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**Cover**

The 22nd AIP Congress is being held jointly with the 13th Asia Pacific Physics Conference in Brisbane 4-8 December, 2016. For more details see page 101.

Image credit: iStock by Getty Images.

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**Australian Institute of Physics**

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

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EDITORIAL

AIP AND AAPPS

For this issue I have decided to use the cover to advertise the AIP Congress in Brisbane, 4-8 December. It is particularly significant this year as it is a joint meeting with the Asia Pacific Physics Conference (for further details see p101). The Asia Pacific Physics Conferences are the triannual conference series organised by the Association of Asia Pacific Physical Societies (AAPPS), of which the AIP is one of 18 member organisations (note, however, that membership does not extend to the eastern seaboard of the Pacific Ocean). The AAPPS publish the AAPPS Bulletin, which became an online publication several years ago (www.aapps.org).

I have just agreed to replace Rob Robinson on the Editorial Board of the Bulletin. I can see synergies flowing from my membership of this Board. I hope it will facilitate more Australian content in the Bulletin and help me to occasionally have an article from our region of the world in Australian Physics. After having an article from Indonesia a few years ago, I have struggled without success to obtain articles from other nearby countries.

Cedric Powell, now at NIST, in his article, Early History of the Electron Spectroscopy Project at the University of Western Australia: First Definitive Identification of Surface and Bulk Plasmons, gives an account of his work at UWA in the late 1950s and its significance for the field of plasmonics. I hope to publish in a forthcoming issue an article describing subsequent research at UWA in the field up to present times.

It is an exciting time for cosmology: last year we celebrated the centenary of Einstein’s General Theory of Relativity and this year we had the announcement of the first detection of gravitation waves. In his article On The Relativity of Redshifts: Does Space Really “Expand”? Geraint Lewis of the University of Sydney looks at the various misconceptions commonly held about the various situations that lead to redshifts of electromagnetic radiation, and provides a definitive resolution of conflicting views.

Finally we continue to make progress with placing electronic copies of past issues online. To see the current state go to www.aip.org.au and select Australian Physics from the Publications menu.

Brian James
**Future strategic directions and an AIP Congress ‘Lite’?**

After the excitement of the first direct detection of gravitational waves that was announced back in February, the last couple of months have been relatively quiet. As such, it is a good opportunity to use my column in this issue to focus on matters of considerable importance to the AIP as an organization: its future strategic directions and the AIP Congress.

The AIP Executive is very mindful of the need for it to regularly review the state of the AIP and its portfolio of activities, setting its future strategic directions accordingly so as to best serve its membership and maximize its effectiveness in carrying its mission of “promoting the role of Physics in research, education, industry and the community”. Every two years, therefore, it holds a Strategy Day for this purpose, the most recent being held in November last year at UNSW. It was facilitated by Brian Boyle (Acting DVC-R at UNSW), and the Executive was joined at various times during the day by Catriona Jackson (CEO, STA), Helen Maynard-Caseley (WiP-Chair), Sven Rogge (Head, School of Physics, UNSW), and John Chapman (GEMETRIX), each of whom provided important perspectives from a science lobbyist, gender/WiP, institutional, and industry point of view, respectively.

The main outcome of this strategy day was the establishment of a set of strategic objectives for the next 2-3 years, with quantitative targets set for each. The development of a detailed plan for their implementation is now one of the Executive’s highest priorities. To summarize, the Executive identified 3 key areas where the AIP has to focus more of its resources and effort: in communications, networking, and advocacy. Communications are not just vital to keeping AIP members informed and connecting them with policy decision makers, the rest of the science community, and the public at large, but also in informing potential members of the value propositions the AIP has to offer. While the AIP does communicate far and wide via numerous channels (e.g. email, website, social media, Australian Physics), it needs to do more of it, expanding its use of social media. How it does this (outsourcing versus doing it in-house) also needs to be given careful consideration. The networking opportunities that the AIP provides, particularly through the biennial congresses, is seen as a very important benefit by the AIP membership. However, these need to be expanded, with a more international outlook, and the congresses made more accessible cost-wise. Finally, in its advocacy role, the AIP needs to do more to promote the value of physics to society and the economy, as well as draw attention to systemic gender and equity issues in physics education, drawing on the support of STA, the Academy, and industry.

The accessibility of the biennial AIP congresses in terms of cost is an issue that has been raised numerous times in the past. The specific concern is that even with the reduced registration fees for AIP members and student members, they are still sufficiently high that the cost of having entire research groups attend (including postdocs and PhD students) is very expensive. An interesting suggestion that was made at the Strategy Day was to significantly change the current model for organising the congresses, running them much more cheaply (and hence with much lower registration costs), and holding them annually – what we might call an AIP Congress ‘Lite’. This possibility was discussed at the last AIP Council meeting held in early February. In addition, it is very important that AIP members have their say on this topic, and I strongly urge all of you to email me (aip_president@aip.org.au) with your views. One alternative that has been suggested in input already received is to retain the biennial AIP Congress in its current form – it being too significant and valuable an event in terms of its scope and scientific standing to dispense with – but to hold a Congress ‘Lite’ in intervening years.

Finally, another very important function of the AIP is to recognise and reward excellence in Physics through its awards and medals program. It therefore gives me very great pleasure to announce that Dr Phiala Shanahan is this year’s winner of the AIP Bragg Gold Medal for the best PhD thesis in Australia. Phiala’s thesis, entitled “Strangeness and Charge Symmetry Violation in Nucleon Structure”, was done at the University of Adelaide. Look out for an article on Phiala’s thesis work in the next issue of Australian Physics, and I very much hope to be able to present Phiala with her medal at the joint 13th Asian-Pacific Physics Conference and 22nd AIP Congress in Brisbane in December (see www.appc-aip2016.org.au).

Warrick Couch
Letter to the Editor

I would like to thank John Pilbrow and those who assisted him for their wonderful obituary to Dr Gordon Troup that appeared in the March-April 2016 issue of *Australian Physics* (53(2), p48). He certainly was a remarkable man.

I concur that Dr Luciano Navarini from Trieste would have been surprised by Gordon’s prompt reply in ‘perfect Italian’. In the final stages of my PhD research at Monash University, I was trying to come up with a theoretical description for the effect of sweeping non-adiabatically through a nuclear magnetic resonance. I had come across a 1932 article published by the enigmatic Ettore Majorana. It dealt with a molecular beam passing through a region of varying magnetic field and it seemed to be relevant. However it was published in Italian. Gordon said that he was just about to travel by sea to his Italian sabbatical and was planning to ‘learn Italian on the voyage’. He did just that and subsequently sent me a fully translated version of the article. I have never ceased to be impressed by that feat.

Glen Stewart
Senior Visiting Fellow, UNSW Canberra

NEWS & COMMENT

Academy elected to international Academies leadership

The Australian Academy of Science has been elected to the Executive Committee of The InterAcademy Partnership (IAP): the global network of science academies.

IAP was launched in 1993 and includes 111 science academies from around the world. Its primary goal is to help member academies work together to advise citizens and public officials on scientific aspects of critical issues. IAP programs involve interdisciplinary activities and studies on matters related to science and technology. At its General Assembly in March 2016 the Australian Academy of Science was elected to the IAP Executive Committee along with the African Academy of Sciences, Academia Chilena de Ciencias, the Academy of the Islamic Republic of Iran, the Korean Academy of Science and Technology, and The Royal Society, UK. The Academy previously served on the Executive Committee of the IAP from 2007-2012.

New ten-year plan for mathematics launched

Mid-level maths should be made a pre-requisite for students looking to enrol in science, engineering or commerce degrees according to a new ten-year plan for mathematics in Australia, which was launched in March by the education minister Simon Birmingham.

Currently only 14 per cent of Australian universities require science students to have studied intermediate mathematics in Year 12. The plan, developed by the National Committee for Mathematical Sciences, makes a dozen key recommendations including increasing professional development for out-of-field maths teachers and a new national mathematics research centre to link industry and research. It also highlights an urgent need to address the low participation of women and rural Australians in the mathematical sciences.
CSIRO Alumni Scholarship in Physics for 2016

The 2016 CSIRO Alumni Scholarship in Physics has been awarded to Ms. Brianna Ganly, who was presented with the award by Dr Dave Williams, Executive Director at CSIRO and Ms Leanne Harris, General Manager of Laboratories Credit Union in March 2016.

Brianna Ganly with Dr Dave Williams and Ms Leanne Harris.

Brianna is undertaking her PhD studies with CSIRO Mineral Resources in conjunction with the UNSW. Although the main objective of her thesis is to develop new methods for measuring the metal content in unprepared rock samples for the Australian mining industry, she discovered that the University of Guelph PIXE (Particle Induced X-ray Emission) group in Canada shares the same interests in improving measurements of the element content of unprepared samples. The group is led by Professor Campbell, a world leading expert on PIXE, who is also a co-investigator on the Mars rover Curiosity’s APXS instrument.

The scholarship will fund Brianna to visit Canada and perform particle size experiments with access to specialised equipment, including a proton beam line which has recently been designed to emulate the Curiosity APXS as closely as possible. The results of these PIXE experiments will hopefully increase the understanding of particle size effects in a way that can be applied to improving XRF analysis of ore.

The CSIRO Alumni Scholarship in Physics is awarded annually in commemoration of Drs John Dunlop, Don Price, Tony Farmer and Gerry Haddad, all former CSIRO physicists tragically lost in a helicopter crash in 2013. Colleagues, CSIRO alumni, friends and family congregated at CSIRO Lindfield on 21st March to celebrate the lives and legacies of the four great men and to congratulate this year’s recipient of the scholarship. They were delighted to receive a report from Ms. Claire-Elise Green, the 2015 recipient, who used her scholarship to visit the Max-Planck-Institut für Radioastronomie to collaborate on their Chilean radio telescope data to study the birth of stars. As a result of her visit, Claire-Elise jointly published a paper with Max-Planck and was offered a post-doctoral fellowship when she completes her PhD.

2015 Outstanding Service to Physics Award

Cathy Foley has been awarded the Outstanding Service to Physics Award for 2015 in recognition of her leadership and many outstanding contributions to physics and the physics community. Cathy is presently Deputy Director and Science Director, Manufacturing – CSIRO and is a past Chief of CSIRO’s Division of Materials Science and Engineering. She is also a past President of the AIP (2007-8).

2016 Women in Physics Lecturer

This year’s AIP Women in Physics Lecturer is Dr Catalina Curceanu. As Head Researcher of the National Institute of Nuclear Physics, she deals with the planning and management of experiments of nuclear and hadronic physics in Italy’s National Laboratories of Gran Sasso. She received her doctorate in research in the field of spectroscopic meson physics in the OBELEX (CERN) experiment. For this work, she received the prestigious, scientific prize awarded by the Romanian Academy in Rome.

Dr Cathy Foley

Dr Catalina Curceanu
AINST opened
The Australian Institute of Nanoscale Science and Technology (AINST) at the University of Sydney was officially opened on 20th April. The interdisciplinary Institute brings together the University’s collective academic expertise in nanoscale research in a purpose-built facility - the Sydney Nanoscience Hub. The Hub includes a nanofabrication cleanroom and a dedicated microscopy suite.

Nanoscience Hub, University of Sydney

Research is grouped into three themes: energy and environment; health and medicine; and communications computing and security. The research leaders of three physics-related flagship programs are Prof David Reilly (Measurement and Control at the Nanoscale); A/Prof Michael Biercuk (Quantum Simulation) and Prof Ben Eggleton (Nanoscale Photonic Circuits).

New corresponding members elected to the Academy

A physicist, Professor John Spence, and a molecular biologist, Professor Matthias Hentze, have been elected to the Academy for their outstanding contributions to their fields. Corresponding members are a special category within the Academy’s Fellowship comprising eminent international scientists with strong ties to Australia.

Professor Spence, based at Arizona State University, was born in Australia and is internationally recognised for his contributions to the development and application of X-ray lasers to biology and molecular movies, and to atomic-resolution electron microscopy.

Along with corresponding members, the Academy elects up to twenty ordinary Fellows and normally one specially elected Fellow each year. These new Fellows will be announced in the final week of May.

Where could STEM take you?

Australians with qualifications in science, technology, engineering and mathematics (STEM) are working across the economy in many roles from wine-makers to financial analysts, according to a new report from The Office of the Chief Scientist. Australia’s Chief Scientist Dr Alan Finkel said that the report Australia’s STEM Workforce is the first comprehensive analysis of the STEM-qualified population and is a valuable resource for students, parents, teachers and policy makers. The report is based on data from the 2011 Census, the most recent comprehensive and detailed data set of this type of information. The report will serve as a benchmark for future studies.

“...This report provides a wealth of information on where STEM qualifications – from both the university and the vocational education and training (VET) sectors – may
take you, what jobs you may have and what salary you may earn,” Dr Finkel said. “Studying STEM opens up countless job options and this report shows that Australians are taking diverse career paths.”

The report investigates the workforce destinations of people with qualifications in STEM fields, looking at the demographics, industries, occupations and salaries that students studying for those qualifications can expect in the workforce. It found that fewer than one-third of STEM university graduates were female, with Physics, Astronomy and Engineering having even lower proportions of female graduates. Biological Sciences and Environmental Studies graduates were evenly split between the genders. In the VET sector, only 9 per cent of those with STEM qualifications were women.

Dr Finkel said that even more worrying than the gender imbalance in some STEM fields, was the pay-gap between men and women in all STEM fields revealed in the report. These differences cannot be fully explained by having children or by the increased proportion of women working part-time.

The analysis also found that gaining a doctorate is a sound investment, with more STEM PhD graduates in the top income bracket than their Bachelor-qualified counterparts. However, these same STEM PhD holders are less likely to own their own business or to work in the private sector.

**BRANCH NEWS**

**New South Wales**

The Branch hosted the presentation of the 2015 Bragg Gold Medal for Excellence in Physics to Dr Jarryd Pla (UNSW) on Tuesday 12 April. On Thursday 28 April Dr Christopher P.J. Barty presented a lecture entitled *Bringing Star Power to Earth - The Story of the World’s Most Extreme Lasers and the Pursuit of Fusion for Environmentally Clean Energy.*

A joint event with RACI, RSNSW and ANSTO, *Planetary Parliament*, was held at 6 pm on Tuesday 10 May 2016 at the CSIRO Life Sciences Centre. A panel consisting of Prof Andrew Hopkins (AAO), Dr Gail Iles (European Astronaut Centre) and Dr Helen Maynard-Casely (ANSTO) answered your questions on the Universe and beyond.

The Branch is calling for nominations for its 2016 Community Outreach to Physics Award. The Award seeks to acknowledge an individual with a passion for the study of physics in New South Wales who has made an outstanding contribution to community outreach and physics education.

The deadline for nominations is 7 October 2016. Further details of criteria for the Award, which will be presented at the Branch’s Postgraduate Awards and Annual Dinner on Tuesday 15 November 2016 at the University of New South Wales, are available on the Branch’s webpage (http://nsw.aip.org.au/).

Caption: AIP president Prof Warrick Couch presenting the Bragg Medal for 2015 to Dr Jarryd Pla.

**22nd AIP Congress - in association with the 13th Asia Pacific Physics Conference.**

4-8 December 2016,
Brisbane Convention Centre
aip-appc2016.org.au
Early History of the Electron Spectroscopy Project at the University of Western Australia: First Definitive Identification of Surface and Bulk Plasmons

Cedric Powell
Materials Measurement Science Division, National Institute of Standards and Technology, Gaithersburg, Maryland 20899-8370, USA
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A personal account is given of the electron spectroscopy project at the University of Western Australia that was initiated by the late Dr. John B. Swan. The author was John Swan’s first Ph.D. student, and he describes his work in 1956-59 that led to the first definitive identification of surface and bulk plasmons in solids.

Introduction
I began my association with the University of Western Australia (UWA) Electron Spectroscopy Project as an Honours student in 1955. I then became the first Ph.D. student to work on this project during 1956-59. John Robins was the second Ph.D. student on this project during 1957-60. Our adviser was the late Dr. John B. Swan (see Figure 1) whose career has been summarised in Issue 6 of the UWA Physics History series [1].

John Swan has described his research in β-ray spectroscopy at the University of Illinois, which stimulated him to consider investigations of atomic energy levels at energies less than about 1 keV [1]. During my initial meetings with John, I can recall him showing me a then-current compilation of binding energies by Hill et al. [2] and pointing out the inadequacies of the available data at such low energies. He had planned to investigate low-energy binding energies using γ-photoelectron spectroscopy (via internal conversion electrons), and then X-ray photoelectron spectroscopy (XPS) and Auger-electron spectroscopy (AES). He had considered doing XPS experiments with carbon Kα X-rays but realised that an X-ray monochromator would be needed to reduce the width of this X-ray line. John was also aware of Burhop’s book on the physics of AES [3] and of a recently published paper by Lander [4] who reported AES spectra of seven elemental solids and some oxides at low energies.

Description of the Electron Spectrometer
John Swan designed the electron spectrometer (a 127° cylindrical electrostatic analyser) in 1953 and this with its vacuum system was constructed in the Physics Department Workshop. John also began the design and construction of needed electronics units. My initial Ph.D. work in 1956 involved testing the spectrometer, first using electrons from a thermionic source and later electrons from a simple electron gun that had been scattered by a tungsten-wire target. Not surprisingly, a number of experimental problems had to be resolved. The plates of the analyser were mounted in grooves machined on pieces of Perspex®, and the latter surfaces charged when our electron beams entered the analyser. Many different coatings were tried on the Perspex® surfaces before one was found that was sufficiently uniform (so as not to distort the desired electric field) and that had a sufficiently high resistance. While a coil system had been installed to neutralize the vertical component of the earth’s magnetic field, it was later realized that this was inadequate. A new coil system was designed to provide a larger volume of field uniformity (i.e., over the detected-electron trajectories in the analyser) and the spectrometer was tilted so that the analyser axis was parallel to the field direction; originally, the analyser axis was vertical. In addition, some extra electronic units had to be designed, constructed, and tested.

First Experimental Measurements in 1957
After tests of spectrometer performance and resolution reached design expectations, it was decided to measure the intensities of elastically and inelastically scattered electrons from a tungsten-wire target with a primary-beam energy of 850 eV and to measure the intensity of...
carbon Auger electrons as a function of time following cleaning of the tungsten surface by heating to about 1500°C. Many previous workers had shown that the results of electron scattering and secondary-electron-emission experiments were affected by two common types of surface contamination, the adsorption of a monolayer of residual gas and the deposition of carbonaceous contamination on the electron-irradiated surface. The high-vacuum system for our spectrometer, conventional for the time, was constructed of brass and had an oil diffusion pump; flanges were sealed using O-rings and grease. Although ultra-high vacua had been previously utilized for some earlier electron-scattering experiments elsewhere, UWA did not have a skilled glass blower and other technology for producing such low pressures. Nevertheless, we were able to follow the adsorption of ambient gases (such as nitrogen, oxygen, water and organic compounds from pump oil, etc.) on the cleaned tungsten wire from changes in the elastic and inelastic intensities and the subsequent intensity changes of the carbon Auger peak as carbonaceous contamination was deposited during electron bombardment [5]. While Lander had suggested that Auger electrons could provide a useful method of surface analysis [4], our measurements were the first use of AES for assessing cleanliness of a sample (tungsten in our case) following a cleaning procedure.

Following the initial measurements with the tungsten sample in 1957 [5], it was decided to make further measurements of inelastically-scattered electrons that involved energy losses of typically between 5 eV and 50 eV. A number of groups, mainly in the USA, France, Germany, England, and Japan, had been measuring these so-called characteristic loss spectra of 20-50 keV electrons transmitted through thin sample films (e.g., of 20 nm to 50 nm thickness) of various solids [6,7]. The thin films were often prepared by vacuum evaporation (in conventional high-vacuum systems) onto suitably thin substrates or onto substrates that could later be removed. The characteristic-loss measurements were also made in similar high-vacuum systems, and so it is not surprising that inconsistencies occurred in the reported energy losses for various solids [6,7]. Differences in energy-loss spectra and energy-loss values could reasonably be attributed to surface impurities (e.g., oxides on elemental solids), the possible presence of a substrate, and to various instrumental factors (e.g., different energy resolutions and angular acceptances of the analysers) [6].

Measurements of characteristic loss spectra were also attractive in that they could be made relatively quickly (thus minimizing the risk of surface contaminations) whereas Auger peaks were much weaker and these measurements would take longer. The early measurements [5] were made manually by stepping the voltage across the analyser deflection plates and recording the average count rate. This tedious process was later replaced by a system in which the deflection plate voltage was continuously scanned and the corresponding count rate recorded on a moving strip-chart recorder.

Early Theories of Characteristic Energy Losses in Solids

At that time (ca. 1956), three main theories had been proposed to describe the characteristic energy losses. First, Leder et al. [8] found numerical correlations between energy losses measured for many solids and the positions of fine structure in near-edge X-ray absorption spectra. These correlations suggested that the energy losses were due predominantly to single electron excitations from the valence band that could be related to the band structure of each solid. Second, Pines [7] and coworkers proposed that the energy losses were due to plasma oscillations of the valence electrons, i.e., to bulk plasmons. While good correlations existed between observed and predicted energy losses for some solids (e.g., the so-called free-electron solids such as Mg, Al, and Si), there were appreciable inconsistencies for other solids (e.g., transition and noble metals). Third, a dielectric model for describing inelastic scattering had been proposed [9], but the lack of reliable optical data for the region of interest (wavelengths between 50 nm and 400 nm) made interpretations difficult. In 1957, Ritchie [10] proposed that surface plasma losses (i.e., surface plasmons) should be observable at energy losses of $\hbar \omega_p / \sqrt{2}$ for a solid with planar surfaces or at $\hbar \omega_p / \sqrt{3}$ for a spherical particle, where $\hbar \omega_p$ is the bulk plasmon energy (with plasma frequency $\omega_p$ that depended on the square root of the valence-electron density). Ritchie also commented that “Existing experimental evidence … does not seem to be detailed enough as yet to judge whether … these losses really occur” [10].

“Existing experimental evidence … does not seem to be detailed enough as yet to judge whether … these losses really occur”
Plans to Measure Characteristic Energy Loss Spectra

I designed a new target chamber for the spectrometer with an improved pumping system, a liquid-air cold trap surrounding the target assembly (which could be heated by electron bombardment), and two evaporators and shutters (so that films could be deposited on the target after outgassing of each evaporator). Multiple evaporations could also serve to getter the chamber. We believed that samples with surfaces of sufficient purity could be prepared by multiple evaporations. Our initial plans were to measure characteristic loss spectra of evaporated metals, to measure loss spectra of one material on a substrate as a function of thickness, and to measure characteristic loss spectra of binary alloys such as Al-Mg and Al-Cu. These three prototypical elements were selected as Al and Mg were typical free-electron solids with energy losses close to $\hbar \omega_p$, and the prominent loss in Cu was broad and considerably different from $\hbar \omega_p$. Figure 2 shows a schematic of the spectrometer, the new target chamber, and the key electronics [11]. Figure 3 is a photo of the instrument and Figure 4 shows the target chamber.
Identification of Surface and Bulk Plasmons in Al and Mg

Our measurements of the characteristic loss spectra of evaporated Al with primary energies of 760, 1000, 1520, and 2020 eV showed that the loss spectra were composed entirely of multiples of 10.3 eV and 15.3 eV energy losses, as shown in Figure 5 [12]. The ratio of the intensity of the 10.3 eV loss to that of the 15.3 eV loss increased with decreasing primary energy, consistent with Ritchie’s prediction [10]. The 10.3 eV loss was therefore identified as the surface plasmon and the 15.3 eV loss as the bulk plasmon. The ratio of these energy losses was 1.49, close to but slightly different from the predicted free-electron ratio of 1.41; the difference in these ratios was later associated with a weak single-electron excitation. Similar results were found for Mg, where the surface-plasmon loss was 7.1 eV and the bulk-plasmon loss was 10.6 eV [13].

In early 1959, Stern predicted that the 7 eV Al loss commonly observed in transmission energy-loss experiments was due to the presence of thin oxide coatings on the Al films [14]. Shortly thereafter, I contacted Stern and sent him a preprint of our paper reporting observation of the 10.3 eV surface-plasmon loss on unoxidised Al surfaces [12]. In return, he sent details of his calculations that predicted the surface plasmon loss at $\hbar \omega_p / \left(1 + \varepsilon_\infty(\omega)\right)$ where $\varepsilon_\infty(\omega)$ is the frequency-dependent dielectric constant of an oxide on the Al film [15]. For an oxide-free surface, $\varepsilon_\infty = 1$, and Ritchie’s result is obtained [10]. For an Al$_2$O$_3$ film on Al, Stern expected a 6.5 eV modified surface-plasmon loss.

A series of measurements was then made to determine the effects of oxidation on the characteristic loss spectra of Al and Mg in order to check the predictions of Stern and Ferrell [14,15]. Figure 6 shows illustrative Al loss spectra (recorded with a primary energy of 750 eV) as oxidation proceeded [16]. The number against each curve is the average value of $(t/t_0)$ where $t$ was the elapsed time after Al evaporation and $t_0$ was the time during which the measured intensity of the 15.3 eV bulk plasmon loss decreased to half of its initial value. The oxidation rate in this work was such that $t_0$ was between 1 and 5 minutes. Measurement of each loss spectrum in Figure 6 took approximately 1 minute. For the previous measurements of Al loss spectra [12] where repeated Al evaporations were made, $t_0$ was about 30 minutes. Even though the base pressure in the target chamber was about $3 \times 10^{-4}$ Pa, the partial pressure of active gases such as oxygen and water must have been reduced by repeated gettering actions to about $10^{-7}$ Pa.
Figure 6 clearly shows that the 15.3 eV Al bulk plasmon loss gradually decreased in intensity as oxidation proceeded. The intensity of the 10.3 eV surface plasmon loss, however, decreased much more rapidly, and was replaced with a new loss at 7.1 eV, which then decreased in intensity. The intensities of these three energy losses are plotted as a function of $t/t_0$ in Figure 7 [16]. These changes, together with similar results for Mg, were consistent with the predictions of Stern and Ferrell [14,15] and reinforced the previous interpretation of the 10.3 eV Al loss as the surface plasmon. The 7.1 eV Al loss, seen frequently in transmission experiments, was thus a “modified” surface plasmon due to the presence of aluminium oxide on the surfaces of the specimen film.

A modified surface plasmon loss was observed following oxidation of the alloys, and the positions of this loss and the surface plasmon loss varied roughly linearly with the bulk plasmon loss, in each case between the values for each element of the alloy. These changes were interpreted in terms of the changing free-electron density (and thus of $\hbar\omega_p$) in alloys of varying composition.

These early UWA experiments showed that novel and significant measurements could be made of characteristic loss spectra from evaporated solids. These measurements, made with a “reflection” scattering configuration, proved that inconsistencies in previous transmission experiments were largely due to surface impurities and particularly to the effects of oxides. References to the definitive UWA identification of surface and bulk plasmons for Al and Mg were included in the widely used text on Solid State Physics by Kittel [19] and some recent review articles [20-25].

The spectrometer was utilized by a number of subsequent research students, particularly John Robins, Phil Best, Bruce Hartley, and Mervyn Lynch, who performed characteristic loss studies of additional elemental solids and compounds [26-40]. Numerous improvements were made to the electronics and the vacuum system. The spectrometer was “finally retired to honoured rest in 1977 after churning out numerous papers, M.Sc.’s, and Ph.D.’s” [41].

Concluding Remarks

Subsequent work has shown that the dielectric model, as described by Fano [9] and many others, provided a comprehensive description of the inelastic scattering of electrons in solids. It is now recognized that this model incorporates excitations of bulk plasmons and single-electron excitations; the model can also describe surface-plasmon excitations. In an interesting application, Werner et al. have shown that optical properties of solids for photon energies between 0.5 eV and 70 eV can be derived from reflection energy-loss spectra acquired at two different primary energies [42]. Measurements of inner-shell excitations in energy-loss spectroscopy of electrons transmitted through thin films, particularly in the transmission electron microscope, have now become a useful method of thin-film analysis [43]. Some inner-shell excitations, with energy losses of less than 100 eV, were also observed in the “reflection” energy-loss experiments at UWA.
Postscripts

1. X-ray photoelectron spectroscopy (XPS) has become the most widely used method of surface analysis. A useful history of the development of XPS from 1900 to 1960 was published by John Jenkin and colleagues at La Trobe University in the late 1970’s [44,45]. They pointed out that it was the sustained work of H. R. Robinson, FRAS, at several British universities between 1914 and 1940, that identified some basic XPS phenomena. Robinson’s final research before his retirement was C. J. Birkett Clews who became Head of the Physics Department at UWA in 1952. Robinson and Clews published two papers together, one in 1935 [46] and the other in 1940 [47]. The first paper described measurements of the energies of photoelectrons from the K shell of Cu, two L subshells of Ag, and the M subshells of Pt and Au by Mo Kα X-rays. These energies were compared with X-ray emission energies to derive a value for e/m of the electron. The second paper reports similar measurements with the same solids using excitation by Ag Kα X-rays; these results together with prior measurements with the same solids using excitation by Ag Kα X-rays. If we had been, we might have built an X-ray spectrometer for measuring energies of low-energy electrons from the K shell and L subshells of Cu and CuO that were excited by Mo Kα X-rays; these results together with prior measurements of characteristic energy losses in their XPS spectra. Unfortunately, neither John nor I were familiar at that time with the widths of characteristic Al and Mg Kα X-rays. If we had been, we might have built an X-ray spectrometer. As John later noted, “with their massive effort [at Uppsala] and Kai Siegbahn’s single-mindedness, you know what they went on to achieve” [41]. Kai Siegbahn was a winner of the Nobel Prize for Physics in 1981 for his development of high-resolution XPS.

2. Surface plasmon photonics has been a rapidly growing field of scientific and technological interest during the past 20 years, and particularly during the past 10 years [20-25,50,51]. In early 2011, I was invited to be the opening plenary speaker at the 5th International Conference on Surface Plasmon Photonics in Busan, Korea on May 15-20, 2011 [52]. I was asked to speak on “The Early Years of Surface Plasmons” and specifically on my UWA work that showed definitive evidence of surface plasmons in solids [12,13,16].

Acknowledgements

I am grateful to the late John Swan for launching my research career, the late John Robins for suggesting the preparation of this article, Mervyn Lynch for suggestions, and Jim Williams for encouragement.

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**AUTHOR BIOGRAPHY**

After a postdoctoral position at Imperial College, Cedric (Ced) Powell accepted a temporary one year position in 1962 as a Physicist at the US National Bureau of Standards, now the National Institute of Standards and Technology (NIST). This appointment was renewed several times and later converted to a permanent position. He became Chief of the Surface Science Division, a NIST Fellow, and a Scientist Emeritus after retirement in 2006. Ced continues to work on a part-time basis at NIST on the quantitative use of X-ray photoelectron spectroscopy (XPS) and Auger-electron spectroscopy (AES) for surface analysis. He oversees the development and application of seven NIST databases for AES and XPS (http://www.nist.gov/srd/surface.cfm).

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On The Relativity of Redshifts: Does Space Really “Expand”?  

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The University of Sydney, NSW 2006  

In classes on cosmology, students are often told that photons stretch as space expands, but just how physical is this picture? Does space really expand? In this article, we explore the notion of the redshift of light within Einstein’s general theory of relativity, showing that the core underpinning principles reveal that redshifts are both simpler and more complex than you might naively think. This has significant implications for the observed redshifting of photons as they travel across the universe, often referred to as the cosmological redshift, and for the idea of expanding space.  

Stretching Photons  
In an expanding universe, the light from distant galaxies is redshifted, with the wavelength of observed spectral features being longer than those measured in the laboratory. To anyone who has taken an undergraduate course on cosmology, the source of this redshifting is obvious, having been told that photons “stretch” as the space expands. This statement is often accompanied with a picture like Figure 1, with a blue photon stretched into a red photon as space expands during its journey between two cosmological observers.  

All of this is pretty satisfying, and life can happily continue. But with a little more thought, a few niggling issues appear. If expanding space can stretch a photon, a photon that is extremely tiny, is expanding space stretching atoms and molecules? Is expanding space stretching stars and galaxies? And are Brooklyn and its inhabitants expanding with the universe, as discussed in the wonderful scene in Woody Allen’s “Annie Hall”. When faced with such questions, you may turn to Google and find out what the experts have to say, and you may find yourself rather surprised.  

Figure 1: Typical diagram demonstrating how expanding space stretches photons as they travel across the universe.  

John Peacock, author of “Cosmological Physics”, attacks the misconceptions in cosmology, noting that “[t]he worst of these is the ‘expanding space’ fallacy” [1]. But Peacock is just one cosmologist, and you may turn to others for further scientific insight, but you’ll find no solace there. Cosmological giants, Martin Rees and Steven Weinberg, tell us  

“...how is it possible for space, which is utterly empty, to expand? How can nothing expand? The answer is: space does not expand. Cosmologists sometimes talk about expanding space, but they should know better.”  

So experts tell us that space doesn’t expand! Just what is the layperson to make of this? And if space doesn’t expand, just what stretches a photon traveling across the universe? To start to answer these questions, we need to take a step back and really understand the mechanism of the redshifting of light in a relativistic universe.  

Three Types of Redshift?  
When flipping through a physics textbook, students are typically told that there are three different redshifts seen within Einstein’s relativity, each applicable in particular circumstances. These are;  

Doppler Redshift: first encountered in the flat spacetime of special relativity, this concerns the observation of photons by observers who are moving relative to one another.  

Gravitational Redshift: a classical consequence of general relativity, observers at different locations in a gravitational field measure different wavelengths when exchanging photons.
Cosmological Redshift: a staple of cosmology classes, this is the case where observers exchange photons over cosmological distances in an expanding universe.

These appear to be distinct physical processes, and governed by quite different equations. But let’s again ask ourselves the mechanism by which the redshifting occurs. We’ve already seen what students are told that in the cosmological case. In the case of the gravitational redshift, photons apparently lose energy as they climb out of a gravitational potential.

But what about the first case considered above, the Doppler shifting of special relativity? Just where does the redshifting occur in this scenario? Understanding this is key to understanding relativistic redshifts in general. But let’s start with a photon moving in a gravitational field.

Of Gravity and Rockets

As already mentioned, the gravitational redshift appears to occur as photons lose energy as they climb in a gravitational field, a situation we can represent schematically shown in Figure 2.

Considered one of the classical test of general relativity, this phenomenon was experimentally verified in 1959 by Robert Pound and Glen Rebka in the Harvard tower experiment, where photons were sent on journeys up and down a 22m path and their energies measured, finding precise agreement with the predictions of general relativity. This was a particularly difficult experiment, mainly due to the weakness of the Earth’s gravitational field, but using the Mossbauer effect, where the emitting and absorbing atoms are locked into a crystal lattice, allowed the extremely fine measurement of the photon energies and hence the redshift. But let’s not worry about the messiness of experimental physics and instead consider the theoretical aspects of gravitational redshifting.

Let’s start with an initially blue photon on an upward journey in a gravitational field. For a significantly large change in the gravitational potential, the detected photon at the end of the journey will be red. But where does the redshifting occur? It seems to be that this is a continuous effect on the photon as it travels, with each step upwards robbing the photon of a little bit more energy. Hence, in the representation above, the intermediate photon, the one half way along in its journey, is green. This seems to make intuitive sense, but the story does not end here.

Let’s take a further step back to one of the founding principles of general relativity; in particular what Einstein called the “happiest thought in my life”. This was the realisation that for someone in free fall, the gravitational field vanishes; as a trip in the “vomit-comet” demonstrates, all those in free-fall float around like astronauts in deep space. More formally, this is known as the “Equivalence Principle” and can be stated that no physical experiment can reveal to an observer (with no visual clues) whether they are floating in deep space, far from sources of gravity, or in free fall in a gravitational fields, and this property, known as “local flatness”, is one of the key features of the space-time of general relativity.

However, there is another side of the equivalence principle that will be useful here, namely that there is no physical experiment our observer, who still has no external visual clues, could do to distinguish between being at rest in a gravitational field or being inside a uniformly accelerating rocket in deep space. Throw a ball on the surface of the Earth, and throw an identical ball on a deep space rocket accelerating at 1-g, the resultant paths will be the same.

So, according to the equivalence principle, if we repeat the Harvard tower experiment in a rocket accelerating at 1-g, we should get an identical result, namely that a photon fired from the back of the ship should be at a lower energy when detected at the front of the ship (see Figure 3). In the following, we will consider an extreme acceleration (probably not conducive to comfortable spaceflight) such that the photon fired the back of the ship is blue, while that detected at the front of the ship is red. So what colour is the photon half way up the rocket?

Figure 2: Schematic representation of the famous Harvard Tower experiment of Pound and Rebka, showing photons are redshifted when then travel in a gravitational field.
Figure 3: According to the equivalence principle, repeating the Harvard Tower experiment in an accelerating rocket is deep space should yield the same results as on Earth.

Let’s turn our attention to some observers who are not accelerating, observers who are simply sitting in space, at rest with respect to each other. We can initially place the rocket at rest with these observers, with the engines ready to fire. The button is pressed and the rocket roars, and at the same instant the photon is fired from the base of the rocket. At this instant, as observers inside and outside of the rocket are at rest with each other, both measure this newly emitted photon as being blue.

Now, let’s think of the photon halfway through its journey, traveling through the middle of the rocket. We know from the equivalence principle, that the situation on-board the rocket must be identical to those in a gravitational field and so an on-board observer would see this photon as being green. However, what does an external, at rest observer see? To these observers, the photon has simply travelled through empty, flat space-time, and an observer measuring the photon at the midpoint would find it unredshifted and as blue as when it was emitted. So is the photon blue or green?

How are we to reconcile this situation? Does this mean that the Equivalence Principle, one of the founding ideas of general relativity, breaks down? The answer is no, and the reason is that it matters who is observing the photon at the midpoint of the rocket.

Let’s look at what happens once the photon has been emitted. The rocket accelerates as the photon travels, so compared to the observers at rest outside the ship, those inside are moving at high velocity when the photon is traveling though the midpoint of the rocket. So, it should come as no surprise that they measure the energy of the photon to have a different value. And when the photon is absorbed at the top of the rocket, the relative velocity is even larger, and so while the external observers see the photon as still being blue, in a laboratory at the top of the rocket, the photon is now red (see Figure 4).

So, the key feature here is that the observed energy of a photon is a local thing, determined locally in an observer’s laboratory, and the energy this depends upon what the photon and laboratory are doing. And given that we can analyse the situation in two apparently different ways, is there a more fundamental way of defining redshifts in relativity. The answer is yes!

But before we get to that, a little homework. Let’s flip the situation and consider not a rocket in deep space, but observers in a gravitational field, some at rest, and some in free-fall. They repeat the Harvard tower experiment, and so those at rest see the photon redshifted as it climbs. What do the freefalling observers see? No calculations should be necessary!

Figure 4: What is the wavelength of a photon as seen by accelerating and non-accelerating observers?
Universal Redshifting

In 1994, Jayant Narlikar published a nice little paper in the American Journal of Physics titled “Spectral shifts in general relativity” [2], generalising some earlier work of John Synge in the early 1960s [3]. The central thrust of this paper is that it is incorrect to think that there are three distinct mechanisms for redshifting photons in relativity, and that there is truly only a single underlying mathematical description for use in all occasions.

Narlikar’s paper is rather mathematical, but the basic idea is straightforward. In relativity, a photon is represented as a vector, a vector pointing in four-dimensional space-time. Unlike the nice vectors we are generally used to in classical physics, the magnitude of photon vectors is always zero, but they are mathematically very well behaved. Similarly, an observer’s laboratory is defined by a collection of four-vectors (for those in the know, this is an orthonormal tetrad, or, if you want to sound very smart, a vierbein), each consisting of three pointing along the observer’s spatial directions and one in their time direction. And to calculate the energy of a photon as seen by an observer in their laboratory, what we need to do is project the photon’s four-vector on to the time component of the observer’s coordinates (more technically, we take the vector dot-product between the two).

The dot-product of two vectors is done at a particular location so, as we expect, a photon measurement is a local thing, and we expect two laboratories with two different sets of laboratory four-vectors, will measure the same photon at the same location to have different energies. This local nature of the measurement of photon energies implies that the redshifting is something related to the properties of the observers, and the photon is not redshifted on its journey.

You may not like the above statement, as we know that in the curved space-time of general relativity, we have to “parallel-transport” our photon four-vector between our two observers; surely this is changing the photon as it travels? Let’s go back to our rocket example. For our external observers, we can cover the space-time with the Minkowski metric of special relativity, allowing us to define the components of the photon’s four-vector. But with this, these vector components do not change as the photon travels, and take the vector dot-product of this photon with observers in this space-time, be they stationary, moving with uniform velocity, or accelerating, reveals each sees a differing photon energy.

But, through the equivalence principle, we can explain the same scenario as being in a uniform gravitational field, and so can employ an appropriate space-time metric to describe this. In this metric, those originally on-board the rocket are at rest at different heights in the gravitational field, whereas our previously stationary observers are now in free-fall. As the photon travels in this coordinate system, the parallel propagation modifies the values of its four-vector, so these will be different at different location. But, again, taking the vector dot-products with the photon with observers reveals the same photon energies as before.

Remember, this is, physically, describing the same situation, and in one coordinate system the photon four-vector changes during its journey, whereas in the other the components do not. Does asking where does the redshifting of the photon occurs even mean anything? And what does the wavelength of a photon mean when there is no observer there to observe it?

Does Space Really Expand?

After our journey around relativistic redshifts, we arrive back at the question we opened this article with, namely “Does space really expand?” As we have seen, the wavelength of a photon is not a unique thing, with the components of the photon four-vector dependent upon the choice of the metric to describe the underlying space-time, while the observed energy of a photon is dependent upon precisely what a particular observer is doing at the time they make the measurement. So, you should not think of the photon as travelling along with a little tag attached that records its wavelength. Wavelength is not a property of the photon, but of the “photon+observer” system.

So, let’s look at the cosmological case in a little more detail. In a typical cosmology course, students are introduced to the Friedmann-Robertson-Walker metric to describe the space-time of an expanding homogeneous and isotropic universe, although they are not often told that this is not the only mathematical description of this space-time. But let’s stick with the Friedmann-Robertson-Walker space-time for now. With this we typically consider a special group of observers, those at rest with regards to the coordinates of this metric, the so-called “co-moving observers”.
Let’s consider two of these special observers, A and B, separated by a large distance in a Friedmann-Robertson-Walker universe, and let’s assume A sends a photon to B. We know that this photon’s wavelength will be stretched by the amount the universe has expanded during its journey. But let’s also consider a myriad of additional observers, each at rest with regards to the Friedmann-Robertson-Walker coordinates, spread evenly between A and B, and as the photon passes, each will measure its energy. Each will see the wavelength of the photon as being progressively larger, with the photon apparently stretching in its journey.

However, if we consider one of the intermediate observers, we can ask what they see. To them, their adjacent observers are moving away in locally flat space-time, and that the redshifting they see is simply the Doppler shift due to motion. So the entire redshift between A and B can be considered just a long series of Doppler shifts. But, again, this is difficult to visualise without inserting our long chain of observers into the picture.

Hence, we arrive at the crux of this article, namely that the concept of expanding space is useful in a particular scenario, considering a particular set of observers, those “co-moving” with the coordinates in a space-time described by the Friedmann-Robertson-Walker metric, where the observed wavelengths of photons grow with the expansion of the universe. But we should not conclude that space must be really expanding “because” photons are being stretched. With a quick change of coordinates, expanding space can be extinguished, replaced with the simple Doppler shift.

While it may seem that railing against the concept of expanding space is somewhat petty, it is actually important to set the scene straight, especially for novices in cosmology. One of the important aspects in growing as a physicist is to develop an intuition, an intuition that can guide you on what to expect from the complex equation under your fingers. But if you assuming that expanding space is something physical, something like a river carrying distant observers along as the universe expands, the consequence of this when considering the motions of objects in the universe will lead to radically incorrect results.

So, what are the take home messages from this article? The first should be that the concept of redshifting in relativity is simpler than most textbooks portray, with a single underlying mathematical framework in which you can calculate the redshift in all cases. The second is that the concept of redshifting in relativity is more complex than most textbooks portray, as redshifting is not necessarily something that happens to a photon, but has more to do with what is happening to observers at the points of emission and absorption of a photon. But on the positive side, this should help students reinforce the concept that no particular metric, motion or location is unique or special when considering a situation. And the final message should address the concept of expanding space, that staple of cosmology textbooks. If all you want is an analogy to picture a photon traveling between two special observers, co-moving with the expansion in a Friedmann-Robertson-Walker metric, so that the wavelength expands with the universe, then you can talk about expanding space. But once you have finished, you should consider the contents of this article, and remind your students that while the picture seems comfortable and intuitive, it is no more than a picture and should be handled with care [4] [5].

Expanding space, a useful cosmological picture. But a picture none-the-less. Don’t push it to too hard!
References


AUTHOR BIOGRAPHY

Geraint F. Lewis is a professor of astrophysics at the Sydney Institute for Astronomy, part of the University of Sydney’s School of Physics. His research encompasses both theoretical and observational aspects of astrophysics, focusing upon cosmology, gravitational lensing and galactic cannibalism. Originally from Old South Wales, he arrived in Australia in 2000, joining the University of Sydney in 2002. He has published more than 250 papers on his research, and his book on the fine-tuning of the laws of physics for life, co-authored with Luke Barnes, will be published by Cambridge University Press in late 2016.

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Early bird registration closes 4 July 2016

Abstracts can only be submitted online and must be uploaded by 5:00 pm AEST, Monday 4 July 2016.

http://aip-appc2016.org.au
Theory of Reflection: Reflection and Transmission of Electromagnetic, Particle and Acoustic Waves (Second Edition)

By John Lekner
Springer (2016)
Hardback, 538 pages
ISBN: 9783319236261
Reviewed by Prof Ross McPhedran, University of Sydney.


The author must have needed to carefully consider which new topics needed to be added to what was already a substantial and heavily-used First Edition. The new chapters deal with uniaxial anisotropy, ellipsometry, periodically stratified media, neutron and X-ray reflection, acoustic waves and chiral isotropic media. Length considerations probably precluded any discussion of the field of metamaterials, but I would have thought the emergence of the field of plasmonics in the period since the First Edition was finalised could have merited a more extended and specific discussion than the one included.

This mild criticism is the only one I would make of a splendid and authoritative treatment of a broad canvas of the phenomena which characterise wave interactions with layered structures. The core of such problems is the interaction of a wave with a single layer lying between two planar boundaries. This topic is dealt with in all introductory textbooks on optics, and has been the subject of ongoing investigations since the time of Newton. What is remarkable is the variety of different questions it has raised, despite its apparent simplicity, and the sophistication and interest of their answers. John Lekner is well fitted to cover much of this wide field, given his extensive contributions to its research literature, and the reader will find in his book clear and well-illustrated theoretical treatments to its key development.

The diversity of the book arises from the number of different categories of wave problems which need to be discussed. Both electromagnetic and scalar waves are considered, the latter including particle beams (the Schrödinger equation corresponding to the Helmholtz equation, with boundary conditions for the former applying to electromagnetism with the electric field of the incident beam perpendicular to the plane of incidence). For vector beams, two principal polarisations must be treated (either the planar s and p cases, or the two circular/helical cases). The layers may be filled with lossy or lossless material, typically characterised by its permittivity. The permittivity may be invariant, or vary with position across the layer, or, in the case of grating-like structures, along the layer. In the second case, the variation may correspond to a case for which exact solution of the reflection and transmission properties of the layer may be obtained. (Five such profiles are considered in the book.) In the absence of an exact solution, it may be possible to obtain valuable approximations in the long wavelength case (wavelength much greater than the layer thickness) or the high frequency case (wavelength much smaller than the thickness). Numerical solutions are always available, based on propagation matrix techniques. The thin film problem may be treated in the forward direction (going from the structure of the film to its reflection and transmission characteristics as a function of wavelength) or as an inverse problem (inferring the nature of the film, and in particular its permittivity function both in terms of spatial and frequency variation). For the inverse case, the solution may be inferred based on intensities, or, the more versatile technique, using ellipsometry, where interference effects between principal polarisation states are measured. The material filling the layer may be isotropic or anisotropic (with uniaxial anisotropy being the principal case treated by Lekner). The beams probing the layers may be temporal pulses, composed of superpositions of different frequencies, or transversely limited, say having a Gaussian profile, and composed of superpositions of plane waves with the one frequency, but travelling in different directions.

All these cases are treated analytically in Lekner’s book, with the results illustrated graphically. The basic equations for numerical techniques are also given.

In summary, this is an authoritative treatment of a range of problems central to wave science. Specialists may well wish to purchase a copy, while those with a general interest should ensure it is available in their departmental or central library.
This is both a challenging book to write and a difficult book to review. The writer and the reviewer need to consider the book both as one for the absolute beginner and one that could be used by a very advanced user. However it all comes down to a few factors, the primary one of which is WIIFM (What’s in it for me?).

The book covers a range of topics from simple uses for Excel such as summing and sorting, up to more advanced applications like system modelling, graphics, numeric integration and regression. It also covers VBA (Visual Basic for Applications). As such, the book spans the physical sciences (only) from about High School to midway through a university course. There is a rather extensive use of shortcuts in the book that should have been left to a separate chapter. Shortcuts are used only by regular users - most would not use (or remember) them. The author seems to be overly familiar with the program which can be a problem. My straw poll asking scientists and engineers if they used Excel frequently came up with only one person and he uses it in a very limited way.

Excel was originally envisaged as software for the use of accountants, stock takers and other non-technical users. It has a 15 digit limitation for precision. This may seem generous but it is not really adequate for advanced calculations. Be aware also that Excel has some odd ways of rounding and calculating. It also has internal limitations on loop sizes and iterations that could be problematic. Excel uses the term “macro” to mean “subroutine” which is more generally today part of a module. This is one of many specialised terms that apply only to Excel and that a user needs to know. The alternatives are many and include Mathematica, Matlab, .NET, R, and Python.

On the plus side the output is usually rather neat and regular which is excellent for publications and reports. It is designed to take inputs from a cell (the Excel term for an array element) and to output the answer into another cell. In the early days of programming this would have been a plus as the input/output part of the coding was a big overhead. Today however with integrated development environments (IDE) this advantage has gone. VBA is compiled but only as P-Code and it is rather slow.

The reader should decide firstly if Excel is suitable for the required purpose. As an experienced programmer I do not think Excel is for me, but I do like the editor (VBE) which works very much like the development environment in .NET. Also VBA code will run in .NET (but not necessarily vice-versa).

There a number of reserved words in Excel like MOD, AVERAGE, IF and SQRT which may be familiar, but there are many more (a few hundred depending on the Excel version) that the user will have to learn. These reserved words cannot be used in any code for other purposes but it is worth knowing that they are optimised for speed and should be used if at all practical. Liengme extensively explains all of this.

A reader with considerable Excel experience is likely to skim from cover to cover so that the contents and scope are known, then select what is needed. Beginners would certainly benefit from working through chapter by chapter (and doing the exercises).

If Excel is used in-house or regularly used by you for other applications it would be worth getting this book and becoming familiar with the more advanced possibilities of the program. However if you are starting from scratch or already using an advanced computing system then it is unlikely that Excel is for you. As Excel is on most computers as part of Microsoft Office, the investment is in the book ($59.00 for the book or $50.00 for the eBook), and in the time to become reasonably familiar with the program, estimated at about 40 hours. It would be practical to use other recent versions of Excel as the book largely applies to Excel generally and not specifically to the 2013 version. Excel 2016 has since been released.
CERN fails to confirm Fermilab tetraquark discovery

A preliminary analysis of data taken by the LHCb collaboration at the CERN particle-physics lab near Geneva casts doubt on the recent claim by physicists on the D0 experiment at Fermilab in the US that they have discovered an exotic particle containing four quarks. Dubbed X(5568), the tetraquark was believed to contain "up" and "bottom" quarks as well as "down" and "strange" antiquarks. Quarks normally group together in pairs to form mesons or threes to make baryons.

The new particle has a mass of 5568 MeV/c² and was found in proton–antiproton collision data taken over nine years by D0, which ran on the now-defunct Tevatron collider. In a paper submitted to Physical Review Letters and posted on the arXiv server in February, the D0 collaboration identified the tetraquark with a statistical significance of 5.1σ. That is greater than the 5σ that is normally required for a discovery in particle physics.

Missing tetraquark: LHCb has not been able to detect X(5568)

Rather than spotting the X(5568) particle itself, however, the D0 physicists identified pairs of BS mesons and pi mesons that are created when X(5568) decays. They spotted an excess of 133 such pairs above the expected background level. Each pair had a total energy of about 5568 MeV, corresponding to the mass of the tetraquark.

As X(5568) should also be produced in proton–proton collisions on the Large Hadron Collider (LHC) at CERN, the LHCb experiment – which is designed to detect B mesons – is in a perfect position to study the new tetraquark. Unfortunately, however, physicists working on LHCb have found no evidence for X(5568), despite having analysed 20 times as many BS meson events as had the D0 team.

Tetraquarks are of great interest to particle physicists because most known hadrons are either mesons, which contain a quark and an antiquark, or baryons, which comprise three quarks. The theory of the strong force – quantum chromodynamics (QCD) – allows for other types of exotic baryons with four quarks (a tetraquark) or five quarks (a pentaquark). But doing calculations using QCD is extremely difficult, so it is not clear what tetraquark or pentaquark configurations are possible.

X(5568) is particularly interesting because it contains four distinct flavours of quark and antiquark. This is unlike all other known tetraquarks and pentaquarks, which all contain a charm quark/antiquark pair. This led some physicists to speculate that charmonium – a bound state of a charm quark and antiquark – creates a "core" around which tetraquarks and pentaquarks can form.

Extracted with permission from an item by Hamish Johnston at physicsworld.com.

Indian gravitational-wave observatory wins governmental approval

Hot on the heels of last week’s monumental discovery of gravitational waves – made by researchers working on the Advanced Laser Interferometer Gravitational-wave Observatory (aLIGO) in the US – India’s Union Cabinet has given its "in-principle" approval for a similar observatory, dubbed LIGO-India, to be built in the country. The project will be led by the Indian Initiative in Gravitational-wave Observations (IndIGO), which has been a member of the international LIGO collaboration since 2011 and contributed towards last week’s discovery. Once built, LIGO-India will join the global network of LIGO observatories, which currently includes the US, Germany, Italy and Japan. LIGO-India will be backed by the government’s Department of Atomic Energy (DAE) and the Department of Science and Technology (DST), together with its US counterparts.
Universal ear: LIGO-India will help refine gravitational-wave detections

The aLIGO collaboration announced in February that it had detected gravitational waves produced from the collision of two black holes of 36 and 29 solar masses some 1.3 billion light-years from Earth. The holes had merged to form a spinning, 62 solar-mass black hole, in an event dubbed GW150914.

For GW109914, a signal was picked up by both of LIGO’s US observatories, in Hanford, Washington, and in Livingston, Louisiana, which are separated by 3002 km. But researchers are keen to refine their observations and improve their measurement sensitivity by having a global network of detectors, which would simultaneously detect incoming gravitational-wave signals and reveal more about where they come from.

With each added observatory, the researchers can pick up even more signals, boosting the chances of a confirmed wave. Such a network would also let researchers narrow and localize the gravitational-wave’s source in the sky – with two detectors, LIGO can currently only gauge the general direction from which the waves have come. Pinpointing a fixed location requires data to be combined from geographically separated detectors.

Apart from the two LIGO observatories in the US, astronomers have access to data from the GEO600 detector in Germany, which is currently online, while the Virgo detector in Italy (HHLV) and the KAGRA detector in Japan are both currently being upgraded. According to the IndIGO collaboration, adding a new detector in India a long way from existing detectors would "dramatically improve the source-localization accuracies (five to 10 times), thus enabling us to use gravitational-wave observations as an excellent astronomical tool".

Extracted from an item by Tushna Commissariat at physicsworld.com.

'Quantum manifesto' for Europe calls for €1bn in funding

Researchers across Europe are calling on the European Union (EU) to launch a €1bn initiative in quantum technologies to ensure that the continent remains a leader in the field. The group is asking industries, research institutes and scientists in Europe to endorse its "quantum manifesto" before putting it forward to the European Commission.

The manifesto has been written in response to a request by Günther Oettinger – the European Commissioner for Digital Economy and Society – for a common European strategy on quantum technologies. The manifesto calls for a "flagship-scale initiative" – similar to the EU’s 10 year €1bn Graphene Flagship initiative – to begin in 2018, which would invest in education, science, engineering and innovation to unlock the full potential of quantum technologies.

According to the manifesto, a "second quantum revolution" is under way that will bring transformative advances to science, industry and society. Yet it points out that there is currently no coherent, large-scale Europe-wide quantum-technologies programme comparable with those in the US and other countries. If this is not addressed, the authors warn that research and development on quantum technologies in Europe "risks fragmentation and replication of efforts". Indeed, the manifesto points out that a global race for technology and talent has already started, and that Europe cannot afford to lag behind.
Through a flagship programme, the authors say that the EU could support growth in quantum-technology research and propose short- (0–5 years), medium- (5–10 years) and long-term (>10 years) research goals. A flagship programme could build a favourable innovation and business environment for such technologies, facilitate co-ordination between academia and industry, create "quantum-technology professionals", and co-ordinate public investments and strategies across Europe, as well as promote the involvement of all member regions.

Extracted from an item by Michael Allen at physicsworld.com.

Surreal behaviour spotted in photon experiment

By studying how photons travel through a double slit, physicists in Canada have now shown that some photons follow "surreal trajectories" that appear to defy the laws of physics. Upon closer inspection, however, the experiment reveals that the behaviour of these rogue photons can be explained using the principle of quantum entanglement. The work has resolved a 25-year-old debate based on an alternative interpretation of quantum mechanics.

In the conventional interpretation of quantum mechanics, the motion of a particle is defined by a wave function that gives the probability of the particle being at a certain place at a certain time. The uncertainty principle means that a precise measurement of the particle’s position at a specific time will result in a large uncertainty in what its momentum is at that time – and vice versa. As a result, the concept of a trajectory in the sense of a unique path followed by an object does not exist in quantum mechanics.

In 1952 David Bohm came up with an alternative interpretation of quantum mechanics in which a particle follows a trajectory that is guided by a "pilot" wave function. The probabilistic nature of quantum mechanics would arise from the fact that the initial conditions of the particle are unknown – this is built into the pilot wave function. A precise measurement of the position of a Bohmian particle, for example, would alter the wave function such that a simultaneous measurement of the particle’s momentum must lie within the bounds of the uncertainty principle.

In 1992 Berthold-Georg Englert and colleagues argued that under certain circumstances – such as when a particle passes through a double slit – some Bohmian trajectories defied explanation. Dubbed "surreal trajectories", their assertion sparked a debate in the quantum-physics community as to the validity of Bohm’s approach to quantum mechanics. Now, Aephraim Steinberg and colleagues at the University of Toronto have measured surreal trajectories and showed that they are consistent with quantum theory.

The team used a technique called "weak measurement" to trace out the set of trajectories taken by photons through a double slit. This technique involved a gentle probing of the direction of motion of the photons to build up an understanding of the possible routes taken by photons through the apparatus. Crucially, each measurement is so gentle that it does not have a significant effect on the pilot wave function.

Their "double-slit" experiment begins with the production of a pair of photons that are entangled in terms of their polarization. Photon-1 is then sent into a polarizing beam splitter, which produces two parallel beams – one with horizontal polarization and the other with vertical polarization.

The researchers also perform a weak measurement on the transverse velocity of photon-1 after it emerges from the slits. This is done by passing the photon through a calcite crystal, which causes a tiny shift in its polarization, which is proportional to its transverse velocity. Using focusable optics, the team was able to measure the transverse velocity at different locations, as the photons travel over a distance of about 5 m. Using this information, Steinberg and colleagues were able to build up a set of trajectories taken by the photons. Because photon-1 and photon-2 are entangled, a measurement of the polarization of photon-2 will reveal which slit photon-1 passed through. However, when Steinberg and colleagues looked at the set of pho-
Photon-1 trajectories that should have passed through the lower slit (according to photon-2’s polarization), they found that some of the trajectories appeared to have taken photon-1 through the upper slit — and vice versa. These are the surreal trajectories predicted by Englert and colleagues.

However, closer examination of the data revealed that this apparent surrealism depended upon where along the trajectory the measurements were made. Indeed, Steinberg and colleagues identified cases in which photon-1 begins on a trajectory from the lower slit, but then swerves upward into a trajectory that appears to be from the upper slit. Using a technique called quantum-state tomography, they were able to monitor the polarization of photon-2 during this swerve, and saw its value rotate from horizontal (indicating the lower slit) to vertical (indicating the upper slit). As a result, a measurement on photon-2 at the end of the trajectory gives the “wrong” slit. Steinberg and colleagues believe that the photon’s swerve is thanks to quantum interference that occurs when they emerge from the slits. As well as resolving the surreal-trajectory problem, the experiment also provides a vivid illustration of how a property of one entangled particle — the polarization of photon-2 — can be affected by the trajectory of its distant partner.

[Extracted with permission from an item by Hamish Johnston at physicsworld.com.

New radio antenna avoids unwanted signals

A new simpler, cheaper and potentially more effective way to prevent radio antennas from picking up unwanted signals has been created by researchers in the US. With further development, the technique could also be used to help prevent thermophotovoltaic cells from re-emitting radiation they absorb — according to the team.

The laws of electromagnetism work exactly the same way if you run time in the opposite direction. One logical consequence of this is that an antenna designed to broadcast at a certain radio frequency will also be very good at absorbing radiation at that frequency. This is problematic for broadcast radio antennas, which will absorb radiation that has bounced back from surrounding objects — something that can have a negative impact on their operation. While there are ways of minimizing the effect of these echoes, they can be expensive and reduce the performance of the antenna.

Now, Andrea Alù and colleagues at the University of Texas at Austin have developed a new way of dealing with echoes. Their design is based on a traditional leaky-wave antenna, in which electromagnetic waves of certain frequencies couple to the space around the antenna and “leak out” as they travel along it. They added a series of variable capacitors called varactors to the antenna circuit. The capacitance of a varactor varies with the voltage applied to it, and this is used to adjust the operational frequency of the antenna. The researchers added a second, lower-frequency wave sent down the same antenna. This second wave does not couple to the space around the antenna and is therefore not radiated. However, the wave modulates the voltage on the varactors and therefore alters the operational frequency of the antenna while it is transmitting.

The modulation caused by the second wave means that the antenna no longer has time-reversal symmetry. Waves emitted from the antenna are produced by waves travelling in the same direction as the modulation. However, if the antenna absorbs reflected signals coming back from the broadcast direction, this results in waves in the antenna travelling in the opposite direction to the modulation. This asymmetry between emission and absorption allows the antenna to be operated such that reflected waves do not couple efficiently back into the antenna.

[Extracted with permission from an item by Tim Wogan at physicsworld.com]
**PRODUCT NEWS**

**COHERENT SCIENTIFIC**

**Quantel Q-scan – The Next Generation Scanning Dye Laser**

Building on proven dye laser technology, Quantel has released the latest innovation in dye laser technology. Introducing the Q-scan, a Nd:YAG pumped dye laser with a tuning range of 200 nm – 4.5 μm.

The Q-scan utilises the highest precision mechanics to provide unrivalled wavelength accuracy (< 10 pm), reproducibility (< 5 pm) and tuning linearity to ensure the high wavelength accuracy during a scan. The Q-scan has also been designed with ease-of-use in mind, allowing for alignment-free grating changes and plug-and-play dye cells, making changes to the laser wavelength range simpler than ever.

Key features of the Q-scan include:
- Wide spectral coverage: 200 nm – 4.5 μm.
- Extreme wavelength accuracy, repeatability and linearity.
- High efficiency conversion and excellent beam quality.
- Fully integrated system with Quantel Nd:YAG lasers: the most compact dye laser available when paired with the Q-smart 850.

For further information contact Jeshua Graham: jeshua.graham@coherent.com.au

**New and Improved Linear Stages**

All of the Aerotech PRO series of stages have been redesigned and optimised for increased performance providing up to 98% improvement in positioning resolution and up to 46% improvement in positioning repeatability. Additionally, there are two new sizes available in the PRO series – the PRO115LM and PRO190LM.

Other new features include a linear encoder option on the ball-screw stages, absolute encoder options on both the linear motor and ball-screw stages, and direct mounting to English and metric optical tables.

**New Compact, Rapid-Scan CW/Pulsed Mid-IR Laser**

Molecular spectroscopy applications benefit from rapid, high Signal-to-Noise Ratio data acquisition. This demands fast-scan, mid-IR lasers delivering high-quality light. Until now, high tuning speed has come with compromises. The new Hedgehog from Daylight Solutions changes this. For the first time, fast and broad tuning, and high-fidelity output is available from a compact, robust mid-IR laser.

Hedgehog is built on Daylight’s field-proven Quantum Cascade Laser (QCL) technology. Available centre wavelengths span the mid-IR spectrum from < 4 to >13 μm, and Hedgehog can operate in pulsed or CW modes. Hedgehog is highly optimised for mid-IR spectroscopy, and model options include: high power, broad tuning, high wavelength repeatability, narrow linewidth, low noise and multiple tuning modes.

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

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**Lastek**

**2 W of high power tunable green-yellow lasers available from TOPTICA!**

TOPTICA has released a new class of multi-Watt laser sources for use in the laboratory but also opening up opportunities for future OEM integration. Based on the TA-SHG pro product line, a resonantly frequency-doubled tapered amplified diode laser, more than 2 W of single frequency output covering the spectral range from 550 nm to 565 nm are now available. The dramatic leap towards higher power levels is possible due to proprietary tapered amplifier technology, modified electrical & thermal management and further improvements of the frequency-doubling resonator technology.

With a tunability of several nanometres, mode-hop-free scanning of 30 GHz and a linewidth of less than 100 kHz, the novel laser source allows numerous applications in quantum technologies. Similar performances are achieved around 400 nm, 430 nm and 480 nm.

The TA-SHG pro product line covers a wavelength range of 316 nm to 675 nm with only few gaps and maximum power levels ranging to more than 2 W. The digitally controlled version DLC TA-SHG pro offers remote control via PC, touch screen operation, automatic alignment and active output power stabilisation.

For further information please contact our Toptica Product Manager Jessica Mackintosh on 08 8443 8668 or jessica@lastek.com.au.

**New compact laser power meter for low power measurements from Gentec-EO**

Gentec-EO is pleased to announce the addition of a new member to the pronto family of compact laser power meters. As its name indicates, the Pronto-Si presents a large 1 cm² silicon sensor, the largest in its category, perfect for measuring very low powers. When combined with the integrated slide-In OD1 attenuator, the total power range of the Pronto-Si extends from 0.3 nW to 800 mW. The measurements are done in continuous mode, so you can install the pronto in the laser beam path and leave it there indefinitely. The internal memory also allows you to acquire data and transfer it to a PC for further analysis. The sensor part has a very slim profile of only 6 mm, allowing it to be used in very tight spaces.

**Features:**
- Pocket-sized
- Colour touch screen display
- Screen and sensor are protected when you flip it close
- Extend your power range with the slide-In OD1 attenuator (0.3 nW to 800 mW)
- Use it in very tight spaces (Only 6 mm at the Sensor)
- Set the wavelength, brightness and screen orientation
- Advanced features like data logging and data transfer to PC

**Bayspec RamSpec™ Deep-Cooled Benchtop Raman Spectrometer**

BaySpec’s RamSpec™ series Raman spectrometers are turn-key solutions designed for best-in-class performance and long-term reliability. Integrating an ultra-sensitive, deep-cooled transmission spectrometer, a class 3B laser source, an optional integrated computer and fibre connectivity, the RamSpec™ offers a high-performance scientific-grade Raman system in a rugged, portable benchtop platform.
The RamSpec™ employs a highly efficient volume phase grating (VPG®) as the spectral dispersion element and a deep-cooled, ultra-sensitive CCD or InGaAs array detector, thereby providing high-speed parallel processing and continuous spectral measurement. As an input, the device uses a fibre optic bundle or slit based on customer preferences. The included Spec 2020 software platform allows full control of spectral acquisition as well as library search functionality. The new-generation RamSpec™ has optional dual excitation wavelengths and automatic mapping function for well-plates.

**Key features:**
- 532, 785, and 1064 nm lasers (custom wavelengths available), single or dual
- Ultra-sensitive, deep-cooled CCD or InGaAs detector
- High-throughput, fast (f/2) spectrograph
- Automatic well-plates sampling (optional)

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

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Zurich Instruments

**Arbitrary Waveform Generator and Signal Acquisition Instrument**

With the UHF-AWG 1.8 GSa/s Arbitrary Waveform Generator, Zurich Instruments presents a unique solution for the generation and acquisition of complex signals. On each of the 2 channels signals can be generated and measured from DC up 600 MHz with 14 bit resolution. AWG pulse sequences can be varied based on feedback from the demodulated signals or photon counter. The UHF-AWG is completely integrated into the LabOne software and can easily be controlled through a web-browser based user-interface whilst the included LabOne APIs allow a straightforward integration into an existing experimental control environment using LabVIEW, MATLAB, Python or C.

Arbitrary waveforms can be generated and played up to a length of 128 MSa. These signals can be used for the modulation of the 8 internal oscillators, guaranteeing perfect phase-coherence and, using the internal trigger functions, precise synchronization of the measured signal. All relevant signal parameters such as frequency, delays and amplitudes can be adjusted using the advanced sweeper and trigger tools.

The two low-noise signal inputs allow the detection of the resulting signals and direct verification of the programmed pulse sequences, and additionally the powerful toolset of the UHF platform is available: the world’s fastest digital lock-in amplifier, the UHF-BOX Averager and the UHF-DIG Digitizer.

The UHF-AWG is perfect for applications requiring pulsed excitation in combination with fast measurement: Quantum computing, NMR- and EPR spectroscopy, radar, lidar, photon counting and tests with mixed signal circuits.

For more information contact Zurich Instruments AG at info@zhinst.com

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Warsash Scientific

**NIR and timing resolution optimised SPCM**

Warsash Scientific is pleased to announce the release of the all new high performance NIR and TR enhanced single photon counting modules (SPCM) from Excelitas Technologies.

Excelitas Technologies have extended it’s portfolio of low-light-level detection modules with enhanced versions of the well-known SPCM single photon counting module that is based on a unique silicon avalanche photodiode with a circular active area, achieving extremely high photon detection efficiency over a 180 µm diame-
ter with unmatched uniformity over the photodiode. In addition to the standard AQRH series of modules offering 6 output signal options, the SPCM-AQ4C 4-channel photon counting array module, there are now more choices for various single photon counting applications. The new SPCM-AQRH-TR is a fast timing enhanced version with timing resolution of less than 250 ps, designed to support applications such as time correlated single photon counting (TCSPC), fluorescence lifetime measurements and fluorescence lifetime imaging microscopy (FLIM).

The new SPCM-NIR is a high Photon Detection Efficiency enhanced version with optimized sensitivity in near infrared wavelengths, designed to support long range LIDAR, quantum communication, photon entanglement, and other photon counting applications in the NIR (700-1060 nm).

**ProFilm3D low-cost optical profiler**
Warsash Scientific are pleased to announce the release of the ProFilm3D low-cost optical profiler from Filmetrics, leader in affordable thin film measurement solutions. The Profilm3D uses the state-of-the-art methods of vertical scanning interferometry and phase shifting interferometry to measure 3D surfaces with high accuracy. With these technologies, it is possible to measure surface features and roughness with sub-nanometre resolution.

Important measurements such as surface profiles, step heights, and roughness can be made optically for less than the cost of a stylus profilometer. This is especially important for users who want to measure metal thickness in seconds and with a single mouse click.

Every Profilm3D comes equipped with intuitive step-height measurement and roughness measurement software. For more advanced data manipulation, Filmetrics offers a great deal on TrueMap, from our partners at TrueGage. Profilm3D data is, of course, also compatible with other industry-standard software analysis packages.

**Labsphere Launches Benchtop Goniospectrometer**
Warsash Scientific are pleased to announce the release of Labsphere’s newest light metrology solution, a full feature goniospectrometer that fits securely on a lab bench. The Benchtop Goniospectrometer is the perfect option for customers requiring the performance of a Type C goniospectrometer, but are limited by lab space and budget. It is ideal for measuring virtually any light source quickly in one or more C planes. The reduced footprint allows users to benefit from Labsphere’s expertise in light measurement technology without the hassle and expense of building an additional room for a traditional full size instrument.

The Benchtop Goniospectrometer has an angular resolution of 0.1° per step and measures: Lumens, Peak Candela, CCT, CRI, Beam Angle, Power, Power Factor and Lumen/Watt. User-friendly software allows for customizable reporting with over 20 data points reported in IES format for compliance to global standards and specifications. The main applications for this goniospectrometer include measurement and calibration of light source colour/intensity/stability, as well as spatial/spectral characterisation.

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

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