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FRONT COVER
Photograph of an isometric intensity plot of a tomogram representing a section through a 30mm diameter slice of Australian hardwood. Regions of central and peripheral fungal decay show up as darker grey levels in this display.

The tomogram was produced on an EMI CT1010 Computerised Axial Tomography (CAT) scanner at the Chirnside Institute of Technology. The two dimensional image was then transferred from the CT scanner to an Olivetti M128P microcomputer for further image processing. The isometric plot of grey scale intensity is displayed on an IBM professional graphics monitor that has a resolution of 640 x 480 pixels, each of which is quantized into 256 grey levels.

PREsIDENT’S COLUMN

The woeful state of industrial R & D and the recognition that Australia’s economic future depends upon greater exploitation of our scientific and technological capacities has resulted in a number of government incentives to encourage a more vigorous attitude by industry towards research and development. Such incentives as the 150% tax rebate and the offset arrangements are as yet in their infancy, but nevertheless, have the potential to inject millions of dollars into the R & D sector. Has the country the trained research personnel to fill the positions resulting from such an expanded R & D effort?

A detailed analysis of the present demand for the first degree and higher degree graduates in physics, based upon the AIP Employment Committee’s annual review of advertised positions and AIP statistics on the number of physics graduates, clearly indicates that the production rate falls short of the demand by at least a factor of three in both categories.

Yet, if Australia is to raise the production of the industrial workforce employed in the R & D sector to the median for the OECD medium R & D performing countries, it would require an additional twenty times the present supply of higher degree graduates and over four times the production of first degree graduates.

A survey of university physicists at the level of lecturer and above reveals that approximately 13% are due to retire in the next five years and a further 40% in the following ten; a total of approximately 200. To maintain the present level of staffing requires the recruitment of at least fifteen new staff per year. This raises the serious question of whether the university physics departments will be able to recruit the necessary staff to maintain their present teaching and research programmes, let alone meeting an increased demand for physics graduates.

These figures, taken from an AIP Science Policy Committee report which has been submitted to the Department of Science and to be published in Search, represent but one area of the scientific workforce. Whilst the statistics in other scientific disciplines are not so comprehensive as those collected for physics, a survey of its Member Societies by FASTS and preliminary analysis by the Department of Science indicate that the crisis is widespread in all areas of the scientific and technological community with the possible exception of plant biology.

There is no short-term solution to this problem. Nevertheless, urgent action is called for. Incentives must be found to encourage wider participation in scientific education. Specialist teachers in physics, mathematics and chemistry must be recruited.

In the face of this massive, long-term shortage of trained personnel, the Federal Government appears determined to shoot itself in the head by placing many areas of university research in jeopardy through the extension of the Overseas Students Charge to encompass higher degree candidates receiving university scholarships.

Approximately 40% of university research is conducted by post-graduate students undertaking higher degree studies. Recent years have seen a steady decline in the number of Australian students electing to continue into higher degree studies in areas such as the physical sciences and engineering. This decline has, to a large extent, been off-set by the increasing number
of applications from highly qualified overseas students.

Currently, approximately one in five post-graduate students in science and engineering are from overseas. These students have become vital to the continuity of research programmes. It would be wrong to believe that the benefit lies entirely with the students. The stark reality is that without them, research in certain areas would cease.

Research programmes require several years from conception to reach fruition, extending well beyond the candidature of an individual student. It is essential for the continuity of the programme that there are succeeding generations of graduate students who have the opportunity to benefit from the skills and expertise of their more senior colleagues. This would not be possible without the overseas students.

Aside from the direct benefits that Australia derives from the research undertaken by overseas graduate students, the training they receive here furthers the establishment of links with the research communities in their home countries. These have been instrumental in establishing Australia’s prominence in the Asia Pacific scientific community. The barrier that the Overseas Students Charge will place before the very highly qualified applicants from the People’s Republic of China is particularly inappropriate at a time when the Australian government is actively promoting stronger industrial links between the two countries.

The crisis faced in Australia in maintaining university research programmes in physics is not unique to Australia. A similar situation exists in the USA where 42% of first year physics graduate students are drawn from overseas. However, in the case of the United States, a positive effort is made to recruit foreign born students to compensate for the lack of US born physics graduates seeking higher degrees.

University research in physics in recent years has suffered from a declining proportion of the overall university funding, obsolete equipment and staffing that is both ageing and decreasing in numbers. I believe that it is not an exaggeration to claim that its vitality is now so fragile that the loss of overseas graduate students could inflict serious and lasting damage.

T.F. Smith

and we believe that Australian physicists also wish to know about the interesting work that their colleagues are doing. So we have made physics review articles an important item. Branch News is also an important item and we would again like to encourage the Branch Editors and Secretaries to send information, especially about overseas visitors, so that they can be invited by other branches. If overseas visitors are encouraged to book their airline tickets all the way to Perth the expense is trivial; once in this country it becomes prohibitive for the outlying states to meet the cost of reimbursement.

So you states with large memberships, who get most of the A.I.P. support, please note your obligation! Also the moment your AGM is over, please send your newly elected names of officers to me in time for the February issue. Victoria, which all year sent no Branch News and appeared not to like contributing to the ‘house’ has finally tired of the outside and sent a report. We welcome them!

We also hope to be able to encourage Industry to come for more frequent visits. We must convince them that this is a comfortable house and not an ivory tower. We, the Physicists, must make more effort. Just writing the odd letter is not enough as was clearly indicated by the dismal industrial support for the A.I.P. Congress. This issue therefore contains a report about the Technology Park of S.A. and, hopefully, more such contributions will follow.

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T.F. Smith

Errata

Erase 2 lines from CONTENTS.
Insert ‘VIC’ page 237 line 20.
Replace ‘photograph’ by ‘photoproton’, page 223, line 29.

Superstrings

A string knows but its length —
Its ends, perhaps.
Unless it leaves
The flat plane,
It cannot tie a knot.
But my true love has dimensions I do not know,
And in them there is
I know not how to undo.

J.R. Prescott

The Australian Physicist, Vol. 23, November 1986 — Page 243
TOSHIBA LEADS THE WAY BY FORMING A PHYSICS GROUP WITHIN THEIR MEDICAL DIVISION.

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X-Ray Computed Tomography I: A Non-Medical Perspective

J.R. Davis, M.J. Morgan, P. Wells, P. Shadbolt and B. Suendermann, Computer Imaging Group, Department of Applied Physics, Chisholm Institute of Technology.

Introduction

The Applied Physics Department at the Chisholm Institute of Technology has for many years retained a strong instrumentation and measurement emphasis in its undergraduate physics courses. The increasing need to include more digital instrumentation over recent years was one factor which lead to the formation of the Computer Imaging Group within the department.

The area of particular interest to the Computer Imaging Group is that brings together areas of conventional undergraduate physics, high speed computing requirements and an appreciation of modern digital processing methods is that of computed tomography. It is the aim of this paper, and a subsequent one, to outline the fundamental ideas behind X-ray computed tomography and to discuss some of the instrumentation involved in acquiring data and processing it to form meaningful images.

X-ray computed tomography (CT) was introduced into diagnostic radiology in 1971. This revolutionary technique utilises X-rays to- gether with computer image processing to reconstruct an X-ray attenuation map \(\rho(x,y)\), that is a slice, of any cross-section in the human body. The major credit for the early work belongs jointly to Allan Cormack and Godfrey Hounsfield who shared the Nobel prize for medicine in 1979.

Although CT has been used mainly in medicine, its application to industrial problems, particularly non-destructive testing, has grown rapidly in recent years [see e.g., Gordon, 1985]. In the present article CT will be discussed within this wider context.

Image Reconstruction from Projections

The problem inherent in conventional radiography is that it produces a 'shadowgraph' in which all depth information is lost. This is because a radiograph results from projecting many overlapping planes in a three-dimensional object onto a single two-dimensional plane containing an X-ray sensitive film or image intensifier.

Tomography, derived from the Greek word tomos meaning 'slice', is a method of isolating a single plane, completely eliminating information from other planes in the object under investigation.

The mathematical basis for image reconstruction is quite old, dating back to the work of Radon [1917]. The basic idea is to produce an image of the two-dimensional distribution of some physical property, in this case the linear attenuation coefficient, from estimates of its line integrals along a finite number of rays through the object.

It is interesting to note that one of the earliest applications of this reconstruction method was developed by Ronald Bracewell in the context of radio astronomy. This work was carried out at the CSIRO and published in the Australian Journal of Physics in 1956 [Bracewell, 1956].

To reconstruct the two-dimensional attenuation map \(\rho(x,y)\) a large number of transmission measurements are made through the section of the object under examination. In this way information is gathered from a single slice, excluding data from adjacent regions in the object. An arrangement for obtaining this data is shown in Figure 1, which represent the so called first generation (translate-rotate) scanner. Present fourth generation machines utilise a ring of stationary detectors and a moving source that emits a fan beam of X-rays. The basic reconstruction procedure is outlined with reference to the translate-rotate geometry shown in Figure 1.

Figure 1: A schematic illustration of the scanning scheme of a first generation CT system showing the linear (translate) and rotational motions involved in the collection of data prior to computer image reconstruction of a scanned slice through the object.

Furthermore, it is assumed that the parallel line integrals, also called ray sums, constitute continuous data sets, however, in practice discretely sampled data is acquired. The transition from continuous data sets to discretely sampled data is the subject of a second paper that deals with the practical implementation of digital filters in CT.

Figure 2: The object is represented as a two-dimensional map of linear attenuation coefficients \(\mu(x)\). The X-ray source \(S\) and detector \(D\) rotate about the \(x\)-axis, and with the \(x\)-rays travelling parallel to the \(x\)-axis. \(P\) is a general point in the object. A single projection consisting of a set of parallel ray sums is also illustrated.

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Figure 2 shows the basic coordinate system. When a monochromatic and collimated X-ray beam of intensity $I_0$ passes through an inhomogeneous object, it is attenuated in the main by the attenuation processes Compton scattering and photoelectric absorption according to

$$ I = I_0 \exp \left( - \int_S \mu(x, y) \, dy \right). \tag{1} $$

Linearising Eq. (1) defines the line integral (ray sum).

$$ p_\phi(x) = - \ln(I/L) = \int_S^D \mu(x, y) \, dy. \tag{2} $$

The complete set of parallel ray sums $\{p_\phi(x)\}$ represents a single projection for that 'view' of the cross-section of the object. The task of image reconstruction is to estimate $\mu(x, y)$ from a sufficiently large number of projections obtained at various angles $\phi$. The estimate of $\mu(x, y)$ will naturally be limited by noise and sampling considerations in any practical implementation.

A simple reconstruction algorithm is based on a process called summation back-projection which is denoted by $B[ ]$. In this process an estimate of the attenuation coefficient at a point in the object is obtained by adding up (integrating) all the line integrals of the rays through that point according to

$$ B[p_\phi(x)] = b(x) = \frac{1}{\pi} \int_0^\pi p_\phi(x, \theta) \, d\theta. \tag{3} $$

In effect what Eq. (3) says is, smear each projection back along the direction in which the original projection was made and repeat this process for each angle $\phi$ to form a reconstruction of the object. The basic limitation of this procedure is that it blurs out sharp features, producing a highly degraded image. This arises because the back-projected sum is a convolution with the point spread function (PSF) of the system. Thus

$$ b(x) = \mu(x) \ast (\text{PSF})^{-1}, \tag{4} $$

where $(\text{PSF})^{-1}$ represents the PSF and the double asterisk denotes a two-dimensional convolution. The origin of this degradation is quite simple. Consider a number of ray sums of an object that consists of a single point. The result of back-projecting and summing would be a star shaped image centred on the point. Since a complex object may be considered as a superposition of points, a naive implementation of the back-projection algorithm will blur out the features in the reconstructed image.

To ameliorate this situation the effects of the PSF must be corrected by filtering. In practice the filtering is performed on the one-dimensional projection data before back-projecting. This procedure is known as filtered back-projection and is the preferred method of image reconstruction used by the majority of commercial CT scanners. Correcting for the effects of the PSF can be achieved in either the Fourier domain by using spatial frequency filters or, equivalently, the correction can be done in the direct space domain by convolving with an appropriate deblurring function. The reconstruction algorithm is now written as

$$ \hat{\mu}(x) = B[w(x) \ast p_\phi(x)], \tag{5} $$

where $\hat{\mu}(x)$ represents the estimate of the attenuation coefficient distribution and $w(x)$ is an appropriate filter function. The one-dimensional convolution is designated by the single asterisk.

Suitable filters have a main positive central peak with negative side lobes whose amplitudes approach zero at large distances from the origin. In this way the filtered projections contain negative as well as positive components that cancel out when back-projected to points outside the original object, thereby eliminating the star artifact.

Applications of CT

Industrial applications of CT began in earnest in the mid-seventies when its potential for non-destructive testing and evaluation was realised. Although CT is technically far superior to conventional radiography it is also a more costly technique. Therefore, industrial applications will generally be developed in those areas where material or component failure may have catastrophic consequences.

The scope for industrial applications of CT is enormous and it grows larger every year. For example, a short list of areas where CT has already been employed includes: the inspection of Trident rocket motors [Burstein et al. 1982], the measurement of fatigue and stress damage in polymeric materials [Persson and Ostman, 1985], silk culture and forest management [Onoe et al. 1983], multiphase fluid flow problems [MacCuaig et al. 1985], testing for the progress of cracks and the presence of voids [Tonger and Tosello, 1983], the evaluation of structural timber [Taylor et al. 1980], examination of ceramics [Kress and Feldkamp, 1983], the nuclear industry [Allan et al. 1985], plasma physics [Myers and Levine, 1978] and archaeology [Tate and Cann, 1982].

![Figure 3: Reconstructed CT image of a section through a 320mm timber pole. Internal rot is clearly evident as the light areas. Sapwood (low density) rings structure and radial checks are also clearly visible.](image-url)
exploited in a diverse range of applications and its
development continues in many directions. The US
industrial CT market alone is put at US$200 million in
1986 and predictions indicate that it will be substantially
higher by the end of the decade. The present high capital
cost of CT systems ($700,000 and upwards) restricts
their routine use to those situations where the potential
cost of failure exceeds the cost of inspection. However,
overseas experience shows that laboratory based centres
can offer CT services at moderate cost. The value of
CT as a non-destructive testing and evaluation technique
has been demonstrated here in the inspection of
reinforced concrete, timber and a number of other
materials. The range of applications can be greatly
extended by utilising a γ-ray source, where the higher
photon energies allow access to high atomic number
materials such as might be encountered in metal
castings.

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Optical-fibre loop will serve as a test bed

Telecom's $3 million pilot optical-fibre program will be
operating by November.

A Melbourne central business district optical-fibre
loop will pass about 50 major business houses and will
be used as a test bed for Telecom's commercial and
technical methods. A similar system is being considered
for Sydney.

Telecom plans to link all mainland capital cities with a
$300 million fibre-optic system by 1992.

The 980km Melbourne-Sydney link should be
completed in 1987. It will have a capacity equal to
60,000 simultaneous telephone conversations over and
above existing facilities.

This will be followed by a 1725km Adelaide-Darwin
link in 1988, a 2700km Perth-Adelaide link in 1988 and
3150km Adelaide-Brisbane link in 1992.

Telecom claims the Perth-Adelaide link will be the
longest optical-fibre link without immediate terminals
in the world.

From Engineers Australia
Professor D.B. Melrose

The Australian Institute of Physics announced the award of the Walter Boas Medal to Professor D.B. Melrose of the School of Physics for his research on radiation in astrophysical and geophysical plasmas. The medal was established in 1984 to promote excellence in research in physics in Australia and is awarded annually for original research work in papers published over the preceding four years. The announcement of the award for 1986 to Professor Melrose was made on August 26 at the AIP Congress in Adelaide. The announcement almost coincided with the publication (on August 14) of his latest book “Instabilities in Space and Laboratory Plasmas” which was on display at the Congress by the publishers Cambridge University Press.

Professor Melrose joined the University of Sydney in 1979 as Professor of Physics (Theoretical). Previously he had been a Reader in Theoretical Physics in the School of General Studies at the Australian National University. He was originally from Tasmania, and his early schooling was in Hobart, Sydney (at North Sydney Boys’ High) and Fremantle (at John Curtin High). He graduated from the University of Tasmania, and was Rhodes Scholar for Tasmania for 1962. After completing his doctorate on elementary particle physics at Oxford, he changed his field of interest to astrophysics and plasma physics in a post-doctoral year at the University of Sussex and then spent three further years in post-doctoral positions in the United States before returning to Australia in 1969. His main research interest has been in processes producing radio emission and other non-thermal emissions from the Sun, the planets, pulsars and some stars. He was awarded the Pawsy Medal by the Australian Academy of Science in 1974, and was elected a Fellow of the Academy earlier this year. He has published over 150 scientific papers and a two-volume book “Plasma Astrophysics” in 1980. He has collaborated with the Solar group at the CSIRO Division of Radiophysics, and contributed to seven chapters of a book “Solar Radiophysics” published in 1985 by members of that group and their collaborators.

Professor Melrose’s main interests outside academic life are sporting. He played Rugby Union until late in his 30’s, having reached the peak of his career by being the first Tasmanian to captain the Combined Australian Universities in 1962. More recently his sporting activities have been confined to jogging, surfing and squash. He lives in Wollstonecraft on the lower North Shore with his wife Chris and children Jenny (16) and Stephen (14).

Coherent Emission Processes in Astrophysics

D.B. Melrose, School of Physics, The University of Sydney

Talk presented to the Victorian branch of the Australian Institute of Physics on the award of the Walter Boas Medal for 1986

Introduction

Before discussing the current status of the theory of coherent emission processes, I would like to introduce you to the ideas involved by telling you how my interest in the topic developed.

Let me start in 1969 when I was at the University of Maryland giving a course of graduate lectures in a new field which had been named “plasma astrophysics”. The lecture course was concerned with waves in astrophysical plasmas and more specifically with radiation processes and the scattering and acceleration of fast particles by waves. The radio emission processes in astrophysical plasmas include bremsstrahlung and synchrotron radiation, both of which were well understood. However, there were two classes of radio emission then known which were clearly not due to either of these processes. These were solar radio bursts and Jupiter’s radio bursts. Also, the radio emission from pulsars, which had only just been discovered at that time, is not due to either of these mechanisms. These radio emissions are bursty and they are also intrinsically very bright, up to $10^{14}$K for solar radio bursts, at least $10^{14}$K for Jupiter’s bursts, and much higher still for pulsar radio emission. These very high brightness temperatures cannot be explained in terms of any incoherent mechanism, and it is for this reason that I refer to them as “coherent emission processes”. The topic of my talk is thus the radiation emission mechanisms operating in solar radio bursts, Jupiter’s radio bursts, and in pulsars. All these are different and I shall concentrate on the first two.

Let me outline how I came to be at the University of Maryland lecturing on what was then a new field. My Honours year was at the University of Tasmania where I did research projects on magnetospheric physics with G.R.A. (Bill) Ellis and on quantum mechanics with H.A. (Hans) Buchdahl. The latter led on to research in elementary particle theory which I pursued for my D.Phil. at Oxford. However, I felt I was not suited to

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the field, and during a post-doctoral year at the University of Sussex, my interest turned to astrophysics, and specifically to a problem concerning the magnetosphere of Jupiter suggested to me by Bill Ellis when I visited Hobart on completing my D.Phil. The decision to concentrate on astrophysics was motivated partly by interest, and partly by the fact that I foresaw opportunities for a theoretical astrophysicist with expertise in radio astronomy in Australia. I set about teaching myself plasma physics. I was greatly encouraged by the fact that I was able to solve the problem of Jupiter’s magnetosphere to my own (and the referee’s) satisfaction.

My initial attempts at finding a post-doctoral position in my new field met with difficulties, with several likely prospects falling through at the last minute. My first big opportunity came when I was accepted to participate in the Les Houches Summer School in 1966. The topics for the lectures that year strongly emphasized radiation and other nonthermal processes in astrophysical plasmas. One of the leading speakers was to be V.L. Ginzburg, who unfortunately could not come at the last minute. Ginzburg was the recognized world expert in this area, and although his lecture notes were available his absence was regrettable. One of the lecturers at the School introduced me to the work of another Russian, V.N. Tsyovablev, through lectures on the acceleration of fast particles in astrophysical plasmas. I was fascinated by the ideas and found Tsyovablev’s treatment of wave-particle interactions in plasmas very appealing.

At this point it is relevant to remark on the different ways in which plasma theory developed in the Soviet Union and in the West. Astrophysicists in the West had played a dominant role in the development of the fluid theory of plasmas, called MHD theory, up till around 1950. At about that time classification research on plasmas in connection with controlled fusion began in earnest. In the West astrophysicists did not take part in the classified research, to the detriment of both the astrophysical and fusion communities. In the Soviet Union close contact with astrophysicists was maintained, and as a consequence the modern plasma physics came into astrophysical thinking largely through Russian workers.

Returning to my time at Les Houches, I had a lucky break towards the end of the School when I met A.G.W. Cameron who offered me a post-doctoral position with him in New York as an expert on astrophysical plasmas. A.G.W. knowledge of astrophysics is almost encyclopaedic and I learnt a great deal from him over the next two years, primarily over lunches in a local restaurant. He also recognized the importance of plasma astrophysics, despite the gap in his knowledge in this field, and gave me every opportunity to make a success of my new field. After two years with A.G.W. I decided to move to the University of Maryland for a year to broaden my experience before my planned return to Australia. Thus it was that I came to be giving a graduate course in plasma astrophysics there in 1969.

The lecture notes for my plasma astrophysics course were published internally, and when A.G.W. received a copy of the book he offered to arrange for its publication as a book. Being flattered I agreed and signed a contract. I wanted, however, to rewrite the notes, and felt that more research was required on the coherent emission processes. It was clear to me that the then existing ideas on these processes had been outdated by the rapid advances in plasma theory through the 1960s. On returning to Australia to join Hans Buchdahl’s department — Hans had since moved to the A.N.U. — my first research projects were to update the theory of “plasma emission” for solar radio bursts and of “coherent cyclotron emission” for Jupiter’s radio bursts, with the specific object of having updated versions for inclusion in my book. Let me now discuss these two topics separately.

**Plasma Emission**

Solar radio bursts were classified by J.P. (Paul) Wild in 1950. At that time and for many years thereafter, the solar group at the C.S.I.R.O. Division of Radiophysics was pre-eminent in the field. (This group remained a major part of the solar radiophysics community until its demise three years ago.) The observed radiation is predominantly at either the fundamental or second harmonic of the plasma frequency in the source and hence the emission processes were called “plasma emission”. The first detailed theory for plasma emission was presented by Ginzburg and Zheleznyakov in 1958. This theory is illustrated schematically in Figure 1a. It involves three

![Diagram](image_url)

**Figures 1a and 1b:** A schematic for the generation of fundamental and second harmonic plasma emission (a) the original form proposed by Ginzburg and Zheleznyakov in 1958, and (b) the alternative form when three wave processes involving ion-sound waves dominate the intermediate stages.
WALTER BOAS MEDAL

stages: Stage 1 — Generation of Langmuir waves, which are longitudinal plasma oscillations near the plasma frequency which are excited by a streaming instability due to a low density stream of fast electrons propagating through a background plasma. Stage 2 — Scattering of Langmuir waves off thermal ions allows their partial conversion into transverse waves, which escape to be observed as fundamental emission. Stage 3 — The stream excited Langmuir waves coalesce with thermal Langmuir waves to produce the escaping second harmonic transverse waves.

Ginzburg and Zheleznyakov’s theory was remarkably innovative. Stages 2 and 3 involve nonlinear plasma processes, and their paper was amongst the first in which nonlinear plasma processes were discussed at all. By 1969 however, the details of their theory had become outdated. For example, for stage 1 they appealed to a streaming instability discussed by Bohn and Gross in 1949, the theory of which involved thermal motions. A different instability which depends intrinsically on the velocity spread had been developed by several authors in 1959, and this version was clearly the more appropriate for solar radio bursts. Also Tsytovich’s treatment of nonlinear plasma processes allowed one to include alternative and more effective processes than those invoked by Ginzburg and Zheleznyakov for stages 2 and 3. Indeed, Tsytovich (with Kaplan) had pointed this out for fundamental plasma emission in 1968, but their paper was one of the few attempts at updating the original theory prior to 1970. There was a flurry of activity in 1970 when several authors, myself included, argued for various different modifications and variations to the details of the stages in Ginzburg and Zheleznyakov’s theory.

My first two papers on plasma emission were published in the Australian Journal of Physics in 1970. A specific contribution was the demonstration that Ginzburg and Zheleznyakov’s mechanism for stage 3, that is for second harmonic generation, does not work. This is because reabsorption by the inverse of the emission process limits the brightness temperature to twice the thermal temperature. This follows directly for the formalism used by Tsytovich for three-wave interactions, which is also familiar in nonlinear optics. Consider a beat between three waves with frequencies \( \omega_1, \omega_2 \) and \( \omega_1 + \omega_2 \) and wavevectors \( k_1, k_2 \) and \( k_1 + k_2 \) satisfying

\[
\omega = \omega_1 + \omega_2, \quad k_1 = k_2 = k_3 \quad \text{(1a,b)}
\]

Let the waves be described as a collection of wave quanta with energy \( h\omega \), momentum \( hk \) and occupation number \( N(k) \). The condition for wave 3 to be generated is

\[
N(k_3) > N(k_1) \quad \text{(2)}
\]

The product on the left of (2) determines the rate the coalescence \( 1 \leftrightarrow 2 \) occurs, and the product on the right determines the rate the inverse decay \( 3 \leftrightarrow 1 + 2 \) occurs. Saturation results, when the inequality (2) is replaced by an equality. The effective temperature or brightness temperature for the waves \( T_L(k) \) is related to the occupation number by

\[
x T_L(k) = h\omega N(k) \quad \text{(3)}
\]

where \( x \) is Boltzmann’s constant. If the waves are thermal one has \( T_L(k) = T_e \), where \( T_e \) is the electron temperature. With \( \omega_1 = \omega_2 = \omega_p \) and \( \omega_1 + \omega_2 = 2\omega_p \), where \( \omega_p \) is the plasma frequency, and with \( T_L(k) > T(k) = T_e \), the result 1 found is \( T_L(k) < 2T_e \), which is inconsistent with highly nonthermal radiation at the second harmonic. Ginzburg and Zheleznyakov’s theory therefore needs to be revised by allowing scattering of Langmuir waves into other Langmuir waves to occur as an intermediate stage in the generation of the second harmonic.

One other idea in these earlier papers was developed in more detail latter. This is that the conversion of Langmuir waves into fundamental transverse waves and this required that intermediate scattering of Langmuir waves into other Langmuir waves can occur most efficiently through a three-wave process when the third wave is a low frequency (e.g., ion sound wave). This is illustrated schematically in Figure 1(b). Over the past year or so there has been direct observational evidence for this from spacecraft data in the interplanetary plasma — the electron streams which generate the so-called type III bursts in Wild’s classification can propagate to well beyond the orbit of the Earth and can be studied in situ near the Earth. If coalescence with ion sound waves is indeed important, it leads to a very major simplification in the analysis of plasma emission. The reason is that each step should proceed to saturation. Then, for each of the daughter Langmuir waves and for the fundamental and second harmonic of the transverse waves, the effective temperatures saturate at the same value as the effective temperature of the initial Langmuir waves.

Let me explain how this idea may be used to make a prediction. For a given stream of electrons, and one may use real data obtained from spacecraft observations, one may calculate the free energy density \( W_f \) available for excitation of Langmuir waves. One may also use the theory of the streaming instability to estimate the range \( \Delta k \) wavevectors over which the waves are generated, and so define their coherence volume \( V_c \) by

\[
\frac{1}{V_c} = \int \frac{d^3k}{(2\pi)^3} \quad \text{(4)}
\]

One can then estimate the initial effective temperature of the Langmuir waves from

\[
\frac{V_c}{T_L} = W_f 
\]

If both the fundamental and second harmonic generation processes proceed to saturation then the brightness temperatures should be equal to \( T_L \) they must be less than \( T_L \) if scattering of the escaping radiation increases the apparent size of the source and thereby reduces its apparent brightness. This idea has been tested for type III events in the interplanetary plasma where the bursts are observed to have brightness temperatures concentrated around \( 10^8K \). The calculated value using (5) is about \( 10^8K \). The agreement is satisfactory because there is independent evidence that the observed sources are enhanced scatter images of actual sources about one tenth the apparent area.

I have jumped forward in time to bring you up to date with this particular aspect of the theory of plasma emission. Let me return to my own involvement in the early 1970’s. After my initial papers, the next project was to include the role of the magnetic field in plasma emission. Initially this was motivated by some of Bill
Ellis' data on fine structures in solar radio bursts. The idea was that these splittings might be due to magnetic effects. The generalization of plasma emission to include a magnetic field turned out to be a major project as it involved generalizing the theory of nonlinear plasma processes to the magnetized case. About the time I started on this, I made contact with Paul Wild's group at the C.S.I.R.O. through S.F. (Steve) Smerd, who had taken over as leader. I learnt a great deal from Steve about solar radio bursts over the subsequent eight years, until his death, and through him initially made such fruitful contacts with the solar radiophysics community, notably G.A. (George) Dulk at the University of Colorado, with whom I continue to collaborate. The theory of plasma emission in a magnetic field turned out to be particularly relevant to the interpretation of polarization data on the radio bursts. Detailed polarization data became available in the mid-1970's when a spectropolarimeter developed by the C.S.I.R.O. group came into operation. As a consequence I managed to build a reputation as an expert on the polarization of solar radio bursts.

More recently, as I have already indicated, the emphasis in solar radio bursts has changed from ground-based observations of bursts from the solar corona, to spacecraft observations of radio-generating and other events in the interplanetary plasma. Thus, in a sense, it has become part of the field called space plasma physics.

**Electron Cyclotron Maser Emission**

Electron cyclotron maser emission is an area in which significant progress has been made quite recently, even in the 1980's. In one sense, this is rather surprising, because the basic ideas had been presented in one form or another by about 1960. However, in another sense it is not so surprising because the physics is much more subtle than would appear at first sight. Recall that the streaming instability which generates Langmuir waves comes in two different forms. One version I shall call the **reactive version**, involves phase coherent growth and involves no thermal motions. Indeed the effect of a thermal spread is to suppress it by phase mixing. The other version, which I shall call the **resistive version** involves a maser type mechanism and may be treated using the random phase approximation. Both types of mechanism are possible for an instability involving growth of waves near the electron cyclotron frequency due to electrons spiralling a magnetic field. However, the situation is complicated further by the fact that there are two intrinsically different types of resonant interaction. One is purely nonrelativistic and the other is intrinsically relativistic but remains relevant even for electrons for which other relativistic effects are entirely negligible. Thus there are four types of instability: these are reactive and resistive versions of both the nonrelativistic and the relativistic forms. All four forms were pointed out by 1960. I shall not discuss the reactive versions, but merely comment that the identification of the reactive relativistic form by A.V. Gaponov in 1959 initiated research into the development of the gyrotron as a source of intense microwave radiation.

After my two papers on plasma emission in 1970, I worked on the section of my book on the magnetooionic theory and on coherent electron cyclotron emission. In 1971 I submitted five papers together to the Australian Journal of Physics; one was on the reactive version and another on the resistive version of the electron cyclotron instability. All five papers were rejected. I was sufficiently put out that I did not try again for two years, when my first paper on the theory of coherent cyclotron emission was accepted for publication. In 1975, while at the University of Colorado visiting George Dulk, I was writing a paper applying this theory to the radio bursts from Jupiter, when a paper describing analogous radiation from the Earth appeared. This radiation was first detected in the mid to late 1960's by spacecraft designed to observe type III bursts in the interplanetary plasma; intense noise from the Earth was found to prevent observations of the solar bursts on many occasions. Initially the Earth noise was regarded only as a nuisance, and it was not until 1974 that a definite study of it was reported. The Earth noise is now called **auroral kilometric radiation** (AKR). It was found that AKR correlates with a certain class of auroral electron precipitation event, called inverted V events. I quickly adapted my theory to apply to AKR as well. The theory made three basic predictions, two of which subsequently turned out to be satisfied, but the third, relating to the required form of the electron distribution function, turned out not to be satisfied for the inverted V electrons. A more satisfactory theory was presented by Wu and Lee in 1979, based on the intrinsically relativistic effect mentioned above. Let me explain in a little detail the difference between these two theories.

The relativistic version is somewhat easier to understand in its simplest form. It was first pointed out by R.O. Twiss in a paper in 1938 in the Australian Journal of Physics on negative absorption processes in radio astronomy. The cyclotron resonance condition between an electron with velocity \( \mathbf{v} \) and a wave is

\[
\omega - \Omega_x \gamma - k_x v_x = 0
\]

where \( \Omega_x = eB/m \) is the electron cyclotron frequency, \( \gamma \) is the electron's Lorentz factor, and subscript \( x \) denotes components along the magnetic field. Twiss considered only the case \( k_x v_x \approx 0 \). Then (6) implies that electrons with a given energy \( \epsilon \), and with waves of a given frequency \( \omega = \Omega_x \gamma \), Twiss showed that negative absorption, which is equivalent to maser emission, occurs if the distribution of electrons is an increasing function of \( \gamma \). Actually Twiss assumed \( v_x = 0 \), so his instability requires

\[
\frac{\partial f}{\partial v} + \left( \frac{\partial f}{\partial v} \right)_0 > 0
\]

where \( f \) is the electron distribution function. Twiss' theory had little success because the emission is in the extraordinary magnetooionic mode at \( \omega < \Omega_x \), and cannot escape from the plasma.

The nonrelativistic version corresponds to setting \( \gamma = 1 \) in (6). The resonance condition then involves only \( v_x \). Electrons with \( v_x = (\omega - \Omega_x)/k_x \), and arbitrary \( v_z \), resonate with the wave \( \omega, k_x \). The two cases are illustrated in Figure 2(a & b), which shows all the electrons which can resonate with a given wave as a plot in \( v_z, v_x \) space. Twiss' case corresponds to a circle centred on the origin, and the non-relativistic case corresponds to a vertical line. It turns out that the contribution from \( \partial f/\partial v \) cannot lead to negative absorption in the nonrelativistic case. This may be shown by a partial integration with the integrated term vanishing at both \( v_z = \infty \) and \( v_x = 0 \). Hence any
cone anisotropy due to those with small \( \alpha \) escaping from the ends of the trap. Then one has \( \delta f / \delta v_L > 0 \) in the loss cone region. This case seems to apply to the auroral kilometric radiation. It has been shown directly that instability should occur, that is that the maser should operate, through calculations of the growth rate with observational data on the distribution function as input. Thus, with \( k x v_L > 0 \) one predicts efficient maser emission in the extraordinary mode above the cut-off frequency.

There is strong evidence that this same instability applies to Jupiter's radio bursts as well as to AKR. It was found by George Dulk in 1967 that the angular distribution of Jupiter's radiation is quite peculiar: he found the emission confined to the surface of a cone, about 1° thick and about 80° half angle with the axis along a magnetic field. The growth of the instability is confined to just such a small range. This is because the properties of the resonance circle are very sensitive to the angle \( \theta \) through \( k_r = k \cos \theta \). One requires \( \cos \theta = v_L = 0.1 c \) and a change in \( \theta \) by \( \Delta \theta = 1.2^\circ \) can then change the resonance circle sufficiently that growth is replaced by damping.

Electron cyclotron maser emission has now become the accepted emission mechanism for these planetary radio emissions, and for similar emissions from Saturn and Uranus. It is also thought to be the mechanism for a certain type of intense bursty microwave emission from the Sun and for microwave emission from some flare stars.

**Pulsar Radio Emission**

When it came to including a section in my book on the radio emission from pulsars, again I found the existing discussions in the literature to be unsatisfactory. In this case the prevailing idea was that the coherent emission is due to bunches of highly relativistic electrons emitted due to curvature radiation. Curvature radiation is due to the transverse acceleration as the particles stream out along curved field lines. My objection to this is twofold. First, the mechanisms for formation of the bunches are not believable. One needs pancake shaped bunches with the flat part within a few tenths of a degree...
to be perpendicular to the field line. Second, even if these bunches could be formed they would not survive long enough to cause significant emission. For example the angle between the flat part of the pancake and the magnetic field must change due to the curvature of the field lines, as illustrated in Figure 3, and this quickly suppresses the radiation. If a maser version of curvature radiation existed, then this would seem an acceptable alternative. However, curvature radiation like synchrotron radiation has no maser counterpart.

As a possible alternative mechanism, I proposed a maser mechanism related to free-electron maser emission. Although I am still inclined to the view that pulsars do radiate by such a mechanism, there is no direct evidence for this. Over the past decade there has been little progress in understanding the radio emission from pulsars, and most experts now agree that we simply do not understand the physics well enough to make any definitive statements on how the radiation is actually generated. The theory of pulsar radio emission has been relegated to the "too hard" basket to await further developments either from observations or from the electrodynamics of pulsar magnetospheres.

Conclusion

Discussions of these three coherent emission mechanisms were included in the manuscript for my book, which was finally submitted early in 1977 and published in 1980.

How far have we progressed in understanding coherent emission processes in astrophysics? We have made major progress in understanding the qualitative nature of plasma emission and of electron cyclotron maser emission. We have also developed useful semiquantitative ideas, notably those involving limits on brightness temperatures. Also we have been able to show that observational data on the relevant particles imply that the instabilities we believe to occur do indeed have positive growth rates. However, the problem is far from solved. There are fine structures in the observed emissions which cannot be explained in terms of a maser theory, and there are small scale space and time structures which are still not understood. This is one area of current interest in my research.

What is particularly challenging about this field is the uniqueness of the processes involved. It is true that there are laboratory devices, notably the gyrotron and the free-electron maser, which have some analogy to these coherent radiation processes in astrophysics. However, these laboratory devices operate in the "reactive" rather than the "resistive" regime, and thus the analogy is not as close as it might at first appear. A similar comment could be made in relation to laboratory plasma instabilities. Thus the study of coherent emission in astrophysics involves the investigation of processes which cannot be studied in any other way directly. A successful detailed theory for these processes will be a significant contribution to physics.

References

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WE ARE AN EQUAL OPPORTUNITY EMPLOYER

The Australian Physicist, Vol. 33, November 1986 — Page 254
AJP Crisis, Letter to the Editor

The October issue of the Physicist contained two letters in response to the President’s editorial in the August issue calling for physicists to voice their support for the continuation of the Australian Journal of Physics. Kenneth Clarke’s letter represents a point of

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view that is not uncommon among scientists generally, not just physicists; Paul Hewitt's puts the case from the perspective of those within CSIRO who are understandably concerned with putting to most effective use the limited number of dollars assigned by the Organization to communications of various kinds, including publicising its own activities and thus heightening the "community awareness of CSIRO's role". Both letters call for a response.

Paul Hewitt's point is well taken although his letter oversimplifies the issue. As is well known, CSIRO receives a one-line budget. But one of the justifications for the Organization's total budgetary allocation is, surely, the provision of funds to publish the 10 Australian Journals, unless the net cost to CSIRO is considered to be so small that it is not worth itemising. In this context CSIRO's present obligation to publish the Journals should be recognized since it publishes them not because they are an affordable luxury but to honour an agreement between CSIRO and the Australian Academy of Science to publish learned journals for the benefit of Australian science as a whole. Thus, properly viewed, CSIRO's expenditure on the Journals is not a generous subsidy by CSIRO to scientists outside the Organization but the responsible action of a Commonwealth agency discharging obligations for which it is funded.

Of course, the most obvious way to regularize a situation that is poorly understood both within and outside CSIRO would be for the budget for the Journals to be clearly identified within the overall CSIRO budget, but in the past there has been resistance to doing this. Application of the "user pays" principle is somewhat different in Australia from elsewhere since nearly all the research reported in the Journals is funded by the Australian taxpayer in one way or another. The small but growing number of papers from overseas authors does not fall in this category, but Australia has an obligation to meet the cost of publishing these papers as its contribution towards the worldwide responsibility of funding scientific journal publication. After all, the majority of Australian research is still published in overseas journals, generally without payment. Thus, whether the taxpayer's money for this purpose is allocated solely through CSIRO or whether the same money is allocated through a network of Commonwealth and State agencies makes no difference in principle. To many of us a single direct allocation to the Journals through CSIRO, or to a Journal trust fund, makes more sense; it would certainly be administratively simpler and cheaper.

Kenneth Clarke makes a somewhat different point, although along the general line that the user should pay. While it is a worthy initiative on behalf of ACPSM to publish its own quarterly, and one the College has been able to maintain thus far, the AIP does not have the resources to contribute significantly to the cost of publishing the AIP while maintaining publication of its house journal, 'The Australian Physicist', which serves a different purpose. My understanding is that The Australian Physicist costs a net $30,000 (?) annually to produce and absorbs something like one third of members' subscriptions. But there is a point of principle here as well. Few, if any, physicists personally pay for the research that leads to the papers they write, and all would agree that the final publication is as integral and vital a part of the research program as any of its other components. It therefore seems illogical that the individual scientist should be asked to pay the costs of publication as it is that, increasingly, (at least in universities) he or she should be asked to fund his or her attendance at local and overseas conferences. To make this point is not to deny the important role that individual scientific societies can and do play in scientific publication. The Canadian government recognizes this, and in addition to funding directly its stable of journals — the Canadian Journals of Scientific Research, the exact counterparts of the AJSR — it provides a substantial grant ($Can0.5M in 1986) available to assist individual societies with their journals. Nevertheless, with a relatively small population Canada also recognizes the advantages that flow from the economy of scale associated with publishing a family of journals.

The President is to be applauded for drawing the attention of AIP members to this problem. There has been a flood of letters to the Minister for Science, the President of the Academy and to the Chairman of CSIRO in support of the Journals. These letters have undoubtedly had a significant influence on recent events. Those of us who publish regularly in AIP know its value and its reputation amongst our colleagues overseas. The quality of its refereeing, editing, and production are second to none. At a time when there is a disquiet internationally about falling standards in this field, and essential, component of every research program Australian physicists have been urged to add their voice to those who have already spoken out in defence of a valuable asset. Now is the time to speak, for if the AIP is allowed to decline through an erosion of its financial support to the point where it is no longer viable it seems unlikely that Australia would ever again have its own international physics journal.

R. W. Crompton FAIP
Chairman, Board of the AJSR

Highlights of August 1986 AIP Council Meeting
I. M. Bassett, Hon. Secretary AIP

The Council of the AIP meets annually. It consists of the Branch Presidents (one from each state, plus one from the ACT), the members of the Executive (President, Vice-President, Registrar, Treasurer and Secretary — the last three being designated Honorary to make it clear that they too are gentlemen) and the immediate Past President. The preponderant voting power lies with the Branch Presidents, who each have two votes or three, according to a formula based on Branch Membership, while members of the Executive have one vote each.

The Council met in Adelaide on Friday & Saturday, 22-23 August 1986, just before the AIP National Congress. The Council was assisted by three non-voting "observers", Dr G. H. Thompson (Editor of The Australian Physicist), Ms Jan Powe (Education Convenor) and Professor John Prescott (Employment Committee).

Council receives and considers annual reports from its various standing committees, from The Australian Physicist, from the Branches and Groups, and from its representative on outside bodies (such as some
P.O.LICY AND POLITICS

committees of the Australian Standards Association. As the governing body of the AIP, Council also initiates policy and distributes funds.

An important event in 1986 was the formation of FASTS, the Federation of Australian Scientific and Technological Societies. This consists of some fifty six member societies. The total number of individual members of these societies is about 50,000; this figure is somewhat inflated by overlapping memberships.

The AIP has played a leading role in the formation of FASTS and in setting the initial directions through the initiatives of the AIP's immediate Past President, Prof Geoff Wilson, and the President, T.F. Smith. (See President's Column TAP page 106). Its present budget review will include a public forum in November followed by a published analysis. FASTS now has a full time Executive Director (Dr David Widup), with an office in Canberra. Apart from articles in "TAP", communication of FASTS news to members of the AIP will be via a regular column in "Search" (TAP page 223).

Council discussed the AIP's relationship with its Groups (e.g., Solar Terrestrial and Space Physics) and with kindred societies (e.g., the Australian Optical Society). Many physicists are members of such specialist kindred societies, but are not members of the AIP, and see little point in paying two subscriptions. The Executive was asked by Council to see how the AIP might act more effectively as an umbrella organization for physics-related specialties, perhaps along the lines of the American Institute of Physics. It is relevant that, under present rules, it is possible for a member of an AIP Group without being a member of the AIP. Council agreed that the present professional criteria for AIP membership should be retained.

A recent Executive policy decision regarding funding of conferences was reversed by Council. The Executive or Council may now freely fund conferences, rather than merely underwriting them. This change of principle may make little difference in practice because funds are stretched to the limit anyway.

The Institute's membership file (with additional information regarding age, dates of grade changes and area of employment) is now on CSIRONET. Up-to-date Branch membership lists or sticky label sets are now easily and cheaply available at any CSIRONET terminal in Australia. The NSW Branch is using this service and others should consider following suit. In future, and with the help of the enriched computer data base, members are to be encouraged to upgrade when they appear to be eligible to do so. A "vestible" grade (at present Graduate member) will be retained, but henceforward, an individual may not remain in it for more than ten years. There were recently as many as 450 Graduate members, some approaching retirement. Retired members (who wish to receive 'The Australian Physicist') are to be required to pay a modest service charge as a further measure designed to spread the Institute's costs more fairly while maintaining easy terms for new members who tend to be young and impoverished.

The Institute runs on voluntary service. The most arduous of these voluntary roles is that of Editor of "The Australian Physicist". Dr Thompson, who recently took on this task, has adopted a more active editorial policy than her predecessors. Dr Thompson and her team of volunteers are sparing no effort to keep improving the layout and content and at the same time to minimise costs and attract paid advertising.

The Australian Journal of Physics and its sister journals are again threatened with closure. Council resolved to ask the Minister of Science to renew scientific publication in Australia and consider its value before taking any action which would bring it to an end. While doubts have been expressed about the financial viability of publishing a general physics journal in Australia, it is worth noting that a new series of physics journals is being vigorously launched in Singapore (by World Scientific).

There was some discussion of physics education. Ms Powl stated that many physics teachers have insufficient knowledge of physics, the problem being exacerbated by the fact that some state education authorities, while recognizing science teachers, will not recognize physics teachers; there is also a certain philosophical opposition to specialization.

Council struck a small blow for excellence by agreeing to sponsor an Australian team to compete in the 1987 International Physics Olympiad — a gruelling and exhilarating competitive examination for final-year school children held annually in the Northern Hemisphere summer.

As the author of this partial summary of Council's discussions I will take the liberty of adding an editorial remark of my own. Policy-making by Committee is beset with words, too numerous to read. Paradoxically, it is also usually done with insufficient information, without any clear conceptual framework and in haste. The making of reports, sometimes seem a pointless and non-convergent process. The AIP has itself contributed a number of reports and submissions to Government bodies over the last year — in particular submissions to ASTEC on CSIRO, and on research in universities and colleges. Unsatisfactorily though the making and reading of reports may be, it is an indispensable part of the process by which decision-makers are informed.

Through membership in the AIP individual physicists can play a useful part in this collective. In doing so we can contribute from our own bit of specialized first-hand experience to the pool of information available to policy-makers in business and Government.

The AIP Membership

A. Pryor, A.I.P. Hon Registrar,
J. Collins, A.I.P. Hon Vice President.

The first thing to realize about the AIP is that it is a small society speaking for a large subject. The 7000 members of the RACI represent Chemistry; the 60000 members of the IEA represent Engineering; our 2300 members have to carry the banner for Physics, the most essential scientific subject of all. We need to be well organized and dedicated.

The second thing to realize is that the AIP is a society with graded membership. Our grades — Student, Subscriber, Associate, Graduate, Member and Fellow — represent status in the field of Physics. They are not based on ability to pay; still less on willingness to pay.

Students (fee $11, 176 enrolled) are students majoring in Physics who have not yet graduated at Pass level.

Subscribers (fee $39, 25 enrolled) are mature non-graduates interested in Physics.

Associates (fee $39, 42 enrolled) are University graduates, but not with acceptable Physics major,

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working in Physics. The Council has recently ruled that Associate would be suitable as a permanent grade for those Graduates whose employment has become entirely non-Physics.

Graduates (fee $46, 959 enrolled) must have a B.Sc. with Physics major. It has always been intended as a temporary grade for young graduates, to be held for a few years before progressing to the normal professional grade of Member. Many members, however, through economy or modesty have remained permanently in the grade of Graduate. It is not unknown, for example, for a Professor of Physics to be still a Graduate of the AIP. The Council, at its meeting in Adelaide in August 1986, decided not just that it did not approve of such inertia but that it would no longer allow it. A new Article was put forward: "the grade of Graduate is a vestige grade and is not to be held for more than 10 years". A change in Articles must be approved by a General Meeting, next scheduled for March 1987, so this ruling is not yet binding. It will mean that of our 959 Graduate members about 500 will have to change grade. The great majority of them will up-grade to Member but some may become Associate if — and only if — they are employed in an area in no way connected with Physics. (Note that computing, physical chemistry, high-school Physics teaching and scientific administration or sales will be all taken as employment in Physics, with Member being the appropriate grade.) Over the next few months the Registrar will be sending a letter to all over-mature Graduates urging them to early conformity with this impending new Article.

Members (fee $69, 727 enrolled) must have as a minimal requirement a B.Sc. in Physics plus five years appropriate experience. It is to be looked on as the normal grade for a mature, qualified person earning a living at Physics.

Fellows (fee $94, 340 enrolled) must have as a minimal requirement a B.Sc. plus ten years experience at a level acceptable to Council. But whereas for Members the minimum suffices without further question, Fellows are expected also to have attained some distinction in Physics. Applications for Fellow are considered very closely by the Membership Committee. The normal profile of a successful applicant is to be over 35 (though we have admitted Fellows as young as 30) and to have published at least about 15 papers in refereed journals or, alternatively, to occupy a position of scientific influence in industry or the civil service. Our standards, in short, are high but not by any means exalted. We believe that, of our 727 present Members, perhaps 200 could be acceptable as Fellows and should be encouraged to put in an application for the grade.

These changes involve a lot of administrative work in setting up computer files to allow us to follow members' progress through the grades and in processing the applications. They will disturb a lot of our members — about 300 Graduates and about 200 Members will be urged to up-grade. It is not just a matter of getting higher fees out of our members. It is a question of the stature and image of our Institute. We have grades; if we have them they should mean something. The spectacle of a distinguished 50-year-old physicist still as a Graduate makes a mockery of our whole system. What we aim at is that all mature working physicists in Australia should be Members and all physicists with some level of achievement should be Fellows. The absence of the letters MAIP or FAIP should be something that draws comment.

Profile of the AIP Membership

We have recently undertaken the major task of extending our computerized data base to include age, sex, date of admission or transfer to grades and area of employment of our members. This information was taken from our files and is incomplete. We do not know, for example, the field of work of over 200 of our present Graduates who joined us before they had found a permanent job. We will be asking for your cooperation each year, when the subscription notices are sent out, in updating information about your qualifications and field of work. The present information profile of our membership is as follows.

### ACADEMIC QUALIFICATIONS

<table>
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<th>Degree</th>
<th>Fellows</th>
<th>Members</th>
<th>Graduates</th>
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<tr>
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<td>0</td>
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<tr>
<td>Ph.D.</td>
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<td>415</td>
<td>141</td>
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<tr>
<td>M.Sc.</td>
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<td>116</td>
<td>50</td>
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<tr>
<td>B.Sc.(Hons)</td>
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<td>67</td>
<td>351</td>
</tr>
<tr>
<td>B.Sc.</td>
<td>5</td>
<td>116</td>
<td>386</td>
</tr>
<tr>
<td>Other</td>
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<td>12</td>
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### EMPLOYMENT OF AIP MEMBERS

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<th>Graduates</th>
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<tr>
<td>Sec. Educ.</td>
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<td>32</td>
<td>111</td>
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<tr>
<td>Hospital</td>
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<td>21</td>
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<tr>
<td>CSIRO</td>
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<td>74</td>
<td>48</td>
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<tr>
<td>Fed. non-CSIRO</td>
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<td>Unknown</td>
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<td>207</td>
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Several comments can be made on these data: We have 1040 members with higher degrees. On the basis of ABS Census figures and other sources we believe that this represents about 65% of such people in Australia. Our 937 B.Sc.'s represent only about 33% of those eligible.

2 of our 340 Fellows, 38 of our 727 Members, 89 of our 959 Graduates, and 31 of our 176 students are female.

Physics in Australia is very much concentrated in tertiary education and in the Government research establishments; 88% of Fellows, 79% of Members, and 68% of Graduates are so employed. We have comparatively few employed in private industry, surprisingly few employed by State Governments, and almost none who are self-employed. Only 154 High School Physics teachers in the whole of Australia are AIP members.

The Role of the Institute

In many ways, and especially considering its small membership, the AIP is an active organization: think of its monthly meetings in nearly every State, the monthly "Australian Physicist", the many large conferences, and our active role in the Federation of Australian Scientific and Technological Societies — which is the only major social initiative by Australian
scientists since the Australian Association of Scientific Workers folded up back in 1949. One of our greatest current problems is the fragmentation of Physics. Some of the separate groups, such as the Condensed Matter Physics group and the Nuclear Physics group, stay loosely attached to the AIP, but the Astronomers and the Optics Society have, in effect, severed all connection with us (e.g., of the 220 members of the Astronomical Society, only 48 are AIP members and those are predominantly among the older generation; the younger generation of Astronomers has deserted us.) One could put several arguments to these “limited subject” groups; first, that their groups, in the long run, may decline in status and bargaining power without the AIP somewhere in the background; second, they may find it easier to organize conferences if they have the security of financial underwriting by the AIP; and third, that many of their members are also University teachers in Physics and, as such, have obligations to Physics as well as to their special subject. The Council, in Adelaide, decided to explore ways of offering attractive terms for joint membership in an effort to recover some of the potential members who now confine themselves to one of those professional interest groups.

It is also necessary for the AIP itself to sharpen up its organization. We must make an effort to see that our members are appropriately graded. We must never forget the necessity to recruit, especially among the young graduates. We have to rely here on the University staff members. Let us try to see that no graduate ever gets away from a tertiary institution unless a GAIP enrolment form is put in his or her hands accompanied by an exhortation to fill it in. The status of Physics is under challenge. The AIP is its only effective champion.

University and business leaders to hold to-level meeting

University, business and government leaders have met in Sydney on 2 and 3 October in a new initiative designed to lay the foundation for greater future cooperation in the national interest.

The meeting, called the Forum on Business and University Co-Operation in Australia, is the first of its kind and was opened by the Prime Minister, Mr R.J. Hawke, at a dinner at the Sydney Hilton Hotel on the evening of Thursday, 2 October.

It is the outcome of two years of consultation by a working party of the Australian Vice-Chancellors' Committee (AVCC), representing Australia's nineteen universities, and the Business Council of Australia. The Working Party's establishment coincided with suggestions by Mr Hawke that there needed to be closer consultation between the two sectors.

The Working Party reported that the application of new technology and manpower planning to lift industry performance depended on a much greater involvement between business and universities. A new mechanism was needed to bring together the country's leading entrepreneurial forces and its primary intellectual resources in a common cause.

The Forum is an immediate outcome of these discussions and is aimed at encouraging the joint consideration of major issues, improving the two-way flow of communication, examining the steps necessary to apply new technology to industry and to let senior ministers and government officials know of issues of concern in research planning.

As well as Federal ministers and departmental secretaries, vice-chancellors and leading business representatives, the Forum will be attended by representatives of organisations of scientists, engineers, university staff and postgraduate students. The Chairman of Commonwealth advisory bodies on science, education and research policy will also be there.

For further information contact Neville Petersen 692 316869 or 449/4526 (h).

National Medical Cyclotron Facility

The Budget provides $0.2 million for the first phase in the development of a national medical cyclotron facility to be owned and operated by the Australian Atomic Energy Commission (AAEC) and located at the Royal Prince Alfred Hospital in Sydney. The total cost is estimated at $14.2 million over the next four years.

A Cyclotron Committee established by the Minister for Health recommended support for such a facility in its report submitted in November 1985. The proposal also had the support of the Australian Science and Technology Council (ASTEC) and the National Health and Medical Research Council as well as strong support from within the medical community.

The cyclotron will produce radioisotopes on a commercial basis for distribution to nuclear medicine departments in hospitals throughout Australia for use in the clinical diagnosis of a wide variety of health conditions. Cyclotron radioisotopes which are too short-lived to be imported will become available; also, longer-lived radioisotopes which are currently imported at a substantial cost will be domestically produced. The production and distribution of cyclotron radioisotopes will complement reactor-produced radioisotopes currently provided by the AAEC from its research reactor HIFAR.

The cyclotron will also be used for the production of very short-lived radioisotopes for use in a national positron emission tomography (PET) research centre associated with the cyclotron. This will allow advanced medical research studies expected to improve understanding and treatment of many common medical disorders of high social cost, e.g. epilepsy, schizophrenia, drug addiction, dementia and stroke, heart disease and industrial occupational disorders. PET is a recently developed technique which provides quantitative information on the physiology and biochemistry of discrete regions of body tissue using body fluids labelled with cyclotron radioisotopes.

Australia has been, with New Zealand, the only advanced country not to possess a medical cyclotron, and this decision represents a major — and overdue — step in bringing us back into the mainstream of research and applications of peaceful nuclear technology.

Contact Officer: Dr. R. Smith.
Phone: (02) 543 3702 (work).

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When I was learning electromagnetic theory, I thought that there were many difficulties associated with it. There were but many of them have been removed in my further study. In particular I was very concerned about the origin of an EM field. Maxwell's equations seemed fine as long as no questions were asked about how the fields were created. The solutions of the equations with their interpretation of propagation by the differential equation of wave motion seemed wonderful at first sight and still retain their fascination. But I recall asking myself where the plane wave came from to find that it came from an infinite medium, infinitely large source. I found this hard to accept and the advice I got from my teachers was that Maxwell's equations are good for propagation and the interpretation of light phenomena but pragmatically, accept them and forget how the fields escape from the source. Unusually I accepted this interpretation and was a little relieved to find that Poisson's equation for static fields was contained within the analysis. If I put a Dirac delta function at the origin, I could deduce the inverse first law for the potential and this was reassuring, but only at the cost of putting this singularity at the origin. By this time I was aware that this wasn't what Maxwell had meant when he talked about electromagnetism. His world had been described in terms of familiar continuous functions extending through all space, which must include the sources. The aether, too, had been a classical entity with a continuum description and had played a part in Maxwell's thinking.

I don't think that my student experiences were unique and in fact I am still confused in classical ideas presented for me in another set of lectures on Kinetics Theory in which I was taught collapsed Boltzmann distribution of point gas atoms and I learnt how to deduce Boyle's Law from an atomic basis. So matter was not continuous! The resolution of these difficulties came for me and no doubt for others on learning the Lorentz force on an electron in a magnetic field and the recognition that there were in fact singular sources for the electromagnetic field. And the electron was a good experimental object having been found in gas discharges by J.J. Thomson and put into metals by Drude. Lorentz' book on the Theory of Elecrons and its modern version by L. Rosenfeld summarized the whole of this situation and both books still have much to offer me.

However, I should not have been so complacent. If I had been troubled by this problem of the interaction between a classical field and matter then I ought to have understood that Maxwell's successors in the latter part of the nineteenth century would also have been, and especially with nothing in the way of atomic experiments to help them. This book by Buchwald is the history of this troubled period. It is not easy reading, being a historical discussion of the physics and the physicists of those days. There is no attempt to say that a wrong move was taken because of modern knowledge; the moves in the game are seen against the background of the articles and of the arguments of the time. This makes it difficult reading because the ideas of aether, especially of equations of motion of the aether (a continuous medium) are entirely forgotten in modern physics and even when modern students are given a historical introduction to any subject it is usually condensed, and often dismissed in the preliminary lecture. The word that came to mind when I was reading the book was the Italian cimento which can be translated as a hazardous trial. Every article before the concept of the electron was involved taking a bet that the equations would represent reality. The physical difficulty was concentrated in conductivity. It is easy to write that the current density vector was linearly proportional to the electric field vector (in an isotropic body) and we recognize this as Ohm's Law. But this implies that the energy in the field was being lost to the matter in Joule heating and the physical mechanism of this effect was very obscure. In ways that made me as a modern reader say, "No, don't do that, it will get you into trouble" the writers of that time kept bringing in the aether as an intermediary. And their electric charges and currents were continuous. The displacement current of Maxwell played a very large role in this thinking. Because it was so startling and so new in physics and impressed the physics community it dominated the thinking of the "Maxwellians" as Buchwald calls them. Thus the conduction current to a Maxwellian was derived from a change of displacement current and when the American Hall in 1879 discovered the effect of the action of a transverse magnetic field on the current in a metallic lamella, one interpretation was that the magnetic field acted on the displacement current. The fact that the energy in the pure electromagnetic field without interaction could be interpreted in terms of quadratic terms suggested that Maxwell's equations could be derived as Euler equations using a minimal principle. Such principles were at the heart of much classical thinking and therefore the Maxwellians were upset to find that when a conduction current was included and consequently dissipation, they could not find a suitable minimal principle. The conduction current was the link to matter and the loss of energy was from the field into Joule heat. In passing we note that Jeans in his book on electricity and magnetism (1908) gives a minimal principle for conduction currents alone showing that Ohm's Law follows from the minimisation of the total Joule Heat in a circuit.

It was Larmor who in the early 1900's realised eventually that an "electron" had to be introduced into physics. He approached it through considerations of electrolysis and of convection currents, both ideas rooted in recent experiments. With Thomson's measurement of electron mass in gas discharge experiments, the whole subject of electromagnetism changed and by 1898 very few British articles appeared without microscopic considerations. From that time onwards electron dynamics became important and the electron's universality was accepted. Although Lorentz' "Theory of Electrons" (1909) is the early book that is most often recalled when thinking about electrons, the first to popularise the concept of the electron was Drude's "Lehrbuch der Optik" (1900) which was translated into English by C.R. Mann and R.A. Millikan in 1905; this is another example of Millikan's understanding of these problems of the structure of electricity.

There is one aspect of Buchwald's book in which I was most interested. He uses the solidus notation consistently for the algebra so that every equation occupies only one line of type. It is presumably easier.
for the composers. I have often wondered what it is like to read, at some length, in this notation. The use of many brackets and nested brackets needs getting used to. In my last article, in the Aust. J. Phys., I used this also but of course I could not be an objective judge. I think that Buchwald’s “solidus text” takes a little more effort to read than if, for instance, fractions are displayed with the usual horizontal bar. No doubt Buchwald found it helped to reduce the length of the book. The font is small and there is much algebra.

This is a good book. It is very comprehensive and if you like Kuhn’s language it discusses a paradigm (the continuum structure of matter) that failed. But that is part of our common physical heritage. The book should be in all tertiary libraries joining a steadily increasing number of good historical studies in science.

Reviewed by L.K. Fifield, Research School of Physical Sciences, The Australian National University.

Clustering phenomena in nuclei have been an active field of study in nuclear physics since its earliest days when α-particles were observed emerging from nuclei. The question of α-particle clustering is still with us, but the field has expanded greatly to include many other phenomena which touch on most aspects of modern nuclear physics. The volume of invited papers from the 4th conference in the series reviews the current status of a broad range of topics each of which has some connection to the existence of clusters in the atomic nuclei.

The volume opens with an introductory paper by Bromley which summarizes recent achievements in the field and outlines challenges for the future. A paper by Buck shows that the simple picture of a cluster moving in a potential well is remarkably successful in reproducing many of the properties of the light nuclei. A different approach to clustering is adopted by Lachiello, who introduces bosonic degrees of freedom (vibrations) and uses group theoretical techniques to solve the resulting many-body problem. Heavy-ion resonances are discussed in two papers. Moseley discusses the \(^6\)Li + \(^9\)Be system and concludes that, despite 20 years of effort, there is still no definitive experiment proving the existence of molecular resonances, but sees hope in a new generation of sophisticated experiments. Betts presents the evidence for similar resonances in the \(^5\)Li + \(^5\)Li system. These are at excitation energies of 70 MeV, have spins of 40, and may be related to a super-deformed shape in the \(^{44}\)Ti compound nucleus. Two papers address the long-standing problem of the preformation of an α-particle within the nucleus. Arima, in his concluding remarks, notes that the situation here is still “very bad”. A number of other papers deal with projectile break-up, with angular correlation techniques to determine spins of cluster states, and with knock-out of clusters by various probes.

No nuclear physics conference would be complete without at least one paper on the role of quarks in nuclei. In one of three papers on this subject, Thomas concludes that, although quark degrees of freedom are expected to be essential to a truly microscopic understanding of the atomic nucleus, there is at present no definitive evidence to support this contention. Finally, there is a nod towards both anomalies and the solar neutrino problem.

In summary, this book is a comprehensive review of clustering phenomena in nuclei, and as such merits the attention of all practitioners and students of nuclear physics.

Reviewed by J.R. Shepanski, School of Physics, University of New South Wales.

Among the very many attempts at viewing the phenomenology of Special Relativity from an unconventional stand-point, this book (as well as its predecessor: “The Logic of Special Relativity”) is perhaps the most fascinating and plausible. The author combines in it the idea of a (uniformly) expanding, spatially flat Universe with some very basic physical principles and thus generates a theory which is, at least locally, indistinguishable, in its predictions, from the Einsteinian theory, although it certainly differs from the latter in its interpretation of the Principle of Relativity.

Similarly to his earlier work, Prokhorov develops his arguments from the concept of a fundamental reference frame constituted by so-called fundamental observers in a mutual uniform recession. Relative to that frame, propagation of all c.m. signals is (in vacuo) isotropic and proceeds at a constant speed, the same relative to all fundamental observers. The corresponding space-time is then described by a Robertson-Walker metric with a zero spatial-curvature index (k = 0). The author further supposes that, relative to all other inertial frames, only the “there-and-back” measure of the speed of propagation of those signals remains invariant. With the help of these suppositions, he is able to derive all the standard kinematical and dynamical results usually associated with Special Relativity.

The book also features, in the concluding pages of its main text, considerations concerning the nature of gravitation and of the aforementioned expansion as well as some cosmological descriptions. It closes with a section of 7 Appendices, one for each chapter, and Comments on the Exercises and Problems.

The book is well organized and, in its early parts, could be used as a helpful compendium of concepts and definitions underlying conventional theories of Special and General Relativity. Most of the reasoning within the main body of text is very sound. In Appendix 2, however, (some minor references in the text as well) the author imputes to Einstein a particular interpretation of his “stationary frame” concept which is, in this reviewer’s opinion, quite at variance both with the spirit of Einstein’s writings and with the point of view espoused by the author himself, as evidenced by earlier text discussions. It is hoped that this, the only major fault, together with a number of misprints, will be corrected in future (well-deserved) editions of this book.

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Technology Park, Adelaide Corporation

A. Plevin, Manager
The Corporation

The Technology Park Adelaide Corporation is a statutory authority responding to the South Australian Parliament and was established by Act on 18th March, 1982.

It was established with the twin goals of encouraging, and where appropriate, facilitating:

- the establishment and/or development of new technology based industries in South Australia, particularly those based on local invention and innovation; and
- the development and/or adoption of appropriate new technologies by South Australian industry.

The Corporation administers a number of programmes in keeping with its Corporate objectives, including Technology Park Adelaide, the Adelaide Innovation Centre and the Adelaide Microelectronics Centre.

Technology Park Adelaide was a pioneering venture in Australia which in the short space of three years has firmly established itself as Australia's premier location for innovative, new technology based industry, and with a growth rate matched by few similar developments anywhere in the world.

The Adelaide Innovation Centre, a co-operative venture with the Commonwealth Government, is regarded as the "model" centre in Australia — having successfully commercialised more products than the combined efforts of all other Australian Centres.

The early demands on the services of the Adelaide Microelectronics Centre, another co-operative venture with the Commonwealth Government and established in early 1986, augurs well for the future.

The Park

Technology Park Adelaide was an initiative being vigorously pursued by Government when the Corporation was established in 1982. Responsibility for the establishment and management of the 85 ha Park was formally transferred to the Corporation in June 1982, and site works were completed in late 1983. In the intervening three years the Park was evolved into one of the most successful developments of its type in the world and brought Adelaide international recognition as a Centre of Excellence in Technology.

The development of 10,000m² of multi-tenant incubator accommodation at the Park has been one of the most visible signs of progress.

The three complexes, Innovation House (which has become the symbol of the Park), Innovation House West and Endeavour House provide a new dimension in commercial accommodation.

The availability of well located and very flexible space which can accommodate changing requirements is often more important to companies than the cost of space per se. The multi-tenant buildings were designed with this need in mind and in conjunction with the provision of a range of physical/logistical and shared office services have proved a boon to new start-up ventures.

Since the completion of the first complex, Innovation House, in January 1984, no fewer than 16 start-up ventures have been established. Moreover, many of these companies are experiencing exceptional growth rates and will eventually relocate to purpose built facilities on the Park.

Indeed, one of the unique aspects of the Park compared with similar overseas facilities is the extent to which it is populated by new ventures based on local expertise. The Corporation's Innovation Centre has played an important role in this regard, assisting a number of innovative companies to commercialise their developments and establish at the Park.

Since the beginning of 1984, 31 companies have established operations at the Park in such diverse areas as VLSI design and manufacture, machine vision, remote sensing, optics design, commercial and defence related software development, computer networking, defence electronics and medical diagnostic products. 26 of these 31 companies have their head office at the Park.

Synergy — the attribute of a technology park that sets it apart from a conventional industrial estate — is flourishing. Austek Microsystems, a company which designs and manufactures VLSI chips, successfully concluded a contract with another Technology Park based company, Vision Systems to develop and manufacture a custom chip to be incorporated into a vision processor under commercial development by the Company. In another example of co-operation, the South Australian Centre for Remote Sensing at the Park is working closely with British Aerospace Australia, which recently established its Australasian headquarters at the Park, in the development of an instrumentation package for the European ERS-1 satellite.

Companies are beginning to reap the rewards of co-locating in an environment where R & D is seen as an essential prerequisite to survival.

There is no doubt the Park now represents the most concentrated group of innovative technology oriented companies in Australia — not quite Silicon Valley — but an important engine room for economic resurgence in South Australia.

The Innovation Centre

The Adelaide Innovation Centre commenced operations in April 1984, and is funded jointly by the Commonwealth and State Governments.

The Centre's prime objective is to foster the commercialisation of inventions for the creation of economic wealth in South Australia. Specifically, the Centre provides independent assessment of market potential, technical feasibility and commercial viability in order to facilitate licensing arrangements or investment in new business ventures.

The Centre can claim in its first two and a half years to have contributed directly to the establishment of 7 new companies in South Australia and the conclusion of 10 licensing agreements with local companies.

As a venture manager, the Centre is being utilised by both the State and Commonwealth Governments in support of government sponsored innovation development projects and by academic bodies for the commercialisation of research.

Inventions and ideas for technological advances can be of great value to the community — but only if they are put to work. To be successful, an invention must
be properly evaluated, nurtured, supported with adequate funding, patented, and competently marketed. Rarely do inventors have the facilities or funds to move their ideas to the stage where licensing or investment can take place. The Adelaide Innovation Centre provides these facilities and is proving to be successful in achieving commercialisation of new ideas.

Without the Centre many promising inventions would still be languishing on a shelf or the technology would be exported offshore with little benefit to the State.

The Centre is an important element in the supportive environment for new technology based development in South Australia.

The Microelectronics Centre

Microelectronics is an all pervasive technology — there are few areas of economic pursuit where it has not had a significant impact. In many areas of manufacturing, the use of microelectronics in products and production processes is rapidly becoming synonymous with survival.

The Adelaide Microelectronics Centre, the Corporation’s newest venture, is funded jointly with the Commonwealth Government. Established in early 1986, the Centre’s role is to increase the use of microelectronics in industry, in order to enhance South Australian industry competitiveness and long term growth prospects.

The Centre’s functions encompass a broad range of activities:

- Provision of integrated design, manufacturing and quality assurance advice and services. The Centre has a well equipped laboratory containing electronic Computer Aided Design systems, microprocessor development tools, test and measuring instruments which is available for use by industry. Electronic design advice and assistance is available; small designs are undertaken ‘in-house’ whilst larger designs are referred to consultants.

- Industrial awareness. Awareness programmes are held for company managers and include a video-based pack, small group evening seminars and more intensive one day seminars. Technical awareness seminars are also held for the benefit of technical managers and engineers.

- Technology transfer. A wide range of workshops are organised to provide more detailed information on relevant aspects of microelectronics to practising engineers.

- Information services. An up-to-date library is maintained and a current Press postal service is available to give industry engineers access to the latest technical literature. Databases of local industry capability and also maintained and access to local and overseas electronic data bases is available.

The Adelaide Microelectronics Centre represents an important initiative in the area of technology transfer, an initiative which should significantly assist local industry in an era of rapid technological change.

The companies

Austek Microsystems Ltd. About four years ago the Commonwealth Scientific and Industrial Research Organisation (CSIRO) recruited Dr. Craig Mudge to return from the USA and establish in Australia a design capability for Very Large Scale Integrated circuits (VLSI). It was understood that on completion of a three year VLSI program Dr. Mudge would leave CSIRO to establish a commercial enterprise.

CSIRO’s VLSI team in Adelaide achieved dramatic success. Microchips containing the equivalent of over 100,000 transistors were designed, produced, and demonstrated to work. Technology for designing VLSI chips was made available to numerous Australian industrial companies and university departments. Software was developed for the computer aided design of very large circuits.

While markets are predominantly international, the facilities for the custom design of high and VLSI chips will immensely strengthen the potential of Australian customers of Austek to compete in high technology electronics.

Vision Systems Ltd. The Company has two main product areas;

1. A video movement detection system which was recently selected by the USAF for installation at selected Space Shuttle bases in the U.S.A. and;
2. An intelligent recognition information system — IRIS — which is being hailed internationally as a significant step forward in the development of artificial intelligence for robotics.

Through IRIS, robots can be given artificial vision to enable them to carry out procedures such as inspection, measurement and identification as well as providing guidance or control.

That is a new technique, but the speed at which IRIS operates is the key to its outstanding potential in robotics — an industry which is estimated will be worth $US1 billion a year internationally by 1991.

IRIS operates at speeds 1000 times faster than anything else currently available.

The custom-made chip was conceived in the research and development section of Vision Systems Ltd and produced to Vision Systems’ specifications by Austek Microsystems, both located at Technology Park.

Merino Wool Harvesting Pty. Ltd. Merino Wool Harvesting, with the support of the Australian Wool Corporation and Federal Government, is developing a revolutionary robotic sheep shearing unit.

The robot unit uses mainly off-the-shelf components and standard robotics, avoiding exotic, aerospace technology which would push its cost beyond the reach of the wool industry.

The robot-guided system uses highly accurate sensors fitted to the sheep’s legs to guide it smoothly across the surface of the sheep, rendering skin damage virtually a thing of the past.

It relies on another local invention, a livestock immobiliser, based on instruments now widely used for pain suppression in humans.

Although field trials will not commence until next year, there is already buyer interest from the United States.

Dunitec International Pty. Ltd. Enticed to relocate from the U.S. the Company is involved in audio and antenna-related R & D manufacture. The Company’s achievements include the design of the ground telemetry antenna for the Gemini Space Project and the ground station antenna for the NOAA Weather Satellite Systems.

British Aerospace Australia. The company is involved in the design and manufacture of defence and, increasingly, space electronic systems. The company has been awarded the contract to develop data-processing

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systems for an infra-red scanner on the European ERS-1 remote sensing satellite project.

Andrew Antennas, a subsidiary of the American Andrew Corporation involved in defence and commercial telecommunications R & D.

AEE Pty. Ltd. Australia's major manufacturer of agricultural electronic equipment.

Australian Flight Test Services Pty. Ltd. — Australia's only commercial venture providing engineering and developing support for military aircraft, weapons and systems flight testing.

South Australian Centre for Remote Sensing. Australian leaders in remote sensing and ground truthing technologies.

Barium Fluoride Crystals

W. Macham, GEC-Picker, Perth

Since the discovery of the fast component in the light pulses from BaF₂ crystals [Laval et al, 1983] there is a growing interest in the use of BaF₂ as scintillation material in high energy applications where high timing resolution is essential. As early as 1970 [Farukhi and Swinehart, 1970] reported the possible use of BaF₂ as a scintillator for the detection of gamma rays, and alpha and beta particles. Up till then, barium fluoride had been known for its attractive optical properties in the wavelength region from ultra-violet to infrared and its high radiation resistance.

As a particular advantage of BaF₂ over the alkali iodide scintillators (NaI(Tl), CsI(Tl)) Farukhi and Swinehart mentioned its non-hygrosopic nature and comparable absorption for gamma rays.

However, the scintillation output of BaF₂ is only 10% of the pulse height of the NaI(Tl) pulses which makes the energy resolution inferior to that of NaI(Tl).

Laval et al. found the fast component at 225 nm in the emission spectrum superimposed on the slow decay of the light pulse (with wavelength peak at 325 nm) in their investigation of light pulse shapes using the single photon method. The decay constant of the slow component is 630 ns. (i.e. in between the decay constants of NaI(Tl) (250 ns) and CsI(Tl) (1100 ns) [Farukhi and Swinehart, 1970]. The decay constant of the fast component is only 600 ps. From time resolution studies Laval et al. have obtained a resolution of 112 picoseconds for gamma rays with ⁹⁰Co, measured with small BaF₂ crystals (dia 24mm, 1-4cm thick) and an XP 2020Q photo-multiplier tube with quartz window. This value is comparable with the fastest plastic scintillator known up to now. This makes BaF₂; an attractive alternative to plastic scintillators due to its relatively high density (4.88 g/cm³) and consequently high detection efficiency for gamma rays. The 220 nm. fast scintillation is only a small fraction of the total emission of BaF₂. about 20%. Therefore, the absorption of this U.V. component in BaF₂ is very critical. A light absorption of 12% at this wavelength has been measured in large BaF₂ crystals (length 12cm)] [Wishak and Kappeller, 1984]. For the slow component an absorption of 10% for 15cm thick crystals has been found, which yields even for large crystals good energy resolutions (varying from 11.5% to 12.5% for 662 keV gamma rays). In Table 1 the scintillation properties of BaF₂ are summarized [Moszynski et al, 1984].

Of particular interest in the application of BaF₂ as a gamma ray or particle detector is the small wavelength of the scintillation pulses. This calls for appropriate reflective materials and interface materials between crystal and photomultiplier tubes. For good timing performance a fast PMT with quartz window is needed. The photocathode must have a high sensitivity in the U.V.-region and a good collection efficiency for high energy photon-electrons is also necessary. Moszynski et al. have studied the performance of fast photomultipliers to be used in time-of-flight positron tomography. They compared the XP 2020Q and R1668 (Hamamatsu) PMT's and concluded that timing experiments were limited by poor collection of the photo-electrons produced by the U.V. light, although some modifications in dynode voltage to improve the time resolution have been suggested. Typical time resolutions obtained by Moszynski et al are about 350 ps which are still 20% better than obtained with CsFcrystals in time-of-flight positron tomography applications.

Alternative methods to detect the fast U.V.-component in the BaF₂ scintillation light have been reported in studies of BaF₂ used in high resolution electromagnetic calorimeters. Anderson et al [Anderson et al, 1983] have used a tetraakis (dimethyl-amino) ethylene (TMAE) photocathode coupled to a low pressure wire chamber enabling high count rates, good timing characteristics and high quantum-efficiencies.

Another read-out scheme in BaF₂-calorimetry has been reported by Lorenz et al. [Lorenz et al, 1986], who have used fluorescent flux concentrators (FFCs) and silicon photodiodes. FFCs are wavelength shifters that shift the U.V.-wavelength to longer wavelengths where photodiodes are more sensitive. The photodiodes have the advantage that they work in magnetic fields, are very compact and exhibit no drift.

Apart from its high timing resolution BaF₂ has some other interesting properties that may stimulate new applications of BaF₂ in high energy physics and other related fields. Wishak and Kappeller found no fast component in the scintillation light of BaF₂ when excited with alpha particles. So, gamma rays and alpha particles can be discriminated. Particle identification and photon-neutron discrimination based on time-of-flight measurements and pulse shape analysis with BaF₂ has been reported recently at GSI-Darmstadt (Scientific report 1985). Schotanus et al. [Schotanus et al, 1980] studied the temperature dependence of the scintillation intensity of BaF₂ and observed an increasing intensity of the 315nm slow component with decreasing temperature, whereas the 220 nm fast component was not affected. Finally, in nuclear astrophysical application BaF₂ is an attractive scintillator for its low neutron capture cross sections (in contrast, I in NaI has a very large one) [Wishak and Kappeller, 1984].

**TABLE 1: Physical and timing properties of BaF₂ and CsF scintillators**

<table>
<thead>
<tr>
<th>Properties</th>
<th>BaF₂</th>
<th>CsF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decay time constant</td>
<td>0.6</td>
<td>1.85</td>
</tr>
<tr>
<td>(ns)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow (ns)</td>
<td>620</td>
<td>-</td>
</tr>
<tr>
<td>Intensity¹</td>
<td>400</td>
<td>660</td>
</tr>
<tr>
<td>(p.e./MeV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (p.e./MeV)</td>
<td>2000</td>
<td>-</td>
</tr>
<tr>
<td>Emission wavelength Fast (nm)</td>
<td>220</td>
<td>390</td>
</tr>
<tr>
<td>Slow (nm)</td>
<td>310</td>
<td>-</td>
</tr>
<tr>
<td>Index of refraction</td>
<td>1.495</td>
<td>1.48</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>4.89</td>
<td>4.64</td>
</tr>
<tr>
<td>Energy resolution (%)¹</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Time resolution (ps)¹</td>
<td>115</td>
<td>150</td>
</tr>
</tbody>
</table>

¹: no very
NEWS FROM INDUSTRY

a) Measured with XP 2020 Q photomultiplier. $S_p = 70$ mA/W at 401 nm.
b) For 662 keV gamma rays from a $^{137}$Cs source.
c) For two counters, measured with 1cm. thick crystals coupled to XP 2020Q photomultiplier for Co gamma rays using dynode timing.

References

New Products:

ETP OXFORD

Photomultiplier Catalogue

A new 60 page catalogue from Thorn EMI Electron Tubes contains a wealth of technical information for selection, setting up and operating photomultipliers of nearly 30 different types. A spectral response chart is included and a list of technical reprints for further reading is suggested.

LeCroy Corporation Introduces High Speed Multi-Input Plug-In Pulse Shape Digitizer

The Model 2262 is an 80 megasample/sec, multi-input plug-in pulse shape digitizer which has been introduced by LeCroy Corp. DC-coupled with an analog bandwidth in excess of 40MHz, it also features 10-bit dynamic range and resolution, two or four inputs, and simultaneous sampling. The modular 2262 offers basic digitizer operation without frills at an affordable cost for a broad spectrum of applications including destructive and nondestructive testing, industrial/medical ultrasound scanning, basic digital oscilloscope operation, and image chamber detector development in High Energy and Heavy Ion Physics.

New 200 Megasample/Second Transient Recorder Enhances Multichannel Digital Oscilloscope

A 200 Megasample/sec sampling frequency, 8-bit resolution and a large segmentable memory combine to make the recently introduced LeCroy Model TR8828C Transient Recorder an extraordinarily powerful addition to the LeCroy modular digital oscilloscope family. The PC-based DSO is multichannel, multimeasure, with full waveform acquisition, viewing and archiving capabilities. The LeCroy WAVEFORM-CATALYST Software Package takes full advantage of the TR8828C programmability, and features in providing a user friendly interface. CATALYST allows single keystroke operation and uses familiar scope terminology. The multichannel digital oscilloscope, including the TR8828C, has a wide range of applications — especially in ATE, ultrasound and laser applications and communications research.

For further information, contact:

SYDNEY
ETP Oxford Pty Ltd.
31 Hope Street,
EMINGTON, NSW 2115
Contact: Fred Blake
Tel: (02) 858 5122

MELBOURNE
ETP Oxford Pty Ltd.
214 Berkeley Street,
PARKVILLE, Victoria 3052
Contact: Greg Tate
Tel: (03) 347 0733

QUENTRON OPTICS

Fiber Optic Devices and Resource Material

Newport Corporation have announced the release of a comprehensive series of products and source material for fiber optic applications.

A new brochure titled “New tools for fiber optics” includes a range of devices covering mode scramblers, graded index rod lenses and fiber couplers, fiber inspection microscopes and more. Newport have also released a comprehensive source book entitled “Projects in Fiber Optics”.

United Detector Technology is pleased to announce the availability of its new High Speed PIN Photodetectors for fiber optics applications. They are confident that these products will meet with the fiber optics industry’s requirements for low cost, high volume and high performance detectors.

Opto-Electronics has developed a new fiber cable pigtail method for its pico-second/gigahertz PLS10 and PLS20 laser sources. The new cable pigtail replaces the previously used one meter fiber pigtail and renders laser heads very robust and safe from accidental fiber breakage.

New Large Area/Fast Response Laser Detectors

MOLECRON DETECTOR, INC. has expanded its line of Pyroelectric Joulmeter probes to include 4 new large area, high energy versions...Models J25, J25HR, J50 and J50HR. These detectors feature 25mm and 50mm diameter elements respectively and can be chosen for either high or low repetition rate applications. These are stand alone devices which can be interfaced directly to an oscilloscope and/or peak reading voltmeter like their NEW JD1000 Joulmeter Display.

New! Fast Electronics

EG & G is pleased to announce a new product line to better serve your needs. EG & G recently acquired ELEKTRONIK SERVICE NOGGERATH (ESN), a West German company that develops and manufactures NIM and CAMAC instruments for high data-rate applications. These economical instruments give particular emphasis to the preservation of timing information. We plan to introduce many new EG & G-ESN NIM and CAMAC instruments over the next several months.

For further information please contact:

Mr. R. Hahneheuser or Mr S. Miles
Quentron Optic Pty. Limited
Laser Court, (GPO Box 2212)
ADELAIDE S.A. 5000
Telephone: (08) 223 6224
Telex: QTTRON AAB2809
Fax/Telex: (08) 223 5289

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Letters to the Editor

I am informing you with great pleasure that the 1987 International Conference on Lasers will be held in Xiamen (Amoy), Fujian Province, China, October 24-28, 1987. This meeting is the Third International Conference on Lasers to be held in China, the former two were held in Shanghai, Beijing (1980) and Guangzhou (1983) respectively. It is jointly sponsored by the Optical Society of China, Chinese Physical Society and Chinese Institute of Electronics.

Enquiries should be addressed to:

DENG SHI MING

Secretary General
Organizing Committee
1987 International Conference on Lasers
P.O. Box 8211, Shanghai, China
Cable: 8024, Shanghai, China
Telex: 33275 CASS CN
Tel: 950141 (Office Number)
      952134 (Home Number)

Members of the Australian Institute of Physics are welcomed to present their original papers at the 1987 Annual meeting of the Physical Society of Japan, which is to be held as follows:

42nd Annual Meeting
Date: Friday, 27 March — Monday, 30 March 1987.
Location: Nagoya Institute of Technology, Nagoya City.
Application Deadline for Presentation of Papers: Friday, 12 December 1986.

Presentations of papers at the meetings of the Physical Society of Japan by members of the Australian Institute of Physics are subject to the same rules as for members of the Physical Society of Japan, in accordance with the Agreement between the two Societies.

All inquiries for detailed information about this Annual Meeting should be addressed to:

The Physical Society of Japan, Room 211, Kikai-Shinko Building, 3-5-8 Shiba-Koen, Minato-Ku, Tokyo 105, Japan.

It may be of interest to readers of The Australian Physicist that, at the recent 11th International Congress of Electron Microscopy held in Kyoto, Japan, The General Assembly of The International Federation of Societies of Electron Microscopy elected me as one of their eight executive committee members to hold office for eight years. My nomination came from the Australian Academy of Science.

Yours sincerely
D.J. Cockayne,
Director, Electron Microscope Unit,
The University of Sydney

W.M. Skinner

Particle Beam Adhesion Enhancement at the Institute of Physics, Beijing

W.M. Skinner, Department of Applied Physics, R.M.I.T.

The enhancement of adhesion of thin metal films (up to a few thousand angstroms thick) to a variety of metal and non-metal substrates by particle bombardment has been studied since the early 1970's. The mechanism involved however, is not well understood. For example, reactive (chemisorbed) metals such as Al and Fe on glass have very weak adhesion soon after deposition. After aging in air for up to a few hundred hours, the adhesion may saturate to tenfold the as-deposited value.

This has been shown to occur [Benjamin et al, 1960] because of the formation of an intermediate oxide layer at the metal-glass interface due to migration of oxygen either trapped in the film during deposition, through the film from atmosphere or from the substrate. This upper limit of adhesion in specific systems may be achieved by energetic particle bombardment soon after deposition. However, it is found that the increase in adhesion is limited to the maximum as obtained by aging. In fact with ions, 'over-irradiation' can lead to de-adhesion effects due to stresses induced in the substrate [Scod et al, 1985]. When physically deposited metal films like Pt and Au are deposited on glass, there is no improvement of adhesion with time. However, in some cases, particle bombardment may increase adhesion to some extent. It has been suggested that bombardment produces a mixed layer of film and substrate atoms at the interface. However, this does not account for the improved adhesion achieved with light ions with low nuclear stopping, electrons, UV photons and gamma rays. In these cases of little or no nuclear interaction, it is more important to consider the secondary effects of particle bombardment.
The cascade of electrons produced by ionizations within the film during bombardment excite the electronic configurations in the interface region as they continue through to the substrate, after which, a direct chemical bond may form across the interface. This is an exciting prospect, since the process lends itself to many applications; for example in the microelectronics industry, producing ohmic contacts between materials previously requiring intermediate layers of metallisation.

In recent work, the difficulty has been in detecting satisfactorily such chemical bonds. The problem lies in that the bonding need only occur between the two atomic layers at the interface. Hence any characteristic signal (depending on the analysis technique) will be correspondingly small. Most of the techniques available involve sputtering or do not have the necessary resolution. Auger Electron Spectroscopy (AES) has been employed on films undergoing bombardment during deposition [Dallaporta et al, 1986], but only to monitor the other constituents in the system, and hence infer chemical bonding.

We may, however, take a different path. By measuring the adhesion energy at an interface and hence the energy per bond, we may show the adhesion to be either chemical or physical bonding.

There are both mechanical and non-mechanical methods for measuring adhesion. The most popular techniques are the scratch method which involves scribing the film with an indenter under a known vertical load, and the peel test in which the film with an indenter under a known vertical load, and the peel test in which the film is stripped or peeled also with a known load. The critical loads at which the film is removed will be indicative of the shearing stress applied to the film-substrate interface and hence the adhesion energy.

One of the non-mechanical techniques is the contact angle method. Thin metal films can undergo lateral segregation into beads or droplets when heated on their substrates, even at temperatures well below their melting point. If the surface free energies of the substrate and metal are known, the adhesion energy may be determined from the three-phase equilibrium contact angle.

The Microelectronics Technology Centre and the Department of Applied Physics at RMIT have been working on particle beam "stitching" as it has come to be called for nearly four years and I am at present studying for my Master of Applied Science in this area. In early 1985, Professor Liu Jia-Rui from the People's Republic of China worked at the RMIT on Rutherford Backscattering as a guest of the Department of Applied Physics. Prof. Liu is the Head of the Institute of Physics, Ion Beam Laboratory, Academia Sinica, Beijing. During his visit, Prof. Liu expressed interest in the "stitching" work and invited me to work at his laboratory. The facilities at the Ion-Beam Laboratory include an Ion-X Tanderron accelerator similar to the RMIT machine. However, with their cold Penning and sputter ion sources, they are able to produce beams of virtually any species in the periodic table at energies up to 3MeV (higher for ions of multiple charge). This versatility allowed the design of an experiment that could be carried out with ions of a range of atomic number, ion radius and nuclear stopping power.

Thin films of Cu and Pd, sputter deposited on sapphire substrates were irradiated with 2 MeV H⁺, B⁺ and Au⁺ in the dose range 10¹⁴ - 10¹⁸ ions cm⁻². The Cu/sapphire samples were equilibrated at 850°C for 8 hours and the Pd/sapphire systems at 100°C for 8 hours. After annealing, the sample surfaces were examined (back at RMIT) under a Scanning Electron Microscope (SEM) and photographs taken of the structures observed.

Preliminary observations showed that the dose was increased, the tendency to laterally segregate was retarded as compared to the unirradiated system. Whereas the unirradiated regions exhibited a uniform shearing, the irradiated regions showed clustered and coalesced beads. In the case of the highest ion dose given, 10¹⁸ cm⁻², complete wetting of the substrate was observed.

A thin carbon layer has been shown [Scod, 1986] to retard bead formation. Carbon will be deposited during ion bombardment due to cracking of vacuum system oils on the sample surface, and, will increase with ion dose. The presence of carbon effectively changes the three phase system and hence the adhesion energy result.

This experiment will be repeated at RMIT on the Microelectronics Technology Centre's 150 keV ion implanter with liquid nitrogen cold trapping. Further work will also include large area (4cm²) electron irradiation with in situ deposition and irradiation. The vacuum system is sorption/pumped to minimise carbon deposition during bombardment.

During my stay in Beijing, I had the opportunity to visit a number of other laboratories at the Institute of Physics. Including the Ion Beam Laboratory, the Institute is comprised of 17 separate departments. Some of the most interesting laboratories were Crystallography, where alpha and beta lithium iodide crystals are grown for export as well as ruby rods for use in lasers and the Magnetics Laboratory where research is being done on the magnetic properties of amorphous FeB and FeCoB. Also there are available a variety of analysis techniques, including RBS, AES, SEM, TEM, ESCA, NMR, EXAFS, Laser Scattering and Spectroscopy, Phonon and Mossbaer Spectroscopy.

Since my visit, there has been continued cooperation between the Department of Applied Physics, RMIT and the Academia Sinica. Also, successful negotiations between the Department of Applied Physics and various research establishments in China and Australia have resulted in the "opening up" of a number of laboratories for the purpose of co-operative research. I am hopeful that such exchange will continue in the future.

References

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ACT
Opportunities for Postgraduate Studies and Research in Physics
Canberra College of Advanced Education, Department of Electronics Engineering & Applied Physics, Head: Dr P.J. Edwards

Atmospheric Physics: Wind and solar energy resources; remote area power supply; atmospheric turbulence.
Ionospheric Physics: Very low frequency propagation anomalies.
Instrumentation Physics: Data logging and real-time signal processing techniques; anemometry; stochastic level-crossing processes; real-time spectral analysis; satellite ranging; time and frequency standards; opto-electronic techniques and quantum noise processes; electromagnetic wave reflectometry.

VIC
The regular monthly meetings of the branch have been well attended this year with capacity audiences (100+) on at least three occasions. The programme commenced in March with a public lecture by Robert Wilkinson (Melbourne University) informing and entertaining a crowded lecture theatre on "Halley's and Other Comets", ranging from the earliest observations and thoughts on "hairy stars" to the current (pre-Giotto) theories.

In April Warren Gellie of CSIRO afforded us a view of advances on a range of projects associated with the Division of Manufacturing Technology.

In May the Branch held another public lecture, with Frank Close (Rutherford Appleton Laboratory, UK) discoursing on "The Cosmic Onion". Frank presented a review of the fundamental structure of matter and how this is organized to build our present Universe, even touching on the current ideas that strings may be the underlying unifying constituents.

For our second May meeting Makato Sakata (Nagoya University) and Stephen Wilkins (CSIRO, Chemical Physics) gave us a very different insight into the investigation of the structure of matter in a review of the X-ray scattering facilities at the "Photon Factory" - the 2.5 GeV electron storage ring at Tsukuba, Japan. Professor Sakata gave us a description of the laboratory and an impression of the wide range of X-ray experimental techniques in use there, and Dr. Wilkins briefly discussed prospects for formal Australian participation in research at this hundred million dollar facility.

June saw the alternating of cosmic and laboratory physics continuing with Andrew Prentice discussing "Voyager 2 at Uranus and the Formation of the Solar System". An article by Dr. Prentice in TAP (May 1986) outlines this latest triumph of the "Modern Laplacian Theory", but cannot be more than a shadow of his colourful live presentation. Andrew has assembled much evidence for his view that the single concept of supersonic turbulent convection is central to explaining the spatial and chemical composition of the solar system and its subsidiary satellite and ring systems.

Scott Rashleigh (Australian Optical Fibre Research Pty. Ltd.) introduced us to the technology of Fibre Optic Sensors at our July meeting. This provided a fascinating insight into how fibres can be used directly as detector systems of great sensitivity, by making use of many different ways of modifying their transmission characteristics, even by such direct methods as stretching or squashing them. It was interesting to see how the analogues of all the standard elements of conventional optics (beam splitters, interferometers, etc.) are being realized in these guided wave systems. The evening also gave many of us some insight into the world of commercial technological research.

In August the optics connection continued with Alain Aspect (Institut d'Optique, École Normale Supérieure, Paris) addressing the Branch on "Quantum Mechanics and Reality: Experimental Tests of Bell's Inequality". A large audience heard a presentation of unusual clarity on the background to the debate on the question of "completing" quantum mechanics with supplementary parameters, Bell's contribution in showing that this is not a matter of taste but an experimental question, and Professor Aspect's elegant and decisive experiments which showed that Bell's inequalities are violated in just the way that quantum mechanics predicts.

In conjunction with the University of Melbourne the branch sponsored a seminar in September at which AIP National Congress speaker Barbara Wilson (AT & T Bell Laboratories), the Convener of the American Physical Society Committee on the Status of Women in Physics, presented some of the results that her committee has gathered in their study of problems facing women in physics at the tertiary and research levels. The statistics and the survey interviews showing the many pressures, social factors and perceptions which lead women to opt out of the education paths leading to physics careers also call for attention and investigation in the Australian situation. Dr. Wilson's talk also documented the slow rate of progress in the U.S. in the opening up of opportunities for research employment and university appointments, and the poor level of recognition given to the talents of women participants in our currently male-dominated profession.

In addition to the regular schedule of monthly meetings the Branch held its annual Laboratory visit in July. About 35 members visited the Bureau of Meteorology Head Office in Melbourne. Following some light refreshments and an inspection of the Bureau's current and historical activities, senior staff provided a general briefing on the operations of the Bureau and then guided two groups through the Research Centre, the National Meteorological Centre and the Victorian Regional Forecasting Centre. The opportunity to see the combination of data collection, computation and human insight involved in the applied physics task of weather forecasting was much appreciated.
<table>
<thead>
<tr>
<th>Year</th>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>Dec 3-5</td>
<td>4th National Conference of The Australian Optical Society — Melbourne. Prof. A.G. Klein, School of Physics, University of Melbourne.</td>
</tr>
<tr>
<td>1986</td>
<td>Dec 7-12</td>
<td>Application of Surface Science to Industry, Perth. Dr R. Willis, School of Applied Chemistry, WAIT, Bentley, W.A. 6102.</td>
</tr>
<tr>
<td>1986</td>
<td>Dec 8-12</td>
<td>Asian Regional Conference on Medical Physics, Dr U. Madhvanath, Bhabha Atomic Research Centre, Bombay, 400 085, India.</td>
</tr>
<tr>
<td>1986</td>
<td>Dec 8-13</td>
<td>Application of Surface Science to Processing and Manufacturing International Conference, Royal Australian Chemical Society, Perth. Dr M. Thornber, C.S.I.R.O. Dir. of Min. and Geochemistry, Floreat Pkt., W.A.</td>
</tr>
<tr>
<td>1986</td>
<td>Dec 16-20</td>
<td>International Conference on Metallic and Semiconducting Glasses, University of Hyderabad. Convener MSG-86, School of Physics, University of Hyderabad, P.O. Central University, Hyderabad-500 134, India.</td>
</tr>
<tr>
<td>1987</td>
<td>Jan 12-16</td>
<td>Conasta 36, Australian Science Teachers Association, Brisbane. Mr. E. Burt, 13 Blasdell Street, Tarragindi, Brisbane, Qld. 4121.</td>
</tr>
<tr>
<td>1987</td>
<td>Feb</td>
<td>15th Australian Spectroscopy Conference</td>
</tr>
<tr>
<td>1987</td>
<td>Feb 2-6</td>
<td>Conference Secretariat, Australian Academy of Science, GPO Box 783, Canberra 2600. Eighth NUPP Summer School, Australian Maritime College, Launceston, TAS 7250. The Secretary, 8th NUPP School, Physics Dept., University of Tasmania, Hobart 7001.</td>
</tr>
<tr>
<td>1987</td>
<td>Feb 4-6</td>
<td>11th Condensed Matter Physics Meeting, Pakatou Island, Auckland. Dr. Glynn Jones, Department of Physics, University of Canterbury, Christchurch, New Zealand.</td>
</tr>
<tr>
<td>1987</td>
<td>Feb 8-12</td>
<td>16th Australian Polymer Symposium, Cowes. Dr R.A. Shanks, Chairman, RACI Polymer Division, Applied Chemistry, RMIT, Box 2476V GPO, Melbourne, Vic. 3001.</td>
</tr>
<tr>
<td>1987</td>
<td>Feb 11-13</td>
<td>AAAS Boden Conference, Membrane Science and Technology, Thredbo. Dr R.A. Cornall, CSIRO, P.O. Box 52, North Ryde N.S.W. 2113.</td>
</tr>
<tr>
<td>1987</td>
<td>Apr 6-8</td>
<td>Microscopy of Semiconducting Materials, Oxford. Dr A.G. Cullis, Royal Signals &amp; Radar Establishment, St Andrews Road, Malvern, Worcs WR14 3PS, U.K.</td>
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<td>Apr 14-15</td>
<td>Sonar Transducers — Past, Present and Future, Underwater Acoustics Group, Birmingham. Dr B.V. Smith MIOA, Department of Electronic and Electrical Engineering University of Birmingham, P.O. Box 363, Birmingham B15 2TT U.K.</td>
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<td>1987</td>
<td>Jul 29-31</td>
<td>Neutron Scattering Symposium, Sydney. The Secretary — ANBUG, Cl. AINSE, Private Mail Bag, P.O., Sutherland, NSW 2232. XIV Int. Congress and General Assembly, UC, Perth. Dr E.N. Maslen, Cryst Centre, University of W.A. Nedlands, W.A. 6009.</td>
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