, in 1959 [2]. Many international studies quickly followed. Two papers are noted. Ritchie [3] showed insight with the understanding that “The electron charges on a metal boundary can perform coherent fluctuations which are called surface plasma oscillations”, and it has become well-known to the plasmonic research sector with 2178 citations in Google Scholar whereas the experimental study of Powell and Swan is often overlooked with 238 citations. The subsequent international plasmon development was reviewed by Raether [4,5] often regarded as the “Bible” of surface plasmons, with 6767 citations for the 1988 review [5].

The UWA plasmon achievements continued spasmodically after the 1977 retirement of the first electron energy analyser in Powell’s paper. The appointment of Jim Williams to the Chair in Physics at UWA in 1980 provided emphasis on electron scattering as one of the hottest topics in atomic physics and surface science. A guiding and important role was established for fundamental studies and for potential applications, as the main mediator for mutual energy conversion between chemical, photon, and electrical energies. Apparatus (with PhD student R McAdams) transferred from Queens University, Belfast, enabled the continuation of fundamental quantum studies of atomic hydrogen and inert gas atoms. Also continued were thin film studies in a UHV apparatus (Figure 1) using high energy (3 to 30 keV) electron energy loss and coincidence electron-pair (e,2e) spectrometers to characterize thin amorphous carbon and formvar (C$_x$H$_y$O$_z$)$_n$ foils (QUB PhD theses, Devlin 1974, McBrinn 1979, King 1979). Plasmon formation and decay, accidentally discerned in kinematic variables related to electron transmission scattering, were encouraged by RG Leckey, on sabbatical from LaTrobe in 1973.

Quantum Scattering Asymmetries from 1980 at UWA.

A new vision included grand challenges from knowledge to innovation then discovery with an initial research plan for electron beam scattering experiments addressing the asymmetries of inversion of space coordinates, time reversal and electron spin, particularly following the strong theoretical studies of gaseous atoms from Belfast [6] and the development of spin polarization of electrons from surfaces by Pierce and Celotta [7]. The challenge was...
presented by quantum observables which are averaged characteristics of bound state wave functions and their expectation values are integrals over unmeasured quantities, and the expected asymmetries and quantum interference phenomena required a discernible intensity and resolution from a correlated background. Then the realities of observable phenomena in angular momentum and energy distributions of scattered particles with quantum correlations determined the instrumentation design. That realisation underpinned studies of electron interactions and eventually the influence of electron spin on plasmon formation, as indicated in part (iv).

Consequentially, the new directions for electron scattering from single atoms [8] were discerned from a geometrical representation, such as in Figure 2, showing linear and angular momentum representations of the experimental methodology to determine quantum atomic structure and scattering dynamics. Similarly, in principle, when fast electrons (compared to the Fermi velocity) are transmitted through a thin film the scattering could be described initially as a single encounter between the incoming electron and a bound electron and the spectral properties of the target. In contrast, in scattering reflection mode, grazing incidence allowed surface sensitivity, avoidance of complications of thin films and the study of metals, metal oxides, semiconductors, insulators and polymers even though backscattering from the crystal potential may require a second-order interaction.

It was apparent that “complete” quantum studies should include photon excitation and detection with excellent momentum and time resolutions, sources and detectors of electron spin and the technological advantages of large area channel-plate detection [9, 10]. Such considerations prioritised studies of angular momentum transfer between incident electron and excited atomic states with polarisation detection of the energy loss electrons and multipole radiated photon angular correlations [11]. While both electron and photon impact techniques could measure the energies and wave vectors of the surface electrons, they explore different one-electron surface transitions and interactions; incident photons, (e.g. as now pursued in ARPES), the incident electric field is perpendicular to the photon momentum transfer but in contrast the Coulomb force of electrons is parallel to the momentum transfer. Consequently the direction of the research initially concerned the direct scattering with angular momentum type models as opposed to a plasmon decay model with spin characterisation which did not emerge until about 20 years later as indicated in Part (iv). The approach was expected to probe the mechanisms such as exchange and spin-orbit interactions that lead to correlated electrons for a wide variety of scattering conditions. That approach indicated a perceived advantage of local WA construction of instrumentation with electron beam rather than photon (synchrotron) technology.

Nevertheless, an essential aspect of new directions included a novel and multifunctional scattering instrument that “connected” an immovable source and detector as indicated in Figure 3 [12]. The geometry allowed an electron beam from a fixed source in the horizontal plane to be retarded and then transported into a parallel plane so that it could scatter from a rotatable direction onto a rotatable surface and then enter a fixed detector. The path was reversible which also could allow an incident photon beam. During transportation between planes the beam was energy analysed with a resolution of 1/30 of the pass energy while maintaining an effective 360° scattering angular range. Ion beam accelerator or synchrotron source and/or Mott detector could be used eventually.

Figure 2. A representation of the atomic electron charge cloud (with height, width, length and angular momentum $L_z$ and observables using impact scattering techniques as determined from incident $k_i$, scattered $k_s$ and ejected $k_e$ electron momenta and radiated polarised photon intensities. (Adapted from Andersen and Bartschat 1986). The effects of electron exchange and spin-orbit interactions are deduced.
Polymers and plasmon studies

Meanwhile, the potential suitability of polymers as self-supporting 30 nm thin film substrates for materials led to surface characterizations venturing into elastic forward and back scattering from polymers which could be correlated, for example, with their surface hydrogen, carbon and oxygen content. Such studies also led to transmission electron spectroscopy from molecular solids searching for the conduction bands formed from the free molecule valence levels and additional structure from intermolecular interactions. Initial aims were to study thin and layered films to characterise their in-plane covalent bonds and out-of-plane van der Waals bonds. Expectations of exchange and spin-orbit interactions were wishfully envisaged from layers with magnetic atoms with partially filled d-subshells. But the reality did not progress beyond H, C and O in polymers using high energy spectra indicating plasmon formation, (Figure 4), in graphite and selected polymers, polycarbonate PC [-C_{16}H_{14}O_{3}]; polystyrene PS [-C_{8}H_{8}]; polymethyl-methacrylate PMMA [-C_{5}H_{8}O_{2}]; polytetrafluoroethylene PTFE [-CF_{2}].

The surface hydrogen atom presence was seen, for example at an incident energy $E_0$ of 1500 eV and scattering angle of 120, as an energy shift of about 2.1 eV in agreement with the estimated kinematical value from 

$$
\Delta E = 4E_0\sqrt{m_e/M_H}\sin^2\theta/2(1/1/Z) \quad \text{where} \quad m_\sigma, M_H \text{ and } M_Z \text{ are the masses of the electron, hydrogen atom and other atom } Z, \text{ for a scattering angle } \theta.
$$

Of relevance here are the $\pi$ plasmons at 6 eV from the benzene rings in PS and PC and the corresponding $\sigma+\pi$ bulk plasmons. Subsequently, energy loss spectra revealed surface plasmon formation in the ($e,2e$) binding energy spectrum from collagen ($C_nH_2O_2-(ONO_2)_n$) in the K-electrons ejected spectra from carbon (~283 eV), nitrogen (~ 400 eV) and oxygen (~ 530 eV) and in the electron momentum distributions of carbon L- and K-shells in formvar [polyvinyl formal (C_{5}H_{7}O_{2})n]. The thrust of these studies was developing into explorations of the structure of carbon rings in molecules but was diverted in favour of spin-dependent studies of atoms and magnetic surfaces, as indicated in the next section.

Further exploration of coincidence ($e,2e$) spectra for electron impact ionization by 1500 eV electrons revealed the ratio of true-to-random counts from formvar at (ejected, scattered) angles of (45, 45 deg) and (20,70 deg) combinations. The 90° between detectors indicated an emphasis on electron-electron correlations [13].

Figure 3: Miniature electron energy analyser [12], to scale, to allow an electron beam from a fixed source (a) in the horizontal plane(ab) to be retarded (b) and then transported (via 270°) into a parallel plane (j) so that it could scatter from a rotatable direction onto a rotatable surface and then enter a fixed detector (j). Parts: (a) fixed electron source, (b,g,i) alignment lenses, (c,f,h) 90° and 180° deflectors, (d,e,f) mounts.

Figure 4: Incident 1500 eV electron energy loss spectroscopy in PTFE, PC, PS and PMMA polymers and graphite. The peak heights near zero energy loss have been suppressed. The statistical uncertainties are smaller than the data points.
aluminium and carbon 215 nm films at various symmetric (45°, 45°) and asymmetric scattering angle (20°, 70°) combinations. The 90° between detectors indicated an emphasis on quasi-elastic electron-electron scattering for high energies compared with binding energies to explore long range electron-electron correlations [13].

The plasmon characterisation was deduced from data with energy losses up to 130 eV in formvar films of thicknesses from 10 to 200 nm and, as shown in Figure 5, with energy loss spectra at small angles in aluminium (lower), carbon (middle) and formvar (upper) [14, 15, 16]. In summary, the studies contributed to the systematics of plasmons with surface and volume bonding energies and multiple scattering features all seen in transmission geometries, with their main achievements known in the literature [5]. The probability of plasmon formation was related to a Poisson distribution containing the foil thickness and its mean-free-path. The studies also showed that interband transitions occurred over all scattering angles in contrast to plasmon transitions limited to small angles. The asymmetric scattering required one detector to have good energy resolution at low energies which was useful for other studies. Optimisation of the scattering experiments was guided by the quasi-elastic symmetric scattering as an excellent indication of the probability of coincidence detection. The unpublished identification of hydrogen atoms on surfaces, although a minor spectroscopic feature and with restricted access at the time, was useful for further identification of bonding in polymers.

The experimental techniques used by Swan and Powell in the 1950s continue to be used in the 21st century for the excitation [17] and detection [18] of plasmons in nanostructures by using high resolution high-energy electron beams. This sub-field of plasmonics rapidly evolves since it may allow for more efficient plasmon excitation and direct imaging of surface plasmons [19].

**Polarised electrons and two-electron spectroscopy.**

The arrival of Sergey Samarin from the Max Planck Institute for Microstructure Physics, Halle, in 2000 expanded the UWA spin-polarised electron studies with strength in surface phenomena [20]. The successes of spin-polarized electron beam scattering from magnetic and non-magnetic surfaces using the Time-of-Flight (ToF) technique for electron energy analysis [21] and renewed international interest, encouraged searches for plasmons.

![Figure 5: Energy loss spectra showing relative counts rates from (a) lower: 12 nm aluminium films from near zero to 40 eV at 0°, 1° and 2° scattering angles, (b) middle: carbon films from zero to 20 eV at 0°, 1° and 2° scattering angles, and (c) upper: formvar films from near zero to about 20 eV at 0°, 5° and 10° scattering angles; and with the elastic peak suppressed.](image)

![Figure 6: (top) Spin-dependent plasmon excitation in 4 ML Agon-W(110) for an incident energy of 22 eV, incidence angle of 25° and specular geometry; (bottom) Spin-dependent plasmon excitation for Ag on W(110) with Ag thickness 1.2, 1.6, 3.6, 4.8 ML in specular geometry for 17 eV incident energy.](image)
A most interesting and complicated phenomenon of secondary electron emission from ionic crystals (NaCl, KCl, CaF2, LiF) was explained by observing an excitation and decay of plasmons through an electron ejection and coincidence technique. Then, one of the electrons was the incident electron that lost part of its energy for plasmon excitation and the second one was the electron resulting from the plasmon decay.

Success followed a study of secondary electron emission from LiF films deposited on a Si(001) surface using a combination of time-of-flight single- and two-electron spectroscopies. A very small incident electron current ($10^{-13}$ A) minimized sample surface charging and possible destruction of the film by electron impact. A set of energy distribution curves of secondary electrons excited by electrons with energies in the range of 20 to 50 eV showed emission features at about 7 eV and 11 eV. As shown in Figure 7a the energy positions of these maxima did not depend on the incident electron energy, i.e. these maxima were due to a specific electron emission mechanism, and their origin was confirmed using two-electron coincidence spectroscopy [23]. Here each of the energy distribution curves was spanned in the second dimension $E_2$ as shown pictorially in Figure 7b. The two-dimensional mapping of the energy sharing between correlated electrons shows that above 25 eV incident energy, one electron of the pair is preferentially emitted with $E_1 = 7.2 \pm 0.3$ eV energy and the second one with energy $E_2 = (E_p - 23.3) \pm 0.5$ eV, where $E_p$ is the incident electron energy and 23.3 eV is the energy of plasmon excitation. See Fig 7c. At about 30 eV incident energy, a second favored emission energy of $10.8 \pm 0.3$ eV is observed. It appears that the mechanism of secondary electron emission from the LiF film includes the excitation of two types of plasmons with subsequent decay via electron ejection. The experimentally determined plasmon energies are $\hbar \omega_1 = 23.3 \pm 0.3$ eV and $\hbar \omega_2 = 26.8 \pm 0.4$ eV which are consistent with a plasmon model in which one plasmon is associated with an interband transition and another one with excitons [24]. Also this experiment established a link between an energy loss feature and an emission feature of the secondary emission spectrum of the LiF film (Figure 7c) in contrast to their usual independent analysis of secondary emission spectra.

**Magneto-plasmonics.**

The arrival of M Kostylev in 2005 from St Petersburg Electrotechnical University initiated the pursuit of sur-
face plasmons as coherent oscillations of electrons near a metal surface with local enhancement of the intensity of electromagnetic fields and resurrected plasmons and enhanced the growth of plasmonics and strong nonlinear optical effects in thin film multilayered structures [25]. The technological developments with optically active materials, engineered metal nanostructures (thin metal films) and studies of the magneto-optical activity of ferromagnetic metals [26] were encouraging flexible control over the excitation of plasmons, their propagation, dispersion, confinement, and mode structure. The UWA research perspectives expanded with plasmon-assisted high reflectivity and strong magneto-optical Kerr effect in permalloy gratings to access magnetic nanostructures [27].

For fundamental considerations there is now congruence of the polarised electron beam studies of surface effects and studies of thick materials at the nanometre scale by considerations of the asymmetry studies and angular momentum effects previously not realizable. The magneto-optical effects can be classified according to the relative orientations of the wave vector of light $k$ and the magnetic field $H$, in which light can either travel along the field direction ($k \parallel H$) or perpendicular to it ($k \perp H$) [26,27]. The Magneto-Optical Kerr Effect (MOKE) and Faraday effect are detected as a change in the polarisation state of light reflected from (Kerr effect) or transmitted through (Faraday effect) a magnetised structure. This arises from the influence of the magnetic field on the dielectric permittivity tensor of the medium, it becomes non-symmetric that results in either polarisation rotation or changes in reflection. Changes in reflection occur in the special Transverse-MOKE configuration in which only the $p$-component of incident light is affected by the applied magnetic field, but the $s$-component remains unaffected. However, what is impossible with conventional plasmonics becomes achievable with magneto-plasmonics with a strong enhancement of the magneto-optical effects, which introduce additional degrees of freedom in the control of light at the nano-scale. In certain cases 'non-optical' ferromagnetic nanostructures, such as ferromagnetic metal magnonic crystals [27-30] may operate as magneto-plasmonic nanostructures. This extra and non-designed functionality capitalises on established optical characterisation techniques of magnetic nanomaterials.

While it is not convenient to reach the region of small wave vectors with electrons, fast or slow, a light beam (Xe lamp) may probe the surface plasmon dispersion relation down to very low wave vector values. However, the excitation of surface plasmons with photons meets the difficulty that the dispersion relation is towards the right from the 'light line'. Thus, at a given photon energy the wave vector must be increased to ‘convert’ the photons into surface plasmons. The UWA studies with a strong Magneto-Optical Kerr Effect (MOKE) and plasmon-assisted high-reflectivity of nanogratings made of Ni$_{80}$Fe$_{20}$ (Permalloy) have opened a pathway for active control with magnetic fields [31].

Our permalloy gratings were fabricated at the National University of Singapore on a silicon substrate with a periodic array of parallel permalloy nanostripes separated by air gaps [Figure 8(a)]. Reflectivity spectra for the Permalloy gratings were taken at different white-light incident angles over a wide spectral range using a variable angle spectroscopic ellipsometer, Figure 8(b).

Figure. 8: (a) Scanning electron micrograph and schematic of the investigated Permalloy grating. The total area of the grating is 0.5x0.5 cm$^2$, $h = 100$ nm, $w = 264$ nm, and $s=113$ nm. The thickness of the Si substrate is 0.8 mm. (b) Schematic of the VASE-based experimental setup with a custom designed electromagnet attachment.
The spectra of the Permalloy grating exhibited asymmetric Fano resonances as peaks in reflection with p-polarised light. The results of our simulations (Figure 9) demonstrate consistency of our experimental method and theoretical approach in terms of the lineshape of the peaks in the spectra and confirm that the observed reflectivity peaks represent resonances of plasmonic nature. Figure 9 shows the TMOKE response measured on a 100 nm thick continuous Permalloy film (dashed line) and the Permalloy grating (solid line). The fitting of the experimental data with a Fano resonance function supports the enhancement of the measured TMOKE response as correlated with the plasmonic resonance in the Permalloy gratings as a modification of the light-plasmon coupling in the presence of an external magnetic field.

Figure 9: (a) and (b) Reflectivity showing measured (solid lines) and simulated (dashed lines) reflection spectra of the Permalloy grating. The insets show the grating orientation with respect to the plane of incidence. (b) Measured reflectivity spectrum at the incidence angle of 35°. (c) TMOKE response of the 100 nm reference Permalloy film (dashed line) and Permalloy grating (solid line) measured at the incidence angle of 35° and magnetic field set to 250 Oe. The vertical straight solid line denotes the Fano resonance plasmon wavelength.

The studies have shown that the Transverse-MOKE provides an interaction path between plasmons and spin waves with the ultimate goal to increase efficiency of optical modulators based on scattering of light on travelling spin waves. An all-optical excitation and control of spin waves with a light pulse focused on a magneto-plasmonic nanostructure avoids diffraction limits, and the MOKE enables space-resolved observation of fast magnetisation dynamics with characteristic frequencies in the gigahertz range [26]. In this case, standing and propagating spin waves as well as magnetization switching are typical examples of the magnetic dynamic phenomena that are of paramount importance for microwave signal processing, magnetic memory, logic and sensors. Permalloy (Ni$_{80}$Fe$_{20}$) is paramount for all these applications because of the optimum combination of magnetic properties: the vanishing magnetic anisotropy and the smallest magnetic (Gilbert) damping among ferromagnetic metals. From this point of view, the discovered plasmonic enhancement of the interaction between magnetisation and light in permalloy is very important for future applications.

Consequently plasmonic nanostructures can be expected to show increasingly strong localisation, high intensity and high field gradients to make possible the observation of atomic and molecular transitions which otherwise may be orders of magnitude less probable than dipole or symmetry forbidden transitions.

**Conclusions.**

A brief and historical view of the evolution of plasmon studies with UWA technology indicates how experimental research has responded to technological change with corresponding timely and leading edge achievements. Success has followed a balance between basic physics principles, instrument development and observations made with appropriate instruments and detector sensitivity. The technological developments with optically active materials, engineered metal thin film nanostructures and studies of the magneto-optical activity of ferromagnetic metals are enabling flexible control over the excitation of plasmons, their propagation, dispersion, confinement, and mode structure. The achievements of successive generations of physicists has exceeded expected challenges by building on the shoulders of others with amazing advances in technology.
Acknowledgements
The authors thank the Australian Research Council and the many colleagues whose contributions have made this article possible.

References.
**Jim Williams** (DSc, FAA) has pursued an academic career with teaching, administrative and research into quantum aspects of atoms and surfaces highlighting how angular momentum has underpinned structural and scattering phenomena. After a PhD (ANU 1965) and 15 years overseas at Laval University (Quebec), General Atomic (San Diego) and Queen’s University (Belfast), Jim was appointed Professor of Physics at UWA in 1980. After Head of Division of Science and Agriculture, 1993, his research continues with over 250 publications and a 2016 American Physical Society “Outstanding Referee” Award of the Physical Review journals.

**Sergey Samarin** Graduated from St. Petersburg State University, Russia, with PhD and Doctor of Science degrees. His career includes appointments at St. Petersburg State University, University of Conakry, Max-Planck Institute of Microstructure Physics and the University of Western Australia. He was a member of the ARC Centre of Excellence for Antimatter – Matter Studies (2005-2013). His accomplishments include more than 100 publications in peer-reviewed journals and numerous international conference presentations. His main scientific achievements include the development of the spin-polarized two-electron spectroscopy of surfaces.

**Mikhail Kostylev** completed his Ph.D. (Physics), St. Petersburg Electrotechnical University (SPETU), Russia, 1993. From 1993 to 1995 a Post-doctoral Fellowship, German Academic Exchange Service (DAAD), Osnabruck University (Germany). From 1995 to 2005 Assoc/Prof at SPETU. At UWA since 2005 he is a Professor, School of Physics and leads the Spintronics and Magnetisation Dynamics research group. Mikhail has co-authored more than 130 peer-reviewed publications in the fields of Magnetism, Linear and Nonlinear Waves and Oscillations.

**Nikita Kostylev** graduated with a B.Sc. degree from the University of Western Australia, 2013, majoring in Physics and specialising in Computer Engineering. He received first class Honours, completing a project on Plasmonic Nanostructures and Metamaterials and was awarded the Muriel & Colin Ramm Medal and Scholarship and the Prescott Postgraduate Scholarship (UWA). He expects to complete his Ph.D. degree in 2016 with research encompassing major optical- and microwave-domain experiments, including laser cooling and trapping of Ytterbium atoms for an optical lattice clock, and spectroscopy of crystals for quantum applications.

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Life after physics: a career in defence science

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Science has always been my passion, and physics was where I started. My career at the Defence Science and Technology Group (previously Organisation) has been varied; I started in underwater acoustics where a physics background was essential. An organisational restructure led to a move into operations research, and a short posting as an Executive Support Officer. However, even now, as a system analyst researching and modelling command and control team staffing requirements, the strong foundation in the scientific method and ability to question and understand, which I learnt when studying physics, influences my work. This article is the story of my career after studying physics.

I don’t remember when my interest in science started. From an early age I was known for asking questions, always seeking to understand the world around me. To my cousins I was their mad scientist. My quietly competitive nature to be as good as the boys, which led to success, and an inspiring year 6 relief teacher who showed us tricks with maths fed the interest. I left primary school with the confidence that I could succeed.

This continued into the western Sydney public girls high school I attended. My love for astronomy led my house painting father and stay at home mother to buy me a hand built second hand 15 cm reflective telescope. There were many nights standing out in the cold in our large backyard scanning the skies for planets and nebula. Family were regularly dragged outside to view the latest find that would quickly move through the small telescope aperture. This inquisitive behaviour was supported by my teachers who nominated me to attend the Australian Institute of Science camp in year 11. Exposed to so many intelligent and inspiring scientists gave me the insight I needed to understand that at heart I was an experimental scientist. I wanted to understand the world so that I could improve things. I didn’t want to just understand it, I wanted to apply that knowledge. So, it was natural for me to continue into university studying science at the University of Sydney, with majors in pure maths and physics.

I didn’t wait until I was finished before applying for jobs. I was lucky that the Defence Science and Technology Organisation (DSTO) was looking for new science graduates to apply science for the Defence of Australia. Three of us from the one physics class were employed. I started working with an underwater acoustics research team the Monday after my last university exam. I had a steep learning curve to begin with. My studies had introduced me to some theories but not the field of underwater acoustics, computers, acquisition systems, or working at sea. I found it quite challenging to get up to speed and be able to converse sensibly with people who were experts in the field. At the beginning I seriously wondered whether I was up to the challenge. However, I had been trained to learn, ask questions and I understood the value of good scientific technique. This grounding, and a desire to succeed, helped me get to where I wanted to be, applying science to solve real world problems.

Figure 1: Sandra with the underwater acoustics transmission data collection equipment on board HMAS Cook (1991)

For ten years I worked with these extremely knowledgeable people, world leaders on the effect of the environment on underwater sound propagation. As a team we designed data acquisition systems that we deployed from Navy vessels during month long trials (see Figure 1). My roles included contributing to the design of the acquisition systems, running them when at sea, analysing the collected data, contributing to the interpretation, and writing predictive models. The aim was to contribute...
to the science within the models used by the Australian Navy to determine their sonar settings and appropriate tactics. The teams I worked with were multi-disciplinary. They were led by a research scientist, but just as important were the engineers and technicians that brought the ideas to life.

In July 2003, DSTO reorganised itself and, as part of that, DSTO’s support to Navy’s future concept exploration program moved to Sydney. I was one of a number of staff with a technical background moved to this new program. Rather than fight the change I chose to take up the challenge to learn something new. I think the change came at a time when I was ready to look at more strategic issues. So, the steep learning curve began again, this time in the areas of operations research and analysis, military concept experimentation, war gaming and associated simulation. It was a big change from what I had been doing, but I found my physics background, particularly in underwater acoustics, put me in good stead to assess the validity of the simulation models we were viewing to use in our experimentation. The models did not have to be a perfect replica of real life; they needed to provide sufficient realism to encourage the military who were exposed to their outputs to make the same decisions they would in real life. The hard question was what was good enough? While grappling with this question I was asked to step out of science for a while to take on a management support role, and so change again I did.

In the Executive Support role I did for about a year and a half I did not need my skills in physics, modelling or experimentation. This role required me to hone my organisational and people engagement skills because I became one of a small team charged with organising DST’s move from Pyrmont to Redfern (now Eveleigh). A lot of my time was now taken up with determining how to smooth the way for staff, to ease their many concerns about changing to what was perceived as a less desirable location, and to help them get back to real work as quickly as possible. Although I didn’t need my university trained skills I was still using the fundamental science skill of determining what was important.

Shortly after the move I transitioned back to science, specifically operations analysis. Over time I gravitated to the role I am currently in, a systems analyst providing support to the Navy’s command and control team for amphibious operations. I was attracted to the work because I had become interested in looking at a system as a whole and command and control teams are complex. Although there is a standing core, the full Australian Defence Force’s amphibious command & control team does not come together until they are needed. These teams comprise personnel from all three services, who normally use different jargon, acronyms and methods. The team must come together quickly and coordinate activities to achieve the mission’s goals. Each mission is different, but fundamentally the command and control activities are the same.

I work in a small team with some supplementation of an Army Reservist. Systems analysis, as the title suggests, means looking at a whole system to determine if improvements can be made. We consider the physical systems, the personnel resources that are part of the system, the processes those people use and how the system interacts with other systems (see Figure 2). Although I don’t use the physics equations like I did in the past I find my understanding of the technical systems and the language that surrounds them useful when talking with operators. My background enables me to ask questions that help to tease out the fundamental issues. I also rely heavily on the fundamental scientific methodology to guide what to measure in these diverse systems. Regularly, we find ourselves delving into the personnel resources component of this system. We blend systems engineering tech-

Figure 2: Sandra working with MAJ Chas Viner on a business process model (2016)
niques with those of business analysts to determine the optimal manning or processes to meet the functional requirements of the system.

At present I am doing a Graduate Diploma in Scientific Leadership. I will be implementing what I learn from this course to improve my role in my work program, but also into the solution space for Navy. Many of my engagements with Navy are in workshops where we facilitate discussions to collect data to populate our simulation models.

I feel I have been lucky to have had the opportunities to do applied technical science, executive support, and operations analysis, as well as many opportunities to upskill. I am still interested in trying to understand and improve the world around me, and now I am not limited to considering any particular part. My work allows, and expects, me to consider not only the physical systems but also the people and the methods Defence uses.

Author biography

Sandra Tavener began her career with the Defence Science and Technology Group (previously Organisation) in late 1988, shortly before graduating from the University of Sydney with a Bachelor of Science majoring in physics and pure mathematics. Her career began in underwater acoustics, but then moved to designing and executing wargame experimentation activities, interspersed with a posting as an Executive Support Officer. Since 2009 she has been researching and modelling processes to determine staffing and information requirements for amphibious command and control (Awards: 1996 DSTO Divisional Best Contribution/Advice to Defence; 2008 DSTO Divisional Commendation; and 2010 DSTO Divisional Outstanding Contribution to the Impact on the Warfighter).

From DSTO to DST Group: some background

As mentioned in Sandra Tavener’s article above, DSTO (Defence Science and Technology Organisation) has changed its name to DST Group (Defence Science and Technology Group).

This is one of the consequences of a ‘First Principles’ review that was initiated by the government in 2014. The review panel, chaired by David Peever (former Rio Tinto managing director) and including Peter Leahy (former Chief of Army), Jim McDowell (former BAE Systems executive), Robert Hill (Defence Minister in the Howard government) and Lindsay Tanner (Finance Minister in the Rudd government), was given the task of making recommendations that would ensure that Defence was fit for purpose and was able to deliver against its strategy with the minimum resources necessary.

The review panel’s report, Creating One Defence was released in April 2015 by the Defence Minister, Kevin Andrews. It recommended a transformational change to an organisation, which it described as having drifted from contemporary best practice. In combination the recommendations will change the structure, governance arrangements, accountabilities, processes and systems of Defence.

Noting that around 80 per cent of the DSTO’s work was conducted in support of capability projects, the review recommended that DSTO be folded into a new capability and sustainability group, which would include the former Defence Materiel Organisation (DMO). This recommendation was not accepted by the government. While recommending that wholesale outsourcing would not be wise, the review suggested that there is more opportunity to outsource elements to the broader scientific community, particularly in industry and academia.

Thus DSTO remains independent with a name change to Defence Science and Technology Group taking affect on 1 July 2015. This change, it is said, is in keeping with the business model recommended in the First Principles Review.

Brian James
When I volunteered to review this book I mistakenly assumed that it was a collection of different approaches to the philosophy of science, something like an overview of the current state of play. My expectations were not met, while I was looking forward to new ideas in this area and how they sat with existing ideas this was not what the book is about. It is a collection of the author’s papers and a few introductory chapters containing some new ideas. The author is unknown to the reviewer and their work presents some new ideas in the Philosophy of Science. Unfortunately it does not sit within any accepted views nor contradicts any of these, it appears to come from sources outside the accepted current frameworks. Do not expect to see any references to Kuhn or Popper or even Feyerabend. The author does reference all the chapters with current publications but it feels as if it comes from a small circle of like-minded individuals with a smattering of classics.

The biggest stumbling block for me was the opening few chapters on ‘Models and Fiction’ which breaks down to ‘Fictional Models of Science’, ‘The Hypothetical versus the Fictional’ etc. I have never even considered that the philosophy of science would ever entertain these notions. However, I’m being a little harsh here and should put aside my own expectations with what the author wanted to achieve.

To give the author some credit, the work discredits the notion that modelling in science can be regarded as fictional and does accept the notion of hypothesis formation as an essential method in the understanding or modelling of scientific ideas and theories.

The reviewer’s lack of understanding in quantum mechanics does not allow for the reviewer to make any intelligent comments on the content of the author’s published papers, however it should be noted that they have been peer reviewed and published in reputable History and Philosophy of Science journals.

This is not a text for students nor was it intended as such. It is the work of one individual who has their own interpretation of the Philosophy of Science in particular physics and as such is worth a visit.

The awareness of gender disparity in the sciences is being increasingly addressed in Australia, no more so than with the advent of the Science in Australia Gender Equality (SAGE) program with 40 academic and government institutions currently taking part. It should perhaps be of no surprise that, of the physical sciences, the disparity in gender participation is most apparent in physics, echoed across the levels of participation. As more and more research is conducted into the disparity, it is becoming evident that the reasons for this are complex, deeply rooted in society and difficult to overcome without significant cultural change.

In her book ‘Women and Physics’ Laura McCullough seeks to review the state of women in physics in the Anglophone world, drawing on the statistics of participation across the levels and reviewing the research that has been undertaken to understand the problems at each stage. She breaks this down into considering what influences students in their choice (or not) in taking physics, to the university experience and then into the broader community – what problems do women encounter undertaking a career in physics.

She starts by outlining a number of situations that,
though viewed on their own seem pretty innocuous, neatly demonstrates how the barriers against women stack up. This does rather demonstrate the complexity of the situation. As often stated, there is no one over-riding factor that prevents women from fully participating in physics.

An interesting point is that her research shows that, though we may think we have much in common with our fellow Anglophones when it comes to physics, there are very few trends repeated across all these nations. For instance, in her overview of education participation across the English-speaking world she shows that in the US and some Canadian provinces at high school level there is currently no disparity in the students taking physics, which is contrasted sharply by the disparities seen at that level in the UK, Australia and New Zealand. That said, the low rate of participation and the stark drop in numbers as you move to more senior roles is a constant theme in the numbers.

After addressing the statistics, McCullough then breaks the review of the literature to that focused on education and that focused on career paths. This is where the book is at its most useful, as she disseminates a large body of social science literature. She presents this review in these chapters with little critique of each study, and instead uses the next couple of chapters to overview this body of work with a positive and negative bent. The resources that she lists in chapter 5 are particular useful, charting the number of schemes that are working to reduce the gender disparity in physics (including our own annual Women in Physics lectureship). On the negative side she discusses, among other things, how prevalent unconscious bias is and how difficult it can be to both expose and correct.

In short, this book should be required reading for all physics professionals in Australia. It is concise, McCullough’s intention was to write a book that would serve as a general introduction to the issues faced for women entering and remaining in physics, and arm the reader with further links should they wish to pursue them. It is also very easy to get your hands on this book: the IOP offer it as part of their e-book subscriptions so most physics professionals in Australia will have access to it.
**SAMPLINGS**

**Tapping into light’s hidden information to push fundamental diffraction limit**

Scientists have long believed that diffraction limits the minimum distance that can be measured between two adjacent sources of light: if the distance is too short, then the sources appear as one. Now, however, engineers in Singapore have used quantum mechanics to show this not to be the case. The researchers say that new optical techniques based on their discovery might increase the resolving power of microscopes and telescopes by several orders of magnitude.

The resolution of any imaging device is limited by the wave nature of light. That is because light striking a device’s aperture – a lens or mirror, say – are diffracted. These waves arrive at different points on the aperture interfere to produce a diffraction pattern around each point in the image. If the diffraction maximum of one point lies within its neighbour’s minimum, then those two points appear to be merged and are said to be unresolved – a criterion laid down by Lord Rayleigh in the 19th century.

In the latest work, Mankei Tsang and colleagues at the National University of Singapore looked at how to measure the distance between two adjacent light sources that are so close that they violate Rayleigh’s criterion. At that point, noise caused by light’s quantum nature – where an image is built up from discrete photons arriving randomly – means the measurement becomes far more difficult with every tiny decrease in separation. The Singapore group has dubbed this problem “Rayleigh’s curse”.

To date, scientists have devised many clever techniques to essentially sidestep this problem. In microscopy, for example, the distance between fluorescent particles is kept to a manageable minimum by ensuring that only a small subset of particles emits at any one time. Astronomers, meanwhile, can sometimes use signal processing to resolve objects that are slightly closer than the Rayleigh criterion allows.

Tsang and co-workers instead used a theory known as “quantum metrology” to work out which physical measurements would yield the most information when carried out on light. In this way, they found it is possible to measure the distance between two light sources with an accuracy that doesn’t depend on how close the sources are to one another. Even when violating Rayleigh’s criterion, they discovered that the error on their measurements remains roughly constant as they reduce the distance, rather than skyrocketing as it does with existing techniques. “Our study shows that Rayleigh’s curse is not a fundamental limit,” says Tsang.

[Mankei Tsang et al., *Phys. Rev. X*, 6, 031033 (2016)]

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**World’s largest radio telescope completed in China**

The Five-hundred-meter Aperture Spherical radio Telescope

Work has finished on the Five-hundred-meter Aperture Spherical radio Telescope (FAST) in Guizhou province in southern China. The world’s largest radio telescope, FAST comprises 4450 reflecting panels and is located in a natural depression in a remote region that is very quiet in terms of human radio signals. The collection area is more than twice as big in size as its nearest rival – the 300 m Arecibo telescope in Puerto Rico. FAST covers the 70 MHz–3 GHz frequency range and will be twice as sensitive as Arecibo and capable of surveying the sky 5–10 times faster. It will also be able to look at three times more sky than Arecibo. Built by the National Astronomical Observatories under the aegis of the Chinese Academy of Sciences, the telescope will now undergo a
series of tests before astronomers – including some from outside China – are allocated observing time.

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**X-rays yield ghost images**

“Ghost imaging” generates images by analysing correlations between two light beams, the more powerful of which doesn’t bounce off the object in question. The technique has already been demonstrated at visible and infrared wavelengths, but now two groups of scientists – one in Australia and Europe, and the other in China – have extended it to the X-ray region. The new results could lead to new methods for medical diagnoses with lower doses of X-rays and for X-ray crystallography of non-crystalline materials, say the researchers.

Ghost imaging involves splitting a light beam into two beams. The “object beam” directed towards the object to be imaged, which has a single pixel “bucket” light detector behind. Meanwhile, the “reference beam” travels straight to a multi-pixel light detector. The idea is to build up a shadow image by incorporating the output from only some of the pixels in the reference detector: those for whom the corresponding parts of the bucket detector are not blocked by the object.

To do this, the detectors are exposed to a broad “speckled” beam whose cross-sectional intensity distribution varies with time. The changing correspondence between the total intensity recorded at the object detector and the pattern of intensities recorded at the reference detector then allows the image to be reconstructed.

Ghostly wire: image taken by Daniele Pelliccia and colleagues

Ghost imaging at visible wavelengths is already being studied to improve remote imaging of the Earth’s surface by satellites in turbulent conditions. Turbulence scatters light in random directions, which usually makes images noisier. But by measuring the intensity correlations of two correlated beams over an extended period of time, one of which is bounced off the object being observed, the effects of turbulence can be averaged out to almost zero.

There is another advantage of ghost imaging that also makes it attractive at X-ray wavelengths: a good image can still be generated even when the intensity of the object beam is low. This could potentially significantly reduce the size of X-ray doses administered to patients. However, the difficulties involved in building X-ray optics mean that it is far harder to split X-ray beams than it is beams of visible light.

Daniele Pelliccia of RMIT University in Victoria, Australia, and colleagues got round this problem by using X-rays from a synchrotron source – ESRF in Grenoble, France. They directed the synchrotron beam at a sliver of silicon, which left part of the beam undisturbed and diffracted the remainder through a small angle. By placing the object – a copper wire – in one of the beams and then using different portions of a single camera to serve as both object and reference detectors, the researchers were able to generate ghost images of the wire.


Extracted with permission from an item by Edwin Cartlidge at physicsworld.com.

**Proton radius mystery deepens as deuterium measurement comes up short**

The “proton radius puzzle” has been reinforced by a precise measurement of an atomic transition in muonic deuterium, which suggests the radius of the deuterium nucleus is much smaller than expected. This latest result tallies with a similar experiment on muonic hydrogen, which found that the radius of the proton is also smaller than expected. The discrepancy could mean that theory describing how muons and electrons interact with the proton is incorrect, or that there is an error in how the radius is calculated. Another possibility is that the Rydberg constant – which defines the energy scale for atomic transitions in hydrogen – requires a slight correction.
In the decades after the proton was discovered in 1917, physicists began to realize that it has a finite size, unlike the electron, which is essentially a point particle. The internationally recognized proton radius is about 0.8751(61) fm, where the figure in brackets is the uncertainty. This has been measured using two methods that give similar results: electron scattering and atomic spectroscopy.

In 2010, however, an international team led by Randolf Pohl at the Max Planck Institute for Quantum Optics in Garching, Germany, carried out spectroscopic measurements of muonic hydrogen. This comprises a proton bound to a negative muon, which is a much heavier cousin of the electron. These studies suggested that the radius of the proton is only about 0.84087(39) fm – about 4% less than the currently accepted value and with a much smaller uncertainty.

Puzzling problem: Karsten Schuhmann and Aldo Antognini inspect their laser at the Paul Scherrer Institute

In this latest experiment, Pohl and colleagues looked at the Lamb shift in muonic deuterium, which has a nucleus consisting of not just a proton, but a neutron too. Instead of giving the radius of the proton, this measurement provides a measure of the "deuteron charge radius", which is a measure of the size of the deuterium nucleus.

The measurements were done at the Paul Scherrer Institute in Switzerland by firing a muon beam at deuterium gas, which makes some of the deuterium molecules break apart to create atoms of muonic hydrogen. About 1% of the time the muon finds itself in the 2S state, where it can be excited to the 2P state by absorbing a photon from a laser pulse. The 2P state then decays by emitting an X-ray. Counting the number of such X-rays, while scanning the frequency of the laser pulse, gives a very precise measurement of the photon energy required to drive the 2S–2P transition. A complicated QED calculation is then done to obtain the deuteron charge radius.

The team found the deuteron charge radius to be about 2.12562(78) fm, which is smaller than the currently accepted value of 2.1424(21) fm. They could also use the deuteron charge radius to calculate the proton radius. This was found to be about 0.8356(20) fm – much closer to the muonic hydrogen value than to the currently accepted radius.

[Randolf Pohl et al., Science, 353, 669-673 (2016); DOI: 10.1126/science.aaf2468]

Extracted with permission from an item by Hamish Johnston at physicsworld.com.
Dr Owen Bruce Slee

10 August 1924 – 18 August 2016

Bruce Slee, an early pioneer of radio astronomy at CSIRO’s Radiophysics Lab in Sydney, and whose research career spanned an extraordinary 70 years, has died at the age of 92.

Bruce’s long career covered a remarkable range of fields: solar-system phenomena (the solar corona, Jovian bursts, comet tails), Galactic astronomy (active stars, pulsars, the interstellar medium), and extragalactic objects (galaxies, clusters, quasars). He used the leading instruments of the day, from simple Yagi antennas during the early years, to the Australia Telescope Compact Array, and to multi-wavelength programs using space-based telescopes. He collaborated with colleagues from 18 countries, at a time when such a range of connections was rare.

Bruce was born on 10 August 1924 in Adelaide, the second of three children. The Depression of the 1930s brought hard times: the Slees lost their home and went to live with relatives. After Bruce completed his schooling he joined the Royal Australian Air Force in 1942 where he trained to be a radar mechanic. In 1945 while stationed near Darwin Bruce noticed a distinctive ‘static’ when his radar antenna faced west at sunset, which he correctly concluded was caused by radio emission from the Sun. Bruce reported his discovery to CSIRO’s Radiophysics Lab, which had already begun a study of solar radio emission, and this led to an offer for Bruce to join its staff in Sydney.

In December 1946 Bruce was posted to the Dover Heights field station and, with colleagues John Bolton and Gordon Stanley, was given the task of monitoring radio emission from the Sun. In May 1947 the Dover group decided to investigate a report by an English group of a strong concentration of radio emission from the Cygnus constellation. Using a technique known as sea interferometry; they were able not only to confirm the English report, but also to show that the emission came from a discrete point-like source. By the end of 1947 the group had found a further six of these discrete radio sources. Here was a new class of objects previously unknown to astronomers.

The Dover group spent most of 1948 measuring precise positions for their four strongest sources in the hope of identifying them with known optical objects. Cygnus remained a mystery but the Taurus source coincided with a galactic supernova remnant (the Crab Nebula), while the Centaurus and Virgo sources coincided with two unusual extragalactic objects (NGC5128 and M87). A Nature paper in 1949 by Bolton, Stanley and Slee reporting their optical identifications marked the birth of a new branch of astronomy — extragalactic radio astronomy.

Bruce’s initial appointment was as a humble technical assistant, but he made a steady ‘bootstrap’ rise through the research ranks. He studied part-time and gained diplomas in both radio engineering and physics, followed by a BSc (Hons) in 1959 which earned him promotion to a CSIRO research officer. Ten years later the University of NSW awarded him a DSc on the strength of his research record.

In 1954 Bruce transferred to the Fleurs field station in western Sydney to work on a new cross-type radio telescope devised by Bernie Mills. In 1957 Mills, Slee and Eric Hill completed a sky survey which catalogued over 2000 radio sources. The Fleurs catalogue became the centre of a fierce controversy between proponents of the rival steady-state and big-bang cosmologies, with the catalogue appearing to favour the big bang.

Apart from two years at the Royal Radar Establishment in England, Bruce spent his entire career at the Radiophysics Lab (later the Australia Telescope National Facility). He formally retired in 1989 but continued his research until his final few months. In later years he coauthored a series of articles with one of us (WO) on the early history of Australian radio astronomy, a subject he had done so much to create himself.

As a permanent tribute to Bruce’s remarkable career, early in 2016 the International Astronomical Union named an asteroid after him, Minor Planet 9391 Slee. In August a workshop to celebrate Bruce’s achievements was held at the University of Sydney, which revisited many of the topics that Bruce had investigated over his career. Unfortunately, Bruce could not attend after a fall at his home. He died the day after the workshop.

Bruce is survived by his wife Nan, two daughters Sally and Lesley, and grandchildren Ian, Jeanette, Belinda and Megan.

Wayne Orchiston, Helen Sim and Peter Robertson
**PRODUCT NEWS**

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Watt pilot from Altechna - motorized attenuator enhanced for high energy and ultrashort laser pulses

Altechna’s enhanced watt pilot version incorporates rotating quartz λ/2 phase waveplate and one or two thin film polarizers which separate s-polarized and p-polarized beams. The intensity ratio of these two beams is continuously tuned by rotating the waveplate. Watt Pilot is essential in systems, where stable laser power adjusting is necessary. Despite stand alone device look, motorised attenuator is very compact and it can be easily integrated in custom optical systems.

Specifications:
• Clear aperture: 15 mm
• Bandwidth: Up to ±20 nm
• Configuration: Reflection and transmission modes
• Attenuation range @ CWL: Up to 0.3-99%
• Typical application: High power CW and pulsed lasers, LDs
• Damage threshold: >5 J/cm² (10 Hz, 10 ns, 1064 nm); or >100 mJ/cm² (1 kHz, 100 fs, 800 nm)
• Dimensions 91 x 63 x 108 mm³ - reflection mode
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• Resolution: 41.54 arcsec/step
• Step accuracy in full rotation: ± 4 steps
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Ocean Optics QE Pro the highest performance miniature spectrometer

The QE Pro is a high-sensitivity spectrometer ideal for low light level applications such as fluorescence, DNA sequencing and Raman analysis. The QE Pro's back thinned CCD detector has high quantum efficiency and its robust design yields great signal to noise performance and stability. An optional internal shutter is available for effective management of dark measurements. In addition, the interchangeable slit option allows users to switch between absorbance and fluorescence measurements easily.

At a Glance:
• Wavelength range: Configurations support the range of 185-1100 nm
• User interchangeable entrance slits
• Optical resolution: 0.14-7.7 nm (FWHM) depending on configuration
• Internal shutter (optional) for effective management of dark measurements
• System SNR: 1000:1
• A/D resolution: 18 bit
• Dynamic range: 85,000 (typical)
• Stray light: <0.08% at 600 nm; 0.4% at 435 nm
• Buffering: 15,000 spectra
• TEC: Cooling to -40 ºC below ambient, -40 ºC to +50 ºC temperature limits

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Warsash Scientific

M Squared Lasers provide further coverage in the UV, Visible, and IR

M Squared Lasers has launched its new External Mixing Module (SolsTiS-EMM), designed to complement the award-winning ‘SolsTiS’, CW narrow linewidth Ti:Sapphire laser.

The SolsTiS-EMM enables access to previously hard to reach wavelengths in the UV, visible and IR regions, whilst also featuring the narrow linewidth, ease of use and ultra-stable output for which SolsTiS is well-known.

This new addition now gives M Squared’s SolsTiS platform unrivalled wavelength coverage from 210 nm to 3.2 µm, achieved through a variety of extensions which feature doubling, sum frequency and difference frequency mixing schemes.

In particular, this all-solid state, hands free solution for wavelength coverage now supersedes dye lasers, removing the hazards and instabilities associated with this toxic gain material.

SolsTiS represents a step-change in continuous-wave Ti:Sapphire laser technology. It’s a super-compact system with a completely sealed, alignment-free cavity unique to M Squared Lasers. It offers hands-free operation with an unprecedented tuning range, unrivalled power, and the ultimate narrow linewidth, low noise output.

Faster, Larger Tip/Tilt Piezo Beam Steering Mirrors

Warsash Scientific are pleased to announce the S-331 fast tip/tilt platform, the newest piezo steering mirror in PI’s (Physik Instrumente) portfolio. The S-331 utilizes flexure-guided, electro-ceramic driven system that provides precise angular tip/tilt motion of the top platform around two orthogonal axes with millisecond response/setting time, high dynamic linearity, and frictionless backlash-free operation. The single pivot-point design also prevents the drawback of polarization rotation, which is common with conventional 2-axis stacked systems, e.g. galvo scanners. With a tip/tilt angle up to 5 mrad and optical deflection angle up to 10 mrad, these platforms are ideal for compact mirrors up to ½ inch in diameter.

PI piezo steering mirrors are based on a parallel-kinematics design with coplanar rotational axes and a single moving platform driven by two pairs of differential actuators. The advantage is jitter-free, multi-axis motion with symmetrical dynamic performance. In addition, the actuators are 100% insulated which provide a long lifetime and insensitivity to humidity or high operating temperatures.

3D Vibration Measurements for Microsystems

Warsash Scientific are pleased to promote the MSA-100-3D Micro System Analyser from Polytec, the cutting-edge table-top vibrometer system designed for real-time 3D vibration analysis on microscopic objects with high lateral resolution.

The MSA-100-3D utilizes heterodyne Mach-Zehnder interferometry to achieve directionally resolved Doppler shift analysis on the sample surface. This setup enables sub-picometer amplitude resolution for both out-of-plane and in-plane motion, with a frequency bandwidth of up to 25 MHz.

Two configurations of the Microsystem Analyser are available. The MSA-100-3D measures 3D vibration data on spot locations. The MSA-100-3DSV features a software-controlled high-precision XY stage and allows automated full-field scanning measurements. Meaningful visualization of 3D deflection shapes and extensive data analysis is provided by Polytec’s PSV Software.

The MSA-100 Sensor Head adapts a flexible mounting concept to satisfy different application requirements, with either standard or portal stand mounts. The MSA-100-3D can also be adapted to probe stations for automated or semi-automated measurements on wafer-level.

For more information contact Warsash Scientific at sales@warsash.com.au

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