

AUSTRALIAN & NEW ZEALAND
PHYSICIST

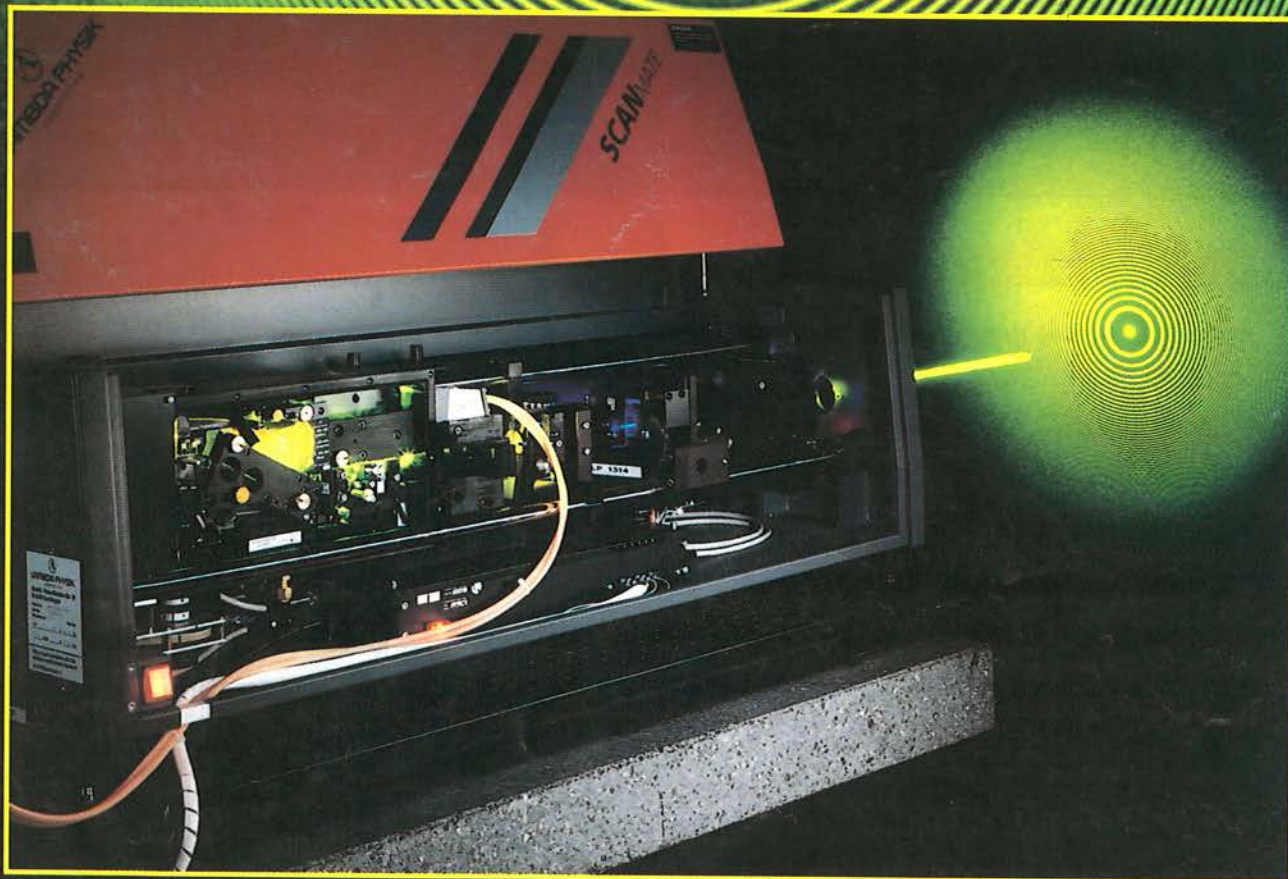
April/May 1998

Volume 35 Number 2

A publication of the Australian Institute of Physics and the New Zealand Institute of Physics

in this issue:

**ANSTO – SPECIAL REPORT
THE NEW REACTOR**



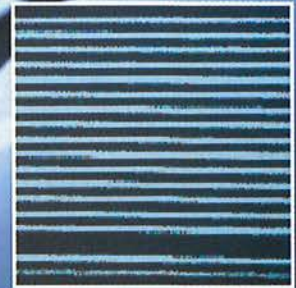
A Generation Ahead!

A State-of-the-Art Instrument with unchallenged performance for any Spectroscopic Imaging Application.



Dual exit port

On-axis triple grating turret



Multiple Fiber Optic Inputs

Triax-320 Features:

- Accommodates more than 20 fibers with excellent Spatial Resolution
- Large 30mm x 15mm Focal Plane
- 320mm Focal Length
- High Throughput: f/4.1
- 0.06nm Resolution with 1200g/mm
- Revolutionary Triple Grating Turret Mechanism
- On Board Electronics for Automated Control
- Built-in RS-232 and IEEE488
- Complete System Integration



LAS  TEK

Lastek Pty. Ltd (ACN 008 153 937)

Thebarton Campus,
University of Adelaide,
10 Reid Street,
THEBARTON SA 5031

Tel: 08 8443 8668

Fax: 08 8443 8427

Email: sales@lastek.com.au

WWW: <http://www.lastek.com.au>



We have our eye on the future of Spectroscopy

NEWS from **WARSASH Scientific**

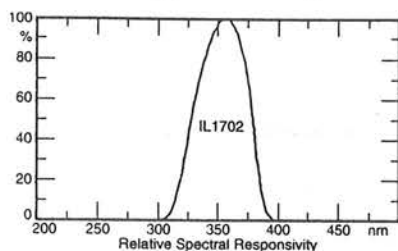
New International Light products detect UVA / UVB

International Light has announced the release of the IL 1402/1702 & IL 1403/1703 Phototherapy Radiometers.

These systems have been specifically developed for fast and accurate UVA & UVB irradiance measurements.

The IL1402/1702 is designed for measuring UVA lamps commonly used in phototherapy apparatus, such as UV booths and hand & foot units.

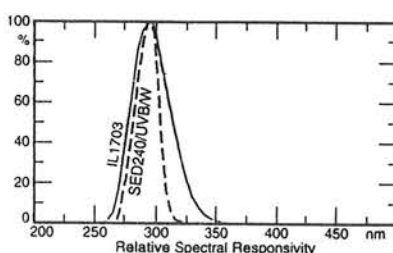
The system can be used as an independently calibrated second party check on the meter built into an exposure system, or to monitor lamp degradation. The useful dose integration capacity (with full integration autoranging) provides the most accurate measure of typical UV exposures.



The IL1403/1703 incorporates a solar-blind detector which is blind to the visible and long wavelength output of most lamps, measuring only the UVB portion.

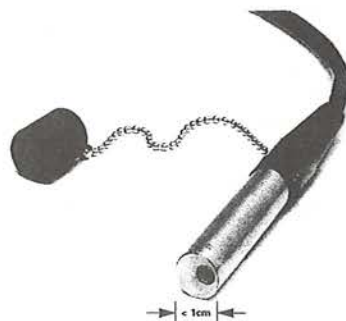
The standard system has been designed with a broad spectral response for measuring standard UVB lamps or even Philip's TL series lamps.

An optional UVB detector that distinctly separates UVA from UVB at 315nm is available for research oriented applications or those requiring a narrower bandwidth. An XIR single-wavelength calibration is also available for TL Series lamps at 311 nm.



Remote Raman Analysis Using a Fibre Optic Probe

Renishaw has recently developed new fibre optic probe solutions for remote Raman measurements. From computer hard discs in clean rooms, to ancient frescoes in churches, to hazardous chemical and nuclear processes, wherever the Raman sample cannot be brought to the spectrometer, Renishaw's fibre optic probes can be used to vastly expand the range of measurement possibilities.



Appointment of WARSASH Scientific to represent CSEM

Warsash Scientific is pleased to announce their appointment as the Australian representatives of CSEM of Switzerland, one of the world's leaders in advanced mechanical surface testing instrumentation.

Our product range now includes:

Scratch-testers for adhesion failure determination, chemical analysis, stress mapping and acoustic emission recording;

CSEM's Tribometers designed for measuring friction and wear to determine sliding lifetime, and for high temperature lubrication studies;

Micro and nano-indenters for hardness measurements, Young's modulus determination, fracture propagation studies and local hardness tests;

Atomic Force Microscope objectives for micro and nano-scale imaging, friction force microscopy, surface inspection and compliance measurements.

Applications for CSEM advanced mechanical surface testing instruments include polymer, ceramic, paints and lacquers, hard coatings and thin film R&D, failure analysis and QC.

WARSASH Scientific

PO Box 1685 Strawberry Hills NSW 2012
tel: (02) 9319 0122 fax: (02) 9318 2192
email: warsash@ozemail.com.au

AUSTRALIAN & NEW ZEALAND PHYSICIST

A PUBLICATION OF THE AUSTRALIAN INSTITUTE OF PHYSICS & THE NEW ZEALAND INSTITUTE OF PHYSICS

March/April 1998

Volume 35, Number 2

Editor

A/Prof CJ Hamer

Reviews Editor

Dr CSL Keay

Editorial Board

Dr MA Box

Prof Ian Johnston

Dr CSL Keay

Prof RJ MacDonald

Dr RJ Stening

Associate Editor - Education

Mr Malcolm Bowling

Associate Editors

Dr Stephen J Buckman

Atomic & Molecular Physics Laboratories

Research School of Physical Sciences

ANU, Canberra ACT 0200

Tel (02) 6249 2402, fax (02) 6249 2452

stephen.buckman@anu.edu.au

Brad Powe

12 Evan Street

Gladesville NSW 2111

poweb@edits.com.au

Dr Ian Edmonds

Physics, QUT

PO Box 2434 QLD 4001

Tel (07) 864 2584, fax (07) 864 1521

i.edmonds@qut.edu.au

Dr ML Duldig

c/- Physics Department

University of Tasmania

GPO Box 252C

Hobart TAS 7001

Marc.Duldig@utas.edu.au

Dr Lloyd Hollenberg

Physics, University of Melbourne

Parkville VIC 3052

Tel (03) 9344 4210, fax (03) 9347 4783

llh@swift.ph.unimelb.edu.au

A/Prof Cyril Edwards

Physics, UWA

Stirling Highway, Nedlands WA 6907

Tel (09) 380 2723

cyril@earwax.pd.uwa.edu.au

Prof Weston J Sandle

Physics, University of Otago

Private Bag 56, Dunedin NZ

Tel +64 3 479 7807, fax +64 3 479 0964

sandle@physics.otago.ac.nz

Dr Laurence Campbell

Dept of Physics

Flinders University

GPO Box 2100

Adelaide SA 5001

Tel (08) 8201 2093, fax (08) 8201 3035

phlc@cc.flinders.edu.au

C O N T E N T S

GUEST PRESIDENT'S COLUMN	39
EDITORIAL - Relief from HECS; ANSTO	40
LETTERS	41
AIP CONGRESS	41
AROUND THE TRAPS	42
UNDERFUNDING PUTS NZ'S SCIENTIFIC WELL-BEING 'AT RISK'	Wes Sandle 44
MAGNETISM IN CAIRNS	Trevor Hicks 45
AIP COUNCIL MEETING	Moirá Welch 47
ANSTO SPECIAL ISSUE	
FOREWORD	Helen Garnett 48
A NEW REACTOR FOR AUSTRALIAN SCIENCE IN THE 21ST CENTURY	Shane Kennedy 49
APPLICATIONS OF PHYSICS AT ANSTO	Claudio Tuniz 55
AMS ANALYSES AT ANSTO	Ewan Lawson, Mike Hotchkis, Andrew Smith and David Fink 58
SNAPSHOTS FROM ANSTO	Centre Spread
ION BEAM ANALYSIS TECHNIQUES AT ANSTO	Nick Dytlewski, Rainer Siegele and David Cohen 65
THE AUSTRALIAN SYNCHROTRON RESEARCH PROGRAM	Richard Garrett and John Boldeman 70
RADIOACTIVE ISOTOPES FOR MEDICAL APPLICATIONS	Stuart Carr 72
FASTS	76
PRODUCT NEWS	77
THE WAGGA MEETING	Jaan Oitmaa 78
AIP & NZIP BRANCH NEWS	79
OBITUARIES	
EUGENE P BASHKIN	Cyril Edwards and David Neilson 80
CHRISTOPHER JOHN MILNER	Jaan Oitmaa 82
REVIEWS Prompt Critical	Colin Keay 84
CONFERENCES & MEETINGS	92

COVER: This month's front cover shows the Lambda Physik ScanMate Optical Parametric Power Amplifier, SMOPPA. The ScanMate OPPIA is a narrow linewidth tunable laser system for spectroscopic experiments requiring wavelength flexibility and high resolution.

Lambda Physik is represented in Australia by Coherent Scientific Pty Ltd. For more information regarding the SMOPPA please refer to page 83.

Contributions should be sent to

A/Prof Chris Hamer, Editor

ANZ Physicist, Physics, UNSW,

Sydney NSW 2052

Tel (02) 9385 4590

Fax (02) 9385 6060

AH Tel (02) 9528 8675

C.Hamer@unsw.edu.au

Design, Artwork & Printing

Scott Williams - Manager

Cronulla Printing Co. Pty. Ltd.

16 Cronulla Plaza, Cronulla 2230

NSW Australia

Phone 02 9523 5954

Fax 02 9523 9637

email: anzp@cronullaprint.com.au

Advertising Enquiries

Leigh Wallbank

c/- 16 Cronulla Plaza,

Cronulla 2230

NSW Australia

Phone: 02 9528 4362

Fax 02 9523 9637

Published 6 times a year, on behalf of the Australian Institute of Physics and the New Zealand Institute of Physics by Cronulla Printing CO. Pty. Ltd..

Copyright 1998 Pub. No. PP 224960/00008 ISSN 1036-3831

The statements made and the opinions expressed in the *Australian and New Zealand Physicist* do not necessarily reflect the views of the Australian Institute of Physics or the New Zealand Institute of Physics, its Councils or Committees.

AIP EXECUTIVE

PRESIDENT

Prof Jaan Oitmaa Tel (02) 9385 4596
aip@phys.unsw.edu.au

VICE PRESIDENT

Prof John Pilbrow Tel (03) 9905 3630

SECRETARY

Moirá Welch Tel (045) 784 328
m.welch@uws.edu.au

HON TREASURER

A/Prof Charles Osborne Tel (03) 9905 3690
charles.osborne@sci.monash.edu.au

REGISTRAR

Prof David Booth Tel (03) 9688 4202
david=booth@vut.edu.au

ADMINISTRATION

Australian Institute of Physics, 1/21 Vale Street
North Melbourne VIC 3051
Tel (03) 9326 6669 Fax (03) 9328 2670
physics@raci.org.au

AIP ACT BRANCH

CHAIR: Dr Ken Baldwin
RSPSE, Australian National University
Canberra ACT 0200 Tel (06) 249 4702
Kenneth.Baldwin@anu.edu.au

SECRETARY: Dr. Sue Stockmeyer
CPAS, Australian National University
Canberra ACT 0200
Tel (06) 279 8157 Fax (06) 249 4950
sue.stockmeyer@anu.edu.au

AIP NSW BRANCH

CHAIR: Prof Ross McPhedran
Physics, University of Sydney, Sydney NSW 2006
Tel (02) 9351 6079
ross@physics.usyd.edu.au

SECRETARIES: Dr Peter Robinson & Dr David Green
PR: Physics, University of Sydney
Sydney NSW 2006 Tel (02) 351 3779
robinson@physics.usyd.edu.au
DG: Appl Physics, UTS,
PO Box 123, Broadway NSW 2007
Tel (02) 514 2203 dcg@phys.uts.edu.au

AIP QLD BRANCH

CHAIR: Prof Bill MacGillivray
Dean, Faculty of Science,
Griffith University Nathan QLD 4111
Tel (07) 3875 7120 Fax (07) 3875 7030
W.Macgillivray@sct.gu.edu.au

DEPUTY CHAIR: Prof Gerard Milburn
Director, Centre for Laser Science
Physics, University of Queensland QLD 4072
Tel (07) 3365 3401 Fax (07) 3365 1242
milburn@physics.uq.edu.au

SECRETARY: Dr Robert Sang
Laser Atomic Physics Laboratory, Faculty of Science
Griffiths University Nathan QLD 4111
Tel (07) 3875 3758 Fax (07) 3875 7656
R.Sang@sct.gu.edu.au

AIP SA BRANCH

CHAIR: Dr. Ray Protheroe
Physics/Math Physics University of Adelaide SA 5005
Tel (08) 8303 5996
rprother@physics.adelaide.edu.au

SECRETARY: Dr Laurence Campbell
Physics, Flinders University
GPO Box 2100 Adelaide SA 5001
Tel (08) 8201 2093 phlc@cc.flinders.edu.au

GUEST PRESIDENT'S COLUMN

I greatly appreciated the invitation to attend the recent Annual Council Meeting of the AIP, and to observe both the many similarities between the situations we face in the Australian and New Zealand Institutes of Physics, as well as to see at first hand some real differences. The most evident difference results from the federal nature in Australia; the NZIP is in many ways akin to a state branch. A more significant difference is that while our Council—similarly to the AIP Council—is constituted mainly of the Executive and representatives from branches (and is particularly responsive to academic concerns), our membership is approaching 50% secondary school physics teachers. We are exploring ways in which an active voice and appropriate representation for teachers in the NZIP Council can be achieved. Educational issues are growing in importance—to even more prominence in NZ than in Australia.

The forceful, effective criticism by the immediate past President of the National Qualifications structure is a good illustration of this changing emphasis (an inappropriate NZQA structure had led to a seriously flawed New Zealand national science examination). Many important issues came up at the AIP council meeting. One was the suggestion for restructuring the Council meeting: formal AIP business could perhaps be dealt with on one day, leaving a second day for concerns and discussions involving kindred physical science societies. This strongly appeals to me as a move in the right direction. Vigorous A-NZ links, as well as broader involvement with kindred societies must have increasing value to both our Institutes.

Another critically important area, both for the health of the physics profession as well as in the long term for the health of our countries, is science funding. A recent issue of *Nature* (29 January, Vol 391, Issue 6686) points out in an editorial as well in the *News Analysis* section, that funding difficulties threaten to 'undermine the bold experiment in science funding that has been underway [in NZ] since the early 1990s.' This experiment, as many readers will know, restructured NZ Government Science into Crown Research Institutes, and converted a substantial fraction of the Government science budget to a contestable "Public Good Science Fund" (PGSF) into which the Crown Institutes bid for the bulk of their funding. In the early 1990s, the Universities purchased into this fund. More recently, a fundamental science "Marsden Fund" has also been set up, expected to rise to around 10% of the (~\$300M) PGSE. The 'lack of financial imagination' mentioned in *Nature* threatens both the fraction set aside for the Marsden Fund as well as the growth target overall. The Government commitment was to 0.8% of GDP by 2010; the reality is public spending has fallen, from 0.59% of GDP in 1992-93 to 0.52% three years later.

The consequences of a real policy change in science funding could be quite severe. A number of us have gone into print expressing our concern. In the interests of bringing the membership of both our Institutes up to date, page 44 of this issue reproduces an opinion article from the *Otago Daily Times* (my local newspaper) which I wrote and have forwarded to the New Zealand Minister for Research, Science and Technology, the Hon Maurice Williamson.

I hope the whole question of science funding in both our countries – very ably handled by the AIP Executive with regard to Australian physics department cut-backs – can be critically examined in the *A&NZ Physicist*, with a view to public airing so that people at large begin to appreciate the profound negative implications of science funding cut-backs. As a "They said it" column in the *ODT* put it (quoting from my article: "In today's ethic of professionalism, if you want something done, you have to pay for it. If science is not properly funded, the science won't be done, and the slow slide to international mediocrity and a reducing quality of life will follow").

This is as surely true of the Australian scene as of the situation in New Zealand.

Wes Sandle

President NZ Institute of Physics

Weston Sandle is Professor of Physics at the University of Otago, and National President of the New Zealand Institute of Physics. He has recently been elected Fellow of the Institute of Physics.

EDITORIAL

Relief from HECS

It has now become very clear that the basic sciences in the university system are in dire straits under the new regime of economic rationalism. Both Amanda Vanstone and David Kemp have promised that the HECS scheme would be adjusted in the future, if the necessity became apparent. It is to be hoped that Dr. Kemp will honour that promise, and give science some relief from HECS in this year's budget.

The whole university system has been under strain, as university budgets are due to be cut 15% over four years to 2001. The situation has been made worse by the government's refusal to fund academic pay rises of 10% (which will only claw back a little of the ground lost over the past 25 years). But science has suffered even worse than other areas.

Enrolments in science had remained fairly steady for many years, while overall university enrolments rose dramatically. But the sharp rise in HECS fees from \$2,500 to \$4,700 has produced an equally sharp decline in applications for the basic sciences: physics, chemistry and mathematics. This decline has been masked to some extent by enrolments in the life sciences, which have held up better; but nevertheless, universities have only been able to fill their science quotas by lowering entry standards. At Sydney and UNSW, for example, the TER cutoff for entry to science fell from 75 in 1995 to 60 in 1998. Overall enrolments in physics fell by 11.6% from 1992 to 1997; and many of today's students are struggling to pass their physics courses.

Staff numbers in physics have suffered heavily. The Oitmaa/Weigold survey two issues ago documented an overall decline of 16.5% in academic staff from 1994 to 1997, and further losses are continuing. Some smaller universities have dropped physics altogether. At QUT and at LaTrobe University, the physics schools have been merged into Engineering. The departments at Flinders and Wollongong were threatened with closure; in the end, Wollongong physics was also merged with Engineering. At the University of South Australia, three-quarters of the staff have been lost, and physics has been absorbed into Electronic Engineering: students can no longer major in the subject. The older universities have also suffered severely. At the University of Tasmania, staff shrank from 17 to 6 in two years, and physics is being merged with Mathematics. At the University of Queensland, the school was closed, about one-third of the staff were sacked, and the remainder were rehired. At UNSW, we have lost 12 of 45 staff over four years. The surviving academics are everywhere under stress, and morale is at rock bottom. Worst of all, bright young researchers coming up through the system are despairing of ever getting a permanent academic appointment.

A very similar story would be told in chemistry departments around the country; and even mathematics, the "queen of sciences", is under pressure. We hear that almost half the staff in mathematics at Monash were lost in a recent putsch. Research funds are also under threat: research infrastructure and research quantum funds are due to fall by 5% in 1999, and 16% by 2000.

At a recent FASTS forum John Niland, President of the AVCC, declared that science was in "deep trouble", and issued a powerful call for a rescue operation to return funding to a safe level. If the government sees any value in a healthy program of basic science in the universities, it must take action to halt and reverse some of the damage. No-one pretends that fees and funding are the only problems: the FASTS article in the last issue, and Jaan Oitmaa's discussions in the President's Column, have discussed measures which we must take ourselves to boost interest in science, increase the supply of well-trained teachers in schools, and make our graduates more attractive to industry. In the meantime, however, the government should provide some much-needed assistance by lowering HECS fees for science to the same level as arts.

ANSTO

It was announced last year that the government would fund a new reactor at Lucas Heights, subject to a satisfactory environmental impact statement. The cost will be in the region \$300-\$400 million, which is a large amount by comparison with recurrent research funds. We felt it would be of interest to present a survey and display of the work going on at ANSTO, and an overview of future directions. A number of articles have been contributed by members of ANSTO, including the Director, Helen Garnett. I hope that our readers will enjoy them.

Chris Hamer

C.Hamer@unsw.edu.au

AIP TAS BRANCH

CHAIR: Dr Ian Newman
Physics, University of Tasmania
GPO Box 252-21, Hobart TAS 7001
Tel (03) 6226 2422
ian.newman@phys.utas.edu.au

SECRETARY: Dr Steven Newbery
Dept of Health, GPO Box 125B, Hobart TAS 7001
Tel (03) 6233 2488(w) Fax (03) 6233 2178
Gary-Bur@antdiv.gov.au

AIP VIC BRANCH

CHAIR: A/Prof Richard O'Sullivan
Appl Physics, RMIT
GPO Box 2476V Melbourne 3001
Tel (03) 9660 3389
ro'sullivan@rmit.edu.au

SECRETARY: Dr Min Gu
Applied Physics, VUT
PO Box 14428 MCMC VIC 8001
Tel (03) 9688 4284 Fax (03) 9699 4698
ming@dingo.vut.edu.au

AIP WA BRANCH

CHAIR: A/Prof Cyril Edwards
Physics, University of WA
Stirling Highway, Nedlands WA 6907
Tel (09) 380 2723
cyril@earwax.pd.uwa.edu.au

SECRETARY: Dr Colin Taylor,
Physics, University of WA
Stirling Highway, Nedlands WA 6907
Tel (08) 9380 2746
Mob 0414 261996
colin@pd.uwa.edu.au

NZIP EXECUTIVE

PRESIDENT

Prof Weston J Sandle
Physics, University of Otago
Private Bag 56, Dunedin NZ
Tel +63 479 7815
Fax +63 479 0964
sandle@physics.otago.ac.nz

VICE PRESIDENT

Prof Crispin W Gardiner
Physics, Victoria University of Wellington,
Wellington NZ
Tel +64 4 495 5233 x 8049
Fax +64 4 495 5237
crispin.gardiner@vuw.ac.nz

SECRETARY

Dr Patricia J Langhorne
Physics, University of Otago
Tel +64 3 479 7787 fax +64 3 479 0964
pjl@physics.otago.ac.nz

TREASURER

Dr John L Bahr
Physics, University of Otago
Tel +63 479 7806 fax +63 479 0964
bahr@physics.otago.ac.nz

ADMINISTRATION:

Department of Physics, University of Otago
Tel +63 479 7815 fax +64 3 479 0964

LETTERS

A COLOURED MOONBOW.

Following in a similar vein to the article by Boccas and Storey (Nov 97, ANZ Phys, v34,186) on 'Ice crystals in the Sky', the note below describes an observation of a coloured 'lunar rainbow' - a rainbow formed by refracted moonlight - in February of this year.

Living in southern Tasmania, where auroral displays can be seen when geomagnetic conditions are right, I am in the habit of checking the sky most evenings before retiring. On the night of 12 February, one day after full moon, at about 10:30 pm summer time, I was engaged in this activity in the vicinity of my lemon tree (which is in the part of my back yard most shielded from local street lights). A bank of low cloud to the south was illuminated by the rising, nearly full, moon in the north east. No auroral display was seen.

However, low to the southwest a faint 'arc' was noticed, about 1 degree in width, and around 10 degrees long, projected in front of another cloud bank. Initially I took this to be moonlight illuminating an arc-shaped cloud in front of a more distant cloud bank, but as I looked I realised that the arc continued in a bow, very faintly, across most of the south west part of the sky. A very light drizzle was

falling at the time, but stars were visible over most of the sky. The centre of the bow was diametrically opposite the moon.

This lunar rainbow initially appeared colourless, but over the course of the next 10 minutes or so it became brighter, and distinct colours developed - I assume this was a consequence of the intensity increasing past my threshold brightness for colour vision. Only three colours were seen - a green inner band, a white-yellow middle, and a red outer band. The display lasted for at least a further 5 minutes, but I did not stay out to watch past this time. The thought occurred to me that I should attempt to photograph the bow, but as I did not have a fast film in my camera at the time, I decided against it. The effect of the coloured bow in the moonlit sky was spectacular.

The following day I consulted the book by M. Minnaert ('Light and Colour in the Outdoors', Springer, 1993 - a revision of his earlier book). According to this work, coloured moonbows are rare, which now makes me wish I had attempted to photograph the event. I had not seen a lunar rainbow before, coloured or otherwise. Denis Coates from Monash drew my attention to the book 'Rainbows, Halos and Glories' by R. Greenler

(Cambridge UP, 1990), which also has a brief reference to lunar rainbows, noting they are usually reported as white.

At the time I attempted to make an estimate of the elevation angle of the bow, using the 'rule of thumb' of a fist at arm's length subtends an angle of about 7 or 8 degrees (which I calibrated using the known separations of some bright stars). This gave an elevation of about 25 degrees for the top of the bow. I also estimated the moon's elevation, by the same method, to be around 20 degrees. The moon's elevation was later checked with a planetarium program on a PC, where the calculated elevation was about 17 degrees. The radius of the rainbow arc is about 42 degrees, centred on the 'sub-lunar point', giving an expected elevation of the bow above the horizon of 25 degrees, in agreement with my rough measurements.

I will be endeavouring to have handy a camera with a wide angle lens and fast film around future full moons, in case I get the chance to see another coloured moonbow. Some readers of this magazine may have seen and or photographed coloured moonbows in the past, but those who haven't may wish to keep an eye on the sky on drizzly full moon nights.

John Innis.
Kingston, Tasmania.
john_inn@antdiv.gov.au

AIP CONGRESS

The organising committee is pleased to announce that the 13th National Congress will now be run in association with:

5th National Congress of the Vacuum Society of Australia (VSA), OzCUPE 4 (Australian Computers in Undergraduate Physics Education), 17th AINSE Nuclear and Particle Physics Conference (NUPP), Solar Terrestrial and Space Physics Group of the AIP (STSP), Atomic Molecular Physics and Quantum Chemistry Group (AMPQC), Science Teachers of Western Australia (STAWA).

We look forward to all these groups staging a successful meeting in Fremantle.

We also have a very exciting program of additional events. The committee is very happy to announce that Kip Thorne, prominent astrophysicist from Cal Tech will present a public lecture on the

Sunday evening before the Congress in the Fremantle Town Hall. During the week as part of our evening program, we will have presentations of the Massey Medal, followed by the Massey Lecture, the Bragg Medal followed by the Bragg Lecture and the Pawsey Lecture. The week is crammed full of top quality events in a very attractive setting.

Our plenary speaker program is now complete and will be of interest to all. It includes:

Prof Susan Bayliss (UK), Prof M Fink (France), Dr R Norris (NSW), Prof H Sugawara (Japan), Prof H Coster (NSW), Dr H Gleeson (UK), Prof C Russell (USA), Prof E Weigold (ACT), Dr D Dickson (UK), Dr M King (USA), Dr C Salomon (France), Prof J White (ACT)

We have extended the deadline for Abstracts until the 30th April. Advice on

how to submit your abstract can be found on the web at:

<http://www.promaco.com.au/conference/98/physics/>

Further details of these and other developments will be arriving through the post as part of our April Update.

A reminder, the Congress will be held from 27th September until 2nd October 1998. Cheaper air fares are possible if you stay one Saturday night. There will be a full range of tours available, so it is a great opportunity to see WA in Springtime, as well as catch up with important developments in your area.

STEPHEN M THURGATE
Associate Professor in Physics

Phone (61) 8 9360 2382
FAX (61) 8 9310 1711

School of MPS
Murdoch University South ST
Murdoch, 6150 WA Australia

AROUND THE TRAPS

Readers are invited to send items which might be of interest for this news column either to the Editor or to one of the Associate Editors.

Gemini project

The Federal Education Minister, Dr. Kemp, has announced that Australia will contribute \$13.5 million over five years to the Gemini project, a joint venture with the US, Britain, Canada, Australia, Chile, Argentina and Brazil. The project involves the construction of two powerful infra-red telescopes, one in Hawaii and one in Chile, each with an eight metre aperture. The aim is to study the early history and evolution of stars, galaxies and the universe. Australia's contribution will buy our astronomers tickets to about a month's viewing time each year. According to Prof. Jeremy Mould, Director of MSSSO, "the Gemini Project is one of the most exciting astronomical projects ever undertaken."

'Downsizing' in Hobart

There have been significant changes and major staff losses in the Physics Department of the University of Tasmania over the past few months. Academic staff members John Greenhill, David Davies and Mike Emery took early retirement in late 1997, and Ian Newman will retire in mid 1998. Technical staff members Kevin Parker and Dennis Phythian have also retired early. None of these will be replaced. The large mechanical workshop is being transferred to another campus site and will be less readily accessible to Physics staff and students. Workshop manager Barry Wilson is also moving to the new location. The remaining academic staff comprise John Humble as Head, Bob Delbourgo, Peter Jarvis, Peter McCulloch, John Phillips and Bob Watson. They are supported by technical staff Keith Bolton, Phil Button and Liz Hynes (part time) with Tammy Riley as School secretary.

On January 1st, the Department was renamed the School of Physics. This applies until 1 July when Physics, Mathematics and the Institute of Antarctic and Southern Ocean Studies (IASOS) merge to form the School of Mathematics and Physics. This school will be headed by a new Professor of Mathematics yet to be appointed.

The Physics building is also undergoing radical changes. The ground floor, eastern end of the first floor and all offices on the second floor are being transferred from Physics to other areas, in particular the Centre for Ore

Deposit Research. The School has thus lost the use of two teaching laboratories and quite a number of offices. All Physics academic and secretarial staff will be located on the third floor. We'll all be delighted to see the building works finished in early June.

Marc Duldig

Amateur planet-spotting

A team of amateur astronomers from the Canberra Astronomical Society may have discovered a planet outside the solar system. Calling themselves the Reynolds Astronomical Photometry Team (RAPT), this 12-member group of computer programmers, librarians and doctors have been spending their nights and weekends observing on the 76 cm Reynolds telescope at Mount Stromlo. Having fallen into disrepair, the telescope was revitalized and equipped with a new electronic camera by the team. In a project with professional astronomers including Bruce Peterson at ANU and Andrew Becker at the University of Washington, they have been looking for "dark matter". Last winter, they observed a "microlensing" event, as a massive dark object passed in front of a bright star near the centre of the Milky Way and distorted its image. Their observations suggest that the dark object was a binary system, with one partner being a body about five-and-a-half times the mass of Jupiter. Their results were reported at a recent meeting of the American Astronomical Society.

The work remains somewhat controversial, and will be hard to verify. But if correct, the discovery represents only the ninth extra-solar planet discovered, and the first ever discovered from the Southern Hemisphere. Congratulations to the RAPT team: Tim Leach, Keith Ward, John Howard, Steven Ring, Brian Crook, Patrick Purcell, Gavin Wyper, Shirley McKeown, John Morland, Eric Pozza, Albert Brakel and Jeff Mitchell - keep up the good work and the hot coffee!

[From an article by Cheryl Jones in 'The Bulletin', March 17, 1998]

FASTS Forum

A forum on "University Science - Crisis or Crossroads?" was organized by the lobby group FASTS at the National Press Club on February 25. Principal speaker was John Niland, President of the AVCC, who called for a program to rescue science from the emerging pattern of declining enrolments. "University science is in deep trouble" he

said, referring particularly to the basic sciences physics, chemistry and mathematics. He called for the government to return some resources to the university sector for science and technology research and teaching. "After all, it was perfectly right and proper to set up a program of rescue for the Katherine floods or Cyclone Tracy .. can we expect anything less for University Science?"

Accelerating universe

The High-z Supernova Search Team from the Mount Stromlo and Siding Spring Observatories, led by Dr. Brian Schmidt, claims to have found evidence that the universe is expanding about 20 per cent faster today than it was 7 billion years ago (Leigh Dayton, 'Sydney Morning Herald', 28/2/98).

If true, this would really put the cat among the theoretical pigeons, since the expansion is normally expected to be slowing due to gravitational attraction. The team speculated that such an acceleration could only be explained by repulsion due to antigravity!

The physics community will take a good deal of convincing that this can possibly be correct. The experiment will have to be checked and rechecked, and confirmed by other methods, before most people will accept the conclusions. But the suggestion should certainly stimulate some frantic activity.

Physics Olympiad

The Australian team performed very well again in the 1997 Physics Olympiad in Canada. George Doukas and Ben Toner won gold medals, Bradley Steel a silver, Matthew Chapman a bronze, and Russell Kliese gained an Honourable Mention. The team was 4th overall, behind Iran. Congratulations to Rod Jory and his team.

Greenhouse row rumbles on

Further question marks have been raised about the quality of advice used by the Federal Government in the lead-up to the Kyoto Summit.

The Australian Bureau of Agricultural and Resource Economics (ABARE) apparently demanded \$50,000 in private sector funding as a price tag for joining the steering committee for their policy research model, Megabare. A key technical adviser, Alan Powell, has resigned from the committee in protest, stating that private sector funding "posed major risks for the integrity and efficiency with which modelling work can be done."

The Commonwealth Ombudsman, Phillipa Smith, has declared that ABARE has

"compromised the credibility of this work", after a complaint from the Australian Conservation Foundation.

The executive director of ABARE, Brian Fisher, responded by saying that the Ombudsman had not questioned his organization's professional integrity and had acknowledged it was operating within government policy by raising 40 per cent of its funding externally.

[From a report by Stephen Lunn in 'The Australian']

SETI Conference

A conference on the Search for Extraterrestrial Intelligence (SETI) was held at the University of Western Sydney Macarthur in January. The guru of the field,

Frank Drake, was in attendance. A search in the southern sky is being funded by UWS, the CSIRO's Australia Telescope and UC Berkeley, using the Parkes radio telescope. Participants include Dr. Ragbir Bhathal of UWS, and Dr. Ray Norris of the CSIRO.

['Sydney Morning Herald', 26/1/98]

Revamp of science advisory mechanisms

The government has decided to revamp its science advisory committees. The old committee ASTEC will be wound up later this year. The Prime Minister's Science, Engineering and Innovation Council (PMSEIC) will take over the science advisory role, under the chairmanship of the chief scientist, John Stocker. One of the first objects

will be a study of national priorities. The AIP should be preparing to contribute to this debate.

Kit Milner

Professor C.J. ('Kit') Milner passed away on 20 February after a short illness. Kit Milner was formerly Professor of Applied Physics and Head of the School of Physics at the University of New South Wales - see obituary this issue.



THE 1998 WALTER BOAS MEDAL

Nominations are invited for the 1998 award of the Walter Boas medal of the Australian Institute of Physics and should reach the Honorary Secretary by June 30th 1998 at the latest.

The Medal was established in 1984 to promote excellence in research in Physics and to perpetuate the name of Walter Boas. The award is for physics research carried out in the five years prior to the date of the award as demonstrated by both published papers and unpublished papers prepared for publication, which should accompany the nomination.

Any AIP member may make nominations or may self nominate for the award. Nominees need not be members of the AIP or be Australian citizens but should have been residents of Australia for at least five of the seven years preceding the closing date for nominations. The Medal shall not be awarded more than once to any person.

The award is conditional on the recipient delivering a seminar on the subject of the award at a meeting of the Victorian Branch of the AIP in November 1997. The recipient is also expected to provide a manuscript based on the seminar for publication in the Australian and New Zealand Physicist.

Further details may be obtained from:
The Honorary Secretary
Australian Institute of Physics
1/21 Vale St, North Melbourne VIC 3051 Fax 03 9328 2670
Phone 045 78 4328 email m.welch@uws.edu.au

PREVIOUS WINNERS OF THE WALTER BOAS MEDAL

- 1984 Professor Jim Piper, Macquarie University
- 1985 Dr Peter Hannaford, CSIRO Division of Materials Technology
- 1986 Professor Don Melrose, Sydney University
- 1987 Professor Tony Thomas, University of Adelaide
- 1988 Professor Robert Delbourgo, University of Tasmania
- 1989 Professor Jim Williams, University of Western Australia
- 1990 Professor Geoff Opat & Professor Tony Klein, University of Melbourne
- 1991 Dr P Hariharan, CSIRO Division of Applied Physics
- 1992 Professor BHJ McKellar, University of Melbourne
- 1993 Professor Jim Williams, Australian National University
- 1994 no medal awarded
- 1995 A/Professor David Blair, University of Western Australia
- 1996 Professor Andris Stelbovics, UWA, and Dr Igor Bray, Flinders University
- 1997 Professor Keith Nugent, U of Melbourne & Dr Stephen Wilkins, CSIRO

UNDERFUNDING PUTS NZ'S SCIENTIFIC WELL-BEING 'AT RISK'

WESTON SANDLE

The following 'opinion' article appeared in the Otago Daily Times, Wednesday, February 11, 1998. The issues, though specific to New Zealand, have relevance to the situation in Australia; and are presented in full. Professor Sandle, of the University of Otago Physics Department, is National President of the New Zealand Institute of Physics, and a recently elected Fellow of the Institute of Physics.

Firm commitment to long-term policy supporting research, science and technology is a crucial issue for New Zealand's future. An Otago Daily Times editorial on Tuesday, 3 February, with its discussion of a recent Nature editorial (29 January, Vol 391, Issue 6686) on science funding in New Zealand and the accompanying strongly-worded statements by the President of the Academy Council of the Royal Society of New Zealand Professor George Petersen [which appeared in the ODT], raises our awareness about the health and vigour of our scientific enterprise.

We live in an increasingly 'globalised' world. Our ability to maintain a decent, fulfilling and competitive way of life, both as a nation and as individuals, depends on our ability to participate fully and on equal terms in this world.

The gap in science funding has already been pointed out – we are at the bottom of the OECD list – and, in the current political climate, this gap threatens to increase.

How important is this? Can we not "survive" on the scientific and technical enterprise of other countries? I believe that a scientific gap is damaging to New Zealand, and that we cannot in the long run simply shirt-tail on others' efforts. We can afford to invest properly in science and technology research, and New Zealand is excellently placed to capture the economic, environmental and social benefits of such investment.

Why is underfunding in science and technology damaging? We have only to look at fields in New Zealand which have, historically, been reasonably well funded – agricultural, medical and biomedical science are examples – to see the striking benefits. New Zealand has not only carried out trail-blazing research in these fields; it has, as a practical result, been among the world leaders in agricultural developments, and it has had one of the healthiest populations anywhere. Similarly, Taiwan puts enormous investment into physical science and engineering (which account for almost 50% of university graduates), and it leads the world in personal-computer technology. In today's ethic of professionalism, if you want something done, you have to pay for it. If science is not properly funded, the science won't be done, and the slow slide to international mediocrity and a reducing quality of life will follow.

Why not utilise accomplishments from elsewhere? But is this slide inevitable? Why can't we simply hang on to the shirt-tails of our better-funded international partners to maintain our way of life? For three excellent reasons: first, the world is incredibly and aggressively competitive, and you have to be really smart to gain an advantage; second, to tailor to New Zealand conditions those developments overseas which we seek to apply here, we need to have local expertise – and the expertise follows the funding; and third, able people have a knack of solving problems that others didn't see even existed, and the spin-off from this is enormous.

But can we afford to invest in science, in the present climate? Can we afford not to? In the interests of economic re-structuring, New Zealand has gone through more than a decade of pain. If by this time we cannot afford important activities like good health care, good education, good science, whenever will we be able to? We will be able to afford the things we need only if we establish a technical and economic competence as of now: and this means a healthy, well-educated populace who have the opportunity to challenge the best in the world in many areas, not just in playing sport and having an attractive natural environment.

But doesn't funding in one area preclude spending in another, equally important area? Not necessarily. I am reminded of the world oil shocks in the 1970s. Oil became more expensive, and money spent on oil ostensibly precluded spending on other things. But, really, did it? Not always. Because the University of Otago's fuel costs were soaring, my colleague Dr Gerry Carrington and I got involved with energy conservation on the campus. We found that by the application of well-known scientific principles, we were able to save the University money and, at the same time, to improve the quality of heating in most areas of the campus. With investment in science, you can have your cake and eat it too! Intelligent investment in science and technology will have a net economic freeing-up effect.

But how can we arrange to capture benefits from scientific research? Good science has been carried out in New Zealand in many areas. What real economic value has most of this had? The answer is that New Zealand, while carrying out very publicly an international experiment in economic management, has been quietly getting on with another revolution, ultimately a more important one in my opinion.

This is the re-direction of public-good science funding towards research of strategic and tactical value. I would recommend a wider reading of the important documents setting out this change [available from both the Ministry of, and the Foundation for, Research, Science and Technology]. But what does such re-direction do to the more conventional activity of science as a personal, human endeavour – an expression of our inherent curiosity to find out more about ourselves and our placement in the scheme of things? Here, the genius of Sir Ian Axford is involved. At a time when the rest of the world was setting about re-directing its own science to more strategic ends, we in New Zealand set up the Marsden Fund. This provides a relatively small, but enormously important, resource to enable the pursuit of excellent science in its own right, whether or not it is strategically or tactically oriented. The most important criteria are that the research is of international significance, that the science is truly excellent, and that the researchers are in a good position to deliver on the science.

New Zealand promises to be a world leader in its vision of how to conduct an integrated science and technology structure, spanning all the way from research as an expression of the human spirit to research as a systematic application of intelligence towards important national goals. We need this to survive. We need the bright young people for our future. We need adequate funding to attract and retain these people, and help solve our problems. We come from a practical, farming-based society with a very healthy 'Number 8 fencing wire' attitude. In the modern world, education, training and research provide the basis for the new Number 8 fencing wire. Let us get on with it!

MAGNETISM IN CAIRNS

INTERNATIONAL
CONFERENCE ON
MAGNETISM 1997



Magnetism in Cairns? Well? Just for a week in July last year! The International Conference on Magnetism (ICM) was hosted there by the Australian Institute of Physics and the Australian magnetism community. This was the first time location of ICM in the Southern Hemisphere and an honour for Australia. This followed a series of European locations (Paris, 1988, Edinburgh, 1991, Warsaw, 1994). With the number of fully participating delegates 833 and 130 accompanying partners this we believe was the largest international conference in the physics subject area ever held in Australia. Countries with twenty or more delegates were: Australia (50), Brazil (21), France (24), Germany (59), Japan (362), Netherlands (20), United Kingdom (56) and United States (50). By region the percentage attendances were: Africa, Middle East and Others (1.9%), America North (6.6%), America South (2.9%), Asia (49.0%), Europe East (5.9%), Europe West (27.8%), Oceania (6.0%). The delegates to the conference in Cairns enjoyed the tropical climates in the southern winter as well as the exotic surroundings of rainforest and reef. In spite of these distractions, the normal activities of any large international conference like ICM, those of exchange of information, giving and receiving fresh ideas, making professional contacts, all continued.

Any of the large international conferences gather a following over the years and for many the conference becomes a sort of family. ICM is no different and we were saddened to learn of the death, earlier in the year, of Professor B.R. Coles FRS, a member of the International Advisory Committee for the Cairns conference and a stalwart of ICM meetings. A short appreciation of Bryan's life and work was presented at the time he was scheduled to give his paper with Dr B. Sarkissian. The conference was shocked when Academician Professor A.S. Borovik-Romanov died on the Thursday of the conference week. On arrival, he and his colleagues from Russia were obviously very pleased to be able to attend ICM with which he had been associated for many years, particularly in 1973 when he was Program Chairman. He was cremated in Cairns on the Saturday of the conference week in the presence of his colleagues and friends from Russia and other countries.

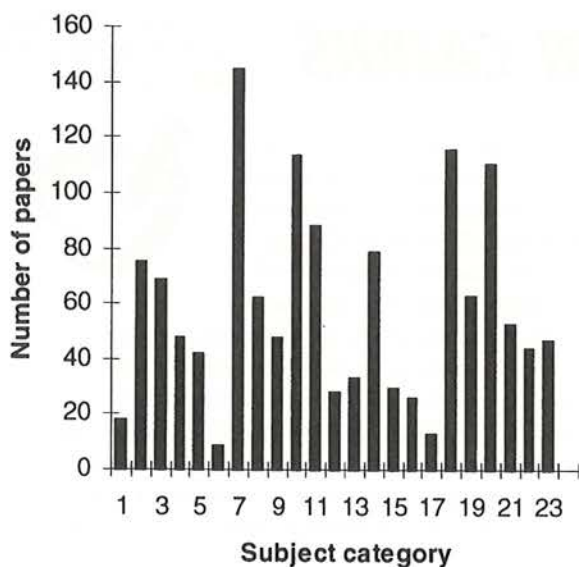
We are fortunate to have experienced the last decade in magnetism. The advent of new hard magnetic materials and of high temperature superconductivity and with magnetic nano-structures very close to application as reading devices in magnetic recording, has meant a very exciting period. These subjects and the very fundamental aspects of magnetism such as quantum spin liquids, non Fermi-liquid behaviour close to critical points in heavy fermion materials, spin glasses, the origins of high temperature superconductivity and other topics were discussed in plenary, oral and poster sessions.

The organisers of ICM'97 were approached at ICM'94 in Warsaw with a request to integrate the Conference on Strongly Correlated Electron Systems, which is normally a satellite meeting, into ICM'97. This we were very pleased to do. The result was an emphasis on this and related topics with dedicat-

ed oral sessions over a total of two days. The responsibility for these sessions was handed to Professor K.A. McEwen of Birkbeck College, London, who became a member of the Programme Committee and consulted with members of the SCES community about invited and oral contributions in the SCES sessions. The other satellite conferences were 'Nuclear Methods in Magnetism', Canberra, organised by Professor D.H. Chaplin of The Australian Defence Forces Academy, 21-23rd July; 'Workshop on High Coercivity Materials', organised by members of the Special Research Centre for Advanced Minerals and Materials Processing with Dr L. Folks as secretary, Perth, 23-25th July; 'International Colloquium on Magnetic Films and Surfaces', organised by Professor T. Shinjo of Kyoto University, Sunshine Coast, 4-8th August; 5th International Conference on 'Research in High Magnetic Fields', hosted by Professor R. Clark and group of UNSW, Sydney, 4-6th August.

At ICM the plenary talks were made the focus of each day. Professor Robert Birgeneau of MIT was the recipient of the third Magnetism Prize. Earlier prizes had been presented in Edinburgh to Professor Art Freeman for spin polarised electron band structure calculations in thin magnetic layers and in Warsaw to Professor Albert Fert (University of Paris South) and Professor Peter Grünberg (KFA, Jülich) for studies of magnetic multilayers leading to giant magnetoresistance devices. Professor Birgeneau's lecture was on random fields in disordered antiferromagnets. Application of a uniform magnetic field to an antiferromagnet with defects results in a net effective field with respect to the sublattices with a random component. This can destabilise the antiferromagnetic order by favouring the growth of domain walls. Professor Birgeneau's talk encapsulated the comprehensive, mostly neutron scattering work, done on this very fundamental topic by him and his colleagues. Other plenary lecturers were Professor Herbert von Löhneysen (heavy fermion systems near quantum critical points), Professor Brian Maple (a survey of recent progress with high TC materials), Professor Teruya Shinjo (nano-structured magnetism) and Professor Eugene Chudnovsky (tunnelling of magnetisation in macroscopic systems).

Contributed papers were received in January 1997. For the first time the preferred mode of reception was electronic. After reception, the abstracts were divided among the Programme Committee members for evaluation, a few were rejected as obviously inappropriate or flawed and some were recommended for oral presentation. A selection of those recommended was then made which would result, along with invited papers, in coherent and balanced oral sessions. The total number of papers finally scheduled for presentation at ICM was 1392. Of these there were 1239 posters, 122 contributed talks, 26 invited talks and 5 plenary talks. The distribution of contributed papers among the subject categories is shown in the following histogram.



1. Actinides
2. Amorphous magnetism and spin glasses
3. Critical phenomena and phase transitions
4. Domain walls and hysteresis
5. Ferrites and garnets
6. Geo- and bio-magnetism
7. Heavy fermion and intermediate valence systems
8. High TC superconductors.
9. Itinerant magnetism.
10. Low dimensional magnetism.
11. Magnetic interactions and ordering.
12. Magnetic recording and other applications.
13. Magnons, solitons and fluctuations.
14. Nano-crystalline systems and small particles.
15. New magnetic and superconducting materials.
16. Permanent magnets.
17. Photoemission and electronic structure.
18. Rare earth metals and compounds.
19. Superlattices.
20. Surfaces and films.
21. Transition metal compounds.
22. Transition metals and alloys.
23. Other topics

The large number in category 7 reflect the emphasis on strongly correlated electron systems. What is of interest to those of us who early in our careers had a strong interest in transition metals, is the relative eclipse evident in categories 9 and 22. The conference proceedings are published in recent issues of the *Journal of Magnetism and Magnetic Materials*.

ICM is convened by the Commission on Magnetism of the International Union of Pure and Applied Physics and the conference in Australia resulted from discussions in Edinburgh in 1991 when I was a member of the commission. I undertook to ascertain whether Australia would be prepared to host the conference. I set up a small interim committee in 1992, which surveyed opinion and possible venues and with a positive response and with the support of the Australian Academy of Science we bid for, and were awarded the conference at ICM'94 in Warsaw. Professor Robert Street was nominated as the President of the

Conference and the Organising Committee was Professor T.F. Smith (Chairman), Professor P.E. Clark (Secretary), Dr R. Pollard (Treasurer), A/Professor S.J. Campbell (Publications), Dr E. McA. Gray (sponsorship/exhibitions), A/Professor D.H. Chaplin, Professor R. Clark, Dr S. J. Collocott, and myself with responsibility for the programme. In early 1995 'The Meeting Planners' of Hawthorn, Melbourne, were engaged as conference organisers and secretariat and were very helpful especially when the conference was transferred from Melbourne to Cairns.

The conference was underwritten by the AIP in 1994. Concerns from the then AIP Executive about the potentially large financial liability that a big conference presents continued throughout 1995. It is inevitable that someone or some organisation must bear a degree of risk, and a scheme was worked out which would limit the risk to the AIP. Finally, through careful financial control, the conference was able to forward funds to ICM'2000 and return a satisfactory profit to the AIP. It is expected that the funds will permit future similar events to be conducted in Australia free of excessive concerns about financial liability.

An International Advisory Committee of about forty distinguished magneticians was recruited and a Programme Committee of twenty consisting of approximately one third Australians and New Zealanders, one third Japanese, and one third from other countries was appointed. The Australian and New Zealand members of the Programme Committee were A/Professor G. Bowden, A/Professor J.D. Cashion, Dr J.B. Dunlop, Dr A. Kaiser, Professor J. Oitmaa, and Dr G. White. Publication was handled by regional co-editors of the *Journal of Magnetism and Magnetic Materials* appointed for the proceedings of the conference. The co-editors handled the regions of Japan, Asia, North and South America, Western Europe, and Central and Eastern Europe and the Middle East. A/Professor J. Cadogan was the co-editor for Asia and A/Professor S.J. Campbell was coordinating editor. Of the 881 papers submitted 654 appeared in the refereed proceedings.

The conference was originally scheduled for Melbourne. However difficulties with the World Congress Centre and the attraction of the new Convention Centre in Cairns resulted in the shift to Cairns. For anyone contemplating a conference with an attendance up to a thousand and beyond I would recommend the Cairns Convention Centre. The only downside is illustrated by the number of messages I received before the conference requesting a visit to the magnetism laboratories at Monash University after the conference. I responded to these messages with enthusiasm requesting only that they nominate a date. Generally there was silence for a while and then a message saying that they had not realised the distance from Cairns to Monash and asking whether I could recommend a magnetism laboratory in Cairns!

Trevor Hicks
Department of Physics
Monash University

AIP COUNCIL MEETING

REPORT TO MEMBERS

The 50th Council meeting of the AIP was held on February 12 and 13 1998 at 1/21 Vale St, North Melbourne. Twenty one delegates attended, including the Executive, Chairs of State Branches, Chairs of AIP Groups, The Convenor of the Science Policy Committee, the AIP Education Convenor, the editor of the ANZ Physicist, Presidents of several kindred Societies, and the President of the NZ Institute of Physics.

Some of the points discussed arising from reports from the President and Treasurer include the serious financial pressure the AIP is experiencing due to non payment of fees by members, and the problem of academic decisions in Universities being made on financial grounds only, with failure to take into account factors other than student numbers. Substantial savings have followed from reducing the number of issues of the Physicist, though it is hoped that this reduction will not be permanent.

Considerable time was devoted to the following issues, which will be presented to the Branches for further discussion:

Future directions of AIP:

It was agreed that work is needed in publicising the activities of physicists and exposing school students to the nature of physics as a career. It is planned to include profiles of physicists in the web pages of Branches. Publicising the involvement of physicists in industry and specialties such as medical physics is considered crucial, to broaden the perceived base of the profession which is often seen as purely academic.

Certified Physicist: The IOP has recently introduced a grade of Chartered Physicist.

Support for introducing a Certified Physicist grade in Australia varied from Branch to Branch. NSW and ACT Branches will submit an item to the Physicist on this issue for members' consideration, so that the Executive can prepare a specific proposal for the next Council meeting.

Establishment of Interest Groups in addition to NUPP, STEPP and WIP:

Our Articles of Association allow the formation of groups, which are intended to be informal networks of members within the AIP. They are not intended to represent the entire subdiscipline and would not be formed if there is already an interdisciplinary society,

for example the Australian Optical Society. This issue is also to be raised in the Physicist. There was some support for making Chairs of Groups full voting members of Council, in addition to Branch Chairs and the Executive. This would require changes to the Articles.

Enhancement of Future Congresses

Members of Council considered that kindred societies should be strongly encouraged to hold their meetings in conjunction with Congress whenever possible. The dates of the Adelaide Congress in 2000 will soon be available.

Recruitment:

Discussion centred on ways of increasing student participation in the AIP. Branches offer financial support to students to attend conferences. This year the names of all new student members will go into a draw for a free air ticket to the Perth Congress. The system of distributing brochures through a State Branch contact who would distribute them to each institution could be reinstated, though many now obtain membership and other information through the AIP web page.

The following motions were passed unanimously by the Council:

1) Election of Office Bearers - Postal voting

That the positions of President, Vice President, Hon. Secretary, Hon. Treasurer and Registrar be determined biennially by a postal ballot of all members.

(This proposal is based on the ACT Branch paper and has the aim of creating greater interest in the policies and operation of the AIP and encouraging a broader range of members to seek election.)

A call for nominations for the positions of Vice President, Honorary Treasurer, Honorary Registrar and Honorary Secretary will be placed in the May/June Physicist in even numbered years, closing date the end of June (the current Vice President automatically

becomes President). Hopefully there will be at least two suitable nominations for each position. Ballot papers will be sent to members in September with a three week return period. The Executive will appoint two scrutineers and a Returning Officer, who will report the result of the election to the President before November 30th. The results to be published in the November/ December issue of the Physicist. Those elected will take office at the next AGM.

2) Conditions for the Award of the Massey Prize and Medal

That the AIP seek a return to the original conditions whereby the Harrie Massey Medal be awarded biennially, in odd numbered years, and be presented at the AIP Congress.

For the last three or four years the award has been made annually, which has created difficulties with the presentation of the award in non Congress years. The increased frequency may also lead to its devaluation.

3) Establishment of Topical Groups within the AIP

That the AIP invite expressions of interest from its membership to establish topical groups in subdisciplinary areas.

4) Establishment of a Conference Support Fund

That the AIP establish a Conference Support Fund to provide advanced support, generally in the form of repayable loans, to approved physics related conferences within Australia.

The International Conference on Magnetism (ICM'97), which was supported by the AIP has made a substantial profit. The organisers have generously offered to return all profits to the AIP to establish such a fund to support future conferences. The funds would be invested with other AIP reserve funds and the status of the Conference Support Fund would be shown as a separate line item on financial reports and budget statements.

*Moira Welch
Hon Secretary*

Student wins Perth flight

All new student members of the AIP in 1997 were included in a draw for an air ticket to attend the 1998 Perth Congress.

The lucky winner is Mr. Djenan Ganic, a student at the Victorian University of Technology.

ANSTO SPECIAL REPORT

FOREWORD

HELEN GARNETT

Executive Director, ANSTO

ANSTO operates Australia's only nuclear research reactor, HIFAR, which is the centrepiece of the Organisation's infrastructure. In addition it operates accelerators which provide complimentary nuclear technology expertise. This Special Report provides an update on the progress in refining the scientific specifications for the replacement reactor and some recent research highlights from the use of ANSTO's accelerators.

ANSTO intends to contribute articles on recent research highlights using neutrons to a future edition of *Australian & New Zealand Physicist*, together with updates on progress on the reactor project.

The decision by the Federal Government last September to fund the replacement of HIFAR offers an exciting range of both scientific research and practical benefits for Australia.

For many years, HIFAR both drew nuclear scientists from other countries and fostered our own to the extent that Australia was regarded as in the top few countries in nuclear-based research.

Although the operation of HIFAR and associated nuclear activities at ANSTO continue to deliver significant benefits to the country, in educational facilities, research, industrial support (especially for the mining and minerals exploration industries), community health through medical radioisotopes, environmental management through the application of radioisotopic tracing and other nuclear-based technologies as well as strategic advice, which underpins Australia's technological, economic and political thrust and performance in the Asia-Pacific region, our reactor is obsolete.

While the reactor continues to operate safely, its watchdog, the Nuclear Safety Bureau, has told the Federal Government that it wishes to apply to HIFAR the standards of a modern research reactor. Hence, it was not willing to license its operations much beyond 2003. Hence, last year the Government considered the options of funding refurbishment to the required modern standards or funding replacement. The latter course was chosen, the replacement to be on ANSTO's land at Lucas Heights where it can be supported by the extensive, extant infrastructure. As the first step, an extensive environmental impact assessment has begun and is expected to take most of 1998. All subsequent stages of the physical specification, construction and management of the reactor will be oversighted and must be approved by a new Federal nuclear regulator, the Australian Radiation Protection and Nuclear Safety Agency, which commence operation on July 1, 1998.

The Australian scientific research community is one of the major stakeholders in the replacement for HIFAR. A replacement for it offers exciting possibilities for research into new materials for applications such as the aerospace, automotive, biotechnology, nanotechnology, petrochemical and telecommunications fields as well as the elucidation of processes for the resource sector, environmental management and process industries. New radiopharmaceuticals, especially in the expanding fields of agents for disease prognosis, palliation and therapy will be possible, with concomitant improvements in patient care and reduced hospitalisation.

ANSTO has already held a series of discussions with the scientific, industrial and medical communities regarding their expectations and the advice from the Beam Facilities Consultative Group is described in this issue. This is essential input for the development of final reactor specifications.

These are invigorating days for the Australian neutron science community. ANSTO looks forward to working closely with this community to develop a world class facility that will deliver exceptional benefits to Australia and to science.



Helen Garnett

A NEW RESEARCH REACTOR FOR AUSTRALIAN SCIENCE IN THE 21ST CENTURY

SHANE KENNEDY

sjk@ansto.gov.au

Australia's multipurpose nuclear reactor, HIFAR, is now in its 40th year of operation. As the only research reactor in the country, it has been the centre for Australian neutron beam research and radioisotope production since the late 1950's. As HIFAR approaches the end of its working life, ANSTO is planning Australia's next generation neutron source. The replacement source will also be a multipurpose reactor providing three times the thermal neutron flux of HIFAR, and will incorporate modern technologies that facilitate access to new areas of condensed matter research that are not currently available in Australia.

The History

Neutron beam research in Australia began in 1958 when the Australian Atomic Energy Commission (AAEC) started operating the HIFAR research reactor at the Lucas Heights Research Laboratories. The reactor is a multipurpose facility, based on the DIDO reactor which operated at Harwell Laboratories in England, until ~1990. HIFAR runs at 10MW thermal power producing a thermal neutron flux of 1014 n/cm²/sec. In 1958 this was considered to be a high flux, but since ~1970 it is more than an order of magnitude less than the world's leading neutron sources. The reactor was initially built for materials testing by AAEC scientists in support of the Federal government's plans to establish a nuclear power program. The Australian Institute of Nuclear Science and Engineering (AINSE), representing the interests of university based research, employed a small team of neutron scattering support staff from ~1960. A change in government policy in the early 1970s led to a shift in priorities at AAEC towards the nuclear fuel cycle and downsizing of the in-house neutron scattering effort. Meanwhile, interest in neutron scattering research at HIFAR by University based scientists remained strong. The AINSE team maintained the local support base over the next two decades when the in-house research program was at its weakest. The establishment of the Australian Nuclear Science and Technology Organisation (ANSTO) in 1987, (replacing the AAEC) brought with it another shift in priorities and some reemergence of neutron scattering research within ANSTO. The AINSE scientific and technical staff were



Dr Shane Kennedy is a Principal Research Scientist in the Neutron Scattering Group at the Australian Nuclear Science and Technology Organisation

absorbed into ANSTO in 1993 and now the group is charged with the responsibility of catering to both in-house and external neutron beam research. For most of its life HIFAR has also produced radioisotopes for medical use and, over the last decade, has been used to produce semiconductor grade silicon by transmutation. A schematic of the current neutron beam

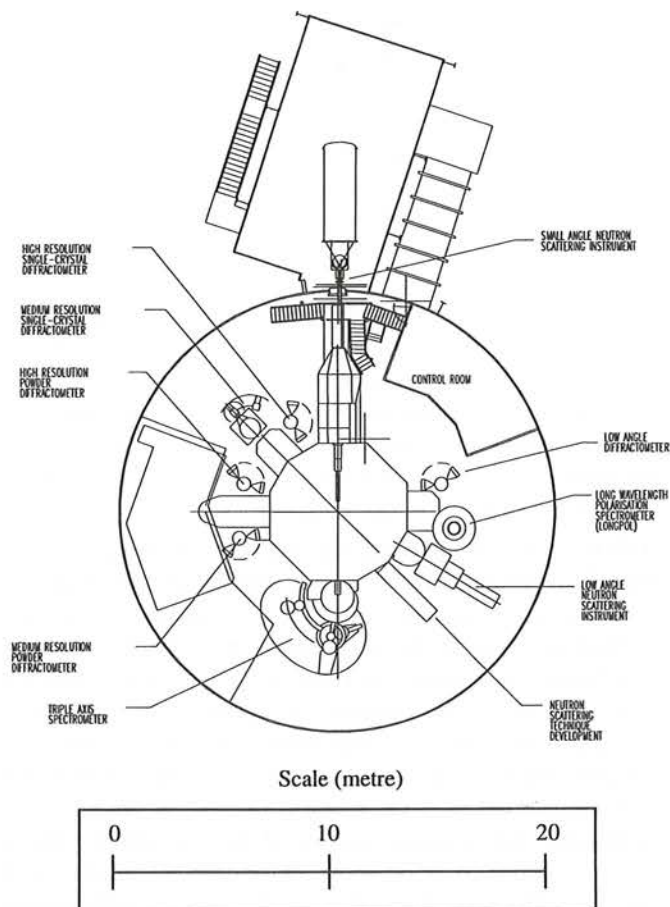


Figure 1 Schematic of the HIFAR reactor, highlighting the neutron beam instruments.

instrumentation in HIFAR is shown in figure 1. All neutron beam instruments, with the exception of the small angle neutron scattering (SANS) instrument, are clustered around the core inside the reactor containment building.

After a little over 50 years, neutron scattering techniques have become an important tool for condensed matter research in advanced nations, with for example ~4000 neutron beam researchers in Europe and over 1000 in North America. In Europe the distribution of users by discipline is Physics 46%, Chemistry 26%, Materials Science 20%, Life Sciences 4%, Engineering 3% and Earth Sciences 1%. In the local context, we can measure the successes and failures of the neutron beam research program at HIFAR in a number of ways. Notably there have been in excess of 130 higher degrees awarded for research involving neutron beams, and between 1960 and 1990 more than 10% of Australian physics PhD graduates used HIFAR's neutron beam facilities. One of the features of the training program has been the export of Australian neutron scattering scientists that have gained recognition for their contributions to the field in overseas neutron scattering centres. Unfortunately the HIFAR facility has been unable to satisfy the research of a number of Australian groups, who have established links with foreign neutron scattering facilities to perform their research. This is reflected in the Australian neutron scattering publications over the life of HIFAR. Although the publication rate of HIFAR based research has increased over the years an increasing portion of publications have involved overseas facilities. Whereas in HIFAR's first two decades of operation 89% of Australia's neutron scattering publications featured HIFAR based research, in its third and fourth decades this figure dropped to 72% and 52% respectively. The drop in significance of the HIFAR operation reflects in part the lack of investment in support of the neutron scattering facility, but equally the trend indicates the vast improvements obtained in the second generation of thermal neutron sources. Over the years neutron scattering techniques have developed considerably in the traditional strengths, such as crystallography and lattice dynamics. It has also expanded enormously in the range of applications, through the development of new reactor and neutron beam technologies into the many emerging areas of condensed matter and Life Science Studies, etc. Neutron beam science has developed to the point where the HIFAR reactor is unable to be used for many of the country's research needs.

HIFAR is now approaching the end of its working life, and must be replaced by 2005 with a modern neutron source if Australia is to maintain its position in nuclear science and technology. The Federal government intends to fund construction of a replacement reactor by 2005 at an estimated cost of \$286M. The Minister for Science and Technology announced this plan on 3 September 1997, stating that 'The research reactor will serve Australia's nuclear science and technology needs well into the next century'. It will be of one of the first new research reactors of the 21st century and is likely to be unique in the Asia-Pacific region. It is envisaged that the HIFAR reactor will operate until the replacement reactor is built and will then be shutdown and decommissioned. ANSTO has now begun the process of defining the structure

and capabilities of the new facility, and is currently working out the detailed specifications for tender. Some of the key issues are to determine the areas of scientific research at the new facility and to define a suite of neutron beam instruments which would best serve that research. For this purpose an advisory committee has been formed, which includes members from Academia, Government research organisations and Industry. The committee has met on six occasions since October 1997, including one open workshop to discuss new research and technologies. In considering these issues, the group has attempted to view the new facility from a national perspective. The members are now largely agreed on the research priorities, and have produced a conceptual design for the facility. The recommendations of the committee form the basis of this article.

The Science

The strength of neutron scattering stems from the unique properties of thermal neutrons. In summary these properties are-

- wavelength around 1-2Å, making them sensitive to atomic spacings in solids and liquids.
- energy around 20-100meV, so they are sensitive to excitations in solids and liquids.
- Strong neutron nuclear interaction... Two consequences of this are
 - The strength of the interaction does not increase monotonically with atomic number as it does with X-rays and electrons, but varies randomly between neighbouring elements and between isotopes of the same element.
 - The nucleus, being relatively compact, acts as a point scatterer so that atomic scattering power does not decrease sharply with scattering angle.
- magnetic moment of 1.913 μ_n making them highly sensitive to magnetic interactions.
- no net electric charge so that they penetrate deeply into matter.

Modern neutron sources are capable of providing useful fluxes of neutrons with energy (wavelength) ranging from 200 μ eV (20 Å) to 500meV (0.4 Å). By selection of the appropriate neutron energy one can access a wide range of spatial correlations and energy transfers in the target material. This is why the technique has found a niche in so many areas of scientific research. Although the bulk of applications in the past have been in Physics, Chemistry and Materials Science, there are a growing number of applications in Life Sciences, Engineering and Earth Sciences. There are also many cross-disciplinary applications.

Physics

This includes condensed matter physics, neutron optics and fundamental physics. Condensed matter physics is generally the starting point for understanding the fundamental properties of novel materials. It includes magnetism, superconductivity, heavy fermions, quantum systems and ferroelectrics. Neutron scattering has had a high impact on this area of science, particularly in the areas of magnetic structures, phase transitions,

flux transport in superconductors and ferroelectric responses. It has also provided great insights into dynamical phenomena such as phonons, magnons, crystal field excitations and diffusion processes. Magnetism is one area where Australia has a good track record in neutron scattering. There exists a considerable amount of local expertise in condensed matter physics that would be enhanced by a modern neutron source. Neutron diffraction, inelastic scattering, reflectometry and Small Angle Neutron Scattering (SANS) techniques are all applicable here. Where magnetic information is sought, polarised neutrons are often used in conjunction with these methods to enhance the signal.

Neutrons provide a useful tool to treat a number of problems in fundamental physics. In particular, the absence of an electrostatic potential in neutrons means that they are oblivious to the strong force which masks more subtle interactions that occur. Neutron optics include the transmission, reflection, refraction and interference effects with materials, interfaces and magnetic fields. The research has often led to the development of new techniques for use with neutron beam technology. There have been significant contributions in this area by Australian scientists, working both here and overseas, adding to the international reputation of Australian science in the field of neutron research.

Chemistry

This includes a wide range of research problems in which determination of the crystal structure, nanostructure or microstructure of a material is important. Many neutron scattering techniques are applied to study particular aspects of the structure and dynamics of materials, with a heavy emphasis on powder diffraction and small-angle scattering, but increasingly comprising inelastic techniques such as neutron vibration spectroscopy. The high penetrating power of neutrons facilitates building environmental cells for the study of materials under non-ambient conditions so chemical reactions and phase transformations can be studied in situ and in real time. Structural chemistry is one of the mainstays of neutron diffraction and there are numerous examples where ability to accurately locate oxygen, hydrogen and other light elements in a lattice have played a key role in elucidating the structural origins of the novel properties of crystalline materials. Examples include new structural materials such as fullerides, smart materials (eg colossal magnetoresistance materials) and functional materials (eg high energy product magnets, High T_C superconductors, Synroc and zirconia ceramics)

If measurement times on second or sub-second time scales are achieved, reaction processes such as catalysis, nucleation and growth, and interstitial modification of porous materials become possible.

Quantitative phase analysis of multiphase materials with neutrons is particularly advanced.

Neutrons have provided a number of scientific insights in molecular materials such as polymer blends, surfactants, emulsions, colloids and gels in the past and are generally expected to become even more relevant as more complex soft materials are developed. The scattering of cold neutrons in SANS has produced a revolution in our understanding of the structure and

dynamics of polymeric solids and fluids. Inelastic scattering of cold neutrons has similarly opened up the understanding of the dynamics of polymeric fluids. The availability of hydrogen/deuterium contrast variation in neutron reflectivity has led to major advances in the study of air-liquid, liquid-liquid and solid-liquid interfaces. The method gives a profile of the interface perpendicular to the surfaces in surfactants and co-surfactants. Australia has a long standing international reputation in colloid and surface science with an excellent track record of theoretical and practical contributions.

Materials Science

Due to the strong overlap between Condensed Matter Physics, Structural Chemistry and Materials Science many of the applications in this category have been mentioned earlier. However there are many semi-crystalline and non-crystalline materials that are of practical importance in our lives for which neutron scattering provides vital information. Examples include glasses, cementitious materials, amorphous materials and liquids. Glasses include window glasses, optical fibres and superionic conductors. Amorphous materials include magnetic tapes and amorphous ceramics. Neutrons have the unique ability to probe the static and dynamic correlations in these materials in a wide range of environments such as temperature, pressure and magnetic field. Neutron diffraction studies of non-crystalline phases using hot neutrons can provide structural information to a resolution of $<0.2\text{\AA}$.

Applications include studies of crystallisation kinetics, sol/gel reactions and liquid/liquid interactions.

Life Sciences

Areas in biology and biotechnology in which neutron scattering is likely to play a significant role are macromolecular assemblies, membranes and proteins. Australia has existing strengths in biomolecular structure determination of individual macromolecules by X-ray crystallography and NMR, but is less advanced in studies of macromolecular assemblies. Studies of the interactions between macromolecules and their assembly into biologically functional complexes is a critically important emerging area of biology where neutron scattering is likely to play an increasingly significant role. These studies are possible through deuteration of macromolecules to make use of contrast capabilities of neutron scattering.

Membranes and their constituents have been examined from a structural perspective much less than proteins and nucleic acids. This reflects the deficiencies of existing technologies for the study of membranes - the difficulty of crystallising membranes and their constituent proteins as far as X-ray is concerned, and their anisotropic nature and size as far as NMR is concerned. Neutron scattering studies offer the possibility of studying both structural and dynamic processes in membranes.

The function of proteins is often intimately associated with a change in their conformation, usually in response to the binding of a ligand or interaction with a receptor. Such processes necessarily occur in solution, excluding X-ray crystallographic methods for their study. NMR methods are also limited as they rely on the detection of short range interactions, so there exists a niche for methods such as SANS which detect global conformational changes in proteins.

Engineering Science

Neutrons are ideally suited to the non-destructive study of bulk samples that must function in extreme environments, such as aircraft and spacecraft components, welds, engines and waste treatment. Although the present use of neutron beam facilities in engineering science is low, potential lies in residual stress and texture studies of engineering components, and in radiography.

Their high penetrating power makes neutrons especially well suited to assessment of residual stress in actual components in their as-fabricated or in-service conditions. The use in the power and petrochemical industries will enable the validation of models describing welding and repair welding procedures in components where creep, fatigue or stress corrosion could result in expensive failures. Measurement of residual stress is also important in the aircraft and nuclear industries, where failure is unacceptable.

Neutron radiography has generally been applied to high valued-added components where the cost of inspection is small in comparison to the risk of failure. The strongest potential for growth is in advanced industries, principally aerospace. Real-time applications include tribology and lubrication, transport of hydrogenous fluids in materials (such as soil, rock and ceramics) as well as the study of solidification and segregation processes such, as casting, in metallurgy and materials science

Earth Sciences

The application of neutron scattering to problems in earth and environmental science is quite new, but there is considerable potential for expansion in this field as neutron scattering technology evolves. Neutron diffraction studies of the responses of mineral structures to changing temperature, pressure and hydration provide one good example. Determination of the pore structures in rocks that facilitate motion of fluids such as salt water and hydrocarbons using SANS may also be expected to feature. Direct information about the pore space architecture is useful for mining exploration as the formation fluids are either mined directly (oil and gas), or are a serious risk factor (methane in coal seams), or contribute to mineralization.

The Facility

The schematic (figure 2) shows the layout of the new facility, including all instruments that are to be built with project funds, as well as residual stress and radiography instruments, which will be built subject to additional funding being obtained. As most of the neutron beam instruments will be located in the reactor guide hall, the diameter of the reactor containment building need not be any larger than HIFAR. The reactor will generate thermal (50°C), cold (20K) and hot (2000°C) tangential beams for neutron beam research. The use of tangential beams greatly reduces background radiation from fast neutrons and γ -rays. The layout also includes several spare thermal, cold and hot neutron beams. It is anticipated that all named thermal and cold neutron beam instruments will be placed inside the guide hall. The amorphous materials diffractometer, which requires hot neutrons, will be placed in the reactor hall to maximise utilisation of the available hot neutron flux. The thermal

beam instruments can be placed in the guide hall because neutron supermirror technology has advanced to the point where thermal neutron beams can now be efficiently transported over large distances. The neutron beam guides are slightly curved with the effect that, over a distance of ~20metres, fast neutrons and γ -rays, which are not reflected by the mirror surfaces of the guide, are removed from the transmitted beam. Thus the background radiation is further reduced. Other advantages of placing instruments in a guide hall are extra space and relaxed security. These are all factors that will make the new facility far more attractive to beam users. In the event that the facility is extended a second guide hall could be built at right angles to the first guide hall, as indicated in the figure. This guide hall could be serviced by both cold and thermal guides, while still maintaining some capability for thermal and cold beam instrumentation in the reactor hall. Removal of the bulk of the neutron beam instrumentation from the vicinity of the reactor core liberates space at the reactor face for construction of neutron irradiation facilities.

The actual number of instruments built depends on the cost of each instrument. The committee is agreed that the emphasis should be on building only world class instruments. Current expectation is that the first 8 instruments will be ready when the reactor begins operation in 2005 and a further 3 will come into service by 2010. However there is provision in the plan for up to 18 instruments, so that other capabilities could be developed if additional funding were found. The order of priority for neutron beam instruments has been suggested as follows, with instruments of equal rating listed together.

- 1-4 High Intensity Powder Diffractometer, High Resolution Powder Diffractometer, Small Angle Neutron Scattering Instrument (SANS), Neutron Reflectometer
- 5,6 Polarisation Analysis (Time-of-flight) Spectrometer, 4 circle diffractometer
- 7 Quasi Laue Diffractometer
- 8 3 Axis spectrometer
- 9 High Energy Resolution Backscattering Spectrometer
- 10 Amorphous Studies Diffractometer (on the hot source)
- 11-13 Residual Stress Diffractometer, Radiography, 2nd SANS instrument

The Instruments

High Intensity Powder Diffractometer

This instrument will be used to study structural and magnetic phase changes as a function of temperature, pressure, magnetic and electric stimuli and time. To obtain diffraction data in a reasonable time scale, and meet the increasing need to provide kinetics information, the instrument must be optimised for speed, while delivering data of sufficient quality to allow quantitative analysis of the results. The new instrument will have a detecting power at least 100 times that of HIFAR's Medium Resolution Powder Diffractometer, with some improvement also in resolution.

High Resolution Powder Diffractometer

The priority for the new instrument will be a significant improvement in resolution over the current HIFAR instrument, with a reduced average data collection time. The aim will be to collect a powder diffraction pattern in 5 hours from a 1gram sample with complex crystal structure. This machine would then be equal to the best high resolution neutron powder diffractometers currently available overseas.

Small Angle Neutron Scattering Spectrometer (SANS)

HIFAR's first modern SANS is just now being commissioned, it uses a continuously variable monochromator and a locally built two dimensional detector. The new instrument will essentially be built along the same lines but will benefit greatly from access to a broad band of cold neutrons, by the combination of neutron cold source and velocity selector, and a significant increase in length. It is expected to attract a great deal of interest in chemistry, biology and condensed matter physics.

Neutron Reflectometer

The instrument will measure neutron optical reflectivity at grazing angles to probe the neutron refractive index of materials, with high spatial resolution perpendicular to the surface, to depth of $\sim 1000\text{\AA}$. This will allow determination of structural profiles in liquid and solid interfaces and in organic and inorganic multilayers. The option of polarizing the neutron beam will allow magnetic properties near surfaces and magnetic depth profiles to be studied. Applications in physics, chemistry and materials science are likely to be widespread.

Polarization Analysis (Time-of-Flight) Spectrometer

This will be based on the LONGPOL instrument at HIFAR. The instrument uses polarized neutrons, a flipping device that can reverse the polarization direction, and a polarization sensitive detector system. Analysis of polarization allows separation of nuclear and magnetic scattering mechanisms, and pulsing of the flipper permits energy analysis by the time-of-flight method. Cold neutrons will be of great benefit, permitting use at longer wavelengths and providing increased flux. The instrument is particularly useful for studies of magnetic short-range order and flux pinning mechanisms in HTS crystals. It can also measure magnons, phonons, crystal field transitions and diffusion rates.

4 circle Diffractometer

The new single crystal diffractometer will be based on the current high resolution single crystal diffractometer. The instrument will be optimized for conventional high-accuracy crystallography, and will be equipped with a range of sample environment options.

Quasi Laue Diffractometer

The instrument will use a broad band of cold (or thermal) neutrons and a cylindrical image plate detector to record the diffraction peaks. This method of operation, known as quasi-Laue diffraction, facilitates rapid determination of accurate structures on biological single crystals. The instrument will allow the routine use of neutron diffraction to obtain structural information, particularly on the location of hydrogen in biological

samples, which cannot be accurately determined using x-ray studies.

3 Axis spectrometer

This is one of the most versatile instruments for measurement of neutron scattering from single crystals. The instrument allows determination of the energy transfer as a function of momentum transfer (scattering angle). It will be primarily used to study the collective motion of atoms in solids (phonons) and that of their magnetic moments (magnons). Use of polarizing monochromator and analyser facilitates measurement of magnetic excitations.

High energy resolution backscattering spectrometer

Provides micro-electron Volt energy resolution for strong scatterers by combining high takeoff angles (backscattering) combined with Doppler energy scanning. It is particularly useful for quasielastic scattering from diffusive motions of large molecules. It is also useful for measuring the spectrum of more complicated motions in biological materials.

Amorphous Materials Diffractometer

The single most important feature of this diffractometer will be the neutron hot source that will provide access high momentum transfer ($\sim 30\text{\AA}^{-1}$), which translates to spatial resolution of $\sim 0.2\text{\AA}$. The instrument will be built on conventional powder diffraction lines with relaxed angular resolution to provide increased intensity. The instrument is expected to become an integral part of the material science research program based around the powder diffractometers in the guide hall.

Reverse Time of Flight Diffractometer

The instrument will be optimised to investigate residual stress. The key feature of the technique lies in the ability to accurately measure strain in small gauge volumes ($\sim 1\text{ mm}^3$) in the specimen. The scattering volume is defined by measuring the diffracted beam only at right angles to the incident beam, and the incident beam flux must be as high as possible to enable penetration through large samples. The RTOF method maximises flux by using a large fraction of the thermal neutron spectrum, via modulation of the white neutron beam.

Neutron Radiography

The method produces a direct image of the internal structure of a sample where contrasts in attenuation are strong. The facility requires well-collimated high flux thermal beam covering a relatively large area ($\sim 30 \times 30\text{ cm}$). The detector could be a radiographic film for high-resolution studies or video imaging for real time studies. Placed at the end of a thermal neutron guide, it would have high spatial definition and could accommodate large specimens.

Access to the Facility

Adequate staffing is essential for the success of the neutron scattering facility. Cultivation of the core scientific skills in ANSTO staff will provide cohesion in the various areas of research and ensure the continuity of research programs on all instruments. It is the view of some that up to 12 - 16 research scientists will be required to run the basic suite of 10 instruments, with at least

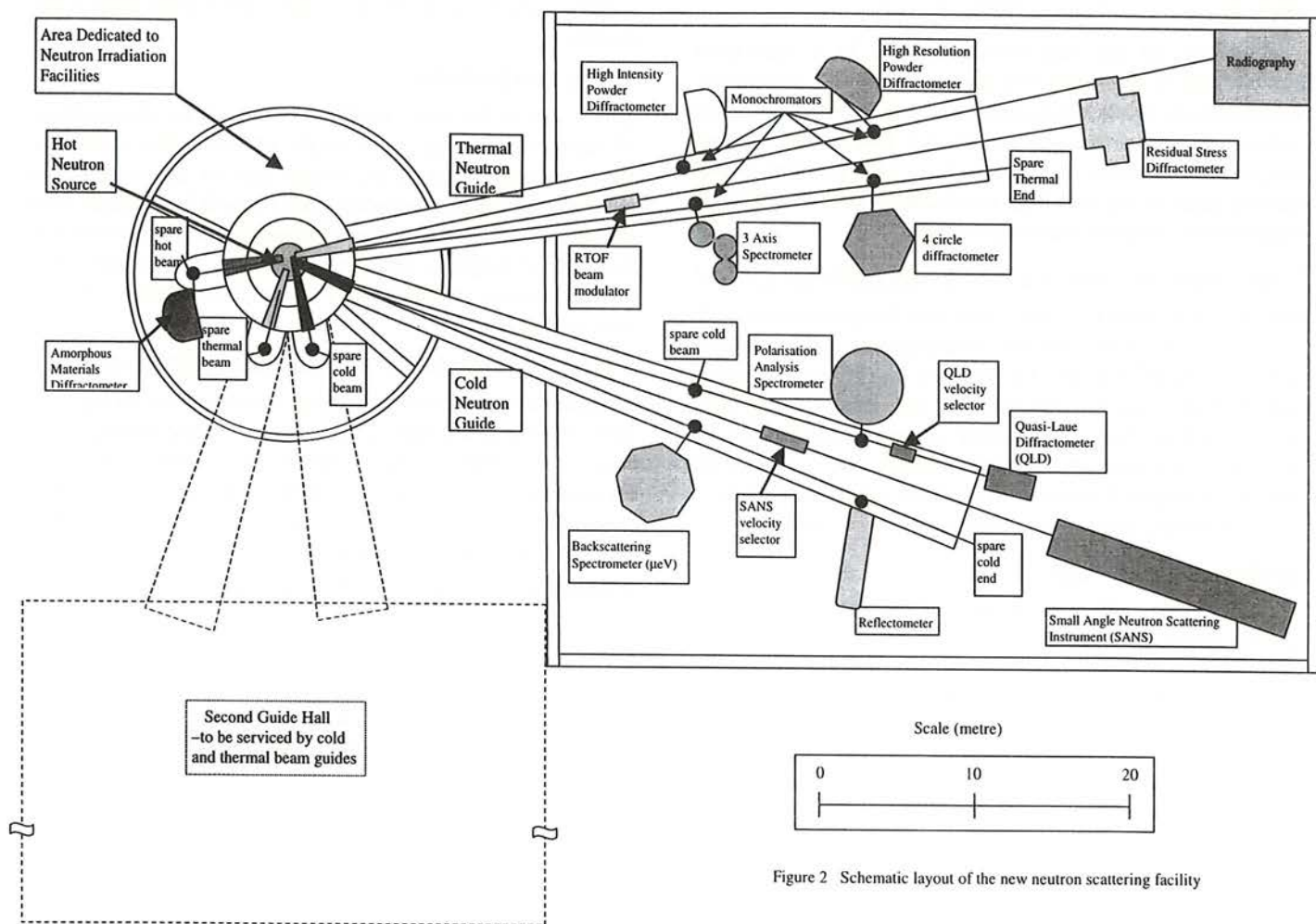


Figure 2 Schematic layout of the new neutron scattering facility

Figure 2 Schematic layout of the new neutron scattering facility

one further scientist for each additional instrument. A core technical support group numbering between 10 and 14 will be established in support of the instrument maintenance and development program and to ensure adequate support to scientists during experiments. It is essential that the facility has the resources to maintain a comprehensive suite of up to date ancillary sample environment devices. Additional administrative support staff will be required to assist in the smooth operation of the facility.

As the reactor will be fuelled by low enriched Uranium (<20% ^{235}U), it will be possible to relax security for neutron beam research. For experiments performed in the guide hall there should be no special security requirements. Easing of access to the neutron beam instruments will also enhance the educational benefits of the facility, allowing involvement of undergraduate students in practical experiments with neutron beam techniques. The educational benefits are both sociological and scientific. The sociological benefits lie in the demonstration of the positive aspects of nuclear reactors, radiation and nuclear power. The scientific benefits flow from exposure of a broad cross-section of undergraduate students (physics, chemistry, biology, materials science and engineering) to the environs of a research reactor and to some of the research possibilities that such a facility provides. There is, in addition, an opportunity to provide training

for people from industry and for students or trainees from overseas, thus generating goodwill and possibly export earnings.

The Committee

The members of the beam facilities consultative group are, alphabetically, Steve Burke (DSTO), David Craik (U. of Qld), Andrea Gerson (U. of S.A), Evan Gray (Griffith U.), Bob Harrison (ANSTO), Trevor Hicks (Monash U.), Shane Kennedy (ANSTO), Tony Klein (Melbourne U.), Brian O'Connor (Curtin U.), Ezio Rizzardo (CSIRO), Gerald Roach (ALCOA), Claudio Tuniz (ANSTO) and John White (ANU). The members have generously contributed to the process of defining the scientific priorities and the conceptual layout of the new reactor. The committee has benefited greatly from the advice of Ross Miller and George Malosh (both of ANSTO). In addition many others in the scientific community both in Australia and overseas have made valuable contributions to the process so far. If the project continues to enjoy such solid support from the scientific community it will, no doubt, be a great success.

APPLICATIONS OF ACCELERATOR PHYSICS AT ANSTO

CLAUDIO TUNIZ

tuniz@ansto.gov.au

The Australian Nuclear Science and Technology Organisation (ANSTO) is involved in advanced research programs based on the use of nuclear science and technology for materials microanalysis. This paper is a review of accelerator-based probes to characterise environmental, biological and industrial materials. Most examples are inspired by the ANSTO research program.

Introduction

Particle accelerators have been developed more than sixty years ago to investigate the nuclear and atomic structure. A major shift toward the use of accelerators in the analysis of materials composition and structure for scientific and industrial applications has been witnessed in the last two decades. Tandem Van de Graaff accelerators have evolved into specialised tools for ion beam analysis (IBA) and accelerator mass spectrometry (AMS). Synchrotron accelerators have become dedicated facilities, optimised for emission of bright electromagnetic radiation, an ideal analytical probe for biology, materials science and other disciplines. Finally, high-energy proton accelerators are used in spallation sources for producing pulsed beams of neutrons to characterise the structure of matter in condensed states.

Ion accelerators

Ion accelerators used for analysis of materials are, for the most part, either single-ended or tandem type Van de Graaff accelerators. Very often these are machines which were originally constructed for nuclear physics research and have been turned to other uses as the effort in low-energy nuclear physics faded away. On the other hand, the field has grown to such an extent that machines designed specifically for analytical applications now exist.

Two ion accelerators are available at the ANSTO, a 3 MV single-ended Van de Graaff accelerator and a 10 MV Tandem Van de Graaff accelerator.

In the 3 MV Van de Graaff accelerator, positive ions are produced from neutral gasses such as hydrogen and helium. The choice of ion type and its energy depends on the elements of interest in the material being analysed. This accelerator was commissioned January in 1964 to produce neutron beams with characteristics suitable to study materials of interest in reactor



Dr. Claudio Tuniz is Director of the Physics Division at ANSTO and coordinates a broad spectrum of interdisciplinary research based on the use AMS, Ion Beam Analysis, Neutron Diffraction and Synchrotron Radiation.

design. The original research program was related to studies of neutron-induced reactions and fission. In the last 30 years, research programs related to ion beam applications in science and industry became dominant.

The ANTARES tandem accelerator is based on the FN tandem accelerator originally built by High Voltage Engineering for Rutgers University (New Jersey, USA). Since its arrival in Australia, in 1989, the accelerator has undergone a complete refurbishment and upgrade. Major items in this transformation are: use of SF₆ insulating gas, new spirally-inclined accelerator tubes, Pelletron charging system, 60-sample computerised ion-source, high resolution and high rigidity injection magnet and fast sequential isotope injection [Tuniz, 1997a]. Versatility is allowed by multiple beamlines for ion beam analysis and accelerator mass spectrometry.

3. Ion Beam Analysis

Ion accelerators provide a variety of MeV-energy ion beams. Advanced methods for production and focusing of ion beams have been developed over the last decades. Ion beams lose energy by ionisation of the atoms composing the stopping material caused by the interaction of the Coulomb field of the projectile with the atomic electrons and also by nuclear scattering from the nuclei of the atoms. The range of ion beams in materials is short, with a relatively well defined end point. By comparison, x-ray beams are attenuated according to an exponential law and sample a much greater amount of material.

Ion beams are used for trace element determinations using the characteristic x rays produced in the ionisation process. Ion beams can also interact directly with atomic nuclei. Nuclear reactions, including elastic and inelastic scattering or Coulomb excitation, are useful to identify specific elements and nuclides present in the sample. Concentration of individual elements or isotopes as a function of depth is possible using narrow nuclear resonances and energy loss of ions as they travel in the material.

Detection methods for x rays, γ rays, charged particles and neutrons have been developed in parallel with the development of accelerators, ion sources and other instruments necessary for the production of ion beams. This work has been driven by the need for basic understanding of nuclear physics, by practical considerations related to nuclear power, medical applications, etc. Many of the analytical uses of ion beams have also stemmed from the applicability of these methods to the study of semiconductor materials used for production of various types of electronic devices.

Combination of different ion beam analysis techniques such as particle induced x-ray emission, nuclear reaction analysis, activation analysis and elastic recoil detection can be used to determine elemental compositions for elements from hydrogen to the transuranic elements.

Accelerator Mass Spectrometry

AMS incorporates an ion accelerator and its beam transport system as elements of an ultra-sensitive mass and charge spectrometer [Tuniz, 1998]. Multiple selection stages for energy, momentum, velocity and atomic charge plus final identification of nuclear mass and charge with an ion detector makes possible measurements of isotopic ratios some four or five orders of magnitude smaller than is possible with conventional mass spectrometry (MS). The high isotopic selectivity of AMS enables a dramatic reduction of the backgrounds that plague MS: molecular and isobaric interferences and tails of abundant neighbouring masses. For instance, AMS allows an isotopic sensitivity of less than one part in 10^{15} for ^{14}C , ^{10}Be and other radionuclides occurring in nature at ultra-trace levels. The sensitivity of AMS is unaffected by the half-life of the isotope being measured, since the atoms, not the radiations that result from their decay, are counted directly. Hence, the efficiency in the detection of the aforementioned radionuclides is improved by several orders of magnitude compared to radiometric counting methods, depending on the half-life of the radionuclide being measured. The size of the sample required for the analysis is reduced accordingly. Also some stable isotopes, often present in the environment at very low concentrations, such as the rare earth and platinum group elements, can be detected by AMS with better sensitivities than conventional MS.

In the last 20 years, AMS systems have been developed at more than 40 laboratories, for the detection of low-abundance radionuclides in environmental, archaeological, biomedical and industrial samples. Three of these facilities are in Australia, at ANSTO, ANU and CSIRO Exploration and Mining. At each of these facilities, accelerator beam time is shared with other users.

ANSTO has a wide-ranging AMS program, which includes measurement of ^{14}C at high precision, ^{26}Al , ^{10}Be , ^{36}Cl and ^{129}I , with Actinides currently under development. This is a key facility supporting scientific projects involved in global climate change studies and international nuclear safeguards, and providing AMS analyses for the Australian research communi-

ty and international collaborators. The ANU accelerator is a leader in ^{36}Cl analysis and has also developed measurements other species including ^{32}Si , ^{59}Ni and plutonium and neptunium isotopes for environmental and biomedical applications [Fifield, 1997]. The CSIRO facility is developing micro-beam AMS for the in-situ microanalysis of trace elements in geological samples [Sie, 1997].

AMS with tandem accelerators

In AMS, the element of interest is chemically separated from the original sample and loaded as a target in a sputter ion source. Negative ions are extracted from the ion source and, after a pre-acceleration stage, their mass is analysed by a magnetic field. The negative ion beam is injected into a Tandem accelerator with a (positive) terminal voltage of several MV. At the high voltage terminal the beam passes through a low pressure gas or a thin foil which strips electrons off the ions. Multi-charged positive ions are then further accelerated by the same positive voltage on the terminal. Following acceleration, combinations of magnetic and electric fields select the momentum, energy and velocity of the ions. Finally, the identification of the rare isotope, accelerated at energies of 10-100 MeV, is performed in an ion detector. Depending on the isotopes to be counted, a variety of detectors are available for this final stage of the AMS spectrometer such as ionisation chambers and time-of-flight detectors. Energy, stopping power, range and velocity can be measured to identify the isotopes of interest.

The main advantages of Tandem accelerators for AMS are firstly, the use of sputter sources producing negative ions and secondly, terminal stripping. The first feature is important as most elements form negative ions and many radionuclides can be analysed. In addition, there are some favourable cases where the interfering isobar does not produce negative ions, eg. ^{14}N in the analysis of ^{14}C and ^{26}Mg in the detection of ^{26}Al . The stripping of 3 or more electrons at the terminal of the tandem causes the break-up of molecules which are the main limitation for conventional MS. High precision AMS analysis is made possible by either using simultaneous injection or rapid sequential injection of the isotopes of interest, in order to overcome variability in source output and accelerator transmission.

Long-lived radionuclides

Radionuclides are used as tracers and chronometers in many disciplines: geology, archaeology, astrophysics, biomedicine and materials science. Low-level decay counting techniques have been developed in the last half century to detect the concentration of cosmogenic, radiogenic and anthropogenic radionuclides in a variety of specimens. However, for long-lived cosmogenic radionuclides, such as ^{10}Be , ^{14}C , ^{26}Al , ^{36}Cl , radiometric methods are made difficult by low counting rates and in some cases the need for complicated radiochemistry procedures and efficient detectors of soft beta particles and low energy x rays. AMS can measure, for example, cosmogenic radionuclides in geological samples up to 10^6 times smaller than those required for radiometric techniques.

5. Synchrotron radiation

ANSTO manages the Australian Synchrotron Radiation Program (ASRP) which provides Australian researchers with access to synchrotron radiation facilities at the Australian National Beamline Facility (ANBF) at the Photon Factory, Tsukuba, Japan, and the Advanced Photon Source (APS) at the Argonne National Laboratory in Chicago, USA.

The Photon Factory is a 2.5 GeV second generation synchrotron light source. The ANBF provides monochromatic synchrotron X-rays in the energy range 4.5-20 keV. The main instrument is a diffractometer based on image plates.

The APS is a 7 GeV third generation synchrotron light source, which produces X-ray beams of much higher brightness, and higher energy, than the Photon Factory. The ASRP provides access to two Collaborative Access Teams (CATs), the Synchrotron Radiation Instrumentation (SRI) CAT and the Consortium for Advanced Radiation Sources (CARS).

The aim of the SRI-CAT is to develop and implement strategic synchrotron radiation instrumentation to fully utilise the extremely high intensity beams produced by the APS. Such instruments are based on the use of sub-micron spot size beams, time-resolved spectroscopy, high energy X-ray beams (up to 200 keV), etc.

CARS is organised along specific disciplinary lines. Australia, via the ASRP, is a member CARS, with guaranteed access to the BioCARS and ChemMatCARS beamline facilities. BioCARS will promote the understanding of basic biological processes by determination of the structures of bio-molecules. ChemMatCARS will support condensed matter studies.

A more detailed treatment of the ASRP and the overseas synchrotron light source facilities is given in a following article.

5.1 XRF microscopy

X-ray fluorescence (XRF) spectroscopy is one of the oldest analytical tools based on x-rays. Synchrotron radiation (SR) has unique properties, very desirable in high-sensitivity elemental analysis using XRF:

- high brightness
- wide energy spectrum
- high degree of polarisation

In general, instruments utilising XRF to obtain two-dimensional maps of element distribution with microscopic resolution are called x-ray microscopes (XRM). The primary requirement for an XRM is a high intensity micron-size beam of SR.

Focusing of energetic photons is difficult because of the short absorption depth and the refraction index being less than unity. The focusing itself is based on refractors that have bent shapes and usually result in more or less monochromatic beams [Zontone, 1991].

Scientists from the Free University of Amsterdam constructed a focusing device at Daresbury (SERC) with bent silicon crys-

tals, which can increase the photon flux more than 104-fold. A double elliptical mirror (Kirkpatrick-Baez) geometry was designed by the Lawrence Berkeley Laboratory that uses parallel beams of photons to produce an image that is demagnified by about a factor of 100 to produce final images of a few micrometers. The mirrors used are multilayers of tungsten carbide that give a quasi-monochromatic beam in the sample plane. Most recent developments are Fresnel zone plates and tapered glass capillaries. The SRI-CAT micro-probe facility is based on Fresnel zone plate optics, and has achieved a photon flux of 10^{10} photons per sec and per mm^2 and a minimum detection limit below 10^{-15}g . This system has been recently used to produce elemental images of fly-ash particles and metal distributions in cells.

Neutron beam analysis

The following properties make thermal neutrons very valuable analytical probes:

- deep penetration in materials, useful for in situ studies in furnaces and pressure vessels, in industrially relevant conditions;
- scattering properties suitable for providing contrast between hydrogen and deuterium, a widely used technique to study biological materials, polymers, colloids etc.;
- wavelengths comparable with spacing between atoms, so that neutron scattering provides unique information on atomic structure.
- the magnetic moment of the neutron makes it a unique probe to study magnetic structures.

The traditional means of producing neutrons is by fission in a nuclear reactor. The neutrons produced from such sources are thermalised in a moderator and their wavelength is selected by Bragg scattering from crystal monochromators. Several neutron scattering instruments are available at HIFAR, the ANSTO reactor. In the last few years, ANSTO has coordinated access for Australian researchers to the neutrons produced by ISIS, the spallation source at the Rutherford Laboratory in United Kingdom. Spallation sources are complementary to reactor sources. ISIS produces neutrons by bombarding a heavy metal target (uranium or tantalum) with a pulsed beam of protons (2.5×10^{13} protons per pulse) accelerated to 800 MeV. Some 25 neutrons are produced for each proton hitting the target. These neutrons are then slowed down in the moderator (water, liquid methane or liquid hydrogen) and used in a variety of techniques such as small-angle scattering, powder diffraction, reflectometry and radiography. The research program spans a variety of scientific applications in biology, condensed matter physics, polymers, surfaces, advanced materials and metallurgy.

Conclusions

Determining structure and composition of materials is a fundamental requirement in research and industry. Ions, photons and neutrons produced by particle accelerators offer an array of

probes and microscopes, which can provide this information effectively.

References

Fifield, L.K., A.P. Clacher, K. Morris, S.J. King, R.G. Cresswell, J.P. Day, F.R. Livens, Accelerator mass spectrometry of the planetary elements, Nucl. Instr. and Methods in Phys. Res. B 123 (1997) 400 - 404.

Sie, S.H., T.R. Niklaus and G.F. Suter, Microbeam AMS: prospects of new geological applications, Nucl. Instr. and Methods in Phys. Res. B123 (1997) 112 - 121.

Tuniz, C., J.R. Bird, D. Fink and G.F. Herzog, Accelerator Mass Spectrometry, CRC Press, LLC, 1998, in press.

Zontone, F., C. Tuniz and F. Zanini, Wavelength spread of doubly bent crystals for X-ray microfocusing applications, Nucl. Instr. and Methods in Phys. Res. B 56/57(1991) 968-970.

AMS ANALYSES AT ANSTO

AMS SUPPORT FOR AUSTRALIAN PREHISTORY RESEARCH

by Ewan M Lawson



Dr. Ewan M Lawson is a Principal Research Scientist in the Physics Division at ANSTO and has been involved with AMS since 1993. He is currently Leader of the AMS Group.

The major use of ANTARES is Accelerator Mass Spectrometry (AMS) with ^{14}C being the most commonly analysed radioisotope - presently about 35 % of the available beam time on ANTARES is used for ^{14}C measurements. The accelerator measurements are supported by, and dependent on, a strong sample preparation section. The ANTARES AMS facility supports a wide range of investigations into fields such as global climate change, ice cores, oceanography, dendrochronology, anthropology, and classical and Australian archaeology. Described here are some examples of the ways in which AMS has been applied to support research into the archaeology, prehistory and culture of this continent's indigenous Aboriginal peoples.

Mud-wasp nests help date rock art

Mud nesting wasps are found in all major biogeographical regions of the world and construct nests that become petrified after the wasps abandon them. The wasps scoop up river muds and use them to make nests on the walls of caves and overhangs. Such nests made by wasps in rock shelters of northern Australia often overlie, and sometimes underlie prehistoric rock paintings. Where paintings are constructed over old nests, maximum ages for the paintings can be determined by dating the nests. The mud nests also contain small amounts of pollen and phytoliths (microscopic fossilised spheres of silica produced by plants and containing occluded carbon). These components may be radiocarbon dated using AMS.

ANSTO has collaborated with other Australian researchers¹ to investigate the age of rock art in the Kimberley region of Western Australia by dating associated mud wasp nests. Two methods of dating were employed; firstly optically stimulated luminescence (OSL) performed at La Trobe University and secondly ^{14}C AMS performed at ANSTO. In the case of OSL

the clock setting exposure to sunlight occurs when the wasp builds the mud nest. However, the technique has certain problems (incomplete zeroing by sunlight for example) with the result that radiocarbon measurements are desirable for supporting evidence whenever possible.

One of the rock paintings examined was in the 'Bradshaw'-style - so named after the explorer Joseph Bradshaw who discovered them late last century. Bradshaw-style paintings are very distinctive; so much so that there is a lively debate amongst archaeologists as to their age and origins. The investigations showed that the Bradshaw-style of rock painting goes back at least 17,000 years.

A 27,000 year holiday from Mt Mulligan

Mt. Mulligan is an imposing, isolated, flat-topped, cliff-lined, sandstone mountain about 100 km west of Cairns. With cliffs between 200 and 400 m high it is about 18 km long and 6.5 km at its widest. When Europeans first arrived they noted that the local Aboriginal people, the Kuku Djungan, did not camp on the summit plateau because this was the home of 'Dreamtime spirits'. While rock art sites exist on the mountain, a paucity of open sites, stone artefacts, ancient fireplaces and ashy deposits in most rockshelters suggest short visits to the mountain-top rather than long periods of occupation. However, commencing in 1991 archaeologist Dr Bruno David² of Monash University, excavated the floor of a cave on the summit plateau, Ngarrabullgan Cave, revealing evidence of human occupation as far back as the late Pleistocene. For several years now the ANTARES AMS Centre has been involved in a detailed study of this occupation site. Samples measured have been individual pieces of charcoal from camp fires. The following diagram shows graphically a set of recently measured samples obtained from an excavation in the cave. The sample depths below

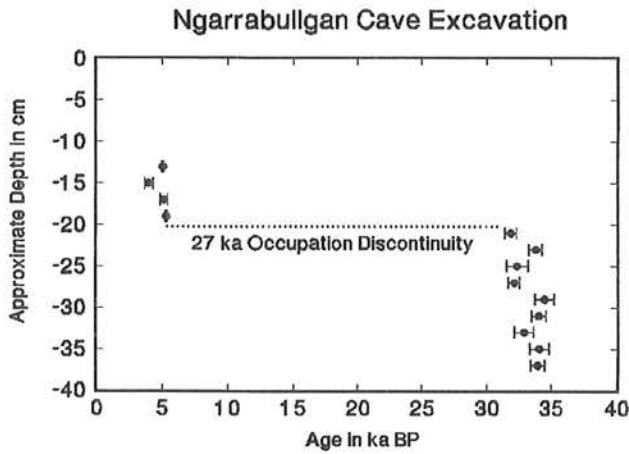


Figure 1 Results from an excavation in Ngarrabullgan Cave on Mt. Mulligan showing the large 27 ka gap in occupancy.

ground surface are approximate since the excavation units were close to, but not exactly constant at 2 cm.

Two very remarkable features are evident in this data: (1) that there are no dates between about 32 ka and 5 ka; and (2) that this enormous gap of 27 ka occurs over a depth of 2 cm (between excavation units 10 and 11). There is no evidence of removal of material from the cave so what is the explanation for this data? Geomorphological investigations by archaeologists are in progress, and indicate an absence of sediment deposition within the cave during times when people were not present. Equally remarkable, although not obvious from the Figure, is a massive increase in the intensity of occupation after about 5 ka, associated with the re-occupation of the cave by people following tens of thousands of years of abandonment.

How old is the Jinmium site ?



Figure 2 A front view of the Jinmium rock-shelter

The question of when humans came to Australia is of great interest in both the local Australian context, and also in the wider world context. Archaeological investigations have continued to push back occupation dates at least to the limit of carbon dating. Using thermoluminescence (TL), dates between 116 ka and 176 ka BP have been suggested³ for the occupation of the rock shelter site at Jinmium (see Figure 2) in the

Northern Territory. Such old dates were unexpected by, and unacceptable to many researchers, the occupation date of Australia having been almost tripled in one go. These results and investigations have become the focus of much academic debate and public attention.

The ANTARES AMS Centre has collaborated with a number of Australian archaeologists to make additional measurements on samples from this site in an attempt to investigate this controversial claim. OSL measurements on both bulk and individual quartz sand grains were made by Roberts at La Trobe University while ¹⁴C analyses were performed by the ANTARES AMS Centre on charcoal fragments. Single grain OSL analyses, although tedious, provide a lot more information than bulk sand analyses. Single grain analyses are not possible with TL. The results of the ¹⁴C measurements are that the Jinmium deposit falls well within the radiocarbon dating range. The same result is obtained by the single grain OSL analyses and does not support the earlier claims based on the TL measurements. The exact dates cannot be disclosed until details are published⁴. The indication is that the TL dates were contaminated with bedrock (old) grains. The work also points out certain problems which are common to the two luminescence dating techniques and which emphasise the importance of ¹⁴C results

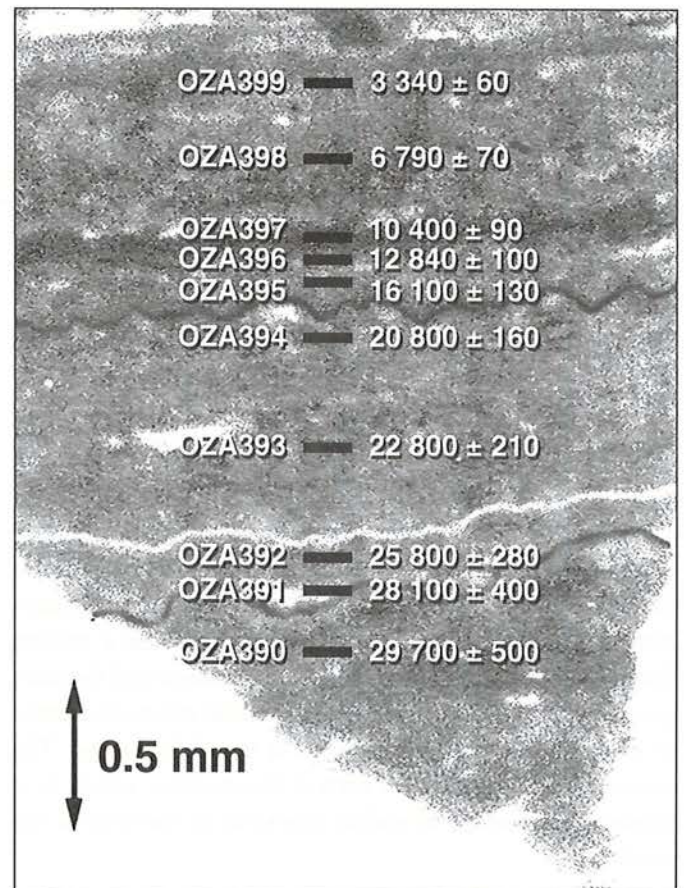


Figure 3 A micrograph showing the approximate laminar positions of the AMS samples and their measured radiocarbon ages. Layers of pigment show up as obvious narrow lines (2 dark, one light)

An examination of rock varnish

The techniques to directly date rock art are extremely difficult and research in this area is very much in its infancy. Coupled with the general acceptance of radiocarbon dating, the sensitivity and small sample capability of ^{14}C AMS make it an obvious technique for consideration. Rock surfaces in some situations accrete over time due to the build up of oxalate crusts and silica skins. Carbon containing minerals such as whewellite may be present and fine grained organic dust may be incorporated into these rock varnishes, thus allowing ^{14}C dating of the micro-stratigraphy formed in the rock surface accretions. Where rock art is incorporated it may be dated with respect to the micro-layers in the accretion. Palaeoclimatic information may also be obtained by studying the micro-stratigraphy.

In a collaboration with a group of archaeologists headed by A/Prof John Campbell at the James Cook University of North Queensland, the ANTARES AMS Centre measured a set of 10 dates from samples extracted from across a 2.1 mm thick section of rock surface accretion. The dates measured across this crust ranged from 3,340 to 29,700 years BP and were stratigraphically consistent (see Figure 3). The gypsum-oxalate accretion layer came from Walkunder Arch Cave at Chillagoe

in north Queensland. Rock art at Chillagoe usually occurs on limestone or gypsum-oxalate crusts on limestone. In this section evidence for rock art (pigment from paintings) was present at various depths (ages) in the cross-section and it was possible to put age constraints on the rock art. For example OZA393 (22.8 ka) and OZA392 (25.8ka) give minimum and maximum ages for the obvious light (yellow in reality) line.

References:

- [1] R Roberts, G Walsh, A Murray, J Olley, R Jones, M Morwood, C Tuniz, E Lawson, M MacPhail, D Bowdery, and I Naumann, *Nature* Vol 387, 12 June 1997, pp 696-699
- [2] B David, R Roberts, C Tuniz, R Jones & J Head. *Antiquity* Vol 71, 1997, pp 183-188.
- [3] R Fullagar, D Price and L Head, *Antiquity* Vol 70, 1996, pp 751-773
- [4] R Roberts, M Bird, J Olley, R Galbraith, E Lawson, G Laslett, H Yoshida, R Jones, R Fullager, G Jacobsen, and Q Hua, accepted by *Nature*
- [1.5] J Campbell, N Cole, E Hatte, C Tuniz and A Watchman, *Tempus* Vol 6, 1996, pp 231-239

NUCLEAR SAFEGUARDS APPLICATIONS

by Mike Hotchkis



Dr Michael Hotchkis, a graduate of Edinburgh University and ANU, is a Senior Research Scientist in the Physics Division at ANSTO. He has 17 years experience in nuclear physics research and its applica-

Following the Gulf War in Iraq, the International Atomic Energy Agency (IAEA) moved to make changes to the international nuclear safeguards regime. A program was initiated, titled 'Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System'. This process has seen the introduction of an 'Additional Safeguards Protocol', to which Australia became the first signatory on 23 September 1997.

Discussions are continuing in the IAEA concerning further safeguards measures, including the practicality and usefulness of environmental sampling. By analysing environmental samples, such as soil, water or vegetation from around a nuclear facility, it may be possible to monitor compliance with the safeguards regime. All nuclear facilities release minute quantities of nuclear materials, through aerial or liquid discharges. The presence and proportion of certain radionuclides would be a signature of the type of nuclear processes in operation at the plant.

ANSTO has participated in an IAEA-sponsored study of the distribution of the fission product ^{129}I from the environs of a reprocessing plant. AMS provides the most sensitive technique for detection of ^{129}I . ANSTO is currently involved in further

assessment of the usefulness of ^{129}I and other isotopes measurable by AMS¹.

The detection of Actinides, particularly the isotopic ratios of uranium and plutonium, provide the clearest signatures for nuclear safeguards purposes. We are currently engaged in a project to evaluate the application of AMS to the measurement of Actinides in environmental samples. Recent work at ANU has demonstrated the high sensitivity of AMS for measuring plutonium².

At the ANTARES accelerator (see Figure 2.1) a new beamline is under construction, incorporating new magnetic and electrostatic analysers, to optimise the efficiency for Actinides detection through selection of high-yield charge states at up to 8MV acceleration voltage. The principle components of the new spectrometer system are:

90° electrostatic analyser (radius 2.5m, gap 25mm, $E/q = 8\text{MeV}$); this component will be moved from its present location where it has been used for ^{129}I detection;

90° magnet (radius 2m, gap 50mm, ME product = 250).

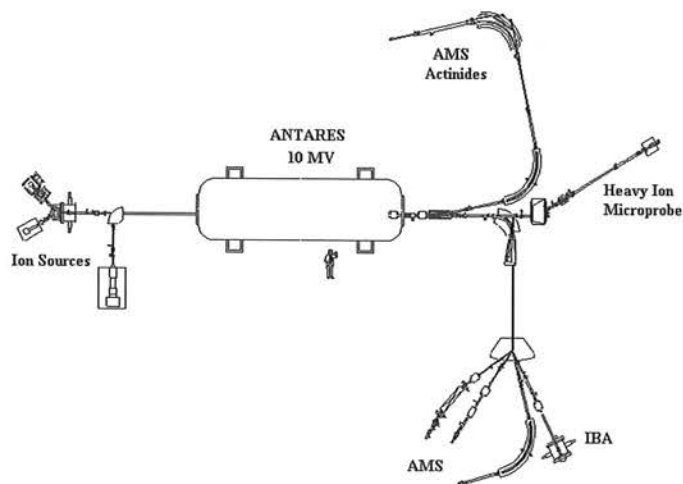
With the new beamline it will be possible to measure a number of isotopes quasi-simultaneously, using the existing isotope cycling system on the injection magnet.

References:

[1] C. Tuniz and M.A.C. Hotchkis, Accelerator Mass Spectrometry to identify signatures of nuclear activities, Proc. International Workshop on the Status of Measurement Techniques for the Identification of Nuclear Signatures, Belgium, 1997 (ESARDA report EUR 17312).

[2] L.K. Fifield R.G. Cresswell, M.L. di Tada, T.R. Ophel, J.P. Day, A.P. Clacher, S.J. King and N.D. Priest, Nucl. Instr. & Meth. B117, (1996) 295

Right: Figure 2.1 Schematic diagram of the AMS facilities on the ANTARES accelerator, including the Actinides beamline which is under construction. Other beamlines and ion sources are not shown.



THE USE OF LONG-LIVED RADIONUCLIDES IN ANTARCTIC ICE AS TRACERS AND CHRONOMETERS IN GLOBAL CLIMATE CHANGE STUDIES.

by Andrew M Smith



Andrew M Smith is currently a Senior Research Scientist in the Physics Division at ANSTO and has been a member of the AMS Group since 1989. He is Project Leader in AMS Studies.

Australian researchers have access to a variety of natural systems where records of the Earth's past climate have been archived. These natural archives of the palaeoclimate include Antarctic ice, ancient Tasmanian pine trees, sediment cores and abundant coral. Each of these media contain a record of past climate and of climate change but the records must be carefully deciphered and compared against one-another in order to extract maximum information. Together, these archives represent a unique resource, being linked geographically in the Southern Hemisphere but often providing complementary information throughout the Holocene.

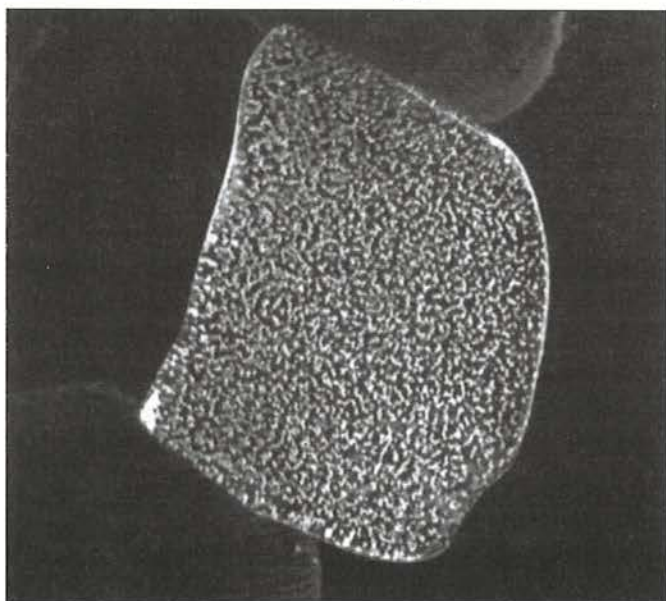
This collaborative project between the Physics Division at ANSTO, the CSIRO Division of Atmospheric Research [DAR], the Australian Antarctic Division [AAD] and the Antarctic Cooperative Research Centre is focused upon the record found in the ice and firn from Law Dome, Antarctica. It brings ANSTO's unique capability to perform precise accelerator mass spectrometry [AMS] on ultra-small samples for a variety of radionuclides together with over twenty year's atmospheric research by the DAR CSIRO and with the expertise and knowledge acquired by the AAD and Antarctic CRC for the Law Dome site. The combined physical and intellectual resources of these organisations result in a potent and effective mix for climate change research which has already been demonstrated in a successful collaborative study entitled 'Determination of the Age and Age Spread of Air in Ice Cores', funded under a National Greenhouse Advisory Committee [NGAC] Grant.^{1,2,3}

The broad objectives of this collaboration are to determine the global atmospheric methane and carbon dioxide budget and to correlate the variability in solar activity and historical climate change in the southern hemisphere. The aim is to define the levels of "natural" variability in global climate change in the Holocene and to identify the mechanisms controlling the variations, with the emphasis on species which force or reflect global environmental change. Clearly answering all of these questions is beyond the scope of a short project, however we hope to develop the techniques and abilities which will allow us to investigate these matters in future studies. The combined effort by the collaborating organisations will result in a precise, high-time resolution, multi species record from Antarctic ice cores which will complement other southern hemisphere palaeo records throughout the Holocene and into the last Glacial.

ANSTO's role is the examination of cosmogenic and bio-geochemical forcing of the atmospheric radionuclides ^{14}C and ^{10}Be in Antarctic ice. Specifically, we are using the ANTARES AMS facility for the measurement of ^{14}C in carbon dioxide and methane contained in air extracted from the porous firn layer overlying the ice and from bubbles trapped within the ice. We are also using AMS to measure ^{10}Be from the firn and ice. An indication of the use of these measurements in climate research is given in the sections below which describe the three main strands of the project.

Determination of the age and age spread of CO₂ from the radiocarbon 'bomb spike'

This study is similar to the NGAC study mentioned above however it involves the Dome Summit South [DSS] core which was drilled by the AAD, 4 km SSW of Law Dome Summit at an elevation of 1370m, finally reaching bedrock at a depth of 1200m in 1993. Ice from this depth is of the order of 50 to 100ka old but in this study we have extracted air from bubbles in the ice close to the surface which dates from earlier this century. The atmospheric nuclear weapons testing in the 1950's artificially raised the levels of many radionuclides, including ¹⁴C, and the so-called 'bomb-spike' has proven to be a useful tool for tracing and timing purposes. Measurement of the ¹⁴CO₂ profile through the ice sheet and comparison with the profile predicted by the numerical model of the diffusion and trapping process from the known atmospheric pulse permits calibration of model parameters, the main aim of this study. The more precisely these parameters are known the better the predictions from the numerical model, so enabling a fuller understanding of the record back through the Holocene. This work is technically challenging, with sample sizes of the carbon derived from CO₂ as small as 12μg.



Bubbles of palaeo-atmosphere trapped in Antarctic ice. [photograph courtesy of David Etheridge].

This study is progressing well and has demonstrated the ability of ANTARES AMS to make precise measurements (of the order of 1%) of the radiocarbon content of samples containing only tens of micrograms of carbon.

Atmospheric methane budget

The aim of this study is to determine the fossil contribution to pre-bomb global methane budget from Law Dome firn air ¹⁴CH₄. Large volume air samples were extracted from the porous firn region overlying the ice during Voyage 4 of the



Large volume gas sampling at Law Dome, January 1998.

Aurora Australis, December '97 to January '98. Preliminary results show that the sampling strategy was successful, and large volumes of air from earlier this century have been returned to Australia for further analysis, which will also include ¹⁴CO₂ 'bomb pulse' measurements to provide the numerical model parameters, as described above. Methane, present at 1 to 2 ppmv, will be extracted from the bulk of these samples and converted into graphite, the form of carbon required for AMS measurement of the radiocarbon content. We expect to obtain graphite samples of the order of 100μg from each 200l of air. Measurement of the ¹⁴C content, prior to the isotopic disturbance caused by the widespread use of nuclear technologies, will allow estimation of the anthropogenic contribution to the global atmospheric methane caused by the combustion of fossil fuels (depleted in ¹⁴C).

¹⁰Be calibration/comparison study

¹⁰Be, like ¹⁴C, is produced by spallation reactions from cosmic rays in the Earth's atmosphere, with most production taking place in the stratosphere. Production rates are affected by intensity and spectral variations of the incoming cosmic rays, by long time-scale variations in the terrestrial magnetic field and by shorter periodic interactions with the solar wind. Once formed, both radionuclides are rapidly oxidised and their different chemistry dictates the pathways and processes by which they are incorporated into the Earth's storage media. ¹⁴CO₂ is quickly mixed in the atmosphere and incorporated into the biosphere by photosynthesis. ¹⁰BeO becomes attached to aerosols which are washed out of the atmosphere by precipitation, to be finally incorporated in sediments and ice sheets. Complex transport processes are involved, including seasonal changes in the tropopause, especially in polar regions, which affect the signal strength.

The ^{10}Be signal in ice may often be regarded as a proxy for radionuclide production and can be used, for example, to separate climatic information from production rate variations in the carbon record. We intend to make use of this to study climate change throughout the Holocene and back into the glacial/interglacial period. Glaciologists can use the measured ^{10}Be concentration as a proxy for snow accumulation rates where the assumptions of constant production and transport are made. Although the ^{10}Be signal has often been used for these purposes, there are large assumptions involved and this study is attempting to determine the conditions under which these may be justifiably made.

This study aims to establish the empirical relationship between ^{10}Be and snow accumulation rate for the Law Dome site. Law Dome is ideally situated for such a study as large variations in accumulation rate occur as the snow is progressively deposited by the prevailing winds. Furthermore, by comparison with neutron monitor data, we intend to quantify the degree to which

^{10}Be can be used to establish radionuclide production rates. We see this work as providing a firm foundation for the interpretation of the ^{10}Be record throughout the Holocene for Law Dome.

References:

- [1] Levchenko V.A., R.J. Francey, D.M. Etheridge, C. Tuniz, J. Head, V.I. Morgan, E. Lawson, & G. Jacobsen, *Geophysical Research Letters*, 23, No. 23, (1996) pp. 3345-3348.
- [2] Trudinger, C.M., I.G. Enting, D.M. Etheridge, R.J. Francey, V.A. Levchenko, L.P. Steele, D. Raynaud and L. Arnaud., *Journal of Geophysical Research*, 102, No. D6, (1997) pp. 6747-6763.
- [3] Levchenko, V.A., D.M. Etheridge, R.J. Francey, C. Trudinger, C. Tuniz, E.M. Lawson, A.M. Smith, G.E. Jacobsen, Q. Hua, M.A.C. Hotchkis, D. Fink, V. Morgan, J. Head, *Nuclear Instruments and Methods in Physics Research*, B123, (1997) pp.290-295.

STUDIES IN EARTH SCIENCES USING IN-SITU PRODUCED COSMOGENIC RADIOISOTOPES

by David Fink



Dr David Fink commenced work in the Physics Division at ANSTO in 1990 bringing 8 years of AMS experience. He is now a Principal Research Scientist and project leader in AMS studies.

The geological processes of glaciation and surface weathering which have moulded and continue to shape our landscape, are inextricably related to the dynamics of climate change. Earth Scientists have long sought an analytical technique based on radiometric methods that would quantify both temporally and spatially, the chronology of glacial cycles and erosion rates. Such a technique is now developing based on the in-situ production by cosmic rays [1] of the long-lived cosmogenic radionuclides ^{10}Be ($T_{1/2}=1.5 \text{ Ma}$), ^{26}Al (0.7 Ma) and ^{36}Cl (0.3Ma) in exposed rocks, surfaces and within the first meter or so of the Earth's crust

Although only a million atoms of ^{10}Be are produced during a 100 ka exposure period per gram of rock, AMS can be applied



Erratic boulder on the Tasmanian Central Plateau sampled for ^{36}Cl exposure age

to measure this telltale signal. Their build-up over time can be utilised as radiometric clocks to elucidate the exposure history of geomorphic formations and surfaces [2,3]. Alternatively, if exposure has been sufficiently long for the in-situ signal to reach equilibrium, an average erosion rate can be determined [4]. The applicability of the technique depends on the radioisotope half-life - in simple terms it works best over exposure periods of 5ka to 5 Ma (for ^{10}Be) and can identify erosion rates from 0.1 to 10 mm/ka.

Glacial Chronology

The objective is a comprehensive and unified investigation of Quaternary glacial chronology in the Southern Hemisphere. Three geographic regions are targeted - Antarctica Tasmania and New Zealand. Glacially polished bedrock surfaces, large erratics and boulders in lateral and terminal moraines and in glacial valleys have been sampled. Glacial geomorphology evidenced in these regions are the result of different aspects of climate change - both regional and global.

The controversial discovery of beechwood and marine fossil remnants in the TransAntarctic Mts suggests an intense deglaciation about 3 Ma ago and thus a dynamic behaviour of the East Antarctic Ice Sheet. Exposure ages from the Prince Charles Mts at Lambert Glacier, whose advances and retreats reflect changes in Ice Sheet size, will add to an understanding of the Pliocene history of the Ice Sheet. Glacial history of the Tasmanian ice cap and its piedmont glacier systems tends to



View of the East Antarctic Ice sheet at the Sth Prince Charles Mts.

archive regional climatic effects. The in-situ method is being applied to date moraines deposited by retreat of the Plateau Ice cap and the extent of glacial advance over the West Coast Ranges during the Pleistocene. Preliminary ^{36}Cl exposure ages from two moraines of major ice retreat on the Plateau indicate the oldest occurred 80 ka ago and that the Last Glacial Maximum was at about 16ka; both ages being younger than previously estimated. The Younger Dryas is a major short-term climatic reversal superimposed on the last deglaciation between 11-13 ka ago and appears throughout climatic records in the Northern Hemisphere. Evidence for such a reversal in the Southern Hemisphere is equivocal. Two sites, one in Tasmania (already sampled) and the other in New Zealand have been identified as excellent candidates to prospect for the Younger Dryas by applying in-situ exposure dating of their terminal moraines. At Lake Te Anau, New Zealand, an impressive staircase-like sequence of lateral moraines is terraced along the glacial valley slopes above the lake level to an altitude of 1300m. The sequence preserves a continuous glacial history of the region estimated to cover the last 1 Ma. Of the 9 terraces sampled for our in-situ exposure age studies, the lower 4 span the last 250 ka based on U/Th dating of associated cave deposits.

Landscape Geomorphology

The antiquity of the Australian landscape generally precludes the application of exposure dating. The preservation of remnants of the Australian craton, and in particular of the Ashburton surface in central Australia, is believed to be the result of its geomorphic and tectonic stability over the past 700 Ma or more. This implies exceptionally low rates of weathering that stands in conflict with recent studies that suggest denudation of several kilometres of relief. Our studies focus on using two independent but complimentary methods - apatite fission track and in-situ cosmogenic isotopes - to measure, respectively, long term (1-100 Ma) and short term (<1 Ma) continental weathering rates of these features and similar ones found in Africa.

Desert dunefields occupy nearly 40% of land area of Australia. The origins of dune material, their mobility and turnover periods are not well identified. In a novel approach to using in-situ produced ^{10}Be coupled with thermoluminescence, we are investigating the formation, movement and relative histories of dunes in the Simpson desert and at Cape Flattery, Queensland. The in-situ method can also record periods of burial during exposure. This aspect is being used in a study to distinguish between local laterization or accumulation of transported material as the formation process of coastal regolith escarpments of the Victorian Plateau, Western Australia.

All studies detailed above are based on the AMS capability at ANSTO and collaborative links with Australian Antarctic Division and Earth Sciences at Australian and New Zealand universities

References:

- [1] D Lal, Earth Plan. Sci. Lett. 104, (1991) 424.
- [2] K Nishiizumi, CP Kohl, EM Shoemaker, JR Arnold, J Klein, D Fink, R Middleton, D Lal, Earth Surface Processes and Landforms 18 A, (1993) 407.
- [3] K Nishiizumi, CP Kohl, JR Arnold, J Klein, D Fink, and R Middleton, Earth Planet Sci. Lett. 104 B (1991) 440
- [4] PR Bierman, J. Geophys. Res 99(B13) (1994) 885.

BIOMEDICAL TRACER STUDIES WITH AMS

by David Fink

The recent introduction of AMS techniques to biomedical tracer studies is rapidly expanding as it offers fundamental advantages over conventional tracer methods based on decay counting. The restriction to short-lived tracers administered at a high radiation dose to allow increased sensitivity does not apply in the case of AMS. Doses at the nanogram level provide both an insignificant radiation danger and a sufficiently high signal to permit AMS studies over many years without disturbing the biological system. Sampling at the milligram level allows focus on specific tissues, and even compounds. Applications using ^{14}C , ^{26}Al and ^{41}Ca include selective molecular labelling of DNA, toxicology, pharmacokinetics,

osteoporosis and drug testing.

The classification of aluminium as a toxic metal in the aetiology of dialysis encephalopathy and anaemia, and its controversial association in the pathology of Alzheimer's disease has highlighted a surprising lack of knowledge with regards to its biochemical behaviour. Being mono-isotopic and offering no suitable short-lived isotopes, conventional tracer studies of aluminium metabolism was ineffectual at quantifying the degree of absorption, retention and its biological pathways under normal physiological conditions.

To investigate the uptake and accumulation of aluminium in the

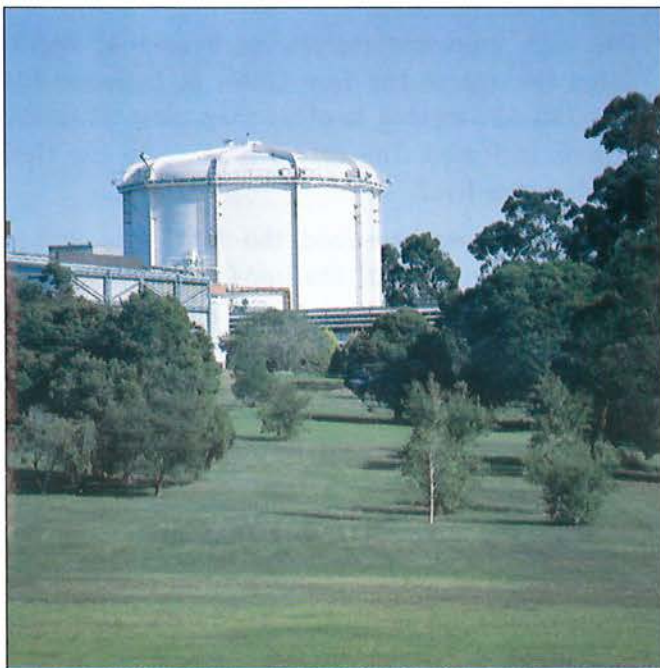
Snapshots from



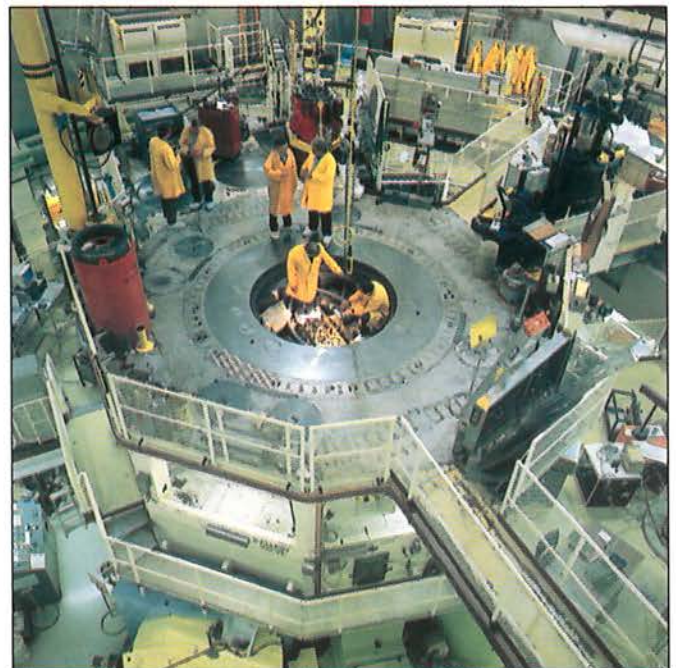
The Australian Nuclear Science and Technology Organisation (ANSTO) is located at Lucas Heights, south of Sydney.

In addition to ANSTO, more than a dozen other organisations, most with science and technology interests, operate at the Centre.

Right: An aerial view of the Lucas Heights Science and Technology Centre.



One of the major landmarks of southern Sydney is the white containment building for the HIFAR research reactor. The actual size of the reactor core where nuclear fission takes place is 600 mm by 800 mm. Its total fuel load is some 7 kg.



ANSTO staff carrying out routine maintenance work on the HIFAR reactor. HIFAR operates on a 28-day cycle, 24 days for operations, and the remainder for maintenance and for replacement of fuel. The reactor uses about 38 fuel elements a year.

ACCELERATOR MASS SPECTROMETRY

The tandem Van de Graaf accelerator ANTARES can be used to carry out dating studies using Accelerator Mass Spectrometry (AMS), thus supporting research into archaeology and prehistory of the continent.

Right: The egg of an Elephant bird found in the sand dunes of Western Australia in 1993 and dated by AMS at ANSTO to be 2000 years old. Photo by T. Tapsell, ANSTO. Left: C. Tuniz. Right: John Bell, auctioneer.



DATING THE CROWN OF CHARLEMAGNE

C. Tuniz

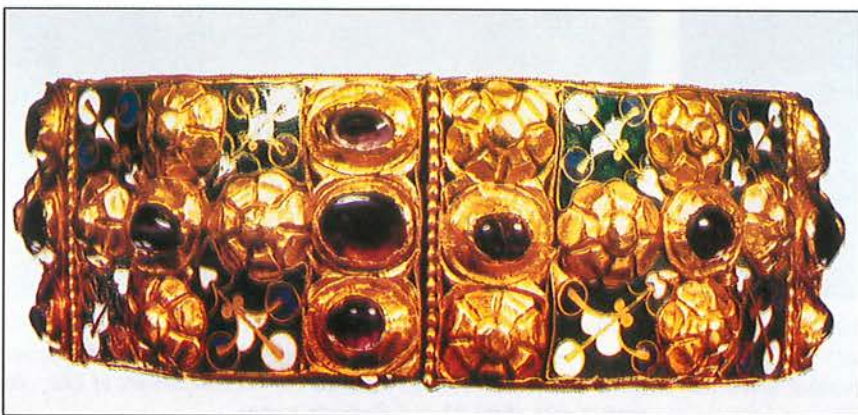
The Iron Crown of the first Holy Roman Emperor, Charlemagne, is held in the Cathedral at Monza, near Milan, in Italy. In 1996, Italian scholars asked ANSTO for assistance in accurately establishing the age of the crown in readiness for forthcoming celebrations of the cathedral's 14th centennial.

Historical records had placed the age of the crown between the late Roman and Middle Ages, a spread of some hundreds of years. Carbon dating is the most accurate means of dating ancient artifacts, but the materials used in the crown – gold, a strip of iron, a nail reputedly from the True Cross, and precious stones – are non-biological and therefore cannot be dated using this technique.

During the study of the crown, however, it was discovered that its precious stones were held in place by a mixture of beeswax and clay. This provided the necessary organic material for AMS analysis.

The high precision analysis performed at ANSTO dated the age of the Iron Crown at between 700 and 780 AD, making it older than most historical records indicated. The dating is close to the time Charlemagne lived.

Charlemagne was crowned the first Holy Roman Emperor, reputedly with the Iron Crown, by Pope Leo III in Rome on Christmas Night, 800 AD. He lived from 782 – 814 AD and, as the King of the Franks, established and ruled over a kingdom that spanned virtually all the Christian States of Western Europe, including what is now France, Switzerland, Belgium, The Netherlands, half of Italy and Germany, part of Austria and a small part of Spain.



Left: The Iron Crown of Charlemagne, first Holy Roman Emperor.

ION BEAM ANALYSIS

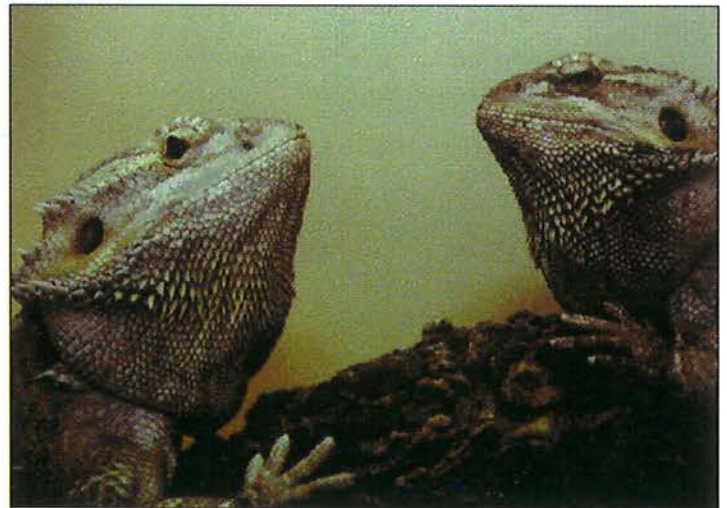


The techniques of Ion Beam Analysis (IBA) are used to analyze the composition of sample materials. For instance, they can be used to find out what is contained in Sydney's smog.

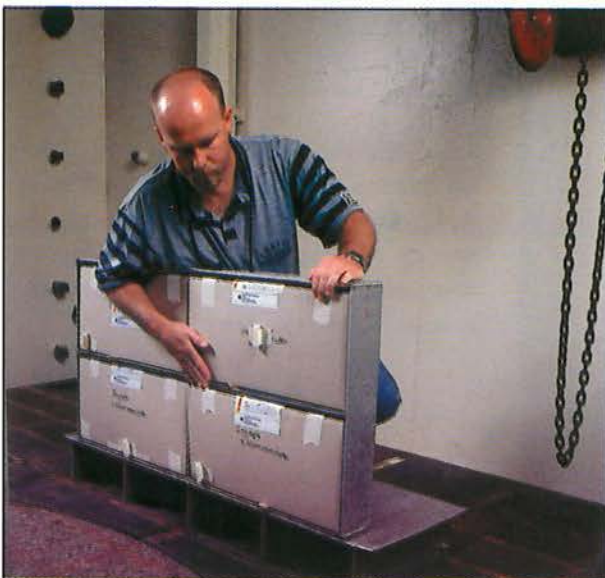
Left: Analysis of particulates in the atmosphere is of especial interest to ANSTO scientists. ANSTO has designed and manufactured atmospheric monitoring stations that are now used extensively in eastern Australia and a series of stations involved in international radon monitoring work.

They can also be used to measure the content of an isotropic tracer ^{18}O introduced into the blood of a desert dragon, and hence estimate its metabolic rate.

*Left: The Desert Dragon (*Ctenophorus nuchalis*) living in the Pilbara region of Western Australia.*



IRRADIATION TECHNOLOGY



ANSTO irradiates up to 25 million Queensland fruit fly pupae each week for agriculture departments in New South Wales, Victoria and South Australia. The irradiated, and sterile, pupae are hatched in major fruit growing areas and released to mix with wild fruit flies as a population control measure.

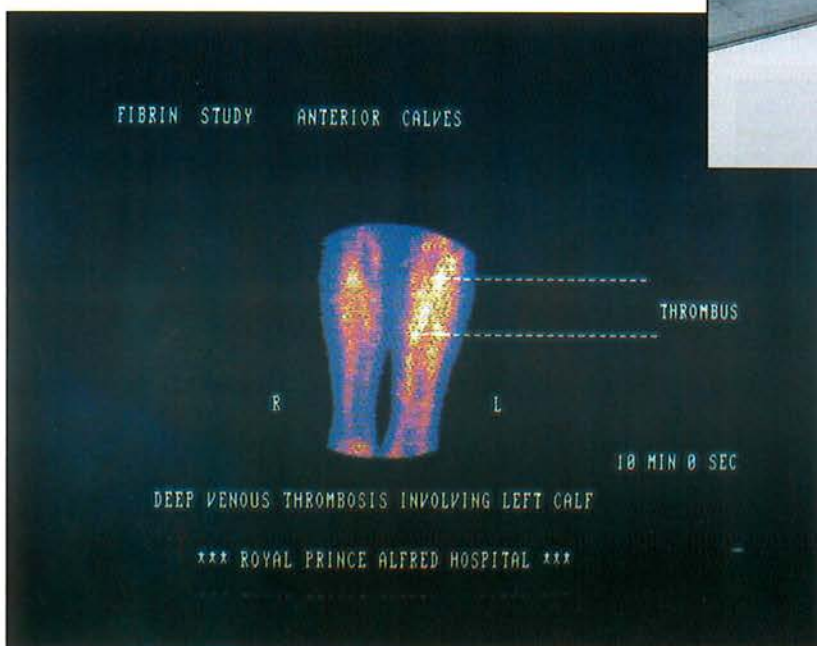
NUCLEAR MEDICINE



ANSTO is Australia's main supplier of radioisotopes for medical applications. In addition to its research reactor, ANSTO also operates the National Medical Cyclotron (left). Together these facilities produce a wide range of medical radioisotopes. The Cyclotron produces mainly short half-life isotopes and is sited on the Royal Prince Alfred Hospital Campus in Sydney to allow fast supply of PET isotopes to its nuclear medicine facilities.



Below: Output from a nuclear medicine procedure, which shows a thrombosis.



Above: More than 160 nuclear medicine facilities are operating throughout Australia. ANSTO will supply more than 450,000 doses this year. This rate of use means that, on average, all Australians can expect to have a nuclear medicine procedure in their lifetime.

body through the ingestion of drinking water, an AMS tracer study using ^{26}Al was conducted at ANSTO¹ in collaboration with the Australian Institute for Biomedical Research (AIBR) and the Sydney Waterboard. Eight Wistar rats, specially bred at AIBR, received an oral gavage of 100 nanograms of ^{26}Al (or 70 Bq) in 4 cc of purified water while two others acted as controls receiving water only. Two weeks following dosing, samples of brain and liver tissue were taken and analysed at ANTARES for their ^{26}Al concentration. Our results² quantified, for the first time, the fraction of aluminium transferred to the brain following ingestion of pure water. Two of the rats showed no evidence of ^{26}Al above that of the controls, the remaining 6 gave brain uptake fractions from 300 to 30 ppb of input dose. The liver samples consistently showed a factor of 7 higher absorption per gram tissue than that of the brain despite the 10-fold variation in absolute aluminium uptake into the blood stream. This indicates that nearly all the variation seen can be explained by differences in Al bioavailability of each rat.

References:

- [1] D Fink, J Walton, MAC Hotchkis, GE Jacobsen, EM Lawson, AM Smith, C Tuniz, and D Wilcox, Nucl. Instrum. & Methods in Phys. Res. B92, (1994) 473.
- [2] J Walton, C Tuniz, D Fink, G Jacobsen. and D Wilcox, Neurotoxicology 16(1) (1995) 187.

Acknowledgements:

The work described here has depended on the efforts of many people, both at ANSTO and at other institutions. The authors wish to acknowledge here the efforts of the other members of the ANTARES AMS Centre - G Jacobsen, Q Hua, Greg Elliott, and U Zoppi. The efforts of the Centre's technical officers are gratefully acknowledged as is the support provided by ANTARES Operations Area under J Fallon.

ION BEAM ANALYSIS TECHNIQUES

NICK DYTLEWSKI, RAINER SIEGELE AND DAVID D. COHEN

The international community introduced Ion Beam Analysis (IBA) in the 1950s, principally as an analytical technique for the characterisation of solid materials. Spectacular growth occurred in the subsequent three decades which was made possible by the increasing availability of Van de Graaff type accelerators, and the development of semiconductor detector technologies. The demonstrated capabilities of speed, versatility, sensitivity and the non-destructive nature of IBA resulted in ion beams being applied to solve problems in many diverse fields such as materials science, biology, geology, medicine and the environment. While much of the low energy and light ion beam techniques are now mature, development of novel instrumentation and techniques using high energy and heavy ion beams is currently a developing field.

In 1964, a 3 MV Van de Graaff Accelerator (fig. 1) began operations at ANSTO principally for high energy neutron production. However by 1980, IBA techniques were well established. Since then, many thousands of samples per year have been analysed using these methods. This accelerator is still operating over 2,000 hours per year, producing valuable results for the Australian research community and industry.

During the 1990's, the IBA capabilities of the Physics Division at ANSTO were expanded with the addition of a 10 MV Tandem Accelerator (fig. 2). This accelerator allows the use of techniques such as heavy ion backscattering and heavy ion time-of-flight recoil spectrometry. Some of the high energy



Dr. Nick Dytlewski is a Senior Research Scientist in the Physics Division of ANSTO. He has extensive experience in the use of ion beams, and is the project leader of high energy heavy ion beam techniques for materials analysis.



Dr. Rainer Siegele, a graduate from the Heidelberg University and the Technical University of Munich, is a Research Scientist in the Physics Division of ANSTO. At the moment he is developing the heavy ion microprobe at ANSTO.



Dr. David D. Cohen, is a Senior Principal Research Scientist in the Physics Division at ANSTO. He has over 20 years research experience in accelerator based techniques and currently heads the Accelerator Applications Area within Physics.



Fig. 1. 3 MV Van de Graaff accelerator. The accelerating tube and high voltage components are housed within the tank, which is pressurised with a mixture of CO_2 and N_2 for electrical insulation.

and heavy ion beam techniques result in better elemental depth profiling and mass resolution for solving problems in today's emerging technologies. In addition, the higher energies allow the detection and quantification of a wider range of light elements such as carbon, nitrogen and oxygen, which are not readily accessible with the smaller 3 MV accelerator.

The Accelerator Applications group at ANSTO operates, maintains and runs analytical facilities utilising both of these accelerators; the 3 MV Van de Graaff and the 10 MV Tandem Accelerator (ANTARES). A variety of sample measurement end-stations, equipped with X-ray, Gamma ray and charged particle detectors are available. The 3 MV accelerator is mainly used for Particle Induced X-ray Emission (PIXE), Rutherford Backscattering Spectroscopy (RBS) and some Nuclear Reaction Analysis (NRA), while the higher energies and the heavier ions from the Tandem accelerator are used for sample characterisations utilising techniques such as recoil time-of-flight spectrometry (RTof), NRA and heavy ion RBS. This article describes some of the techniques used at ANSTO, and some typical applications to which they have been applied.

ION BEAM TECHNIQUES

When an energetic ion beam interacts with an atom, a variety of events can occur giving rise to the different ion beam analytical techniques. The incident ion beam can:

- induce characteristic X-rays via interactions with the atomic electrons (Particle Induced X-ray Emission -PIXE)
- scatter at back angles off target atoms (conventional Rutherford Backscattering using helium beams RBS and heavy ion Rutherford Backscattering HIRBS)
- cause nuclear reactions producing secondary particles (Nuclear Reaction Analysis -NRA) and gamma rays (Particle Induced Gamma Ray Emission PIGME).



Fig. 2. Tandem Accelerator viewed from the high energy (exit end). Negative ions are injected into the accelerator where they are first accelerated to the centre of the tank, then stripped of electrons to form multiply charged positive ions, then accelerated further to higher energies. The tank is pressurised with SF_6 .

- knock and recoil target atoms in the forward direction (conventional Elastic Recoil Detection Analysis using helium beams-ERDA and Heavy Ion Recoil Time of Flight Spectrometry RTof)

From the measured reaction products and their intensities, quantitative data on the sample's constituent elements and their spatial distributions can be readily obtained. Depending on the technique used and the sample under investigation, probing depths are in the range 5 nm to 100 μm , and elemental sensitivities are typically of the order 1 $\mu\text{g/g}$ by weight.

PIXE

Particle Induced X-Ray Emission (PIXE) is a powerful technique for the quantification of trace elements ranging from Al to U. This is usually done with MeV protons produced by the 3 MV accelerator. Sensitivities range from 1–100 $\mu\text{g/g}$ depending on the element. The characteristic X-rays produced by ion bombardment of the material generate a unique fingerprint of its elemental composition. The energy of the X-rays identifies the elements present, and the X-ray intensity is a measure of its concentration.

The PIXE technique has been applied to solve problems in geology, archaeology, biology, environmental and materials science. The PIXE setup is shown in Fig. 3. A significant project in the last few years has been the analysis of atmospheric aerosol with particle diameters below 2.5 μm (PM2.5).

As an example of the effects of aerosols, fig. 4 shows Sydney on a day when a high level of airborne particles causes a significant decrease in visibility, and by comparison, the same view on a clear day when the visibility exceeds 30 km.

Atmospheric fine particles are typically produced by anthropogenic sources such as combustion processes, motor vehicles, industrial plants, mining operations and by natural sources



Fig 3: Beamline end-station equipped with detectors for simultaneous PIXE, PIGE, RBS and ERDA measurements.

such as windblown soil and sea spray. The effect of these fine particles in the atmosphere on the health of the population and the environment is of increasing concern to governments and industry. Fine particles may remain in the atmosphere for weeks, and can travel hundreds or even thousands of kilometres from their original source. It is therefore important to understand the regional and even global movement of these atmospheric aerosols.

In order to assess potential effects on the population and the environment, and to assist with remedial and management pollution programs, it is necessary to fully understand the composition and the relative source contributions to the atmospheric fine particles.

The PIXE technique in aerosol analysis is typically used to analyse for the commonly occurring elements Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Br and Pb. A typical PIXE analysis can be obtained in less than 5 minutes of accelerator running time. Each element present in the aerosol can be linked to a particular source. For example, Al and Si are associated with windblown soil, S with fossil fuel burning, industry and motor vehicles, Cl with sea spray, K with smoke and wood burning, Cr, Mn, Fe, Cu and Zn with industrial processes, and Pb and Br from motor vehicles. Hence PIXE analysis can be a powerful method for source reconciliation. The accelerator based IBA techniques at ANSTO are ideally suited to solving these problems.

RBS

Rutherford Backscattering Spectrometry (RBS) is a simple, but effective technique to measure the composition profile of materials near the surface. It involves measuring the number and the energy of ions, which backscatter after colliding with atoms in the near-surface region. For a given deflection angle, the energy of the scattered ions depends on the mass of the target atom involved in the scattering process, while the number of scattered ions depends on the concentration and atomic number of the particular element. With this information, it is possible to determine elemental concentrations versus depth.

Conventional RBS is performed using helium ions, while heavy ion RBS utilises heavier ions, which have the advantage of a better mass resolution for heavy elements. With its two



Fig. 4a & b July 1997, 25 km view of Sydney skyline.

accelerators, ANSTO has both conventional and heavy ion RBS capabilities.

RBS has been applied to study the degradation of surfaces due to corrosion or sunlight such as the weathering of protective polymer films (bronze paint) on metal surfaces (colour bond steel). Fig. 5a shows a conventional RBS spectrum of a polymer coated steel sample, measured using 2 MeV helium, with the number of backscattered helium ions recorded as a function of their energy. The experimental spectrum is shown as a dotted line, while the solid line represents the fit used to derive the elemental profiles. The spectrum shows a typical staircase structure where each step is associated with an element present in the sample. The horizontal part indicates a constant concentration for each element throughout the surface.

Fig. 5b also shows a spectrum of the same sample after 1,000 hours exposure to ultraviolet light. A dramatic change in the sample composition can be seen. For example, the individual profiles now show an increase of iron (Fe) and titanium (Ti) at the surface. This indicates that the light has broken down the structure of the polymer film, which subsequently allowed the different components of the polymer to diffuse. Measurements like these help to understand the processes involved in the degradation of polymer films and thus help to make more weather resistant polymer coatings.

NRA

Nuclear Reaction Analysis (NRA) has mostly been applied to problems in materials science, where the use of isotopically enriched compounds allows the profiling of specific elements

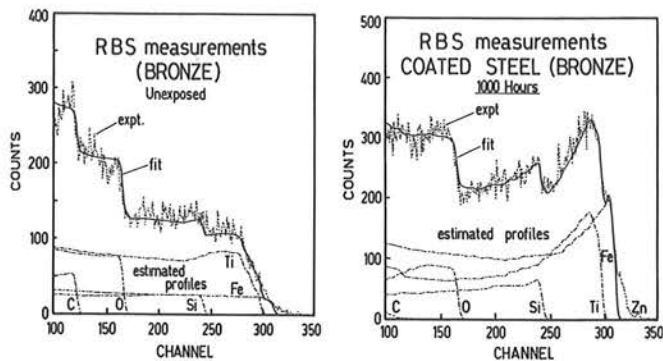


Fig. 5. RBS spectrum of (a) a polymer coated metal surface and (b) the same sample after 1,000 hours exposure to ultraviolet light.

by reactions with its isotopes. For example, in the thermal oxidation of silicon, the growth kinetics and diffusion of oxygen across the Si/SiO₂ interface region has been studied using sequential oxidations in natural and ¹⁸O enriched oxygen gas. This isotopic specificity of NRA allows the differentiation between possible reaction pathways. The same technique as used in materials science has also been applied to help study the nutritional requirements of endangered native fauna.

Many Australian animals inhabiting the arid zone are faced with long periods of poor or inadequate nutrition during periods of low or no rainfall, and must depend for their survival on the efficient utilisation of their stored body reserves. An understanding of their caloric usage is essential for determining their energy and protein requirements. These may then be correlated with the measured availability of natural resources, and help provide guidelines for wildlife managers in developing effective conservation strategies.

Biological tracers using enriched stable isotopes are being used to monitor changes in free-ranging animals in the field. Native animals are dosed with a small quantity of water enriched with the stable isotope ¹⁸O, and a blood sample is taken some hours later when isotopic equilibrium is reached. The animals are then left to roam freely for a few days in their natural environment, before a second blood sample is taken. The ¹⁸O content of the two blood samples is then measured using isotopic

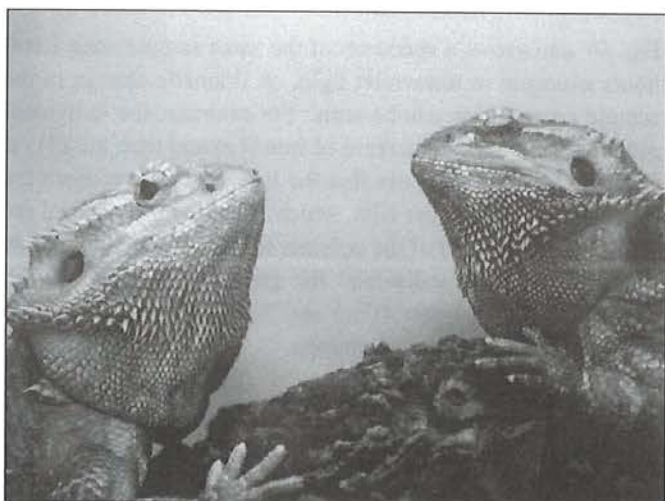


Fig. 6. The desert Dragon (*Ctenophorus nuchalis*) living in the Pilbara region of Western Australia.

analysis on ANSTO's 3 MV Accelerator.

By measuring the loss of the stable isotopic tracer ¹⁸O from the animal as a result of isotopic exchange with the environment, the rate of production of carbon dioxide can be estimated, and thus the metabolic rate of the free-ranging animal can be calculated. This information enables the quantification of the animal's energetic requirements.

A diverse range of small Australian animals such as the desert Dragon (*Ctenophorus nuchalis*) (shown in fig. 6) living in the Pilbara region of Western Australia, and the unique nectar and pollen-feeding Honey Possum (*Tarsipes rostratus*) in the south-west of Western Australia have been studied.

Recoil ToF Spectrometry

Recoil time-of-flight (ToF) spectrometry is a technique used to identify the mass and energies of forward recoiled atoms when an incident heavy ion beam knocks and recoils target atoms out of the sample. In this technique, the heavy incident ion beam is directed at a grazing angle onto the sample's surface. In the ensuing binary collisions with the sample's constituents, lighter recoiling atoms are ejected and are detected at a forward angle. Atoms with a mass lighter than that of the incident ion beam will pass through and be detected. The ready availability of low energy helium beams from small accelerators quickly made this a popular technique for the determination of hydrogen in solids, and studies of polymer interdiffusion.

However, use of a heavy incident ion beam allows a multitude of different elements to be recoiled forward and detected. Unfortunately, the different elemental spectra superimpose on each other, and conventional detection techniques cannot sort these separate masses to provide unambiguous data on the different elemental depth profiles. This can be overcome using the recoil ToF spectrometry system on the ANTARES tandem accelerator, where the time taken for each recoiled ion to travel a fixed distance is recorded.

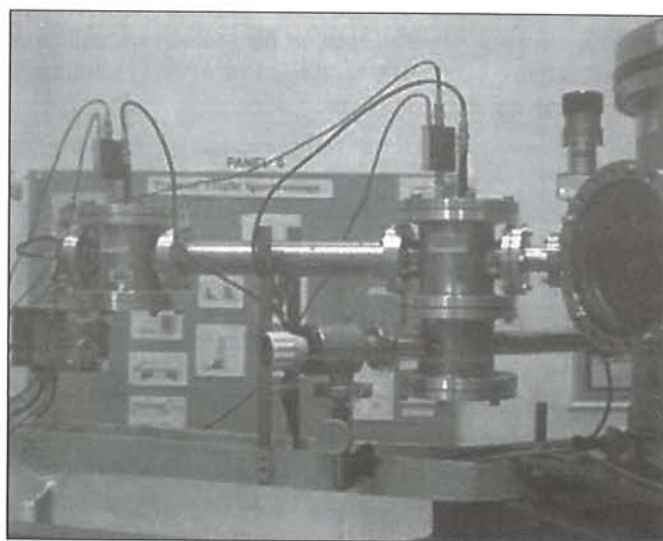


Fig. 7. Recoil ToF spectrometer showing the two timing detectors separated by a flight tube. Recoiled target atoms enter the tube from the sample chamber on the right, travel down the tube and finally into a silicon detector at its end

A high energy, heavy ion beam, typically 60-90 MeV iodine, is used to recoil elements out of the material surface, and into the spectrometer as shown in fig. 7.

The forward recoiled target atoms travel down the spectrometer tube and through two thin carbon foils, which are separated by about 50 cm. As these atoms pass through each of the carbon foils, a burst of secondary electrons is produced, which is then collected and amplified to produce a fast timing signal. The time separation between these two timing signals is a measure of the atom's speed. The recoiled target atoms then come to rest in a silicon detector, which measures their energy. From these two measured quantities of speed and energy, the recoiled atom's mass is uniquely identified. From the determined masses, and their measured energies and yields, elemental concentrations and profiles can be constructed for the sample.

Recoil ToF spectrometry is a powerful technique for profiling multilayered, multi-elemental samples and thin films. As an example, measurements have been made of the ferroelectric barium strontium titanate $Ba_{0.7}Sr_{0.3}TiO_3$ (BST). This ferroelectric material has a very high dielectric constant, and is being developed for use in dynamic random-access memory chips as the storage capacitor dielectric. Recoil ToF spectrometry measurements have been used to map the change in the elemental profiles of a proposed BST device when subject to a heating step in the manufacturing process.

A multilayered sandwich comprising BST (145 nm) / Pt (200 nm) / Ti (30 nm) / Si wafer was subjected to rapid thermal annealing, producing the spectrum shown in fig. 8. The x-axis is the pulse height channel of the signal from the energy detector, while the y-axis is the pulse height channel from time of flight signal. The mass separation of target elements is obvious from this bi-parametric display. The right hand end of each curve represents the target surface and each individual elemental depth profile is represented by moving to lower recoil

energies. Analysis of this data shows that oxygen has diffused through the platinum oxidising the Ti and Si, and strontium has segregated in the BST layer.

HEAVY ION MICROPROBE

Ion microprobes have a long tradition in Australia. Proton and helium microprobes are operating in Melbourne (MARC) and at CSIRO in North Ryde. Both however, use mainly light ions at low energies. In order to expand the energy range as well as the range of ions available for microanalysis, a high energy, heavy ion microprobe has been designed and built at ANSTO. This microprobe is a unique multi-user facility providing new capabilities for ANSTO and the broader Australian research community. It will have applications in materials and environmental research, as well as industry, biology, medicine and geology.

ANSTO's heavy ion microprobe is designed to focus ions ranging from hydrogen to iodine, with a maximum ME/q^2 of at least 100, where M, E and q are the mass, energy and charge of the ion. Due to its wide range of ions and energies, the heavy ion microprobe has the advantage that it can accommodate both low energy, light ion IBA techniques, such as PIXE and NRA, as well as high energy, heavy ion IBA techniques such as heavy ion recoil spectrometry and heavy ion RBS.

Fig. 9 shows a picture of target chamber and the microprobe quadrupoles. A magnetic quadrupole triplet demagnifies the object spot by a factor of about 90 and 30 in the x and y direction, respectively. A beam scanner located before the quadrupoles rasters the beam over a 1×1 mm² area for 2-dimensional elemental mapping. This allows the analysis of lateral variations in sample composition with a resolution of several microns.

Construction of the beamline for the heavy ion microprobe was completed at the end of 1997. Since then, the quadrupoles have been installed and aligned. Tests with the microprobe have shown that ion beams with a ME/q^2 of up to 150, can be focused with these quadrupoles. First tests produced spot sizes between 7 and 25 μ m for C, Cl and I beams with currents up to several tens of nA. These currents are sufficient for IBA analysis, such as RBS, PIXE and heavy ion elastic recoil detection analysis (ERDA).

One of the major applications for the heavy ion microprobe will be heavy ion ERDA. ERDA has the advantage that it allows the detection of light elements such as H, C, N and O, which are difficult to measure with conventional PIXE or RBS. For this purpose, a large area dE-E detector has been designed and will be installed in the near future. The large solid angle area of this detector will permit analysis of samples with low beam currents.

Summary

We have given a brief overview of some of the various IBA techniques available at ANSTO, describing the wide range of instruments and facilities available, and the diversity of applications in which they have been applied. Accelerator based

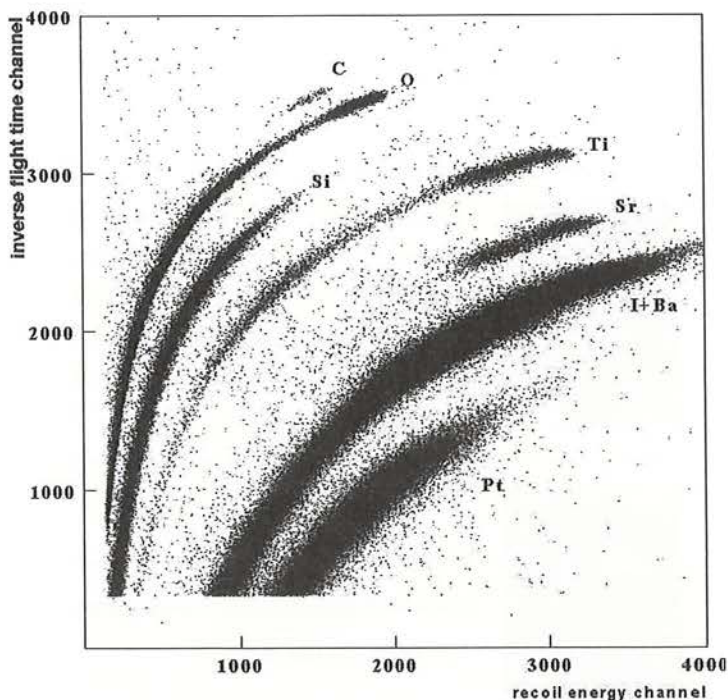


Fig. 8. Recoil ToF spectrometry display of the mass separated spectra of the thermally annealed BST multilayered sandwich

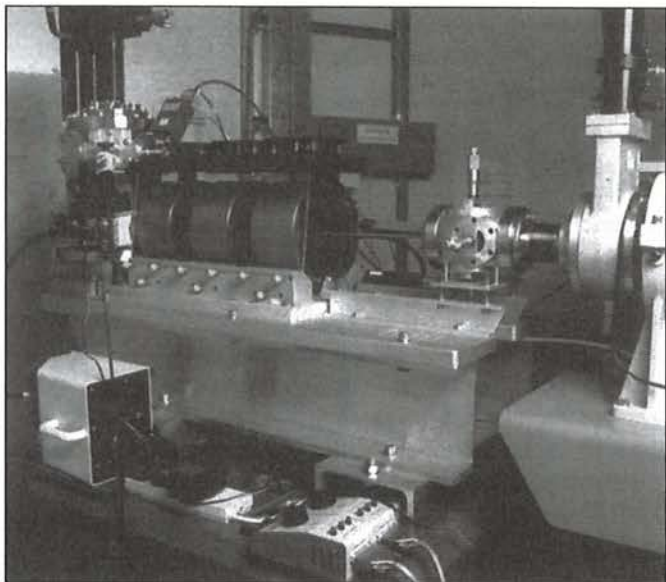


Fig. 9: Picture of the target chamber end of the microprobe beamline. Visible on the left is the octagonal target chamber with its various access ports, the microscope for viewing and alignment of the targets, the quadrupole triplet and the collimating slits.

techniques provide a very useful tool for the non-destructive analysis of samples, with sizes ranging from microns to centimetres, elemental compositions from ppm to many percent, and with sample masses down to hundred micrograms or so. Altogether, ion beam analysis provides a tool for sensitive analysis for most elements of the periodic table.

Acknowledgments

Some of the work described in this article includes research being undertaken by various Australian universities, utilising the facilities at ANSTO through grants from the Australian Institute of Nuclear Science and Engineering (AINSE). The work described using ^{18}O tracers was done in collaboration with Prof. Don Bradshaw, Dept. of Zoology, University of Western Australia. The work described on ferroelectrics was done in collaboration with Warren Stannard, Peter Johnston, Scott Walker and Ian Bubb of the Dept. of Physics, Royal Melbourne Institute of Technology. The authors also wish to acknowledge the valuable technical assistance of all the ANSTO accelerator staff.

References

- Handbook of Modern Ion Beam Materials Analysis, Ed.: J.R. Tesmer and M. Nastasi, Materials Research Society, Pittsburg 1995.
- Ion Beams for Materials Analysis, Ed.: J.R. Bird and J.S. Williams, Academic Press Australia, Sydney 1989.
- Materials Analysis using a Nuclear Microprobe, M.B.H. Breese, D.N. Jamieson and P.J.C. King, John Wiley & Sons, Inc., New York 1996

THE AUSTRALIAN SYNCHROTRON RESEARCH PROGRAM

RICHARD F. GARRETT AND JOHN W. BOLDEMAN

The Australian Synchrotron Research Program (ASRP) provides Australian researchers with access to state-of-the-art synchrotron radiation research capabilities at two overseas synchrotron light source facilities. These are the Australian National Beamline Facility (ANBF) at the Photon Factory, Tsukuba, Japan, and the Advanced Photon Source, at the Argonne National Laboratory in Chicago, USA. The ASRP was funded for five years under the Major National Research Facilities program, with ANSTO acting as the managing agent. The member institutions of the ASRP are ANSTO, ANU, CSIRO, Monash University, UNSW, the University of Melbourne, the University of Queensland and the University of Sydney. The University of Canberra is an associate member.



Dr Richard Garrett is a Principal Research Scientist in the ANSTO Physics Division, and is the Scientific Manager of the ASRP. He has worked in Synchrotron Radiation for 14 years, at Brookhaven National Laboratory and at ANSTO.



Dr John Boldeman is the Facility Director of the ASRP. He is a former Director of the ANSTO Physics Division.

The Australian National Beamline Facility (ANBF)

The ANBF is a multi-capability hard X-ray beamline installed at the 2.5 GeV Photon Factory second generation synchrotron light source, located in Tsukuba Science City in Japan. The ANBF is installed on a bending magnet port, beamline 20B, at the Photon Factory. It delivers monochromatic synchrotron X-rays in the energy range 4.5 - 24 keV to two experimental stations. The beamline and monochromators were constructed in Australia at the Physics Department of ADFA.

The primary instrument is a unique multi-configuration vacuum diffractometer which uses image plates as its primary detector system. This instrument can be configured as a high resolution time resolved powder diffractometer, a grazing incidence diffractometer, a triple crystal diffractometer and a Bonse-Hart small angle scattering diffractometer. This diffractometer was constructed at the CSIRO Division of Materials Science and Technology in collaboration with the ANBF staff. It has proven to be a very successful design; some of its unique capabilities are illustrated in the case study below.

An optical table behind the diffractometer functions as a second experimental station, primarily used for X-ray absorption spectroscopy: XAFS and XANES. This station is equipped for both transmission and fluorescence XAFS, and has a cryostat for sample cooling.

The Advanced Photon Source

The Advanced Photon Source (APS), shown in Figure 1, is a 7 GeV third generation synchrotron light source constructed by the US Department of Energy at the Argonne National Laboratory in Chicago, USA. A key feature of the third generation of synchrotron light sources is the extensive utilisation of undulator 'insertion devices', which produce synchrotron X-ray beams thousands of times brighter than the second generation Photon Factory. The APS will be the premier US synchrotron radiation facility well into the next century.

The ASRP has joined two 'Collaborative Access Teams' or CATs, as the groups constructing and operating beamlines at the APS are known. These are the Synchrotron Radiation Instrumentation (SRI) CAT and the Consortium for Advanced Radiation Sources (CARS) CAT.

The SRI-CAT operates 11 experimental stations on 5 insertion device and 2 bending magnet beamlines. It offers a wide range of experimental capabilities including hard and soft X-ray micro-beam techniques, high energy diffraction, very high resolution X-ray scattering, X-ray polarisation techniques, time resolved XAFS and soft X-ray spectroscopy. All these beamlines are now operational.

The ASRP membership of CARS provides access to BioCARS, which will operate two bending magnet and one insertion device beamline dedicated to macro-molecular crystallography, or protein crystallography, and to ChemMatCARS

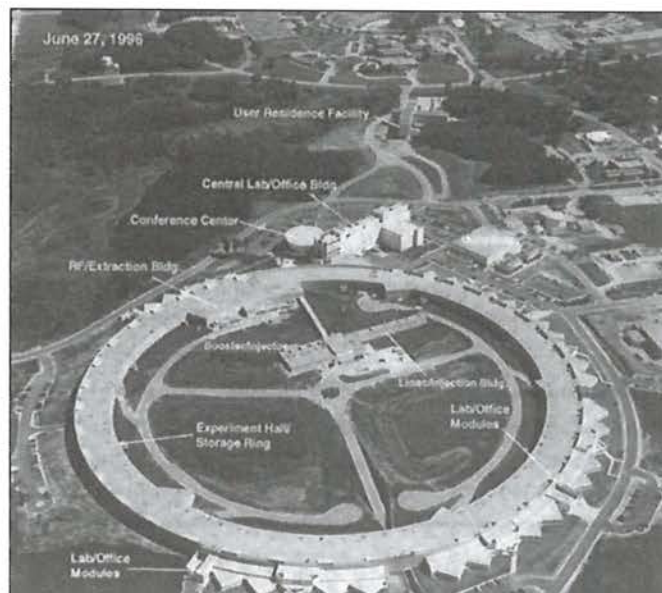


Figure 1. The Advanced Photon Source, Courtesy APS, Argonne National Laboratory

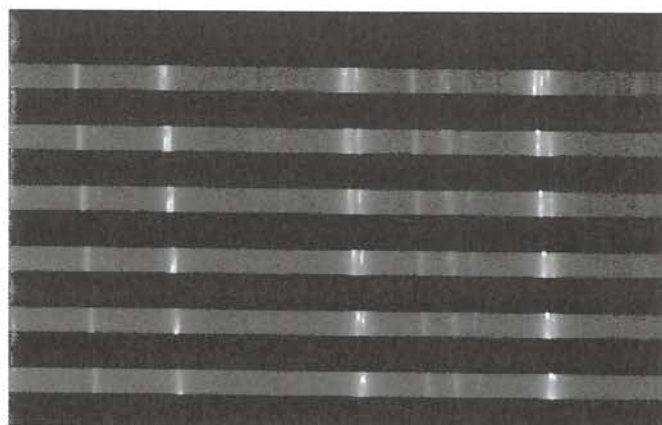


Figure 2. Temperature series of powder diffraction patterns of a CaSr perovskite. The top pattern was taken at room temperature (tetragonal symmetry) and the bottom one at 500C (cubic symmetry). The round spot in the upper right is a fiducial mark to allow the angle scale of the patterns to be determined.

which will operate three experimental stations on an insertion device beamline for structural chemistry and materials science investigations using X-ray crystallography, surface scattering and small angle scattering. The BioCARS beamlines will be operational by mid 1998, and the ChemMatCARS beamlines in 1999.

Access to the ASRP Facilities

The ASRP maintains staff at both the Photon Factory and the APS, and provides travel and subsistence funding to Australian researchers using the facilities. Access is via a peer reviewed proposal system. Further details, and contacts for further information, can be found on the ASRP web page at HYPERLINK: <http://home.ansto.gov.au/natfac/asrp.html> <http://home.ansto.gov.au/natfac/asrp.html>

Case Study: Powder Diffraction Study of Phase Transitions

The key feature of the ANBF diffractometer in powder diffraction mode is that the whole powder pattern is recorded simultaneously at high resolution using Imaging Plates (IPs), X-ray sensitive re-useable storage phosphor plates which are exposed in the diffractometer and then read out electronically in a separate reader. In this way a complete powder pattern (four plates can be used, covering 160° of 2-theta) can be recorded in minutes, compared to many hours in a conventional diffractometer. In addition, a 5mm slit can be interposed between the IPs and the sample, so that only a thin strip of the

IPs is exposed. The IP mount is then translated and multiple powder patterns can be recorded on a single set of IPs, allowing time resolved data to be recorded on a time scale of several minutes. This feature can also be used with a multiple sample holder to achieve a very high throughput of samples.

To illustrate this capability, Figure 2 shows an IP on which a series of seven powder diffraction patterns have been recorded. The sample in this case is a Calcium-Strontium (65%) perovskite ceramic, which is an important component of Synroc, used to immobilise radioactive Sr. The data was taken by C. Ball and co-workers of the ANSTO Materials Division, and D. Cookson of the ANBF. The sample temperature was stepped between each pattern, and a phase transition can be seen from a tetragonal structure at room temperature, to a cubic structure at around 500C.

RADIOISOTOPES FOR MEDICAL APPLICATIONS

DR STUART CARR

Director

Radiopharmaceuticals Division

Australian Nuclear Science & Technology Organisation

PMB 1 Menai 2234

For more than 3 decades, the Australian Nuclear Science and Technology Organisation has been the country's main supplier of radioisotopes for medical applications. The use of radioisotopes in medicine has revolutionised the diagnosis, management and treatment of many serious diseases such as cancer, heart disease and stroke. It is also beginning to play a key role in neurological disorders such as Parkinson and Alzheimers disease and epilepsy. More recently there has been considerable growth in the application of nuclear medicine to treat sport-related injuries - especially wrist, ankle and knees where more common techniques do not always enable accurate diagnosis. Australia is a recognised leader in nuclear medicine. This can be partially attributed to the close relationship between ANSTO and the medical community in providing opportunities to develop and evaluate new agents to support more effective patient care. The Australian and New Zealand Society of Nuclear Medicine (ANZSNM) and the Australian and New Zealand Society of Physicians in Nuclear Medicine are very active societies. The ANZSNM organises an annual Scientific Meeting to share international best practice and to discuss policy issues. Additionally there is also a number of special interest groups.



Dr. Stuart Carr is Director, Radiopharmaceuticals at ANSTO. He has a PhD in Chemistry from University of Melbourne and held positions at Unilever in the UK and ICI (ORICA) in Australia

Principle

The principle of radioisotopes in medicine involves using an unstable radioisotope which decays over a period of time (defined in terms of half lives) emitting detectable radiation. Most diagnostic applications in nuclear medicine use either gamma or positron emitting isotopes. The half-lives of these isotopes required depend on the tissue type and the time-scale of the biological process being monitored. For diagnosis, low energy gamma emitting isotopes are used to ensure that quality images are obtained while limiting the radiation dosage to the patient. Recent advances mean that patients are exposed to very low levels of radiation in the course of treatment. For therapeutic applications higher level dosages are required so that, for example, cancer cells are destroyed. Therapeutic

applications use beta or alpha emitting radioisotopes. Typically the radioisotope is combined with a chemically or biologically active material which is taken up by a specific disease site or organ. In this way it is possible to localise the radioisotope and selectively image the required region of the body.

Imaging Techniques

Conventional planar imaging and Single Photon Emission Computed Tomography (SPECT) imaging techniques utilise gamma emitting isotopes. These are the workhorses of nuclear medicine and most hospitals and private practices will have several cameras for specific imaging applications. A typical scan requires between 30 minutes to one hour and for many indications a rapid and clear diagnosis is possible. SPECT has recently been applied to the study of dynamic body functions, eg heart blood flow.

Positron Emission Tomography (PET) is a more recently developed technique and is reliant on more short-lived positron emitting isotopes. With the PET camera, imaging depends on the simultaneous detection of the two gamma rays produced when positron annihilation occurs. PET cameras are far more expensive than SPECT cameras and there are currently only three in Australia. Over the next few years it is expected that there will be a significant increase in the number of PET cameras. PET has found particular application in determining the biochemistry or physiology in a particular organ, tumour or other metabolically active site.

Irradiation Facilities.

Medical isotopes are typically produced in both nuclear reactors and cyclotrons. Table I gives a chronological list of some of the key developments over the past forty years. Since 1960, radioisotopes have been produced in the reactor HIFAR by ANSTO and its predecessor, The Australian Atomic Energy Commission. This has strongly supported the expansion of nuclear medical technology in Australia. The HIFAR reactor has a variety of irradiation facilities with very useful flux levels which can be used to produce many radioisotopes. The bulk of radiopharmaceutical isotope production is undertaken in hollow fuel element rigs located in elements in the reactor core. Available neutron fluxes range from about 4×10^{12} neutrons \cdot cm $^{-2}$ \cdot s $^{-1}$ to 9.5×10^{12} neutrons \cdot cm $^{-2}$ \cdot s $^{-1}$. Typical reactor based isotopes include I-131, Mo-99/Tc-99m, Sm-153 and Y-90.

The Australian Government provided funding of \$14 million to ANSTO to construct a medical cyclotron facility to be established at the Royal Prince Alfred Hospital (RPAH). The cyclotron produces 'commercial' radioisotopes as well as those for use by the PET camera at RPAH.

The building of this National Medical Cyclotron facility was completed in March 1991 in time for the arrival of an IBA Cyclone 30 negative ion cyclotron. This model cyclotron had been a clear choice on the basis of price, low operating costs and flexibility of operating modes.

The first PET product from the cyclotron was a delivery of Fluorine-18, for calibration purposes, to the RPAH on the 25 October, 1991. This was to be one of many Australian 'firsts'. Routine production for RPAH commenced in mid-1992, with

Table 1

- The first medical radionuclide produced in HIFAR in 1960/61 was Sodium-24.
- Cobalt-60 production was the dominant activity from 1961/62 to 1964/65.
- The first formal export of a radiopharmaceutical took place in 1965/66.
- Production of Mo99/Tc99m generators began in 1967/68.
- Production of Iodine-131 began in 1968/69.
- In 1971/72 the use of Phosphonate complexes of Tc99m for bone scanning became significant in Australia increasing the demand for Technetium-99m.
- Exports of Mo-99/Tc99m generators began in 1976/77.
- The demand for imported cyclotron-based radiopharmaceuticals started to surge over 1977 to 1980.
- Exports and internal sales declined between 1977 and 1985 due to technological competition from international manufacturers.
- ANSTO introduced a sterile Mo99/Tc99m generator in 1984/85.
- ANSTO introduced local manufacture of Iodine-131 capsules in 1987/88
- In 1991, sales effort overseas increased considerably.
- Thallium-201 and Gallium-67 sales (sourced from the Australian cyclotron) expanded from 1994.
- In 1995/96 the general availability of Technetium-99m-based heart diagnostic agents accelerated demand for Technetium-99m generators.
- QUADRAMET™ (Sm-153) commercially available as a palliative radiopharmaceutical for pain relief in secondary bone cancer.
- FDG (fluorodeoxyglucose) commercial production commenced 1998

Table II - Uses of Radiopharmaceuticals

Sodium Bromide

- Determination of extracellular fluids

Sodium Chromate Solution

- Red Blood Cell Labelling for disorders such as - Haemolytic Anaemia (increased destruction of red blood cells.)

Chromium EDTA Injection

- Glomerular filtration rates - Kidney studies

Copper 64

- Copper metabolism disorders

Indium III DTPA

- Cerebrospinal Fluid dynamics (fluid in the spine and surrounding the brain)
- Cisternogram - study of the basal cistern of the brain
- Gastric emptying studies
- Glomerular filtration rates

Iodine 125 - Human Serum Albumin

- Blood and Plasma volume measurements

Iodine 131 - Human Serum Albumin

- Liver scans
- Brain imaging

Sodium Iodine 131

- Thyroid disorders
- Thyroid Cancer

Sodium Iodine 131 MIBG

- Imaging the adrenal Medulla (part of the adrenal gland which is just above the kidneys) to localise pheochromocytomas and neuroblastoma (types of cancer)
- Adrenal medullary hyperplasia (increase in volume)

Sodium Iodine 123 MIBG (Iodine 123 has a lower gamma energy than I131)

- Image the Adrenal Medulla to localise pheochromocytomas and neuroblastoma
- Adrenal medullary hyperplasia (increase in volume)

Phosphorus 32

- Treatment of polycythaemia vera (an increase in the total cell mass of the blood)
- Palliative treatment of pain caused by bone cancer

Samarium 153 EDTMP (QUADRAMET)

- Palliative treatment of secondary bone cancer from lung, breast & prostate cancer

Technetium 99m

- For the preparation of Technetium-99m labelled scintigraphic agents
- Localising of brain lesions
- Thyroid imaging
- Cardiac Imaging
- Lung, kidney, liver function

Technetium 99 Sulfur Colloid

- Liver studies
- Gastric emptying studies
- Detection of Gastric Bleeds

Thallium 201 (cyclotron produced)

- Cardiac Studies - extent and severity of Coronary Artery Disease
 - Thyroid studies - parathyroid adenomas (type of cancer)
 - 18 Fluorodeoxyglucose (FDG)
 - Tumour imaging
- As mentioned above, FDG has recently established itself as a key tool for the diagnosis in cancer with the potential to reduce the need for surgery

Gallium 67 (cyclotron produced)

- Detection of soft tissue tumours and infections

Thallium-201 (cyclotron produced)

- Agent for assessing heart function in diagnosis of cardiac disease.

¹⁸F Fluorodeoxyglucose and ¹³N Ammonia being supplied daily. Of the commercial radioisotopes, Iodine-123 was supplied first, for research purposes, to ANSTO's Research and Development Program. It is now in commercial production.

During the week of 7 February 1994, the National Medical Cyclotron was able to supply Australian Radioisotopes (ARI), ANSTO's commercial radioisotope producer, with its full demand for ¹¹¹Tl-201 for the first time, and coincidentally completed the first test production of Gallium-67.

The cyclotron, which currently operates almost 24 hours per day, now produces most of the ⁶⁷Ga and ¹¹¹Tl-201 used in Australia for nuclear medicine.

Ongoing development of the facility has allowed the increasing demands for commercial SPECT radioisotopes to be met and has underpinned overall production reliability. Commercial production of ¹⁸F, for facilities throughout New South Wales has now begun.

The ANSTO radioactive product with the largest annual sales value, is the ^{99m}Tc/⁹⁹Mo generator. 6200 units are manufactured annually. ANSTO manufactures the fission-product based Molybdenum-99, used in the manufacture of these generators, in its own plant using uranium dioxide targets irradiated in HIFAR. ANSTO has about 90% of the Australian market for this product and is the principal supplier of large ^{99m}Tc/⁹⁹Mo generators to radiopharmacies in Melbourne and Sydney. These supply Technetium-99m solutions directly to users in those cities. ANSTO also uses in-house generators to supply Technetium-99m solutions to a small number of Sydney users.

Iodine-131 is another important medical radioisotope. The largest selling item is Iodine-131 Therapy Capsules with a total of about 6000 shipments per year. ANSTO effectively supplies 100% of the requirements in Australia for radiopharmaceuticals based on Iodine-131.

Samarium-153 EDTMP, sold under the name Quadramet™, is used to relieve the pain associated with skeletal metastases resulting from a range of primary tumours. Production has recently commenced. This radiopharmaceutical may have other therapeutic applications.

Production

The commercial isotopes produced in the reactor or the cyclotron are converted to pharmaceutical products in the facility at Lucas Heights. This facility is certified under the Therapeutic Goods Act and was recently ISO 9002 accredited. The facility has a range of clean rooms.

Radioisotopes are distributed in specially designed packaging to ensure that there is little chance of exposure to radiation during transit. Packages meet international transport regulations and undergo stringent prototype testing before use. An efficient distribution process has been established to ensure that radioisotopes, which decay in a matter of hours to days, reach their destinations on time.

Nuclear
Medicine
Procedures per
Year in Australia

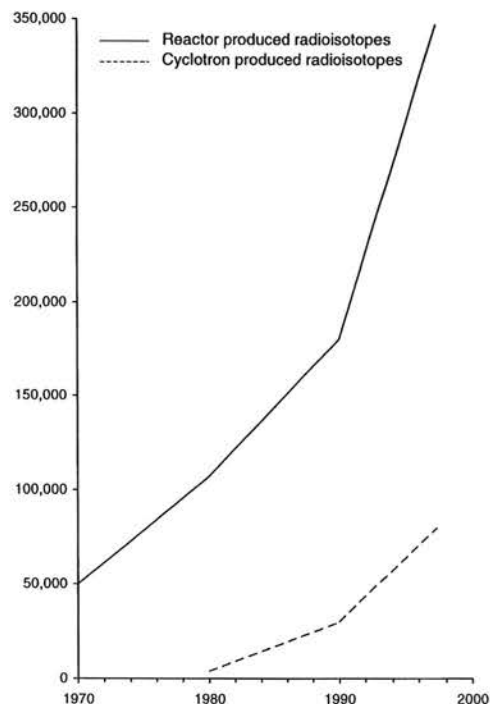


Fig. 1. Annual Total Nuclear Medicine Doses and Annual HIFAR and Cyclotron-based Nuclear Medicine Doses in Australia

Applications

Table II contains a list of radioisotopes used in medical applications. Figure I shows the estimated growth in the utilisation of medical isotopes over the last 38 years. ANSTO supplies over 450,000 doses of nuclear medicine for use in Australia and that number is increasing. A list of medically useful isotopes is given in Table II. It is apparent that radiopharmaceuticals find a place in the diagnosis and treatment of most of the common ailments which effect Australian society.

To date much of nuclear medicine has been dedicated to diagnosis. There is now an increasing emphasis on the potential for therapeutic applications. I-131 has long been used for successful thyroid cancer therapy, but there are an increasing number of studies suggesting that other isotopes can have a therapeutic benefit.

Future Prospects

Nuclear medicine plays an important role in the clinical environment and the timely supply of radioisotopes is a key element. ANSTO will continue to be the premier supplier of currently available and developing isotopes to support the health and well being of the Australian community.

"UNIVERSITY SCIENCE: CRISIS OR CROSSROADS?"

The one-day Forum at the National Press Club has left FASTS with an interesting question - where to now?

We have put together a potentially powerful coalition with concerns over science in the universities. Most Australians would be aware that not all is well in University science, which has been something of a running sore in the media.

The Australian Vice-Chancellors' Committee, the Council of Deans of Science and the National Tertiary Union are groups that one would expect to stand up for university science.

It's good to see other groups joining in to express their concerns - the Minerals Council of Australia, the Australian Chamber of Commerce and Industry, and the Business/Higher Education Round Table (BHERT).

FASTS is keenly aware of the need to build an alliance which spreads beyond the groups and individuals with a direct interest in the outcomes.

This is a key issue, and one which was emphasised at the closing session of the Forum by both Chief Scientist John Stocker and Ashley Goldsworthy of BHERT.

This "Science Alliance" is necessary if S&T is to be a serious election issue in Australia.

If commerce, mining and farming interests stand up in public and say a properly-funded S&T section is essential for national well-being, then it becomes harder for the will and the rhetoric of political parties to evaporate especially under the increased pressure of an election.

The next Executive meeting of March 17 will be addressing the issue of how best to translate the recommendations and ideas of the Forum into hard-edged political and policy actions.

LAUNCH OF POLICY DOCUMENT 1998

The third edition of the FASTS' Policy Document was formally launched at the Forum, and has been sent to key figures in Parliament and the bureaucracy.

In my informal speech at the National Press Club, I asked whether Australia can achieve its vision for the future by priming the science pump and letting the good times roll.

The answer is No. We are going to have to be much smarter about where and how we invest our limited resources to produce the sort of high technology companies that can set prices which command a premium for smart ideas. The Policy Document points the way.

PM's SCIENCE, ENGINEERING AND INNOVATION COUNCIL

PMSEIC members seeking to identify priority issues for Australia held their first sub-committee meeting in February.

Two weeks ago I invited FASTS' Member Societies to contribute their ideas on priorities for Australia. Their responses will be of material assistance in shaping the considerations of this sub-committee, and I thank Members for their thoughtful contributions.

NEW VICE-PRESIDENT

Congratulations to Professor Bob Carter on his election to the position of FASTS' Vice-president. Bob is in the School of Earth Sciences at James Cook University in Townsville. He replaces Dr Geoff Hudson who retains his position as Board Member representing Geological Sciences.

NEW MEMBERS

FASTS continues to attract new Member Societies, with the latest being the Australian and New Zealand Society for Laboratory Animal Science (ANZLAS). Publicity surrounding the November Council meeting, the release of the Ten Top issues, the Forum and the release of the FASTS' Policy Document have generated a steady stream of inquiries.

FASTS can now be confident it has steered away from the rocky shores of three or four years ago, prior to the release of its first policy document, but we can not be complacent.

We are looking to increasing our impact on S&T policy making, and the Executive is currently considering a draft business plan.

HOUSE OF REPRESENTATIVES INQUIRY

In the last Circular I mentioned that FASTS had made a submission to the H. of R. Committee examining the effects on R&D of public policy reform in the past decade.

We have now been invited to appear before the Committee next month. The FASTS' delegation will be led by Ken Baldwin, as Chair of the FASTS' Policy Committee. Chris Easton and Joe Baker who coordinated the

response from FASTS to this Inquiry will both be overseas during the hearings.

Science NOW!

There has been steady progress on establishing a governing body to run the new media-focussed science forum, and I have met with the Presidents (or representatives) of the two science academies, the Science Communicators and ANZAAS to set down broad guidelines.

We hope to have the structure in place shortly. In the meantime, the first Forum in Melbourne in Science Week (May 7 to 10) is proceeding apace.

Member Societies were recently invited to submit the names of people who presented the most interesting papers at their last conference, so the papers could be given a public airing. This invitation is attracting huge interest. For details, contact Niall Byrne on 03 5253 1391, mob. 0417 131 977 or by email: niall@aahl.dah.csiro.au

ANZAAS

It's good to see three women on the new-look ANZAAS Council, more than ever before in its 110 year history. We wish ANZAAS and new President Paul Adam well in their endeavours to find a new path.

*Peter Cullen
14 March*

Mr Toss Gascoigne
Executive Director
Federation of Australian
Scientific and Technological
Societies PO Box 218
DEAKIN WEST ACT 2601

Phones:
02 6257 2891 (work)
02 6249 7400 (home)

Fax: 02 - 6257 2897

Mobile: 0411-704 409

Email:
fasts@anu.edu.au

Web address:
<http://www.usyd.edu.au/su/fast/>

PRODUCT NEWS



Diode Laser for Optical Spectroscopy

The Raman Group of Renishaw Transducer Systems Division has launched a compact diode laser specifically designed as a source for optical spectroscopy, and is available from Warsash Scientific.

Suitable for reduced fluorescence Raman measurement applications, the laser features a 30-mW frequency-stabilised output. It has no side modes and is free from spontaneous radiation. The device's output is a circularised low astigmatism beam with a near Gaussian profile. The laser emits at $780 \text{ nm} \pm 2$. The system features true single-mode operation producing clean Raman spectra to less than 100 cm^{-1} even with long integration times. The device is approved to DCRH and European safety standards.

Further information is available from
WARSASH Scientific P O Box 1685
Strawberry Hills, NSW 2012
tel: (02) 9319-0122, fax: (02) 9318-2192,
email: warsash@ozemail.com.au
<http://www.ozemail.com.au/~warsash>

Newport IsoStation Vibration Isolation Workstation

IsoStation workstations are suitable for a wide range of vibration sensitive applications including optical microscopy, patch clamping, micropositioning, thin film deposition and wafer probing/inspection. Newport's patented stabilizer vibration isolators are used to uncouple the breadboard worktop from floor vibrations in both the horizontal and vertical planes. Damping within the breadboard worktop is also available for the most demanding applications.

The system features an easy-to-clean white powder-coat finish on the workstation frame. Three grades of breadboard worktops are available with a choice of 2" or 4" thickness. Each breadboard worktop features patented corrosion-proof sealed holes for protection from spills.

A wide range of accessories are available, for



example, equipment shelves, monitor arms, and instrument racks. These accessories can be purchased and fitted to the workstation as required.

For more information please contact:
Margaret Skipworth, Bill Petreski or Neil McMahon
Coherent Scientific Pty Ltd
116 Burbridge Road
Hilton South Australia 5033
Phone: (08) 8352 1111 Fax: (08) 8352 2020
Email: cohsci@cohsci.com.au
Web: www.cohsci.com.au

Integrating Sphere Guide

The integrating sphere is a simple, yet often misunderstood device for measuring spherical radiation.

The function of an integrating sphere is to spatially integrate radiant flux. Before one can optimise sphere design for a particular application, it is important to understand how the integrating sphere works.

Now available free from Warsash Scientific is "A Guide to Integrating Sphere Theory and Applications", an 18-page technical guide on integrating sphere theory, design, and applications, just released from Labsphere Inc. of the U.S.

Clearly set out with ample illustrations, topics in the guide include integrating sphere applications in radiometry and photometry, uniform light sources and light collectors, laser power meters, cosine receptors and reflectance spectroscopy.

Included also, is a guide to optical units.

Copies may be obtained from WARSASH Scientific at tel: (02) 9319-0122,
fax: (02) 9318-2192,
email: warsash@ozemail.com.au

New Melles Griot Absorptive Neutral Density Filters

Absorptive neutral density filters attenuate light with absorption rather than reflection, while eliminating back reflections and scattering. These absorptive filters are perfect replacements for metallic neutral density filters in low intensity applications. These ND filters are available in either 25.0 mm round or 50.0 mm square shapes. Special sizes and shapes may be ordered in large or small quantities.

Melles Griot is an international distributor and manufacturer of photonics products including optical components and lenses, laser, instrumentation, and opto-mechanical hardware. Our diverse engineering and production capabilities provide extensive state-of-the-art product offerings, as well as custom and OEM engineering at the most competitive prices.

For further information, please contact Lastek Pty Ltd on tel (08) 8443-8668, fax (08) 8443-8427, or email: sales@lastek.com.au

New Melles Griot Modular Controller System

The new Melles Griot system of opto-mechanical controllers, piezo actuators, stepper motor drives, nanometric positioning drives, and system software takes the term "modular" to a new level.

The new system consists of the main rack and controller PC, which can be bench cabinet or 19-inch rack-mounted. One controller can drive up to 32 module racks, to accommodate system expansion or extremely complex applications.

The main suite of modular control software resides in the controller unit, and offers four control options: Visual Basic, C, LabVIEW, and Melles Griot Macro Environment, running under Windows NT or Windows 95.

Available drive modules include piezo actuators, stepper motor drivers and, for precise nanometric auto-alignment, a NanoTrak™ driver. The new system modules and actuators are compatible with selected existing Melles Griot stages.

To complement these new drivers, two new 3- and 6-axis NanoMax™ stages have been created, featuring a unique "parallel flexure" design.

Melles Griot designs, manufactures, and distributes precision nanometric positioning systems, lasers and laser beam measurement instrumentation, as well as a full range of optics, opto-mechanical hardware, and optical laboratory accessories.

For further information, contact Lastek Pty Ltd on tel: (08) 8443-8668, fax: (08) 8443-8427 or email: sales@lastek.com.au

Product News...



Cordin; Rotating Mirror Synchronous Streak Camera

The Model 132 is a rotating mirror synchronous streak camera which exposes a 60mm x 310mm record on a 70mm film at rates of up to 30mm per microsecond with high linearity over the entire film track. A longer film track is also available allowing a 60mm x 665mm record.

The camera uses the Model 1209 or Model 1231 rotating mirror turbine. The 1209 mirror is a 25mm x 60mm beryllium substrate, aluminium overcoat mirror which is gas turbine driven, and can achieve speeds of 5,000 rps,

equivalent to a recording rate of 20mm/ μ s. The model 1231 mirror is similar, but achieves speeds of 7,500rps, equivalent to 30mm/ μ s.

Will this camera suit your requirement for a particular application?

For more information please contact:

Bill Petreski or Andrew Masters

Coherent Scientific Pty Ltd

116 Burbridge Road

Hilton South Australia 5033

Phone: (08) 8352 1111 Fax: (08) 8352 2020

Email: cohsci@cohsci.com.au

Web: www.cohsci.com.au

Coherent Laser Group Verdi, 532nm, CW, solid state Laser

Coherent Laser Group, is pleased to announce that both the 2 and 5 watt versions of the Verdi CW green (532nm) diode-pumped Nd:YVO4 lasers have been shipping since October 1997, with over 80 units now in operation.

Unlike other solid state diode pumped lasers Verdi requires no cooling water and operates

on single phase power. Both the 2-watt and 5-watt versions are the most efficient and compact lasers of this type available. The single frequency operation means that the lowest possible noise is achieved; <0.1% rms from 10Hz to 1GHz. Other such systems are rated from 10Hz to 2 MHz. Verdi also has the smallest footprint of any such laser system measuring <440mm end to end.

This revolutionary solid-state technology is ideal for both scientific and industrial applications, including spectroscopy, reprographics, semiconductor inspection, holography, particle scattering, disk zone texturing and medical applications.

For more information please contact:

Andrew Masters or Bill Petreski

Coherent Scientific Pty Ltd

116 Burbridge Road

Hilton South Australia 5033

Phone: (08) 8352 1111 Fax: (08) 8352 2020

Email: cohsci@cohsci.com.au

Web: www.cohsci.com.au

ANZIP CONDENSED MATTER PHYSICS MEETING

Charles Sturt University, Wagga Wagga, Feb, 4-6, 1998

Some impressive condensed matter science was displayed in the usual mixture of oral and poster presentations at Wagga '98, the 22nd such annual meeting of condensed matter physicists. The meeting was preceded by a 2-day Workshop on High-Temperature Superconductivity (HTS), with the Workshop overlapping the condensed matter meeting for the first half-day. This gave people attending the Condensed Matter Physics meeting a chance to hear presentations from a number of internationally distinguished high Tc researchers such as Professor Shoji Tanaka (ISTEC) and Professor John Clem (Iowa State).

The main Condensed Matter Physics meeting also had its share of international speakers, with Professor Robert Roth (NIST), Dr Tom Vogt (Brookhaven National Lab.) and Professor Bennett Goldberg (Boston) giving presentations on crystal chemistry and dielectric properties of ceramic oxide materials, negative thermal expansion of oxide systems and near field imaging of semiconducting devices respectively.

The general themes of the meeting's other oral sessions related to areas such as oxide systems, semiconductors and quantum systems, crystal structures, general solid state physics and spectroscopic techniques. A session was also dedicated to presentations and discussion relating to the development of future Neutron and Synchrotron radiation facilities in Australia.

From such a diverse range of Condensed Matter Physics topics came numerous well-received oral and poster presentations. Some examples from an otherwise exhaustive list include talks on quantum computers (Bruce Kane - UNSW), electron capture in GaAs quantum wells (Michael Johnston - UNSW) in the Quantum system session and crystallisation mechanisms (Brenden O'Malley - RMIT) in the Crystal structure session. Other talks in that session included presentations on titanates (Sharon Webb - ANU), mesoscopic billiards (Adam Micolich - UNSW), C60 (Michael James - ANSTO) and olivine polycrystals (Ian Jackson - ANU). The Spectroscopy session featured talks on the quantum yield of asymmetric Bilirubin (Gordon Troup - Monash), Zeeman spectroscopy (Roger

Lewis - Wollongong), photomission line-shapes (Anton Stampfl) and many more. Presentations on layered superconductors (Ross McKenzie - UNSW), Josephson tunneling (Pavel Shevchenko - UNSW), martensitic transformations (Georgie Kelly - Monash) and magnetism (Darren Goossens - Monash) were also given. Over 100 posters on a wide range of Condensed Matter Physics were presented over two days of the meeting.

The presented material was in our view of a high standard and augurs well in general for solid state science in Australia. Attendance was low however, with ~ 140 delegates present. This was in part due to the preceding HTS meeting and the low NZ attendance (they hosted the meeting the previous year). Apart from some international visitors already in Australia or staying on from the HTS Workshop, almost all of the remaining delegates were from NSW/ACT/Victoria. Given that the total cost of registration/accommodation/food was only ~ \$200, it can only be suggested that potentially interested scientists from more distant Australian states and New Zealand found the travel costs to be prohibitive. We believe this question should rank high in the forthcoming ANZIP agenda. In part this was foreshadowed by Jaan Oitmaa's (UNSW) suggestion that condensed matter physics should form a topical group within ANZIP.

AIP & NZIP BRANCH NEWS

NZIP - Wellington

The NZIP-Wellington Branch in association with Science Wellington (formerly the Wellington Branch of the Royal Society of New Zealand) continues to provide free public seminars. Our current seminar schedule includes, "200 Years of the Measurement of the Newtonian Gravitational Constant", a seminar about Marie Curie and the discovery of Radium and a talk by the new president of the RSNZ academy concerning science funding in New Zealand.

We can be found at
<http://www.irl.cri.nz/nzip/>

One of last years talks, "The Science Reforms - Seven Years On" by Dr. Sean Devine, Association of Crown Research Institutes, may be of interest to AIP and NZIP members.

A transcript of this talk is available at <http://www.rsnz.govt.nz/clan/sci-wtn/scital97.htm>

*Grant Williams,
Industrial Research Limited,
PO Box 31-310, Lower Hutt NZ
Phone +64-4-569 0511.*

VIC

Gravitational Lensing: Using Distortions to Map the Universe

The Victorian Branch started the year with a talk on "Gravitational Lensing", by Dr Rachel Webster from the School of Physics, University of Melbourne. Dr Webster began by showing some remarkable images of gravitationally lensed objects obtained with the Hubble Space Telescope, including an Einstein Cross arising from the gravitational lensing of the quasar Q2237+031 and multiple arclets produced by the cluster Abell 2218.

Following this introduction Dr Webster presented the audience with a useful overview of the salient theory of gravitational lensing. It is well known that Einstein's general theory of relativity predicts that the path of light is bent as it passes near a massive object. This remarkable prediction was first confirmed by Arthur Eddington in 1919, in which the bending of starlight was measured during a solar eclipse. In 1937 Fritz Zwicky proposed that light passing through the curved spacetime produced by a massive object (such as a galaxy) could produce multiple images of the source. The first gravitational lens (of the quasar Q0957+561) was discovered in 1979.

Many of the features of a gravitational lens can be simulated by the normal refraction of light by an appropriately shaped glass lens, a fact that Dr Webster exploited to great effect during the talk, in which she produced multiple images of numerous sources, including the exotic "kangaroo source". One particularly interesting image discussed by Dr Webster is the Einstein Ring. This phenomenon was predicted by Einstein in 1936, and arises when the source (e.g., a quasar or galaxy) lies along the line of sight to the lensing mass. Einstein Rings have been observed with radio galaxies (e.g., MG1131+0456) as well as imaged optically. Since the angular radius of an Einstein ring is proportional to the square root of the lensing mass, measurements of the former can be used to deduce the amount of dark matter in a galaxy or cluster of galaxies.

The remainder of the talk was devoted to showing how gravitational lensing can be used to address important questions in cosmology. For example, the ultimate fate of the Universe depends on its average mass density. If the mass density equals a critical value, the Universe is flat and will just (barely) continue to expand forever. However, present observational data is unable to decide whether the Universe is open or closed. There does not appear to be enough matter to deduce that the Universe is closed; nevertheless the known mass is only a few percent of the critical density. The fact that over 90% of matter in the Universe is not luminous suggests that there must be a lot of unobserved dark matter. Gravitational lensing can be used to detect the presence of dark matter by

exploiting the distortions in spacetime produced by the invisible matter source. These distortions depend only on the mass of the dark matter and are insensitive to its composition, whether it be cold dark matter (e.g., weakly interacting massive particles, WIMPS) or hot dark matter (e.g., massive neutrinos). It has been conjectured that this dark matter lurks in the "halos" of galaxies. However, Dr Webster showed that studies of gravitational microlensing of stars in the Large Magellanic Cloud by MACHOs (massive compact halo objects) can only account for about 19% of the mass of our Milky Way. Clearly there are significant unresolved problems in modern cosmology!

In conclusion, Dr Webster's engaging talk communicated the sense of wonder and excitement experienced by contemporary astronomers in their search for a deeper understanding of our physical Universe. However, as Dr Webster pointed out, this search is not just confined to astronomers. Poets too have contemplated the ultimate fate of the Universe. In the words of Robert Frost:

Some say the world will end in fire,
Some say in ice.
From what I've tasted of desire
I hold with those who favor fire.
But if it had to perish twice,
I think I know enough of hate
To know that for destruction ice
Is also great
And would suffice.

*Michael J. Morgan,
Department of Physics,
Monash University.*

APOLOGY TO NEW ZEALAND SUBSCRIBERS

Due to an unfortunate oversight by the new management team, copies of the January/February issue of the *Physicist* were not supplied to New Zealand readers along with the others.

We apologize profusely for this mistake.

Copies of that issue will be mailed along with the March/April issue to our loyal subscribers in NZ.

OBITUARY

EUGENE P. BASHKIN

1952-1997

The Australian and International physics communities were shocked and saddened by the unexpected death of Eugene Bashkin on 2 December 1997. It is a mark of his great courage and strength of character that he kept the serious nature of his illness from all but his immediate family and one or two of his closest colleagues even to the end. The suddenness of that end, when it came, heightened the sense of loss for all who had known him. The Australian physics community lost a very bright star before we really got to know him.

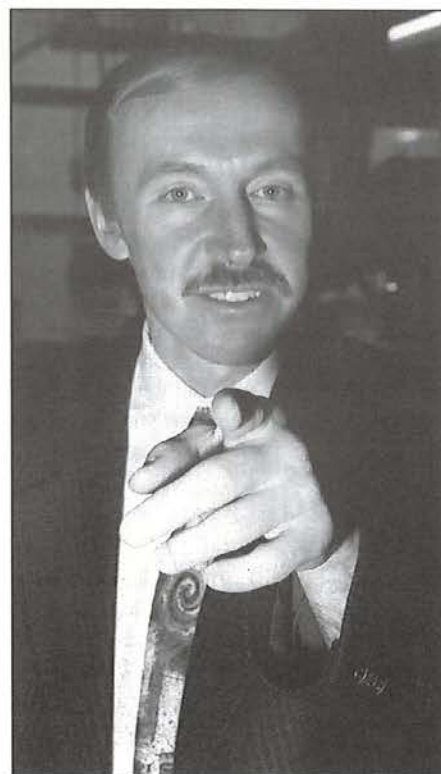
Bashkin took the Chair of Theoretical Physics at the University of Western Australia in August 1995, joining us from the University of Marburg where he was a DFG Research Professor (1994-5). He had earlier held faculty positions at the University of Cologne (1989-92) and Visiting Professorships at the University of Minnesota (1990) and Pennsylvania State University (1993).

When Eugene came to Perth in 1994 as a candidate for the Chair, his invited talk marked him out as a scientist of unique imagination and insight. His recounting of the story of weakly damped spin waves and long range magnetic correlations existing in a dilute paramagnetic gas took those of the audience who were not working in the field by complete surprise. It was clear that here was a physicist of special vision, telling us of a completely new field.

Eugene Bashkin was born in 1952 in the city of Omsk in Western Siberia. After earning his Diploma with honours from the Moscow Physical and Technical Institute in 1975 and his Ph.D. at the Kapitza Institute for Physical Problems in 1978, he was for the next seven years a Research Scientist at the Soviet Bureau of Standards where he headed a theoretical group. During this period he received the honour of the Moscow Lenin Komsomol Prize for the best work

in physics for 1981. Between 1986 and 1989 he was Professor of Physics at the Kapitza Institute.

Eugene had his first opportunity of travelling outside the Eastern Bloc in 1986. His first experience in the West is the stuff of legends and one recalls clearly his hilarious account of it on first meeting him at the International Conference on Recent Progress in Many-Body Theories in Oulu, Finland in 1987. He and Russian Academician Professor Lev Pitaevskii had permission to travel to Rio de Janeiro. In the best touristic tradition, and still dressed in their eastern bloc suits, they headed directly from the airport to Copacabana Beach. They were surveying its wonders when, as Eugene recounted, a strange flapping noise was heard and a shadow obscured the sun. After that he remembered nothing. When they came to, they were without money or documents. On their first day in the West they had been robbed by a hang-glider mugger. Needless to say they reported all this to the Brazilian police who promptly arrested them for lack of identification. They spent their first night in the West in a Brazilian jail before being released the next day. The story was told with a great flair, with a strong sense of irony, and in a distinctive yet fluent English. Both Eugene's work and his charisma made him a great hit at that meeting and he made many friends.



Eugene Bashkin

In 1987 travel restrictions for Soviet scientists were lifted. Free at last to travel, Eugene seized the many opportunities. His work was already well-known in the West and he received many invitations from all over the world. In all he lectured in about 25 countries outside the former Soviet Union. As was characteristic of the man, he revelled in the opportunities for total immersion in new places and new cultures, and the exposure to new ideas and new ways of looking at things. He was deeply interested in multi-culturalism and geography in the broadest senses.

Bashkin was undoubtedly an accomplished physicist with skills and insights in the very best Russian tradition. As Professor at the Kapitza Institute he ran a special course entitled "Solving Physical Problems in Condensed Matter and Nuclear Physics". The course met over a full day once a week. What made it different was that the "sacrificial" professor had to solve on his feet any problem a student in the course cared to bring along. Eugene revelled in challenges like that. But he had something more. A special approach, a special ingenuity, an infectious joy. Bashkin's approach to

physics was in spirit straight from the great Russian theoretical physicist Lev Landau. He did not rely on detailed models nor on tour de force formalisms. He shot instead straight for the heart of the physical mechanism.

There is a strong unifying thread in Bashkin's most significant works. He sought out collective, macroscopic quantum effects in unlikely places, where conventional intuition would dismiss the possibility. For example, one thinks of a dilute Boltzmann gas of particles with short-range interactions as the epitome of a classical system, yet in 1981 Eugene predicted the existence of long-lived macroscopic quantum spin waves in dilute paramagnetic gases [1], a prediction which was initially greeted with a great deal of skepticism. However Eugene was always meticulous in devising experimental ways of detecting his novel predictions, and in 1984 there were experimental confirmations by groups at Cornell University and the Paris Ecole Normale in gases of electron-polarised atomic hydrogen and nuclear-polarised helium-3. Bashkin can rightly be identified as the founder of a new field of physics, Semiquantum systems [2].

Upon taking the Chair in Perth, Eugene began to assemble a powerful group of theoretical physicists concerned with quantum many-body physics. In the best scientific tradition, any new insight which might lead to some exciting new macroscopic phenomena was subject to the question of experimental observation and study. His impact was therefore felt not only by those theoreticians working on the development of his ideas but also by those experimentalists ready to respond to entirely new challenges.

Bashkin took great delight that his predictions so often went against intuition. At the last meeting he attended,

the Many-Body Physics workshop he organised at UWA in August, 1997 he was brimming over with boyish delight that his recent results with Heidi Reinholz of UWA appeared at first sight so surprising. "You'll see we are right", he said with the broadest of grins. Bashkin and Reinholz were working on a proposal that a charge density wave can form in a weakly ionised alkali-atom plasma [3]. The driving mechanism is the short-range interaction acting between the electrons and point defects. Eugene was also working at UWA on the idea of quantum refraction of the wave function of the particles in a atomic or electron beam passing through a semiquantum system, and was trying to describe its effect on each particle by an effective mean field [4]. Based on some of his earlier work, Bashkin and a post-graduate student John Wojdylo were looking at the dimerisation of helium-3 atoms in a thin helium-4 film and in dilute mixtures of helium-3 and helium-4 trapped in narrow channels. With Alexei Vagov of UWA, Bashkin was developing a theory of stratification in multicomponent Bose-Einstein condensates of interacting particles [5], where the components can be different atomic species or even different hyperfine states for a single atomic species.

Eugene Bashkin was characteristically excited about moving to Perth. He felt that he had found the right place, a new home, a place to settle down with his wife Mila and daughter Olga. He confided upon returning from one overseas trip that, as the aircraft began its final descent into Perth, he felt that he was coming home. At the 1996 AIP National Congress in Hobart, he took time out to visit Bruny Island. The silent beauty of that place in mid-winter captured his imagination and he was heard to claim that he had found the perfect location for

his retirement dacha.

He had a vision for UWA as a base upon which he could create a genuinely new centre of study in his own unique style. As an instinctive multi-culturalist he was sensitive about building up the centre within an Australian culture. He said he had no interest in creating a first-class Russian physics colony in the western reaches of Australia. The distinctive theoretical physics program he had started to build up in Perth with such energy and discipline reflected some of the special qualities of the man.

And almost before we knew that Eugene Bashkin was here in Australia, he was gone again. His early death is a deep loss to future Australian physics.

-
- [1] E.P. Bashkin, Spin waves in polarized paramagnetic gases, *Sov. Phys. JETP Lett.* 33, 8 (1981). [2] E.P. Bashkin, *Semiquantum Systems: From Supertransport to Giant Opalescence* (World Scientific, Singapore, 1998), in press. [3] E.P. Bashkin, Charge density waves and related structural transformations in conducting media, in *Condensed Matter Theories*, Vol. 9, ed. J.W. Clark, K.A. Shoaib, and A. Sadiq (Nova, New York, 1994), p. 211. [4] E.P. Bashkin and S.B. Stepaniants, *Phys. Rev. B* 51, 3058 (1995). [5] E.P. Bashkin and A. Vagov, Instability and stratification of a two-component Bose-Einstein condensate in a trapped ultracold gas, *Phys. Rev. B* 56, 6207 (1997).

Cyril Edwards (Perth) David Neilson



OBITUARY

CHRISTOPHER JOHN MILNER

1912-1998

Christopher John Milner, known as Kit to his friends and colleagues, passed away in Sydney on 20th February, 1998 at age 85 after a brief illness.

He was born in England, into an academic family. His father Professor S.R. Milner, was a Fellow of the Royal Society and Head of the Department of Physics at the University of Sheffield. His mother also had a science background having met her husband while both were studying at Bristol University. Kit gained both his first degree and doctorate from the University of Cambridge, where he worked in both Cavendish and Mond Laboratories supervised principally by the eminent Russian physicist Pyotr Kapiza and after Kapitza's failure to return from his annual visit to Russia in 1936, by Sir John Cockcroft and Lord Rutherford himself. His PhD concerned the magneto-resistance of metals at very low temperatures. After graduation in 1936, he pursued an unconventional career for the time, turning his back on academic laboratories and joining the research and development arm of British Thomson - Houston Company. Here he worked in the rapidly growing electronics area. At the outbreak of war, linkages were established between all research labs, both academic and industrial, to facilitate the war-effort and Milner with his good friend and colleague at BHT, Dennis Gabor (later FRS and 1980 Nobel Laureate in Physics) moved into microwave research which contributed to the successful British development of radar. The BTH group teamed with Professor (later Sir) Mark Oliphant, then at Birmingham University, to develop magnetrons and klystrons. In 1944, Kit was sent to the United States on an industrial collaboration mission, but was diverted to be one of 5 British industrial scientists seconded to the "Manhattan Project" in California, where Oliphant was already established. He joined the

team under Prof. Ernest Lawrence at UC Berkeley in the Radiation Laboratory where he contributed to the development of high-current electron beams for the large cyclotron under development. The subsequent applications of this work were only really seen in linear accelerator research many decades later. After the war he rose to head the Physics Section of the BTH labs, where he took pride in his ability to harmonise relations and output from both physicists and engineers - no mean feat when he himself acknowledged that "physicists only really get excited about something when it concerns uncertainty about something quite fundamental. Engineers are the exact opposite - the less certain they are about the fundamentals the less happy they are to undertake anything!".

From British Thomson-Houston Research Laboratories, Kit was recruited by the University of New South Wales, then the New South Wales University of Technology, to take up the Chair of Applied Physics, an important title to him. He arrived in Australia in October 1952 and set himself with characteristic enthusiasm and energy, to develop a modern Physics School, albeit initially in inadequate and unsuitable accommodation at Sydney Technical College in Ultimo. In 1953 the School of Applied Physics, of which he became Head, contained 15 academic staff. Gordon Godfrey was Associate Professor heading the theoretical physics side and there were 5 senior lecturers and nine lecturers. Research was initiated in the areas of nuclear magnetic resonance, X-ray diffraction and acoustics. Kit worked energetically for the establishment of workshop and other facilities need for physics research.



Kit Milner

By 1955 the School of Applied Physics had moved to the new Kensington Campus and was one of the first units to occupy the first permanent building, now known, unpoetically, as the Old Main Building. The school was starting to grow in size and space remained a serious problem. To add to the problems of those early years a severe windstorm in 1956 blew off part of the roof and some damage occurred to equipment and personal materials. The following year a fire caused further damage.

Around 1960 the University introduced a broad-based science course to complement the professional or semi-professional degree programs in existence. The School, now renamed the School of Physics, was still growing with now some 25 academic staff. In 1963 a second chair was filled, by the late E.P. George and the school was well on the way to becoming a significant modern School of Physics. Kit served as Head of the School from 1952 to 1967, during this period of growth and development. In 1967 a separate School of Applied Physics and Optometry was created, with Kit Milner as Head. While the paths of the two Schools diverged somewhat, constructive relations and interactions were continued. It was always Kit's view that the education and preparation of students was the same, whether in Applied or Pure Physics, it would be the temperament and choice of the student which would determine the

career direction.

Kit's role in the University itself, during its period of childhood and adolescence, was also substantial. He served as Dean of the Faculty of Science between 1956 and 1958 and subsequently as Acting Dean on several occasions. He played a major role in the development of Optometry which has been acknowledged by the University and by the Australian Optometrical Association through an Honorary Life Membership. On his retirement from the University in 1976 Optometry became a School in its own right while Applied Physics rejoined the School of Physics as a Department.

Kit Milner thought of himself very much as an applied physicist. Such time as he had at UNSW for research was primarily concerned with road safety research : vehicle guidance and control using Doppler-radar techniques and collision-warning devices. He developed a night

driving simulator to attack problems of drivers falling asleep at the wheel and pursued this project actively after his retirement. He also developed computer simulations for collision evaluation and became an enthusiastic internet user in the last year of his life. He also led a major project in the 1950's in the construction of a solar furnace to achieve temperature approaching 4000 degrees Celsius for high temperature materials research. This was a large structure, prominent on the Kensington campus for many years.

He was a sincere, quiet man with extremely high personal standards of integrity and ethics. He was courteous in argument and willing to listen to others but could be tenacious in holding to his considered views, even if unpopular. It is said that discussions at staff meetings were often vigorous. He took a keen interest in students, often asking about

progress and offering words of encouragement. He took a special pride in delivering first-year lectures himself, believing it to be an important responsibility of a University Professor - a tradition which is continued today in the School. He did not, himself, supervise a large number of PhD students at UNSW but those who were fortunate to work with him were well taught and have gone on to positions of leadership in many fields, in both Australia, the Pacific and South-East Asia. He was a fine scientist, a scholar and a gentleman, in the best sense of those words and one of the people who helped build UNSW. He will be remembered with fondness and respect!

(Compiled by J. Oitmaa, current Head of the School of Physics at UNSW, with input from numerous personal and archived sources).

THIS MONTH'S FRONT COVER

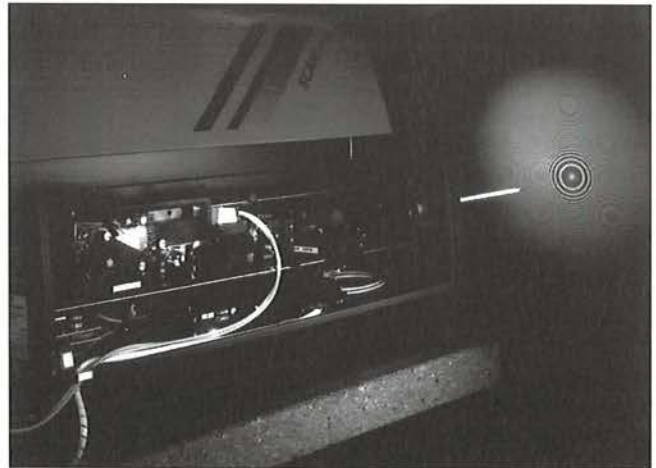
The Optical Parametric Oscillator (OPO), is a source of broadly tunable coherent radiation, which allows experimenters to access wavelengths from the UV to the NIR.

Recently Lambda Physik has released the ScanMate Optical Parametric Power Amplifier, or SMOPPA.

The SMOPPA contains an etalon narrowed dye oscillator (the yellow glow to the left side of the picture), which is used to injection seed the OPA cavity which includes two non-linear BBO crystals. A beam-expanding telescope matches the dye oscillator output to the pump volume of the first BBO crystal.

An injection seeded pulsed Nd:YAG laser such as the Coherent Laser Group "Infinity" or the Quantel "YG" series operating at 355nm is required as the pumping source. This pump beam is split in two with one arm being used to pump the dye oscillator while the other travels via an optical delay line to pump the two BBO crystals contained in the OPA cavity.

The linewidth of the SMOPPA is limited by that of the pump laser. Optically pumping with a seeded Nd:YAG laser the linewidth of the SMOPPA including etalon is $< 0.03\text{cm}^{-1}$.



The ultra-narrow linewidth of the SMOPPA is demonstrated on this month's front cover in the form of interference fringes produced with the aid of a monitor etalon.

The new Lambda Physik, SMOPPA offers wavelength tunability from 410 to 2500nm. Second harmonic generation of the output provides extended wavelength coverage down to 205nm. An extension out to 5microns is also available making the SMOPPA the most flexible system currently available.

For further information, please contact Andrew Masters or Teresa Rosenzweig at Coherent Scientific
Ph : (08) 8352 1111, fax : (08) 8352 2020,
email : andrew@cohsci.com.au

REVIEWS

Prompt Critical

A Questioning Attitude Toward Proclaimed Risks

A beguiling collection of essays titled "What Risk?" investigates the actual, rather than perceived, dangers from some of the headline-grabbing incidents of recent times. They are examined from the standpoints of science, politics and public health by analysts critical of the distortions that have led to public fears that could, and should, have been avoided. The editor, Roger Bate, is Director of the European Science and Environment Forum which he helped found in 1994 to provide an independent voice to the media on the scientific aspects of many issues plagued by misinformation, often wilful, from vested interests and pressure groups. I was first attracted to Z Jaworowski's chapter on "Beneficial Ionising Radiation" which is an up-to-date review of the subject emphasising the evidence for hormesis effects, which have long been evident in the Japanese A-bomb survivors, and their relevance to the health of Chernobyl victims. Their forced evacuation and relocation may have caused more harm than the radiation. Another case study of low dose risks is the chapter by Fournier and Efthymiou on asbestos and its link to lung disease. The authors are scathing about the methodology of epidemiologists "publishing in medicine that which is medical nonsense." The science (or lack of it) behind the benzene and dioxin scares is questioned by Munby and Weedman and Muller respectively in chapters assembling all available evidence to show that alarm was quite unjustified in both cases. For the dreaded dioxins, no deaths have been attributed to dioxin poisoning among the thousands exposed at the

Seveso and Midland (Dow Chemicals) accidents. "What Risk" contains a wealth of thought-provoking material on all aspects of each topic from politics (blame avoidance) to public perception (acceptance of motoring risks far worse than dioxin or radiation dangers). This is a book that should be in all serious library collections to provide a refreshing balance on many scientific issues where the debate has been seriously distorted. It is published by Butterworth-Heinemann, costs A\$80.00 for 350 pages hardbound and has the ISBN 0-7506-3810-9.

Colin Keay Reviews Editor

Reviews

The Infamous Boundary

D. Wick
Copernicus (Springer-Verlag),
New York NY 1995
xvii + 310 pp, DM 34 (paperback)
ISBN 0-387-94726-4

Subtitled "Seven Decades of Heresy in Quantum Physics", this is yet another attempt to explain to the layman the "paradoxes" of quantum physics: wave particle duality, EPR and so on, and to lament the fact that they still do not possess explanations which make intuitive sense. It retraces in agonising detail the history of ideas with all the false steps (and heresies) along the way, ending up with no conclusion other than a lame invitation to the reader to do better. There is a mathematical appendix by William Faris which attempts to explain the concept of probability in Quantum Mechanics. It makes sense to those who know it already but would be incomprehensible to those who don't. There are quite a few good books on the subject; this isn't one of them.

Tony Klein

School of Physics University of Melbourne

Chemical Applications of Density Functional Theory

B B Laird, R B Ross and T Ziegler (eds)
American Chemical Society,
Washington DC 1996
x + 478pp, \$US 126.95 (hardcover).
ISBN 0-8412-3403-5

Density functional theory (DFT) consists, in practice, of a suite of approximate methods for solving interacting many-body problems. Examples include the electronic correlation problem in chemistry and solid-state physics, and the problem of predicting the structure of

classical liquids starting from the intermolecular forces. For physicists, particularly theorists, working in these areas some knowledge of DFT is essential.

This volume deals mainly with electronic density functionals for chemical applications, and with the classical liquid problem, including polymeric liquids. The liquids area is clearly of interest to physicists. The quantum chemistry sections of the book are quite possibly of less interest to many readers of this journal. At the very least the molecular examples discussed are useful test cases for DFT because in many cases more accurate methods (e.g. configuration interaction) can provide benchmarks.

This is in contrast to solid-state calculations where DFT is often the only practical approach to the correlation problem because other methods cannot cope with the large number of electrons. Thus condensed matter physicists will do well to note the successes and failures of DFT as documented for molecules in this volume. Furthermore some contributions treat topics of direct solid state interest, including surfaces, intermetallics and metal clusters, and the prediction of NMR parameters.

The general emphasis of the book is on applications of existing density functionals, rather than the development of improved functionals. Nevertheless most contributions include enough introductory material to ensure comfortable reading for those not already familiar with the relevant density functionals. In addition, there is a brief overview/introduction, and a good index. The price is not excessive for a specialized book of this size, a benefit presumably attributable to the nonprofit status of the publisher.

This book is clearly important reading for those with an interest in DFT per se. It is also recommended for those with a serious interest in the physics of fluids, polymers and their interfaces. Solid state and atomic/molecular physicists should also find some interest.

John Dobson

School of Science Griffith University

Electron Cyclotron Resonance Ion Sources and ECR Plasmas

R. Geller
IOP Publishing, Bristol 1996
xi + 434 pp., UK £99.50 (hardcover)
ISBN 0-7503-0107-4

The author suggests that this book should serve as a review of ECR Ion Sources and Plasmas and a reference for the field. From that vantage point he succeeds. I found the book laden with information which is not easy to understand and which, as the author states, is in many respects, non rigorous because of necessity of

Material for reviews should be handled in the following manner

Email your review as a plain ascii file without embedded codes (and not in LaTeX format) to:

phcslk@cc.newcastle.edu.au

Also snail-mail a paper copy to:

Dr Colin Keay
Reviews Editor
Physics Department
University of Newcastle
Callaghan NSW 2308

The snail-mail copy is essential for proof-reading, to ensure accurate mathematical formulae and correct punctuation.

dealing with non linear effects.

The author states that "specific, high-performance ion beams are extracted from specific high-performance plasmas" and then leads the reader through the argument that in order to obtain high performance ion beams one must understand, to a large extent, ECR plasma physics. He presents various ion source concepts and discusses confinement principles, properties of plasma frequency, particle scattering and collective effects.

A review of many types of ECR ion sources is provided with their advantages and disadvantages. It is in this respect the researcher interested in using an ERC ion source will probably find this book most useful because the author performs this task very well and provides many useful references.

As the book is fairly expensive, most scientists who are interested in the subject will only use the book through the means of a library.

Robert A Langley

*Physics Department University of Newcastle
(Visitor from Oak Ridge TN
bob_langley@compuserve.com)*

Constitutions of Matter: Mathematically Modelling the Most Everyday of Physical Phenomena

M H Krieger

University of Chicago Press, Chicago 1996
xxii + 343 pp., US\$65.00 (hardcover)
ISBN 0-226-45304-9

When we look at the way science (and the wickedness of physics in particular) is considered in a lot of the literature of sociology and the humanities these days, we should welcome any book that explains the flavour of complex ideas in mathematical physics to readers who have little training in advanced mathematics or physics. This genre of explanation is growing, and when successful, does the community of physicists and mathematicians a great service, connecting their thought a little more to the community in which they live. In judging such a book, we might prefer that it be well written and I think we should insist that it contain no real errors or misdirections.

Martin Krieger's "Constitutions of Matter" tries to be such a book, attempting to describe both the development of the idea that statistical mechanics does predict intensive thermodynamic variables and the various techniques that have been used to study the two dimensional Ising model in zero field. With the first topic, he is at great pains to develop the idea that thermodynamic quantities per unit volume of a sample of matter are independent of the shape

of the piece of matter. He picks up this theme in the later section, showing us how at the critical point, this shape independence property can fail. The Ising model section has a great deal of discussion of physical interpretations of solution techniques.

The book also contains reprints of Onsager's papers on how close ionic solution free energies are to electrostatic lower bounds deriving from simple charged hard sphere models of ions, and the celebrated 1944 solution of the Ising model. I think this book fails miserably both on the count of being well written and on the count of containing no misrepresentations. The first section describes the development of the Lebowitz and Lieb proof (and many of its antecedents) that canonical ensemble statistical mechanics predicts the existence of a limiting free energy density per unit volume for systems with electrostatic interactions. It presents this saga as a finished problem. But most physicists know that the response of dielectric materials to external fields is shape dependent. There is no proof yet of the way that such results can come out of statistical mechanics, and Krieger seems to ignore this interesting part of the problem. The field dependent bounds developed by Onsager in his paper may well contribute to the solution of that problem, but it was simpler theorems on fields due to Newton that were crucial in the Lebowitz and Lieb proof.

Indeed, I could not see any proper connection of the first Onsager paper to the argument of the book unless the first part was misguided. The other problem I had with the first part (and much of the second part) was its mathematical notation. This was confused and messy, non-standard in many places and generally made reading difficult.

I found the part on two dimensional Ising model solution techniques very heavy going. These solutions are among the more challenging parts of mathematical physics. It is important to be able to generalise specific mathematical details with physical interpretations if we can, so that we may use the methods on more general models and theories. Krieger seemed to be trying to make the impression that it is useful to examine physical interpretations of the mathematics for just this purpose. Yet these techniques rarely generalise.

There are no similar solutions in external fields, or in higher finite dimensions. I think Krieger makes difficult theory harder to understand by his efforts. Not a good book, certainly not worth \$65, when a photocopier might generate reprints of the papers for you.

Edgar Smith

School of Mathematics La Trobe University

Fluid Physics for Oceanographers and Physicists

Samuel A Elder and Jerome Williams
Butterworth-Heinemann, Oxford 1996
xiii + 395pp., A65.00 (paperback)
ISBN 0-7506-2958-4

This is an excellent middle-level text in fluid mechanics for scientists and engineers. In these days of so-called relevance requirements for university subjects, it is useful to have texts which present basic principles in a way which takes the reader some way towards the applications areas. It is this reviewer's personal belief that the fluid state with its applications in meteorology, oceanography, medicine and health and engineering has been widely neglected by Physics Departments in Australia and New Zealand.

Here is a text book which deals with a broad base of fluid physics at post-first year level with an emphasis on the physical principles, and avoiding the need for prior knowledge of tensor or vector calculus required by the classic advanced reference texts of Pedlovsky or Batchelor. The vector analysis is carefully introduced and developed in a way comparable with the second-year treatment of electromagnetism which one would expect to find in physics programs.

This book covers the basics of fluid dynamics with reference to geophysical applications as its title suggests, but it also has sections on concepts like pipe flow and hydraulic jumps which one would normally find in an engineering text. One minor disappointment for this reviewer is the omission of the logarithmic velocity profile formulation, in the turbulent boundary layer section, in favour of the empirical power law; this does, however, illustrate that the authors have used practical examples and applications. The problems and worked examples at the end of each chapter are of a good second-year standard. It would be useful to students to have numerical answers to all questions instead of only the odd-numbered ones.

The strength of the book lies in its conceptual treatment and ideas, and is an ideal text book for undergraduates rather than a reference text for specialists in geophysical fluid dynamics. At a time when the *raison d'être* for Physics Departments is under scrutiny, this book is a welcome addition to the available texts. It is timely for physicists to present the common core of field physics in electromagnetism and fluid dynamics for physics and engineering undergraduates. I urge physics program designers to take this book seriously. If more people buy a copy, the authors may be able to purchase decent figure-drawing software to overcome the only really negative feature of the volume.

M L Heron

*School of Computer Science, Mathematics
and Physics James Cook University*

Unsolved Problems in Astrophysics

J N Bahcall and J P Ostriker (eds)
Princeton University Press, Princeton NJ 1997
xiv + 377 pp., US\$ 24.95 (paperback)
ISBN 0-691-01606-2

This book contains the talks presented at a conference held at the Institute for Advanced Study, Princeton, in 1995. The year coincided with the 60th birthday of John Bahcall and his 25th year as an IAS member. Although the editors claim that the book is not focused on anniversaries, the wide ranging topics covered in the 18 chapters correlate well with the areas of astrophysics one associates with John Bahcall.

The organisers of this conference asked the contributors to depart from the usual conference format and to write their articles at a level which would be accessible to a second year PhD student in search of a thesis topic. The articles assume that the reader has some background in astrophysics, but this is not a prerequisite. There are very helpful bibliographic notes on background material at the end of each article which should fill in most of the missing gaps.

The book is required reading for all thesis supervisors in the field of astrophysics, and should be consulted by beginning PhD students. It will also be of interest to physicists looking for new problems and challenges.

Agris Kalnajs
Mount Stromlo Observatory
Australian National University

summary of the cosmological questions for the VLT, followed by a description of the suite of instruments which will be available to users. The remainder of the book is dedicated to a categorised compendium of short papers. A number of these papers are from leading experts in various specialized fields of cosmology, reporting fascinating and important new results. As such, the book represents an invaluable resource to fellow specialists. However, the stated aim of the workshop (the 2nd in a series) and proceedings is to explore scientific opportunities for the VLT. The proceedings fail to do this adequately. Instead, the book is an ad hoc collection of scientific papers, as one would find in the proceedings of any typical cosmology conference. It is a pity that this is not a more coordinated, carefully thought-out, scientific report. By the time the VLT (and other forthcoming large telescopes) become fully operational, the Keck I 10m telescope will already have been in use for 5 years. Taking this into account, a more coherent format and contents of a book such as this would have first identified, at the fundamental level, but in detail, the most pressing remaining scientific issues concerning the Early Universe, of which there will be many, followed by sub-sections in which coordinated observational programs are laid out, the aim of which are to arrive at definitive solutions. Perhaps I expect too much.

John Webb
School of Physics
University of New South Wales

dosimeter because existing designs exhibit large discrepancies for the same exposure.

On this point personal models with built in microprocessor and software for the correction of response function for each particular instrument is a possible solution of this problem.

Many groups are developing neutron dosimeters utilising the superheated drop technique. This method of dosimetry offer a viable approach in mixed radiation fields and have recently become available for health physics applications.

Traditional research on solid state detectors for neutron dosimetry, such as TLD and track detectors, have brought new results. Polycarbonate track detectors are proving very useful for monitoring long term occupational exposure at high energy particle accelerators.

Special attention is given to neutron dosimetry in new radiation oncology modalities such as a fast neutron therapy, proton therapy and heavy ion therapy.

A new concept of microdosimetry is based on the recoil particle track chamber with optical readout of delta electrons along the track of secondary particle.

Extensive review papers are presented on dosimetry in boron neutron capture therapy and FNT. The challenge for modern particle therapy and radiation protection is a creation of instrumentation for nanodosimetry which really can predict RBE of the beam.

This book is useful for personnel of accelerator facilities and nuclear reactors who are involved in routine dosimetry and protection calculations, for scientists developing radiation instrumentation as well as for students doing courses in medical physics and health physics.

Anatoly Rosenfeld
Physics Department University of Wollongong

The Early Universe with the VLT

J Bergeron (ed)
Springer-Verlag, Berlin 1997
xxii + 435 pp., DM 48 (hardcover)
ISBN 3-540-62414-7

The VLT (Very Large Telescope) is an array of four 8.2m telescopes which will operate at one of the best astronomical observing sites on Earth, Cerro Paranal in the Atacama Desert in northern Chile, starting in 1998. The ESO (European Southern Observatory) telescopes are funded by a consortium of 8 European countries and managed from the ESO headquarters near Munich. In 1995, high level discussions/negotiations took place to debate ESO's invitation to Australia to become part of ESO. Ultimately, the Australian government declined to fund this participation, contrary to scientific advisors at the time, denying Australian astrophysicists a golden opportunity.

"The Early Universe with the VLT" is a compilation of papers presented orally and as posters at the ESO workshop held at Garching, Germany. The book begins with a brief

Neutron Dosimetry

H G Menzel, J-L Chartier, R Jahr and A Rannou (eds)
Nuclear Technology Publishing,
Ashford, Kent 1997
xvi + 585 pp., UK £97.00 (hardcover)
ISBN 1-870965-43-4

This book is a compilation of the papers devoted to advanced research in neutron dosimetry and its instrumentation for industrial, medical and health physics applications.

Important aspect of neutron dosimetry is correct information about the neutron KERMA factor for tissue equivalent material used for the phantoms and the walls of ionization chambers.

The review of new research in personal electronic neutron dosimeters deserves special attention. Most of these dosimeters are based on semiconductor detectors with different conversion and pulse shape analysis to cover a wide neutron energy range in a mixed radiation field. However more research should be done for the creation of small real-time personal neutron

Sensors Update

Baltes H, Gopel W and Hesse J (eds)
VCH Publishers, Weinheim 1996
xi + 236 pp., DM 348 (hardcover)
ISBN 3-527-29432-5

The topic of sensing and sensor systems has always been difficult to identify as a discipline. Almost every branch of science and engineering has its own preference when it comes to methodologies applied to sensing. The latter has been regarded negatively because sensing is a multidisciplinary activity and would probably never become a discipline in its own right. I, on the other hand, have always regarded the topic in a positive way because it brings people with a variety of expertise together. The Editors of the "Sensor Update", together with other colleagues, have shown to the world of

the rather fragmented discipline, how can one provide a unique resource for those in need of a comprehensive book on various techniques related to such a diverse topic.

Having covered in their previous nine volumes various topics in detail, the book under review provides an excellent summary of the leading edge technology commencing with materials and ending with a buyer's guide. In between, the authors have touched on the most recent developments in sensors and sensor systems covering acoustic sensors, image sensors, ANN-based chips and computers and pattern recognition. The current economic climate has exerted enormous pressure on researchers to do their best with low expenditure. In this respect, authors have not forgotten the need for system modelling and simulation with particular emphasis on microsystems – the Intelligent Technologies (IT) for the future.

Having collated such information and provided readers with material covering various disciplines of science and engineering is one thing, but to maintain the quality of the contents is another matter. "Sensors Update" is a book that has to be possessed by every research group who deals with multidisciplinary research. The individual contributors have covered their material in depth with high level of content integrity. They have also shown a broad breadth of research by including a comprehensive list of references, most of which have been recently published. In summary, if readers and researchers wish to stay within the leading edge of sensor and sensor systems for "Intelligent Technologies", then "Sensors Update" is one of the few available resource material that can make it happen. It is simply what I call "a quick reference library".

Noel Samaan
Microelectronics Centre
University of South Australia

Handbook of Microscopy

S. Amelinckx, D.van Dyck, J.van Landuyt, G van Tendeloo (eds)
VCH Publishers, Weinheim 1997
xxiv + 2355pp, DM 1197 (3 vols, hardcover)
Methods I, ISBN 3-527-29280-2
Methods II, ISBN 3-527-29473-2
Applications, ISBN 3-527-29293-4

This is a great set of reference books, which deserves to be in every University library or central microscopy laboratory. One of the problems facing a beginning researcher is not knowing what microscopy technique is best suited to the problem at hand - often local equipment and techniques are used because of

ease of access rather than optimal suitability for purpose. The beauty of this reference set is that so many techniques are covered in sufficient depth so that a beginner or an expert in a different field of microscopy will have her/his appetite whetted. For those needing more detail each chapter is well referenced and there is also a very good end section to each volume listing general reading (ie, recent relevant texts dedicated to particular topics).

The first two volumes of the set are dedicated to logically grouped "methods", covering all the well-known microscopies and many which deserve to be better known. I found the section on X-ray microscopy very interesting reading even though there was no mention that I could find of the exciting work in this field by Steve Wilkins et al from CSIRO in Melbourne. A common problem with this and many other multi-author volumes is that they can quickly become somewhat dated.

The third volume covers "applications" and is the best of the set. The chapter on microscopy of rocks and minerals for example provides a good overview of this area of study and the usefulness of the different microscopy techniques. The authors are in no doubt as to the difficulty of the task of attempting to draw together a body of knowledge and put it into the context of the series title. The author of the application chapter on the structure of polymers notes the proposition of writing a short chapter "is a task like that of Sisyphus". Nonetheless, reviewing the set over Christmas, I welcomed the Orphean break. I think the series succeeds and is well worth the cost.

A R Moon
Faculty of Science
University of Technology, Sydney

Acceptability of Risk from Radiation - Application to Human Space Flight

Proceedings of Symposium held Virginia May 29 1996. US National Council of Radiation Protection and Measurements (NCRP) Bethesda, MD, USA 1994
vi + 197pp., US\$30 (paperback)

This seminar was a result of a request from NASA for NCRP to provide guidance on acceptable limits for ionising radiation exposure during space flights, particularly for interplanetary missions. The proceedings contain papers on the physical properties of radiation in space, biological effects, ethical issues, acceptability of risk and the views of the astronauts.

The wide ranging expertise of the participants makes the discussions following the papers particularly interesting and relevant.

Radiation doses in space are primarily due to

protons and heavy ions. In low earth orbits, the main contributor to radiation dose is trapped belt radiation, which can produce dose rates as high as 1.5 mSv/d. Over one year in the Mir Space Station, a crew member could receive 550 mSv, which is considerably higher than the radiation worker limit of 20 mSv/y. For interplanetary missions, doses are received from galactic cosmic rays (150 mSv/y at solar maximum and 580 mSv/y at solar minimum) and solar particle events (doses can exceed 1 Sv per event). Even with shielded shelters (10 cm aluminium), a 2 to 5 year trip to Mars could yield total doses as high as 4 Sv.

Participants at the seminar compared the risk from radiation exposure with other risks faced by astronauts. There seemed to be a general consensus that the relatively large risks associated with space missions was no justification for not reducing the accompanying radiation doses. Other issues discussed were the problems of informed consent in a situation where astronauts will volunteer for tests and accept risks if they perceive it increases their chance of a flight, and the implications for the astronauts of the delayed potential consequences of radiation exposure.

This book provides a clear description of the issues and dilemmas associated with setting radiation exposure limits for inherently dangerous occupations like space flight. There is no simple solution; as Dale Moeller said in his summary, the determination of an acceptable limit must involve a careful weighting of the risks and the benefits.

John Harries
ANSTO Lucas Heights

The Theory of Superconductivity in High-Tc Cuprates

P. W. Anderson
Princeton University Press,
Princeton, NJ 1997
446 pages, US\$ 49.50 (hardcover)
ISBN 0-691-04365-5

P. W. Anderson, joint winner of the 1977 Nobel prize for physics, has been a dominant figure in theoretical condensed-matter physics for over 40 years. In his book entitled "The theory of superconductivity in high-Tc cuprates", he outlines one possible direction in which to start out with a theory for high-temperature superconductors (HTS). Despite more than 10 years of intensive research, there is no agreed theory of HTS.

Anderson's book is based on a series of informal lectures, and almost half the book is supplemented by a collection of published and submitted papers. While theory is the main theme, Anderson also reviews many of the

puzzling experimental data on HTS, which are of particular importance in order to assess the validity of any new theory. Anderson argues that because of the highly two-dimensional nature of the cuprates with their CuO₂ planes and the strong repulsive interactions, electrons no longer exist in a conventional Fermi-liquid state. Instead, electrons behave as a tomographic Luttinger liquid where spin and charge are carried by different types of excitation. While the transport of electrons between neighbouring planes is blocked in the non-superconducting state, when Cooper pairs form, pair tunneling between planes set in, creating the superconducting condensate. Anderson admits that the present theory does not claim yet to be comprehensive, but merely not to be inconsistent with the many otherwise puzzling experimental anomalies.

The book will probably provide frustrating reading for students and newcomers in the field, as Anderson, though his style is chatty and informal, assumes familiarity with difficult concepts of condensed matter physics. However, for those involved in HTS theories, this book is more than worth reading, particularly because of the freshness and vitality of his approach.

Karl-Heinz Muller
CSIRO, Division of Telecommunications and Industrial Physics

QCD and Collider Physics

P.K. Ellis, W.J. Stirling and B.R. Webber
Cambridge University Press,
Cambridge 1996
xiv + 435 pp., UK £80.00 (hardcover)
ISBN 0-521-58189-3

The book "QCD and Collider Physics" is written by three well known experts in the area of Quantum Chromodynamics (QCD). In this book the authors comprehensively summarize the experimental state of collider physics. The theoretical foundation, concepts and tools for explaining experimental results are introduced in a clear way. In the first two chapters the authors introduce QCD, which is believed to be the theory for strong interactions. To support this belief the authors then confront theoretical predictions with data from experiments performed at various types of colliders. An overall agreement is found, but certain problems still remain, which are pointed out and discussed in some detail. The theoretical predictions are not only simply presented, but also explained with theoretical depth. The most recent developments in the application of QCD, like heavy quark theory, quarkonium physics, etc. are also well discussed in this book. Some problems are formulated in a new

way. One example is the introduction of the parton model with the diagrammatic expansion method of presentation. Besides the main treatment on the subjects in QCD, the authors also spend three chapters to discuss the electroweak interaction and especially the possible discovery of the Higgs boson at colliders, which is an important ingredient in the standard model. For beginners it is an excellent book to start to study QCD and relevant subjects. However, it is also a good reference book for researchers in the area. For researchers in other areas of high energy physics this book will help them to follow the track of developments in this field.

J P Ma
School of Physics
University of Melbourne

Computational Physics: Problem Solving with Computers

R H Landau & M J Paez
John Wiley & Sons, New York, 1997
xxviii + 520pp., A\$132.95 (hardcover)
ISBN 0-471-11590-8

It seems that each year there is another computational physics book released onto the market and teachers of computational physics look to see whether the new release better suits their needs. Unfortunately, I must say I was disappointed by this book. The area of computing is more argued about than any other in physics, for little or no gain. In other areas of physics the standard textbooks of classical and quantum mechanics largely determine the way those areas are taught at the undergraduate level. This is evidence for a consensus as to the fundamental concepts which students must have. No such consensus exists in the teaching of computational physics. Indeed it is even suggested that computational physics should not be taught, but the skills acquired as and when needed, like laboratory skills in other areas of physics. As a teacher of computational physics I cannot agree, but the argument is not entirely without merit.

The lack of a consensus in teaching computational physics stems in part from a lack of consensus in computing in general. What brand and architecture of computer should be used? What operating system and language should be used? The weakness of this book is that it tries to be everything to everyone, by covering every possible option. In doing so it becomes a collection of computing exercises with no common theme other than physics. It does not even present numerical methods in a unified framework. It is not a book I would recommend to students but it may have some role as

a teaching resource. The wide variety of applications may contain some which would enrich existing computational physics units.

G. P. Morris
School of Physics
University of New South Wales

Californium-252 Isotope for 21st Century Radiotherapy

J C Wierzbicki (ed.)
Kluwer Academic Publishers, Dordrecht 1996
xxi + 300pp., A\$170 (hardcover)
ISBN 0-7923-4543-6

Brachytherapy is the use of sealed radioactive sources to treat cancer, usually by interstitial, intracavitary or surface application. Most commonly used brachytherapy sources are gamma emitters, but there are advantages to brachytherapy by neutron emitters such as Californium-252, particularly on radioresistant and hypoxic (poorly oxygenated) tumours.

Californium-252 is produced by only two reactors in the world (Russia and USA) and is in clinical use in a handful of radiotherapy centres. It has a relatively short half life (2.65 years) making it an expensive prospect for brachytherapy.

This book comprises the proceedings of the NATO Advanced Research on Californium-252, in Detroit, USA, 1996. It is fairly evenly divided between physics (Physics and Dosimetry of Cf-252, Brachytherapy planning with the isotope and Monte Carlo studies) and medical (clinical use for various cancers and sarcomas) papers. The physics half of the book includes contributions from around the world, including one from St George Hospital in Sydney, and gives a reasonable overview of the isotope and its dosimetry. Papers on the Russian Cf-252 source delivery system are interesting as are the papers on Monte Carlo predictions of neutron dose to the tumour and surrounding tissues.

Interest in the book is probably limited to researchers specialising in neutron therapy and brachytherapy. Until Californium-252 is more commonly available, and more clinically relevant trials have been conducted, this book will be of little interest to Radiation Oncology Physicists and Clinicians. Ten years from now, though, the Proceedings of the 2006 Californium-252 NATO Workshop may be required reading.

P. M. Ostwald
Medical Physics Department
Newcastle Mater Hospital.

The Quark Machines: How Europe fought the particle physics war.

G Fraser

IOP Publishing, Bristol 1997
viii + 210 pp., US\$20 (paperback)
ISBN 0-7503-0447-2

This book tells the fascinating story of the rivalry between America and Europe for pre-eminence in building high-energy accelerators, with Nobel Prizes as the stake. It is written by Gordon Fraser, who has been editor of the 'CERN Courier' for the last eighteen years, and has seen the battles at first hand.

The outline of the tale is well known. It begins with Ernest Rutherford, and the era of 'string and sealing wax' experiments at the Cavendish Laboratory. Ernest Lawrence then captured the lead for America with his invention of the cyclotron, and the US was able to hold on to this advantage for the next quarter of a century. Rutherford did not help the European cause with his opposition to these new-fangled and expensive machines.

After the Second World War, it was the US facilities such as the Bevatron at Berkeley, the Cosmotron and AGS at Brookhaven, and the Linear Accelerator at SLAC which captured the spoils for many years, discovering a rich harvest of nuclear and hadronic resonance states. Highlights included the discovery of the Omega-baryon at Brookhaven in 1964, which set the seal on the SU(3) symmetry scheme, and the discovery of deep-inelastic electron scattering at Stanford in 1969, which revealed the quark substructure of hadrons.

The core of the book deals with the building of CERN, which represented Europe's challenge to the dominance of the Americans. CERN is an institution of enormous importance, not only for its concrete scientific achievements, but as a flagship of European unification. It was established at the same time as the first movements towards the political unification of Europe were taking place, around 1950, and one of the moving spirits was Denis de Rougemont, who was also a leading advocate of cultural and political unification. On the purely scientific side, leaders were Pierre Auger of France, Edoardo Amaldi of Italy, and Isidor Rabi from the United States, who gave much friendly impetus to the project.

The initial plans were ambitious, and called for Europe to leapfrog straight into the lead by building a proton synchrotron with a beam energy of 25 GeV, using the new principle of "strong focussing". A new laboratory was established at Geneva, and the new machine was duly completed in 1959, becoming the world's highest energy accelerator. Unfortunately, the instrumentation and experimental facilities to make use of the machine

were not ready at the same time; and it was the AGS at Brookhaven, not completed until six months later, which walked off with all the physics results. CERN was to spend most of the succeeding decade wallowing in the wake of the Americans. It gained a reputation for a precise and 'gold-plated' experimental approach, and became famous for the world's best physics cafeteria; but the Americans, with their expertise and their daring to cut corners, were always the first to the major prizes. The Europeans were becoming desperate to achieve a major breakthrough. Even the construction of the Intersecting Storage Rings (ISR), an amazing technical achievement which blazed a trail for future colliding-beam particle accelerators, did not seem to bring any huge new physical discoveries.

The tide finally turned in 1973, when "neutral current" interactions were first discovered in neutrino beam experiments using the giant bubble chamber Gargamelle. These results provided the first confirmation of the new electroweak theory of Weinberg and Salam, and were a major triumph for CERN. The laboratory's prestige was further cemented by the discovery of the W and Z bosons in 1982. The Europeans were now able to meet the Americans on equal terms in the high-energy physics arena.

The book is hardly one for the layman. It covers a great deal of territory, and yet manages to go into considerable detail. The author makes heroic efforts to explain the concepts in understandable language, but I feel that the man in the street would be simply overwhelmed by the profusion of detail. I would also have liked some more insight into the human side of the leading players, such as Edoardo Amaldi, John Adams or Carlo Rubbia. There are no revealing stories here, such as the one about the Nobel-Prize winning experimentalist who was discovered late one night urinating all over a spark chamber belonging to a rival experiment. But nevertheless, the saga is one that will fascinate any physicist, and should certainly be on the shelves of any library.

The focus nowadays is moving from rivalry towards co-operation between America and Europe. The rivalry has always been friendly, in fact, and there has always been a great deal of fruitful collaboration between the two camps; but with the enormous cost of new accelerators, and the rude shock caused by cancellation of the Supercollider (SSC) by Congress, co-operation has now become essential. The Large Hadron Collider (LHC) has been left as the only remaining ultra-high-energy project on the world horizon; and Japan, Russia, the US, Canada, India and Israel have all pledged to support it. We may hope that CERN, which has been a symbol of European co-operation, can now become a

flagship for world co-operation and unification as we enter the next millennium.

C.J. Hamer
School of Physics
University of NSW

Quantum Chromodynamics and the Pomeron

J. R. Forshaw and D. A. Ross
Cambridge University Press, Cambridge 1997
xv + 248pp, A\$54.95 (paperback)
ISBN 0-521-56880-3

The Pomeron is the particle you have when you don't have a particle. It grew out of Regge theory well over a decade before quantum chromodynamics arrived in the 1970s to provide us with a field theoretic explanation of the strong nuclear force. In quantum chromodynamics, the force between quarks is mediated by gluons. In Regge theory, interactions are mediated by effective particles, called Reggeons, which correspond to poles in the scattering amplitude expressed as a function in the complex angular momentum plane of the exchanged object. As such, Reggeons seem to live in a twilight zone between mathematical abstraction and physical reality. In proton-antiproton collider experiments in which the centre of mass energy is far greater than the momentum transfer (the Regge limit), collisions are dominated by the exchange of a Reggeon with the quantum numbers of the vacuum. This effective particle, called the Pomeron, is named for the Russian physicist Pomeranchuk who proposed its existence in 1958. With the arrival in recent years of particle accelerators capable of probing the Regge limit, there has been a resurgence of interest in understanding strong interactions in terms of Regge theory in a way consistent with quantum chromodynamics. This book is a step by step introduction to Pomerons which brings the reader up to the point of being able to confront contemporary research literature. Having said that, it should be made clear that this is no introductory text on quantum chromodynamics. A sound knowledge of quantum field theory and quantum chromodynamics is assumed, though the authors are careful to give references to appropriate pedagogical literature throughout the book. The authors start with a clear introduction to Regge theory aimed at, as they state in the preface, those of us 'who are too young to have met such material in graduate school'. In subsequent chapters a model Pomeron is derived from the Regge limit of perturbative quantum chromodynamics by summing ladder diagrams of gluon propagators in a leading logarithm approximation. The resulting perturbative Pomeron does not

initially agree closely with the observed Pomeron, and extensions which include further non-perturbative input into the model are discussed. In the final chapters, which assume of the reader a certain familiarity with hadronic scattering experiments, deep inelastic and diffractive scattering experiments are examined from a Pomeron perspective. The book contains a couple of features which I found most helpful. Firstly, each chapter concludes with a concise point-by-point summary which helps to reinforce and clarify the results covered in the chapter. Secondly, technical details such as frequently occurring mathematical techniques are conveniently summarised at the end of relevant chapters. As an added bonus, the book comes with its own World Wide Web page (<http://h2.ph.man.ac.uk/~forshaw/book.html>) listing the contents, publisher's ordering information and (in time, as they are discovered) misprints and corrections. In summary, this book is most suited to the practitioner of particle physics or field theory who wishes to be brought up to speed quickly and painlessly in one of the many facets of the theory of quark physics. Those embarking on the early stages of a career in particle physics may find working through the book a useful exercise which exposes them to and directs them towards discovering in the literature some of the basic concepts of the physics of quarks and gluons.

C. J. Burden

Department of Theoretical Physics, RSPSE
Australian National University

Time's Arrows and Quantum Measurement

L S Schulman

Cambridge University Press, Cambridge 1997
xviii + 346pp., A\$47.95 (paperback)
ISBN 0-521-56122-0

The first thing to say about this book is that it is original both in terms of its ideas and its presentation. Firstly the presentation is in a breezy and informal style. At places I found myself laughing out loud at some aside in the text which is bit of a surprise for a book whose main topic is statistical mechanics. If something is difficult, the author makes that explicit - there is no attempt to pretend, like some authors, "that all this is easy and if you don't understand it, reader, that is because you are not as smart as the author". A feature of the presentation is a Notes and Sources section at the end of each chapter. This provides a very useful and erudite short history of the topics in the chapter and a commentary on the References for the Chapter and is a mine of information and would be a great source of help for students.

The main idea of the book, which has been published in part in a long series of journal articles by the author, is also original. It is that the usual approaches to the arrow of time are flawed because they make some assumption about the "initial" conditions and therefore beg the question. The author's approach is to avoid this logical pitfall by using two-time boundary conditions, roughly speaking the state of the universe at two distant epochs. The arrow of time can then be tied up with Gold's idea of a cosmological arrow if the universe is expanding for at least part of the intervening time. The author is at pains to show that the observations in such a universe would correspond to our own impressions: that only the initial boundary condition is fixed.

The second part of the book is concerned with solving the measurement problem in quantum mechanics using the same two time boundary conditions. The measurement problem is why we never observe superpositions of states, for which the author adopts the vivid term of Griffiths: grotesque states. Basically, the solution is that there is a reasonable final boundary condition which ensures that grotesque states never occur. The final state influences the present because of the time symmetry of the theory. Even if you don't like the idea of time symmetry very much and even if you don't think there is a measurement problem in quantum mechanics, the book is well worth reading because it is enjoyable, for the novel ideas and insights about conventional thermodynamics, as a source of ideas that would be useful in teaching and because, possibly, the ideas will prove to be a significant advance in physics.

D J Miller

School of Physics
University of New South Wales

Astronomy Explained

Gerald North

Springer-Verlag, London 1997
xxii + 330pp., DM39 (paperback)
ISBN 3-540-76136-5

Many introductory astronomy books today abound with the spectacular space imagery that has been garnered from advanced spectral sensors. Most of these however, lack detail beyond descriptive text explaining the plethora of space objects. This current volume is a text book that proffers "a complete self-contained course". Orientation is toward both the interested amateur astronomer and the final year of high school in Britain. As such the chapter questions direct student preparation to sit the UK GCSE astronomy examination.

The list of topics is diverse and comprehensive, from simple celestial mechanics through

to cosmology with everything in between. With numbered sections generally independent of one another, the text is a good elementary reference with an excellent table of contents. Diagrams and photographs are black and white, with several sky shots taken by the author.

The coverage has a "dated" feel, with concentration on "classical" astronomical knowledge. In light of the widespread use of CCD cameras (amateurs included), it is really inadequate to devote only one page to these sensors. Other recent topics are dealt with similar curtness.

The writing covers a very large body of knowledge and the author is not always able to match this adequately. It was painful to read that the ozone layer (at 30 km) is part of the ionosphere (which even with the most ambitious stretching extends no lower than 60 km), to see an erroneous representation of the way debris might have spread around the Leonid meteoroid orbital path, and to learn that we need to know the Earth's mass to compute the mass of the Sun (only the orbital radius and period of the Earth are necessary).

Explanations are generally clear and in a conversational style, and the text could serve for a first year Arts-based astronomy course, supplemented by material from current popular astronomy magazines.

John A Kennewell

Learmonth Solar Observatory
IPS Radio and Space Services

Book Notices

States of Matter, States of Mind

A Barton

Institute of Physics Publishing, Bristol, 1997
xiv + 384 pp, UK £15 (paperback)
ISBN 0-7503-0418-9

This book falls between two or more stools. Anyone who hasn't understood physics and chemistry at school would be unlikely to get past the first two chapters - a laborious discussion of models and the language of science. The "simple" explanations given are not at all clear or accurate. Statements such as "an atom can be split into two waves, which can then recombine and interfere" are unfortunate.

In Physics, "states" has a clear meaning, but this book considers "states of matter" in quite a different sense, giving full range to the imagination. In this sense there is no limit to the number of possible states of matter, but how this is related to "states of mind" makes a rather meaningless title.

Information Dynamics and Open Systems

R S Ingarden, A Kossakowski & M Ohya
Kluwer Academic Publishers, Dordrecht 1997
ix + 307 pp, US \$ 154 (hardcover)

ISBN 0-7923-4473-1

This is a specialist book, and as the preface says it reflects mainly the interests and results of the authors. It is not a single text, as groups of chapters were written by different authors. Perhaps the most interesting part is the one devoted to the area of 'Information Dynamics' pioneered by M Ohya. More information about the field is available in an earlier book by Ohya, and in a new specialist journal "Open Systems and Information Dynamics" published by Kluwer.

The book is clearly aimed at the reference library market. The narrow choice of material, disjoint presentation and a high degree of specialisation make it unsuitable even for our larger universities.

Physically Speaking: A Dictionary of Quotations on Physics and Astronomy

C C Gaither & A E Cavazos-Gaither
Institute of Physics Publishing, Bristol 1997
xii + 492 pp., UK £19.95 (paperback)
ISBN 0-7503-0470-7

This thick paperback is true to title, except that it is a bit of a stretch to consider as quotations page-long humorous entries, such as "Capturing Lions" and "Is There a Santa Claus?" A strength of this collection is its emphasis on fun, while another is its excellent bibliography and two indices. It is an entertaining volume to have around, and for budding authors it's not a bad source of quotes for heading chapters.

The Classical Groups: Their Invariants and Representations

H Weyl
xiii + 320 pp., US\$19.95 (paperback)
ISBN 0-691-05756-7

Riemannian Geometry

L P Eisenhart
ix + 306 pp., US\$19.95 (paperback)
ISBN 0-691-02353-0

Topology from the Differentiable Viewpoint

J W Milnor
ix + 64 pp., US\$9.95 (paperback)
ISBN 0-691-04833-9

Princeton Landmarks in Mathematics and Physics series

Princeton University Press, Princeton NJ 1997
If your interests are in areas of physics which require the mathematics so elegantly presented in these three classic reprints, you will doubtless welcome their renewed availability.

New Books

Matter Matters: On the Material Basis of the Cognitive Activity of Mind

P Arhem, H Liljenstrom and U Svedin (eds)
Springer, Berlin 1997
x + 270 pp., DM 58 (hardcover)
ISBN 3-540-61776-0

Classical, Semiclassical and Quantum Dynamics in Atoms

H Friedrich and B Eckhardt (eds)
Springer, Berlin 1997
viii + 340 pp., DM 98 (hardcover)
ISBN 3-540-63004-X

An Equation that Changed the World

H Fritzsche
University of Chicago Press, Chicago IL 1997
xix + 279 pp., US\$15.95 (paperback)
ISBN 0-226-26558-7

Measuring the Quantum State of Light

U Leonhardt
Cambridge University Press, Cambridge 1997
viii + 194 pp., A\$95.00 (hardcover)
ISBN 0-521-49730-2

Decision-making Support for Off-site Emergency Management

U Baverstam, G Fraser and G N Kelly (eds)
Nuclear Technology Publishing, Ashford, Kent 1997
xiv + 215 pp., US\$171.00 (hardcover)
ISBN 1-870965-49-3

Physics With Answers

A R King and O Regev
Cambridge University Press, Cambridge 1997
xi + 317 pp., A\$52.95 (paperback)
ISBN 0-521-48369-7

Quantum Versus Chaos: Questions Emerging from Mesoscopic Cosmos

K Nakamura
Kluwer Academic Publishers, Dordrecht 1997
x + 213 pp., US\$99.00 (hardcover)
ISBN 0-7923-4557-6

Critical Problems in Physics

V L Fitch, D R Marlow and M A G Dementi
Princeton University Press, Princeton NJ 1997
xvi + 308 pp., US\$24.95 (paperback)
ISBN 0-691-05784-2

The Jahn-Teller Effect in C₆₀ and Other Icosahedral Complexes

C C Chancey and M C M O'Brien
Princeton University Press, Princeton NJ 1997
xv + 204 pp., US\$55.00 (hardcover)
ISBN 0-691-04445-7

Made to Measure: New Materials for the 21st Century

P Ball
Princeton University Press, Princeton NJ 1997
vii + 458 pp., Price not given (hardcover)
ISBN 0-691-02733-1

Fractals and Chaos

P S Addison
Institute of Physics Publishing, Bristol 1997
xii + 256 pp., US\$39.50 (paperback)
ISBN 0-7503-0400-6

Symmetries in Quantum Mechanics

M Chaichian and R Hagedorn
Institute of Physics Publishing, Bristol 1998
xiv + 304 pp., US\$49.50 (paperback)
ISBN 0-7503-0408-1

Fractals, Scaling and growth Far from Equilibrium

P Meakin
Cambridge University Press, Cambridge 1998
xiv + 674 pp., A\$200.00 (hardcover)
ISBN 0-521-45253-8

An Introduction to Computational Physics

T Pang
Cambridge University Press, Cambridge 1997
xvii + 374 pp., A\$64.95 (hardcover)
ISBN 0-521-48592-4

Something New Under the Sun

H Gavaghan
Copernicus (Springer), New York 1998
xviii + 300 pp., US\$26.00 (hardcover)
ISBN 0-387-94914-3

CONFERENCES & MEETINGS 1998

- July 5-10 Conference of The Australian Science Teachers Association (CONASTA 47)
Science education: Beyond the Horizon Darwin, NT.
Contact CONASTA 47 Secretariat PO Box 778 Nightcliff NT 0814
<http://www.topend.com.au/~stant/conasta.htm>
- July 3-8 Workshop on CP Violation
Special Research Centre for the Subatomic Structure of Matter
and the National Institute for Theoretical Physics, University of Adelaide
Contact Dr He Xiao-Gang
Email: hexg@dirac.ph.unimelb.edu.au
<http://www.physics.adelaide.edu.au/itp> or
http://www.physics.adelaide.edu.au/cssm/workshops/CP_98.html
- July 6-10 Second Australian Conference on General Relativity and Gravitation (ACGRG2)
University of Sydney
Contact <http://www.maths.usyd.edu.au:8000/u/ACGRG2/>
- July 9-12 Australasian Science Education Research Association
29th Annual Conference, Darwin.
Contact Bill Palmer, Northern Territory University, Darwin, NT 0909
Phone (08) 8946 6148 Fax (08) 8946 6151
- July 13-17 XXII International Colloquium on Group Theoretical Methods in Physics
University of Tasmania
Contact ICGTMP98 Secretariat Theory Group, Dept of Physics
University of Tasmania, GPO Box 252-21, Hobart TAS 7001
Email: icgtmp98@oberon.phys.utas.edu.au
<http://oberon.phys.utas.edu.au/ICGTMP98/>
- August 17-21 Third Stromlo Symposium, The Galactic Halo: Bright Stars and Dark Matter, Canberra.
Contact: <http://msowww.anu.edu.au/~tss/> Email: tss@mso.anu.edu.au
- Sep 27 - Oct 2 **13th NATIONAL CONGRESS of the AIP**,
including 17th Nuclear and Particle Physics Conference (AINSE),
OZCUPE 4 (Computers in University Physics Education meeting),
5th Congress of the Vacuum Society of Australia (VSA)
Solar, Terrestrial and Space Physics Group (STSP) of the AIP, and
Atomic & Molecular Physics & Quantum Chemistry meeting (AMPQC)
Fremantle, WA
Contact Promaco Conventions Pty Ltd
PO Box 890 Canning Bridge WA 6153
Email: promaco@promaco.com.au <http://www.promaco.com.au/conference/98/physics/>
- Nov 30 - Dec 9 Workshop on Nanostructures: Quantum Confinements
National Centre for Theoretical Physics
Dept of Theoretical Physics, RSPSE, ANU
Contact: Dr Mukunda P Das, Convenor
Tel (02) 6249 3066 Email: mpd105@rsphysse.anu.edu.au
- Dec 14-17 Australasian Conference on Optics, Lasers and Spectroscopy (ACOLS98)
University of Canterbury
Contact Conference Secretary Dr Peter Manson Email: acols98@physics.otago.ac.nz
<http://www.physics.otago.ac.nz/~acols98>

1999

- July 4-9 XIX Pacific Science Congress, Science for Pacific Posterity, Sydney.
Contact XIX Pacific Science Congress Secretariat, GPO Box
2609, Sydney, NSW 2001 Phone (61 2)9241 1478 Fax: (61 2) 9251 3552
Email: reply@icmsaust.com.au

AIP TOPICAL GROUPS

The Council of the Australian Institute of Physics wishes to invite expressions of interest from groups of members to establish new Topical Groups within the AIP. Topical Groups would function as informal networks of members with common interests. They may, if they wish, issue newsletters and organise meetings and would be expected to provide a focus of interest at AIP congresses. It is proposed that Groups be identified on the next AIP membership renewal form and that any AIP members may elect to join one or more groups. A small additional fee may be charged, at the discretion of the group.

Groups already exist in Nuclear and Particle Physics (NUPP) Solar and Terrestrial Physics (STP) and Women in Physics (WIP). A group in Condensed Matter Physics (CMP) is being formed. Other areas might be Atomic and Molecular Physics, Computational Physics and Physics Education.

For Groups in these, or other, areas to be formed it is necessary that the AIP Executive receive a proposal which has the support of a minimum number of members (say 20), the name of a convenor acceptable to the proposers and a brief statement of the anticipated benefits and activities proposed. In order for a Group to be listed on the next membership form I would need to receive such a proposal by 31 August, 1998.

Jaen Oitmaa
President

Make an international career move in a hi-tech industry



As one of the world's leading manufacturers of automotive components, we set ourselves very high standards of quality and performance. If you're one of Australia's most talented and energetic Physicists then it's time to talk to us. We're looking for people to join us to train for roles in our state-of-the-art electronics plant, that will initially take you to our sister plant near Stuttgart, Germany.

This provides the potential to experience product development and production at the leading edge of design for both international and domestic markets. You will be an exceptional Physicist whose strategic and analytical mind and high personal expectations have led you to utilise your talents in either a **production, development or research** role.

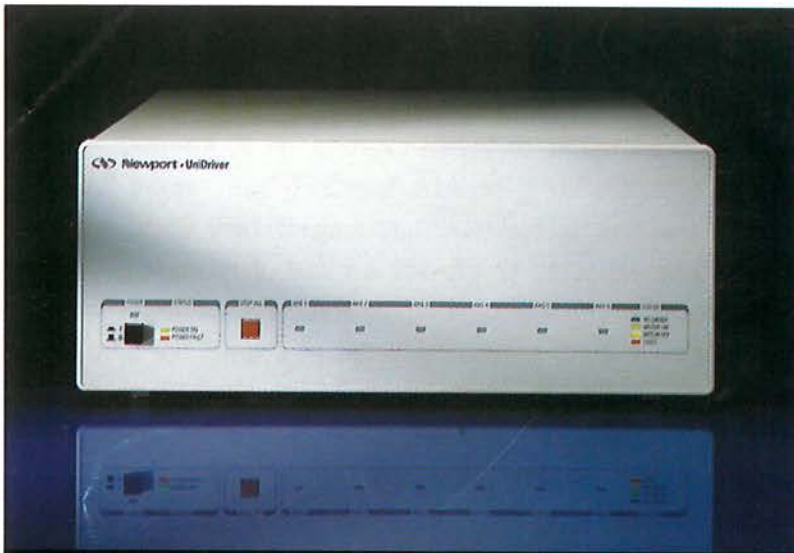
The roles available revolve around the introduction and support of a dynamic product group in our new electronics plant. We are experiencing a significant increase in our Diodes production which requires support from development to product launch, from highly skilled Engineers or Physicists. The project allows for R&D to be fully integrated into all process and product development activities.

To succeed in these roles you will require proven experience in a product development or research role, preferably within the automotive or semiconductor industry. You will also be a degree qualified Physicist or Electrical/ Electronics Engineer who has completed either a Masters or PhD. Obviously excellent communication, planning and project management skills are a must, as is the willingness to relocate overseas. Upon your return to Australia, you will have continuing involvement with projects which operate between here and Germany.

We will offer very competitive salary and benefits packages to the right people. Send 2 copies of your application, clearly showing how your background meets our requirements, to Richard Keely, Recruitment Manager, Robert Bosch Australia, Box 66, Clayton South MDC, Clayton Vic 3169. Fax: (03) 9541 3961. Email: richard.keely@pcm.bosch.de

Physicist

BOSCH 
EXCELLENCE · ALWAYS



◀ Plug-and-play motion control is now a reality—thanks to the ESP6000's auto-configuration capability.



▲ The ESP6000 connects to your PC via a single, PCI plug-in board.

Finally. A motion control platform engineered to move the entire industry.



COMPATIBLE In addition to being plug-and-play with ESP stages, the ESP6000 is compatible with existing Newport stages.



The new ESP6000 motion controller from Newport offers simple and dependable "plug-and-play" micro-positioning.

The ESP6000 instantly identifies every connected Newport stage and automatically configures the driver and motor parameters accordingly, making installation an easy two step process. Connect the Newport stages to the controller and then connect the controller to the PC; installation complete.

The ESP6000 can control up to 6 Newport stages and also handles data acquisition tasks, so additional data acquisition cards are not required.

If you would like to know more about the new ESP6000, please contact Coherent Scientific and ask for Margaret, Bill or Neil.

- 116 Burbridge Road, Hilton, South Australia 5033 ■
- Tel: (08) 8352 1111 ■ Fax: (08) 8352 2020 ■
- Email: cohsci@cohsci.com.au ■
- Web: www.cohsci.com.au ■

Coherent Scientific Pty Ltd Inc in SA ACN 008 265 969



Newport

Tap into the Newport Network.

www.newport.com