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President's Column

This is the first column to be written after the AGM was held on 8 March. I would like to begin by welcoming Fred Smith as Vice President and thanking the other Executive office bearers, John Macfarlane, John Harries and John Collins for staying on. Their professionalism and hard work for the Institute is greatly appreciated. The splendid work of Jim Graham and his Editorial Committee is also much appreciated; for many the 'Physicist' is the most tangible aspect of their membership and the high quality of its production is of great importance to the Institute.

At the request of the Science Policy Committee I have written to the new Minister for Science and Technology, the Hon. Mr Barry O. Jones and have congratulated him and requested a meeting to discuss a variety of issues of importance to the Institute and its members. I will report later on this. Useful meetings were held with the previous Minister, the Hon. Mr David Thomson. Issues relating to nuclear weapons are of interest and concern to many of our members. I commend the report on this from the Science Policy Committee which is published in this issue. Following the enthusiasm of the session on this at the Fifth Congress we are attempting to assist as much as we can in gauging the views of physicists and in fostering rational discussion with the aim of influencing events without loss of our political independence. The Working Party referred to in the paper has now been set up with an initial membership of Professor Alan Runciman, Mr Richard Joseph and myself.

In later columns I will review the operation of the Science Policy Committee and of other ongoing activities of the Institute.

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Editorial

John Prescott's latest analysis of the advertisements in The Australian newspaper is, as he says, surprising. Despite obvious limitations in the database, it is evident that jobs suitable for physicists are available in sufficient numbers. How then is it possible for potential employers to exploit the market to the extent described in the letter on p.76 (April).

I have even less data to go on, but my suggestion is that in the first place, young physicists have too limited a view of the boundaries of physics, and either from choice or ignorance limit themselves to disciplines and applications which are closely related to their previous research experience or course work. In the second place, industrial employers also have limited experience of physics and physicists, and need convincing that physics qualifications are as good an investment (in certain instances better) as the advertised alternatives.

The chairman of M.I.M. Holdings Limited, Sir James Foyles, is also Chairman of the University of Queensland Foundation, established a year ago to build up a capital fund to support University research. He is trying to encourage Queensland industries to make donations to the Foundation on the basis that basic research is the springboard for innovation. Support for the Foundation is thus a form of self-help. He recently told the Foundation that there should be a 150% tax deductibility for research investment and expenditure. I am not sure whether I have got this right, but my calculations suggest that the Government is being asked to pay for the whole of a company's research bill, without having a say in the way this money is spent. My own opinion is that if companies do not pay real money for their own research they should not be surprised if the research is not relevant to them (or to anyone else). While I am a strong believer in basic research, I also believe that the direction and applicability of that research is strongly influenced by the attitude of the research worker, which in turn is influenced by his sense of responsibility to his employer.

Jim Graham
THE LIFE AND DEATH OF STARS

Given as the Pawsey Memorial Lecture, Australian Institute of Physics, Adelaide, 19 October 1982.

R.N. Manchester, Division of Radiophysics, CSIRO, P.O. Box 76, Epping, N.S.W. 2121.

It is a great honour for me to be asked to deliver the 1982 Pawsey Memorial Lecture and I thank you for inviting me to do so. I am perhaps the first of the Pawsey lecturers never to have met Dr Pawsey — at the time of his death in 1962 I was still an undergraduate in my native country, New Zealand. Nevertheless, I owe a great deal to him. It was largely due to his efforts that the CSIRO Division of Radiophysics, where I now work, became one of the leading radio astronomy laboratories in the world. Along with W.N. Christianse, he pioneered the techniques of aperture synthesis, techniques which were developed and applied by Sir Martin Ryle and his group in Cambridge and subsequently by others around the world. It is marvellous that the future of radio astronomy in this country has been assured by the recent decision of the Government to fund construction of the Australia Telescope, an aperture synthesis instrument.

However, it is not about aperture synthesis that I wish to speak to you tonight — rather about the Life and Death of Stars, and in particular about some of the rather exotic objects which remain when the normal stellar evolution has run its course.

To the philosophers of ancient Greece purity of form was of utmost importance. The Sun, the Moon and the planets were believed to be perfect spheres, each located on one of a set of concentric spheres, centred on the Earth. The stars were fixed on an eighth sphere located beyond the others. In the western world until toward the end of the 16th century and the time of Tycho Brahe and Kepler it remained an article of faith that the fixed stars were perfect and unchanging. As well as uncovering the laws of planetary motion, Tycho Brahe and Kepler both observed nova or new stars, which appeared where no star had been before and then, over a period of months, gradually disappeared. (Modern astronomers have reclassified these events as supernovae, reserving the word nova for a less spectacular brightening of a star). It was becoming clear that the Universe was not composed of smooth and incorruptible spheres. The ancient Chinese were not constrained by such ideas and were comfortable with the concept of variations in the heavens, considering guest stars and other celestial phenomena portents of great significance. The most famous of these guest stars was observed in 1054 AD — we now know this as the supernova which created the Crab nebula and the Crab pulsat. Both these objects are of great importance to modern astrophysics and we will return to them later in the talk.

So, eventually, the idea that at least some stars varied became accepted. However, the idea that stars might evolve had to wait until about the middle of the nineteenth century, when physicists such as Kelvin and Helmholtz began considering the source of the Sun's energy. By measuring the amount of solar energy falling on, say, a square metre of ground in one second (a rather difficult but not impossible task), and by knowing the distance of the Sun (which had been determined during the seventeenth century by Cassini), the total amount of energy emitted by the Sun per second, that is the luminosity of the Sun, could be calculated. The only source of energy known to Kelvin and Helmholtz which could account for the enormous luminosity of the Sun was gravitational contraction.

Since this idea of energy release by gravitational contraction enters into this talk several times, we might spend a moment explaining it. When a man lifts a heavy object above his head, he has to do work, and this requires a certain amount of energy. When this weight falls to the ground this energy is released, initially in the form of energy of motion but eventually, after the weight has hit the ground, in the form of heat and, in this case, sound. The same thing happens when the great ball of gas we know as the Sun contracts. The gas atoms fall in the gravitational field of the Sun and so doing release energy, most of which manifests itself as heat. So if the Sun were contracting, its interior would become hot and it could radiate the heat and light that we observe. Kelvin and Helmholtz computed that the Sun could continue to shine at its present rate for about 100 million years, which sounded pretty satisfactory to them. It was not until the present century that geology and nuclear physics were able to show that the age of the Earth and hence the age of the Sun was over 4,000 million years, much too long for the Sun to be sustained by gravitational contraction. So another source of energy had to be found — fortunately Einstein came to the rescue with his famous equation

\[ E = mc^2, \]

where \( E \) is energy, \( m \) is mass and \( c \) is the velocity of light.

By the early 1920s it was known that the mass of a helium nucleus was less than the mass of four hydrogen nuclei and the idea of fusion of hydrogen into helium was proposed as an energy source. Because \( c \) is a large number, fusion is a very powerful energy source. Fusion of 1 gram of hydrogen into helium provides the same amount of energy as the burning of over 2000 tonnes of coal — and it was easily shown that it was more than adequate to maintain the Sun for tens of billions of years.

In the nineteenth century astronomers were also recognizing that not all stars were the same. As early as 1823 Fraunhofer observed the spectra of stars and showed that they were crossed by dark absorption lines just like the spectrum of the Sun which he had earlier observed. Later that century it was found that different stars had different spectra and the science of stellar spectral classification was born. This reached its climax in the first two decades of this century with the production by Harvard astronomer Miss Annie J. Cannon of the Henry Draper Catalogue containing the classifications of 225,000 stars — a lifetime's work! the classification scheme adopted by Miss Cannon used the letters O B A F G K M, originally ordered alphabetically but later rearranged to represent a decreasing sequence of temperature.

A major breakthrough in understanding stellar properties came in 1913, when Henry Norris Russell presented a diagram of stellar luminosity versus spectral class or temperature (figure 1). It was found that only certain zones of this diagram were occupied by stars. Most lay in a band crossing the diagram from upper left (high temperature and high luminosity) to lower right
times as fast as the sun. But their fuel supply is only 30 times as great so their lifetime must be only 30/10,000 x 4,000 million years, or about 12 million years. This means that all such hot bright stars that we observe - the brightest star in the sky, Sirius, a reasonable example - are very young compared to the Sun. Such stars must be forming, evolving and dying in a continuing cycle. Conversely, stars at the lower end of the main sequence have a much lower luminosity than the Sun and have expected lifetimes much greater than the age of the Universe.

Where are the young stars being formed? Bright stars are generally found in clusters associated with giant clouds of interstellar gas and dust. Dense regions of these interstellar clouds are believed to collapse under their own weight, releasing energy as they go. When these collapsing regions become of stellar size, the central core has become so hot, about 10 million degrees, that hydrogen fusion begins. This releases enormous quantities of energy, the escape of which prevents the star from collapsing further. In one of the triumphs of theoretical astrophysics, the British physicist, Arthur Stanley Eddington, was able to show in 1924 that the luminosity of a star stabilized in this way was related to the mass of the star in just the way observed.

So, during this hydrogen-burning phase, the star is stable at a point on the main sequence determined largely by its mass. It is because of the relatively long duration of this phase that most of the stars we see are main-sequence stars. However, soon (for the massive stars) or later (for stars of lower mass), the supply of hydrogen begins to run out and the rate of energy production drops. Since it was the outward flow of this energy which was supporting the star against further collapse, when this flow slows down the star once more begins to collapse. Temperatures in the core, which now mainly consists of helium, again begin to rise. Eventually the core becomes so hot that a second fusion reaction - helium burning to carbon - begins and a second relatively stable phase can begin. But a strange thing has happened during this second core collapse - the energy released has, as well as heating the core, expanded the outer layers of the star so the star now has an enormous radius, comparable to the distance of the Earth from the Sun. The temperature of these outer layers has decreased with the expansion and so we see the star as a red giant (figure 1).

In fact the outer layers of a red giant never stop expanding; the star develops a stellar wind, shedding mass and returning it to the interstellar medium. In the core of the star, helium burning continues until, after a relatively short time, say about one million years, the helium is exhausted. Once again the core begins to contract under the influence of its own gravitation and again its temperature rises. The path followed at this point seems to depend on the initial mass of the star. For stars whose mass was less than about six solar masses, the rise in temperature is insufficient to ignite the next stage of fusion, carbon burning. The collapse continues and the energy released blows off the remaining outer layers of the star leaving the core surrounded by an expanding envelope. Objects of this type are observed and are known as planetary nebulae (their only connection with planets is that some early astronomers they had a similar appearance). The duration of this evolutionary phase is even shorter, perhaps a few tens of thousands of years.

What about the core - does it just keep on contracting forever? The answer is no. Quantum mechanics in the form of the Pauli Exclusion Principle intervenes. This principle states that no two atomic particles can occupy the same space with the same
velocity at the same time. Since as the core contracts the particles are being forced into a smaller and smaller volume, their velocities must increase. This increase in velocity is equivalent to a raising of the gas pressure. A gas whose properties are governed by quantum mechanical effects of this sort is said to be degenerate. In the case of a collapsing stellar core, the electrons the gas is long since ionized are the first particles to become degenerate and the collapse is stopped by electron degeneracy pressure. At this point the star has a diameter of only about 1% of the Sun’s diameter, comparable to that of the Earth, and it is very hot — a white dwarf. Over a thousand white dwarfs have been identified and many of them are members of binary systems; in fact the first one to be identified, in 1914, is the companion of Sirius. Masses determined from the binary system parameters range from about 0.1 to just over 1 solar mass. Their density is therefore very high, about one million times that of water and far denser than anything on Earth.

All fusion has stopped in these stars and there is no other internal source of energy — they are one of the end-points of stellar evolution. From this point on, they just gradually cool. Because their surface area is so small, the time scale for this cooling is very long, many billions of years, so we have a chance to detect quite a few of them despite their low luminosity. The total number in our galaxy may be very large, perhaps ten billion or 10% of all the stars in the Galaxy. This evolutionary path is illustrated on the left side of figure 2.

Figure 2: Possible paths for post-main sequence evolution. Toward the end of the hydrogen burning phase the stellar core begins to collapse and the outer layers of the star expand, forming a red giant. Stars with mass less than about six solar masses then evolve to form planetary nebulae and finally white dwarfs, whereas more massive stars are thought to explode as supernovae leaving an expanding supernova remnant and either a neutron star (which may be detected as a pulsar) or a black hole.

Since these stars have completed their evolution they must have started as stars more massive than the Sun. Consequently most of the gas which originally condensed must have been returned to the interstellar medium in the red giant and planetary nebula phases.

What about the stars more massive than six solar masses? In these stars the core is more massive, and when it contracts at the conclusion of the helium-burning stage temperatures become so high that new fusion reactions can start. These reactions produce heavier elements such as oxygen, neon, and so on up to iron. The iron nucleus is very stable and it is the endpoint of the fusion process. These reactions again proceed relatively quickly and at the conclusion the stellar core collapses once again. This time the collapse is too strong to be stopped by electron degeneracy pressure and it continues past this point accelerating rapidly. Two final states are possible (figure 2). When the core density reaches the enormous value of a million million times that of water, it consists mainly of neutrons (the nuclei having being destroyed by the extreme densities and temperatures) and these neutrons form a degenerate gas. Provided the core is not too massive (calculations suggest that the upper limit is two or three solar masses) the neutron degeneracy pressure can stop the collapse and one is left with a neutron star. Neutron stars have a radius of only about 10 km and are essentially a giant nucleus having about the same mean density as nuclear matter. Their existence was predicted by the astronomers Baade and Zwicky in 1934, soon after the discovery of neutrons. If the core is more massive than three solar masses no known force can stop the collapse and a black hole is formed. A black hole is an incredible object which is so dense that nothing, not even light, can escape from it. The existence of black holes is a natural consequence of Einstein’s General Theory of Relativity, developed in 1916.

The final stages of collapse to either a neutron star or a black hole are incredibly rapid, taking only seconds to complete. In the collapse an enormous amount of gravitational energy is released — as much energy as the Sun has radiated in its entire lifetime. So there is a gigantic explosion, a supernova, enormous amounts of heat and light are generated and most of the star is blasted away at enormous velocities, thousands of kilometres per second. Supernovae are observed relatively rarely in our galaxy — examples are the “new stars” observed by the Chinese in 1054 AD, by Tycho Brahe in 1572 and by Kepler in 1604. We can however observe the expanding remnants of supernova explosions — the best known example is the Crab nebula, but many others are known: over 100 in our galaxy alone.

Figure 3: The stellar life cycle. Stars condense from the gases of the interstellar medium and in the course of the evolution return most of their mass back to the interstellar medium. Only the matter locked up in the compact remnants, white dwarfs, neutron stars or black holes, is removed from the cycle.

As we have mentioned, in each of these stages of evolution — red giants, planetary nebulae and supernovae — matter from the star is returned to the interstellar medium. Only a small fraction of the initial stellar mass remains locked in as a compact star — white dwarf, neutron star or black hole. This then completes the stellar life cycle illustrated in figure 3. There is however a major difference between the material which condenses and the material which is returned to the interstellar medium — the former mostly consists of
hydrogen while the latter is enriched with heavy elements resulting from the various fusion reactions. It is believed that all elements heavier than helium have been formed in this way — it is an intriguing thought that the atoms which make up our houses, our cars and us, were long ago formed in the middle of a star.

If this were the first Pawsey Memorial Lecture rather than the eighteenth, this would be the end of the lecture. But this is the eighteenth, and this is not the end of the story. The last 15 years or so have seen some remarkable discoveries, brought about mainly by the maturing of other branches of astronomy, in particular radio astronomy and X-ray astronomy.

The first of these discoveries which concerns us here is the detection in 1967, by the Cambridge astronomers Jocelyn Bell and Antony Hewish, of the remarkable pulsating radio sources known as pulsars. These objects emit a series of clock-like pulses, with the interval between the pulses, the pulse period, being typically a second or so. The pulse periods are amazingly stable; as clocks, many pulsars would be in error by no more than a few milliseconds after one year. There are very few astronomical phenomena which can produce this kind of accuracy. Rotation of a star is one: imagine a beacon attached to the star sending out a beam of radiation which sweeps around the sky and across an observer once per revolution of the star. But if rotation is the pulsar mechanism, the very short periods observed mean that the star has to be very compact — a white dwarf or neutron star — otherwise it will fly apart. Then, late in 1968, the discovery of two pulsars with extremely short periods was announced. These were the Crab pulsar with a period of 33 ms and the Vela pulsar with a period of 89 ms. Only a neutron star could spin as fast as this and stay in one piece. The rotating neutron star model for pulsars, illustrated in figure 4, was established. Both the Crab and Vela pulsars are located near the centre of supernova remnants. So 34 years after Baade and Zwicky’s prediction that neutron stars would be formed in supernova explosions, they were finally found.

![Figure 4: The rotating neutron star model for pulsars. Radio energy is emitted in narrow beams, probably in opposite directions along the magnetic axis, and as the star rotates these beams sweep across the sky in a manner similar to a lighthouse beam. If a beam passes across the Earth, we see one pulse per revolution of the star.](image)

In 1974 another discovery of major importance was made. My friend and colleague, Joe Taylor, was making a sensitive search for new pulsars using the giant radio telescope at Arecibo in Puerto Rico. Among the pulsars he and his colleagues found was one with the very short period of 59 ms which immediately excited their interest. But when they went back to make more detailed observations of this pulsar they were astonished to find that the period was not stable as for other pulsars but was varying on a time scale of hours by up to one part in one thousand. They soon established that the pulsar, designated PSR 1913+16, was a member of a binary system with the very short orbital period of 7.75 hours (figure 6). For the first time, direct information on the mass of a pulsar could be obtained. It turns out that both the pulsar and its binary companion have masses very close to 1.44 solar masses and it is very likely that both are neutron stars. No pulses have ever been detected from the companion however, perhaps because its beams are not pointing in our direction. This binary system has also turned out to be of major importance as a testbed for theories of General Relativity. Since the two neutron stars orbit each other at speeds which are a significant fraction of the velocity of light and at closest approach are only about 0.3 solar radius apart, relativistic effects are very significant. Evidence has been found for energy loss from the system in the form of gravitational waves, the first observational evidence for these waves which are predicted by General Relativity.

![Figure 5: Galactic distribution of pulsars. Most are concentrated along the galactic equator or Milky Way. The concentration close to longitude 59° results from a sensitive search made at Arecibo Observatory.](image)

![Figure 6: Schematic diagram illustrating the system containing the binary pulsar PSR 1913+16. The companion star is also believed to be a neutron star but has not been observed as a pulsar.](image)
Of the several relativistic theories proposed, only the original one of Einstein is fully consistent with the observations — a remarkable tribute to this great scientist.

![Galactic Distribution of X-Ray Sources](image)

Figure 7: Galactic distribution of X-ray sources detected by the X-ray observatory satellite UHURU. As with pulsars there is a concentration toward the galactic equator. However, unlike pulsars, there is also a more widely distributed or isotropic component which probably consists of extragalactic sources.

If systems of two neutron stars in orbit exist then systems consisting of a single neutron star in orbit around a more normal star should exist. In fact, two other radio pulsars in orbit around companions which are probably not neutron stars have been discovered. But the main evidence for the existence of such systems comes from the relatively new science of X-ray astronomy. Late in 1970 a satellite known as UHURU (Swahili for Freedom) was launched by the United States from a site in Kenya. This satellite carried detectors sensitive to X-rays (which cannot penetrate the Earth's atmosphere) and during the next couple of years searched the whole sky for sources of X-ray emission. Over 100 new sources were detected (figure 7). As with pulsars, most of these sources are located near the galactic plane and hence are most probably galactic objects, but unlike pulsars, a substantial number are at high galactic latitudes and are probably extragalactic in origin. Several observations suggest that most of the X-ray sources consist of a compact star — for example, a neutron star — in orbit around a relatively normal star. Firstly, regular eclipses of the X-ray emission are observed in many sources, suggesting binary motion. Secondly, in several cases a star coincident in position with the X-ray source has been shown to vary in synchronism with it, thereby confirming the association. Thirdly, and perhaps most interestingly, the X-ray emission from some sources has been found to be in the form of pulses, with pulse periods within the range of observed pulsar periods. Thus the identification of many of these sources as neutron stars in orbit around normal stars is well established (figure 8).

![Schematic Diagram Illustrating the Neutron Star Binary System Model for Galactic X-Ray Sources](image)

Figure 8: Schematic diagram illustrating the neutron star binary system model for galactic X-ray sources. Gas flows from the outer layers of the "normal" star, forming an accretion disk around the neutron star. As the gas spirals into the neutron star it is compressed and heated so that it forms a powerful source of X-rays.

How is the X-ray emission produced? Again heating by gravitational contraction plays a dominant role. Material flowing from the companion star is captured by the neutron star. Because it has considerable angular momentum it does not fall directly on to the star, but forms an accretion disk around the neutron star. Nevertheless, as the material falls toward the neutron star, it is compressed and heated to a million degrees or more. At this temperature most of the radiation is in the form of X-rays. Calculations show that the X-ray luminosities observed, typically thousands of times the total luminosity of the Sun, can easily be accounted for by this mechanism.

These objects, with their great clouds of hot gas being sucked on to a neutron star, are extraordinary enough, but in one case an even more remarkable phenomenon has been observed. About three years ago, the American astronomer Bruce Margon was making a survey of stars known to emit strong optical spectral lines. In one of these, known as SS 433, he discovered that the star was emitting two highly collimated beams of plasma at incredibly high velocities, up to one-third of the velocity of light. Furthermore, it was found that the apparent velocity of these jets varied in a well-determined and periodic way, with the repetition period being 164 days. At about the same time, this star was shown to be a strong X-ray source, strongly suggesting that it was a member of a binary system with a compact companion. This was later confirmed when a 13-day modulation of the stellar optical emission was found. So in this source we have the standard model for a binary X-ray source with the added feature that two intense plasma jets are being ejected from the system (figure 9). The 164-day period is attributed to precession of jet axis — how this axis is defined is not really known at the moment. It could be the rotation axis of the neutron star or it could be the axis of the accretion disk.

![Schematic Diagram Illustrating a Model for the Peculiar System known as SS 433](image)

Figure 9: Schematic diagram illustrating a model for the peculiar system known as SS 433. In this model a compact star orbits around a normal star with accretion powering a strong X-ray source. In addition, strong plasma beams are emitted at very high velocities (about one-third of the velocity of light) in opposite directions from the compact star. The axis of these beams precesses around a perpendicular axis with a precessional period of 164 days.

What about black holes? Do they exist? Clearly they are not easy to find since they are tiny and emit nothing. As far as gravitation is concerned however they act like any other mass. They can orbit around another star and they can accrete matter which can radiate before it falls into the hole. So if a strong X-ray source is found for which the mass of the compact companion is greater than three solar masses, then the companion is probably a black hole. One strong X-ray source, Cygnus X-1,
GALACTIC DISTRIBUTION OF BLACK HOLES

Figure 10: Galactic distribution of confirmed detections of black holes. There are none, although there are several strong X-ray sources in which the compact object may be a black hole.

Obituary — Sir Leslie Harold Martin

Professor Emeritus Sir Leslie Martin, Kt., C.B.E., D.Sc. (A.N.U., Melb., Q'land., N.S.W., and Adel.), LL.D. (W.A. and Melb.), D.Litt. (Syd.), Ph.D. (Cantab.), F.R.S., F.A.A., F.Inst.P., F.A.L.P., died in Melbourne on 1 February, 1983. As his honours infer, he was a most distinguished scientist, educator and administrator. He served Australia nobly in many ways but most of all he would have wished to be remembered as Les Martin — Physicist.

He was born on 21 December, 1900, in Melbourne. Educated at Melbourne High School, he entered the University of Melbourne in 1919 to study science. He qualified for the B.Sc. degree in 1921 and the M.Sc. in March 1923, obtaining First class honours in each degree and the Dixon and Kernot scholarships in Physics (then Natural Philosophy).

Despite his high academic distinctions, he was not actually to become a graduate of the University of Melbourne until 1959 when the University conferred on him the degree of Doctor of Science, Honoris Causa. He never felt the need to go through the formality of taking out those earlier degrees.

In 1923, having won an Exhibition of 1851 Overseas Science Research Scholarship and the Fred Knight Research Scholarship, he took his bride, Gladys, to Trinity College, Cambridge, where he worked under Rutherford at The Cavendish Laboratory. It was there that he developed his interest in nuclear physics and it was from Rutherford that he learned to do research with meagre funds and an ability for improvisation.

He obtained his Ph.D. with a thesis entitled "Absorption Measurements of Homogeneous X-Rays in Metals" and, in 1927, returned to work under Professor T.H. Laby in the Natural Philosophy Department of the University of Melbourne. There he rapidly gained a reputation as a teacher and research worker. His research was recognized by the award in 1934 of the David Syme Research Prize. In 1938 he was promoted to Associate Professor, a position of considerable importance in the department at that time.

During the war years, the research interests of the Melbourne department changed and it became deeply involved in solving the problems of optical munitions, Australia being cut off from world supplies. Dr. Martin spent much of that period in Sydney working on problems of vital importance for Australia's defence.

In 1945, he was appointed to the Chamber of Manufactures Chair of Physics, and began the great post-war development of physics in Melbourne. The previously small Department of Physics had to cope with a huge wave of ex servicemen, and the third year in 1946 numbered nearly ninety in a department more accustomed to classes of twenty or thirty. Many would-be physicists had left the University in the middle of their courses to serve in the armed forces and were anxious to obtain their degrees as soon as possible.

The final year students in 1946 were a mixed bunch. Some had arrived by the usual route from school and two previous years at the University. They were outnumbered by people who had never actually completed second year and by many who had forgotten its content long since. Dealing with all that must have been a formidable task for the new professor but he never seemed perturbed and always found time to talk to the students.

It was about this time that Martin decided to create a major research school in nuclear physics in Melbourne.

In 1954, he was appointed Head of the Nuclear Physics School which was the beginning of the Institute of Nuclear Science. He was appointed to the chair of physics in 1956 and a few years later became a member of the Institute's governing council.

Dr. Martin was a Fellow of the American Physical Society, the British Association for the Advancement of Science, the Australian Academy of Science, and the Institute of Physics. He was also a member of the Royal Society of London, the American Physical Society, and the Australian Academy of Science.

He published over 70 scientific papers in his lifetime, and he was co-author of the book 'Nuclear Physics', which was widely used in universities around the world.

Dr. Martin was a gentle and kind man, always ready to help others. He was deeply respected by his students and colleagues, and his legacy continues to live on in the field of nuclear physics.

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A young Leslie Martin — thought to be during early days of the optical munitions programme.
It was a bold decision because money was short. The Ph.D. was only just being introduced in Australian Universities and many of the best students still went abroad for post-graduate studies.

Leslie Martin's insistence on the need for research in Universities, his insistence that Australian physics should be of world standard, his ability to beg and borrow apparatus and the bit of which to build it, and above all his ability to arouse the interest and respect of staff and graduate students, were the things needed for the phenomenal growth which occurred in the decade after the war.

Sir Leslie Martin opening the new Physics Building at Melbourne University on 28 February 1974.

In the 1950's two Van de Graaf generators and a Variable Energy Cyclotron were built in his department and a Betatron was purchased. Staff and students worked long hours in those days. Most felt they should arrive before the Professor and he was likely to drop in by 8.30 in the morning. He rarely left before six o'clock at night and at any time he would walk in to a laboratory and enquire: "How's it going son?"

It was an exciting time for Australian physics after the war and a time when Australia's dependence on overseas degrees waned. Les Martin was the leader who ensured that the University of Melbourne was a good place to work.

Running a physics department as the only professor (there are now four) was not enough for his energies. After the war, he continued his national work as Defence Scientific Adviser. From 1948 to 1968 he was Chairman of the Defence Research and Development Policy Committee. He had a major responsibility for the safety of the British nuclear weapons tests in Australia. From 1958 to 1968 he was a member of the Australian Atomic Energy Commission and from 1953 to 1963 he was a Trustee of the Science Museum of Victoria, being the Chairman in 1962-63.

He somehow managed to fit this busy public life around the necessary routine of an academic department. His lectures were a model of clarity and when it was necessary to substitute for him because of a national commitment, it was a daunting task for his more junior staff.

Within his University, he was willing to accept further responsibilities. In the post-war years, he was Chairman of the Proctorial Board, a member of the Council, a Pro Vice-Chancellor and a wise member of many committees. He was the University officer mainly responsible for the establishment of the RAAF Academy and later he was to be deeply involved in the planning for what is about to become the Australian Defence Forces Academy.

In 1957 his contributions to science were recognized by his election as a Fellow of the Royal Society and he was knighted in the same year for outstanding services to education and science.

In 1959, he resigned from the University to become the first Chairman of the Australian Universities Commission. To him must go the credit for establishing an organisation able to co-ordinate State and Commonwealth interests in the Universities and he did much to help the Universities achieve national status and international standards.

As Chairman of the Committee on the Future of Tertiary Education in Australia, now known as the "Martin" Committee, he was responsible for the detailed proposals which led to the establishment of the three-sector structure which now characterises higher education in Australia.

Sir Leslie retired from the Australian Universities Commission in 1966 but it was not yet to be a real retirement. From 1967 to 1970 he returned to his first interest in physics and served as Professor of Physics and Dean of the Faculty of Military Studies of the University of New South Wales at Duntroon.

Following his retirement in 1970 he lived firstly in Canberra and then moved to Melbourne to be near his family.

A quiet, rather retiring person, Sir Leslie never sought fame and the public eye but his intellect, his ability to lead and his friendliness towards all who worked with him ensured that he would be a public person. He contributed a great deal to science and to education in Australia and he influenced the careers of a large number of physicists.

When Sir Leslie left the University of Melbourne in 1959, the University Council recorded a Minute of Appreciation which still catches the quality of the man and the esteem and affection his colleagues had for him: "Impressive as the mere recital of his achievements may be, Leslie Martin the man is greater than the record shows... His successes have not come to him easily nor have they spoiled him. He has been a great teacher, in love with his subject and also with his students; he has excelled as a researcher and as a scientific administrator and adviser. But, beyond all this, he has been a man of the utmost integrity and the most friendly of colleagues".

Leslie Martin was a most distinguished physicist, a great Australian who had a profound influence on higher education and above all a good friend and colleague of all who were fortunate to know him.

Our sympathy goes to his widow, Lady Martin, his son, Professor Ray Martin, Vice-Chancellor of Monash University, and his grandchildren, Leon, Lisa, Anthony and Michael.
MAGNETIC REFRIGERATION*

William A. Steyert, Air Products and Chemicals, Allentown, PA, USA.

In many countries magnetic refrigerators are being developed. The function of most of the units being built is to pump heat from liquid helium temperatures (2 K to 4 K) to liquid hydrogen temperatures (20 K). At liquid helium temperatures paramagnetic working materials absorb several hundred joules of heat per litre each cycle. Magnetic refrigerator development began in 1975 and has led to several successful refrigerators which pump about one watt of heat from below 2 K and deposit the heat at 4 K. This could be a significant development because NbTi superconducting magnets perform better at 2 K than at 4 K and because 2 K gas refrigerators are poorly developed. Studies made on gadolinium gallium garnet show that it is an excellent material for refrigeration at liquid helium temperature.

INTRODUCTION

Applications of low temperature phenomena, including superconductivity, are being introduced into modern technology. Many superconducting magnets are used in particle accelerators and in particle experiments, and large magnets are being used in plasma and fusion research. Magnetically levitated trains, superconducting motors and generators and other applications of superconductivity are currently being tested. All of these require refrigeration at liquid helium temperatures.

The Principles of Magnetic Refrigeration

Application of a magnetic field to paramagnetic materials at low temperatures and ferromagnetic materials near their Curie temperatures causes them to warm up; alternatively, heat is expelled from such materials if the temperature is held constant during the field application. Conversely, removal of the field will cool the material or, at constant temperature, allow absorption of heat by the material. For temperatures at and below room temperature, the temperature changes can be of the order of 10-20 K if fields of about 7 T are applied to an appropriately chosen material.

The principle of a magnetic refrigerator can be illustrated with the conventional Carnot-cycle device shown in Figure 1. With thermal switch TS1 closed, thermal switch TS2 is opened, and a magnetic field is applied to the paramagnetic material (PM). The field aligns the magnetic spins in the paramagnetic material, decreasing the randomness (i.e., entropy S) of the spin system. The spin system is now in good thermal contact with the fixed temperature of the hot thermal reservoir (HTR), and heat will flow out of PM into HTR. Next, TS1 is opened while TS2 remains open, and the magnetic field is partially removed; the spin system becomes partially randomized, requiring energy and thus cooling PM to the temperature of the substance to be refrigerated (SR). TS2 is then closed while the magnetic field is decreased to zero, completing the spin-randomization process and allowing heat to be absorbed from SR. TS2 is then opened and a small magnetic field applied, so that PM warms to the temperature of HTR. The cycle can be repeated if TS1 is closed as the full field is again applied to PM.

Actual Entropy-Temperature Diagram Illustrating the Cycles

Figure 1: Schematic diagram of conventional magnetic Carnot refrigeration principles.

Figure 2: Thermodynamic cycle executed by Gd₃(SO₄)₂·8H₂O in a magnetic Carnot cycle. Entropy per gram of Gd₃⁺ versus temperature for various applied fields is obtained from Pratt et al. 1977. Utilization of Gd₃(SO₄)₂·8H₂O, or GdPO₄, would reduce the magnetic field requirements and allow heat exudation at higher temperatures without any appreciable performance deterioration.

Figure 2 illustrates the Carnot cycle that could be executed by low temperature magnetic refrigerators like the one shown in Figure 1. The material illustrated is the paramagnet Gd₃(SO₄)₂·8H₂O. From a heat source at 1.7 K, this material would absorb Q = TΔS = 9.9 J/mol each cycle (ΔS is the entropy change at temperature T = 1.7 K, as shown in Figure 2, and R is the gas constant). This represents 8.2 J/°C of Gd₃(SO₄)₂·8H₂O each cycle. For higher density materials, such as gadolinium gallium garnet (GGG) about twice this refrigeration per unit volume would be available.

Figure 3 illustrates the entropy temperatures (S-T) diagram (Barclay and Steyert, 1982) for GGG from specific heat measurements at Los Alamos. The S-T diagram of GGG has also been measured by the

*Work performed at the Los Alamos National Laboratory.
†With partial support from the California Institute of Technology Jet Propulsion Laboratory.

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Grenoble workers (Daudin et al., 1983). Their results are similar to those of Figure 3, however, near 5 K their S/R values in fields above 2.5 T are about 0.1 higher than those shown in Figure 3.

The most important result from the specific heat measurements is the confirmation of the very low lattice specific heat. C. Barcellay and Steyert (1982) show (per gram-ion of Gd***) that C/R = (3 + 0.3) x 10^{-7} T^3 in agreement with the remarkably accurate value extrapolated from measurement made below 4.2 K by Brodale et al. (1975). Reference 2 also showed that adiabatic demagnetization from 21.6 K and 9.4 T cooled GGG to 1.6 K.

Another important feature of GGG is its thermal conductivity (Daudin et al., 1983; Slack and Oliver, 1971) which is a factor of 100 higher than that of a pressed Gd_2(SO_4)_3·8H_2O powder. This important difference would apply to most single crystal versus powder comparisons at low temperatures. The results from a 2 to 4 K magnetic refrigerator experiment show that the performance was limited almost entirely by thermal conduction considerations. The magnetic refrigerator in that unit was in the form of a 1.6 cm thick wheel rim (10.2 cm od and 5.7 cm id) pressed from Gd_2(SO_4)_3·8H_2O powder. Because of the poor thermal conductivity of the refrigerator, the device was limited to operation below 0.8 Hz; this was barely fast enough to overcome parasitic losses and provide 200 mW of refrigeration capacity in superfluid helium. The refrigerant in the center of the rim was not used because of poor thermal contact to baths. For refrigerators in general, solving the problem of getting heat in and out of the refrigerant dominates their design and performance.

**REFRIGERATORS**

**Two-Switch Refrigerator of Figure 1**

The units built so far (Herr et al., 1954; Zimmerman et al., 1962; Rosenblum et al., 1976) are limited to operation below 1 K because of the character of the superconducting switches which they use. Refrigerators could be built using magnetoresistive switches (Radebaugh, 1977), such as single crystals of beryllium, with switching ratios of 1000 at temperatures as high as 15 K. These would pump several watts from 2 K to 10 K with 70% of Carnot efficiency using a Carnot cycle.

Better performance could be obtained if heat were carried to and from the paramagnetic working material by a liquid made to flow through a porous paramagnetic salt. Higher temperature operation would be feasible since switch limitations would not enter.

**Other Refrigerators**

Figure 4 shows a conceptual low temperature rotating refrigerator (Pratt et al., 1977) operating on a Carnot cycle similar to that shown in Figure 2. On the upper left-hand side of Figure 4 and point A of the cycles in Figure 2, supercritical helium enters the porous wheel and is forced to flow in heat exchange with the moving wheel. St.etc., 1978a, gives one example of how the heat exchange might be implemented.) The wheel absorbs heat from the helium as it is demagnetized to point B in the cycle shown in Figure 2; the helium cools to 1.7 K. The helium then absorbs heat Q_h from the load and reenters the wheel heat-exchanger area at a slightly warmer temperature. Similarly, in the lower right-hand side of Figure 4, supercritical helium (at essentially the same pressure as the helium in the left-hand side) enters the porous wheel at 15 K; this corresponds to point C in the cycle in Figure 2. The wheel deposits heat in the helium as the material is magnetized to point D, while the fluid leaves the wheel at a slightly warmer temperature. This heat Q_h is deposited externally, completing the cycle, with the net result that work is used to rotate the wheel and heat is absorbed at a low temperature and expelled at a high temperature. Note in Figure 4 that the wheel is adiabatically magnetized as it goes from the lower left-hand to the lower right-hand side and adiabatically demagnetized as it goes from the upper right-hand to the upper left-hand side. These are the horizontal sections of the cycles shown in Figure 2.

A more primitive type of rotating refrigerator was built at Los Alamos (Pratt et al., 1977); it works also on a Carnot cycle but without using forced flow through a porous wheel. In steady state operation it carries 0.2 W from an electrical heater in a superfluid helium bath at 2.1 K into a boiling helium bath at 4 K. The refrigerator has maximum capacity at 0.25 Hz. As previously mentioned, performance of this unit with GGG would be significantly improved.

More recently a reciprocating magnetic refrigerator using GGG as a working material has been tested in France (LaCaze et al., 1988). It absorbs one watt of heat from 2 K, depositing the heat at 4 K. A low temperature reciprocating refrigerator was also tested in Australia (Barclay et al., 1979).
Fundamental Limitations on Magnetic Refrigerators

The magnetic refrigeration process itself is essentially reversible. In a refrigerator that is mechanically optimized (i.e., minimum leakage around fluid seals, minimum mechanical friction, minimum heat leak, etc.) performance will be limited by heat transfer considerations. The question then becomes, how fast can heat be absorbed and expelled by the working material without excessive entropy production associated with heat flowing across a finite temperature difference $\Delta T$ and heat transfer fluid flowing across a finite pressure drop $\Delta P$? This question has been reviewed in Steyert, 1978b.

Allowable Temperature Drops and Pressure Drops

Consider a refrigerator absorbing heat $Q_a$ and entropy $S_a$ each cycle at the cold temperature $T_c$. The work input $W$ allows the expulsion of heat $Q_e$ and entropy $S_e$ at the hotter temperature $T_h$. Inside the real irreversible refrigerator there is a net entropy produced $\Delta S$ after the refrigerator has returned to its initial state upon completion of one cycle. Because

$$S_e = S_a + \Delta S$$  \hspace{1cm} (1)

and from the First Law

$$W = Q_e - Q_a$$  \hspace{1cm} (2)

we can deduce that

$$W = (T_h - T_c)S_a + T_n\Delta S.$$  \hspace{1cm} (3)

Thus the work in the irreversible refrigerator, compared to the work $W_r$ in a reversible refrigerator where $\Delta S = 0$ is

$$\frac{W}{W_r} = 1 + \frac{\Delta S}{S_e} = 1 + \frac{\Delta S}{S_a}$$  \hspace{1cm} (4)

The relationship (4) can be used to estimate the allowable heat transfer fluid $P$ and fluid-magnetic material $\Delta T$ in a refrigerator. In a mechanically optimized refrigerator,

$$\Delta S_r = PV/TT$$  \hspace{1cm} (5)

is the entropy net production associated with the conversion of work from a 100% efficient pump in frictional heat at mean temperature $T$. The volume of fluid flowing thru each cycle is $V.$ It can be shown that

$$\Delta S_r = QAV TT^2$$  \hspace{1cm} (6)

is the net entropy production associated with an amount of heat $Q$ flowing across a small temperature difference $\Delta T$ at a mean temperature $T.$ The sum of $\Delta S$ is from (5) and (6) when entered into (4) must not lead to excessive work $W$, or the refrigerator is very inefficient. Note that in a real refrigerator, if $\Delta S$ is too large, this simple approach fails because the working material no longer follows a cycle approaching the ideal cycle of Figure 2; (4) underestimates the performance deterioration associated with $\Delta S$.

CONCLUSIONS

Rotating and reciprocating magnetic refrigerators have been successful in pumping up to 1 watt of heat from superfluid helium and depositing the heat in a 4 K liquid helium bath. Using the recently tested magnetic working material, GGG, attempts are currently under way to carry heat from 4 K to 20 K. After one half a century, the Nobel prize winning work of Giauque may be moving from the research laboratory into applications of large superconducting machinery.

REFERENCES


A new Journal

The Higher Education Research and Development Society of Australasia is proud to announce the launching of its first journal, Higher Education Research and Development. The aim of the journal is to serve the needs of teachers, researchers, students, administrators and everyone concerned with the future of higher education. It is published twice a year (May and October). All editorial and business correspondence should be addressed to: HERDSA c/o TERC, P.O. Box 1, Kensington, NSW 2033, Australia.

NUCLEAR ARMAMENT AND WARFARE

AIP Science Policy Committee

Introduction

The nuclear armament and warfare issue is perhaps the most important issue facing mankind today. Many professional societies have decided recently to alert the general public of the need for nuclear disarmament and the threat of nuclear war. The AIP Science Policy Committee has maintained an interest in nuclear matters since its inception in 1975. Questions such as the role that the AIP can have in this debate and how the Institute can make a meaningful contribution to furthering our understanding of the issues involved are of vital importance and the Science Policy Committee believes that it is important to determine an appropriate role for the Institute in this debate.

Within a professional body such as the Institute, it could be expected that a wide range of opinions and suggestions on what should be done exist. This article discusses some of the initial conclusions reached by the Science Policy Committee in its consideration of the nuclear armament and warfare issue. In particular, some proposals for possible immediate action are suggested and a basis for further Institute involvement is proposed.

Background

In early 1982 the Committee and the Organising Committee of the Fifth National Physics Congress agreed on the need to have informed public discussion on topics relating to the nuclear arms race. The subsequent Nuclear War Forum at the Congress in Canberra in August last year was very successful and confirmed that Australian physicists are intensely interested. On detailed policies such as the role of US bases in Australia, it was clear that there were major differences in the viewpoints of members. The Forum generated publicity in the Canberra newspapers and ABC news and radio interviews (Australian Physicist, October 1982). The number of articles about nuclear war in recent issues of the Australian Physicist affirms the importance accorded to this topic by physicists.

Participants at the Forum voted to request the AIP to consider policies for future action (Australian Physicist, November 1982). The AIP has not as yet responded to this request. In accord with the Science Policy Committee's terms of reference to investigate matters of importance to physicists and policy, considerable time has been devoted to discussing this issue. The 20th Annual Report of the AIP (Australian Physicist, February 1983) noted that:

"The public meeting on nuclear warfare clearly demonstrated the need for the AIP to be alive to such matters of public concern, where there is a hunger for factual knowledge.... The Executive and the Science Policy Committee are considering the policy of the AIP in this matter and meanwhile have expressed support for the aims of the organisation SANA (Scientists Against Nuclear Arms)."

This paper has been prepared by the Committee with the aim of providing advice to the AIP in its consideration of the Forum's request that policies for future action be considered.

An Australian Perspective

The Committee recognises that the threat of nuclear war and the arms race is not only a matter of grave public concern but of fundamental importance to the future of humanity. The involvement of physicists in the development of the first nuclear weapons and the continued escalation of the arms race is such that physicists are often seen by the public as contributing to this threat to humanity. Physicists therefore have a special responsibility to contribute to public debate over nuclear matters and to be aware of the social and military consequences of their work and research in certain areas.

While Australian physicists may seem somewhat removed from their colleagues working for military establishments in the USA and the USSR, the Committee believes that circumstances peculiar to Australia could provide a focus for further Institute involvement in public discussion and debate. At one extreme, Australia's low involvement on nuclear weapons research could enable it to play a role in discussions with the advantage of low apparent self-interest or prejudice. The development of nuclear technology in Australia, for example enrichment technology, and the long-term effects of the British A-bomb tests at Maralinga in the 1950's, are topics specific to Australia. Even these 'Australian' issues, however, could be connected with 'international' topics such as nuclear proliferation and the ethics of working on nuclear weapons. Another issue is the effect of nuclear war on Australia and the role played by US bases here.

The Committee's Position

The interest shown in nuclear war matters by the media at the successful Nuclear War Forum at the Fifth National Congress showed that considerable public profile and information dissemination can be attained by the Institute through participation in activities similar to the Forum. In addition, the Forum also showed that there was a significant demand for reliable information on nuclear war matters by physicists and the public at large. The Committee believes that through such public forums, the AIP can have a significant role to play in assisting public discussion without devoting excessive resources to the task.

One view is that because of the range of issues and associated political factors involved in the nuclear war debate, it may be inappropriate for the Institute to make a policy statement on such matters. It may be considered that activities such as this are best left to organisations such as Scientists Against Nuclear Arms (SANA) and Medical Association for the Prevention of War (MAPW).

On the other hand, a recent statement by the American Physical Society on the nuclear arms race which was sent to leaders in the US, the Soviet Union, China, France and Britain provides considerable support to the view that it is an appropriate time for the AIP to contribute to this debate.

The American Physical Society advocated the following measures to prevent nuclear war:

- Soviet-American negotiations 'without preconditions' on a verifiable agreement to limit strategic nuclear arms and reduce the number of such weapons and delivery systems in existence.
- negotiations to restrict the deployment of battlefield nuclear weapons
- resumed talks on preventing the spread of nuclear weapons
- measures to keep nuclear arms from countries not now possessing them

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steps to reduce the risks of a nuclear war started by accident or miscalculation
honouring existing arms-control agreements as well as the still-unratified Strategic Arms Limitation Treaties (SALT II)
eschewing military doctrines 'that treat nuclear explosives as ordinary weapons of war'
negotiations to ban testing of nuclear weapons 'in all environments for all time' (Canberra Times, 9 February 1983, p. 5).

The Committee believes that if the Institute made a policy statement on nuclear armament and warfare, the Institute could find itself entering a political debate which the Institute would be ill equipped to continue. The issuing of a detailed policy statement could well be internally divisive, have a stifling effect on future public discussions and compromise the significant role the AIP could play in assisting information dissemination and public discussion.

In view of the above constraints, the Committee believes it should endeavour to raise the level of informed debate about nuclear war matters among Institute members and the public generally. The Committee believes that this aim is an appropriate basis upon which proposals for immediate action can be suggested as well as a basis for further Institute involvement. This paper can also be seen as an interim response from the Committee to the request from the Nuclear War Forum that the AIP should consider policies for further action.

Possible Initiatives

While there are constraints on the range of issues which can be dealt with by the Committee, it is well placed to implement a number of policy initiatives. It is proposed that a Canberra-based Working Group of the Committee be established to organise and coordinate a range of activities relating to the nuclear armament and warfare issue. The proposed Working Group's activities are only tentative and may include the following:

- organisation of a nuclear war symposium by the Committee at the 54th Congress of the Australian and New Zealand Association for the Advancement of Science (ANZSAS) in Canberra (14-18 May 1984) and the public dissemination of topics discussed at that symposium.
- the encouragement of physicists to talk on nuclear armament and warfare at schools, seminars etc.
- circulation of a questionnaire to Institute members canvassing attitudes
- distribution of information to members on nuclear war matters (e.g. The Freeze Appeal by concerned physicists)
- the encouragement of AIP Branches to take an active role
- running an essay competition for articles published in the Australian Physicist on nuclear war matters
- compilation of a 'data base' on physicists in Australia willing to contribute to public discussion on nuclear war topics and in particular, on factors affecting Australia
- the maintenance of contact with other organisations with an interest such as SANA and the reporting of further developments in the Australian Physicist by the Committee.

These policy initiatives are in no way meant to represent an exhaustive list. The Committee would welcome suggestions from members on other ways it could contribute to informal public discussion on nuclear war and the arms race. In making suggestions, members are asked to bear in mind the Committee's aim and the resource constraints mentioned above. It is anticipated that the primary concern of the proposed Working Group would be the organisation of the ANZAAS symposium. The Working Group would aim to ensure that a balanced view of the nuclear debate is put forward at all times.

Informed public discussion will be facilitated if the people best able and motivated to contribute do so. The Committee feels that there is particular merit in improving and developing our knowledge about how nuclear war may affect Australia, the impact of the arms race on our regional security, Australian Government policies and the effectiveness of civilian defence measures in Australia.

Conclusion

There is a need for the Institute to respond to the request arising out of the Nuclear War Forum that the AIP should consider policies for future action. However, at this stage, the Committee does not suggest that either the Institute or itself should make a policy statement on nuclear war issues. Rather, the Committee aims to raise the level of informed discussion and more importantly, the level of social awareness of AIP members. The establishment of a Working Group of the Committee with the aim of organising a range of activities is a clear indication that nuclear armament and warfare is a matter of great importance deserving immediate attention. The initial stand taken by the Committee recognises that there is likely to be a wide variety of views within the Institute on how best to proceed. The great benefit of the approach adopted by the Committee is that considerable public discussion would be generated with the commitment of limited resources, while preserving the AIP's neutrality on political issues.

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When every drop counts

When you're trying to establish pasture or crop in hot, arid country every drop of rain counts.

Using a grant from the Australian Industrial Research and Development Incentives Board (AIRDIB), a West Australian company has developed a technique which increases the water catchment area for germinating seeds by planting the seeds in a pit.

The Kinseed Pitter Seeder has been developed by Kimberley Seeds Pty Ltd, who specialise in the manufacturing of regeneration machinery for establishing pastures and shrubs on arid soil.

Proven in the arid regions of Western Australia and the Northern Territory the method has already attracted a high level of interest from overseas - especially Africa and the Middle East. The company has recently won a major contract in North Africa, an area which has been devastated by drought over the past decade.

The process, in fact, is fairly simple: the pitter seeder forms furrows (or pits) 300mm wide and 1.5 to 2m long. Seeds and/or fertilisers are dropped into the furrows at the same time.

In suitable soil, if there is rainfall of a mere 20mm a volume equivalent to 100mm will run to the bottom of the furrows and germinate the seeds.

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Jobs for Physicists in 1982 — a surprising year

John R. Prescott, Physics Department, University of Adelaide.

Methodology

This is the fourth in a series of surveys begun in 1978 to monitor the “market” for physicists by looking at the advertisements in the daily press. The original survey, which covered part of 1978 and all of 1979, cast its net fairly widely. In addition to the Australian three days per week, it covered the Adelaide Advertiser, Sydney Morning Herald and Age every Saturday and the Brisbane Courier Mail, Hobart Mercury and West Australian by sampling. The general conclusions of the original article1 are still valid and readers are referred to it for details of the various classes of employment and their position in the Australian community of physicists.

In 1980, 1981 and 1982 only those advertisements appearing in the Weekend Australian and the Australian Higher Education Supplement are included. Advertisements in these publications cover essentially all positions for which an honours or higher degree in physics, applied physics or geophysics would be appropriate. The 1982 survey is reported here.

In the past, a large proportion of advertisements for jobs requiring a pass degree or diploma in physics or applied physics has appeared only in the state newspapers (about 60% in 1978-79). The coverage of the survey is appropriate to those levels of qualification is therefore incomplete. Further comments on these points appear below.

Different Trends

One of the most intriguing features of 1982 was the way in which, as the year drew on, it began to be clear, notwithstanding the recession and growing general unemployment, that the demand for physicists was holding very firm. According to the ANZ Bank Employment Advertisement Series, the number of advertisements in all classes of employment for the whole of Australia fell by 50% in the twelve months to November 1982. This trend, which was first discernable late in 1981, accelerated through 1982 and is still continuing. On the other hand, the number of positions in the Australian suitable for a graduate in physics or applied physics was 680 compared with 690 for 1981 and 680 in 1980. The proportion of positions for which a Ph.D. was a stated requirement has been steady at close to 20% since 1973.

Within this total there are some interesting trends which are illustrated in the table, which contains also the corresponding data for 1980 and 1981. Except for the total posts given at the head of each column, all figures are percentages.

The number of positions advertised in the Commonwealth Government area as a whole is higher than it has been since the surveys began and is up to about 50% over the five-year average. Recruiting for CSIRO seems relatively stable if not exactly vigorous. The biggest surprise is the active recruiting by the new Department of Defence Support which dominated the Commonwealth Government advertising after July and accounted for almost half of the classification in the second half of the year. A spokesman for the new Department suggested that this increase was perhaps more apparent than real, since a number of recruiting activities were now consolidated under the one heading.

Nevertheless, recruiting by this department and other defence science agencies accounts for one third of the Commonwealth Government jobs outside the CSIRO.

It is clear from various official and unofficial sources that the Defence Science area is having difficulty attracting well-qualified applicants in both physics and engineering and a number of the positions advertised remained unfilled. It is therefore possible that some of the positions were re-advertised but, if so, it was under a different position number. Discussion with students reveals that many are just not interested in jobs in Defence Science. Nevertheless, for whatever reason, this is one area where demand exceeds supply. Another interesting idiosyncrasy of the Defence Science advertisements is that there were seventeen positions listed in the Advertiser and not in the Australian and which therefore do not appear in the table. This is probably related to the location of the Defence research Centre, Salisbury and may not be mirrored in other states.

Another area where supply and demand do not match is in teaching. Advertisements from independent schools for teachers of physics (specified as such in the advertisement) rose from 41 in 1980 to 75 in 1981 and 89 in 1982. This shortage of teachers is not confined to independent schools. As recorded last year, State and Territory Departments of Education are now also advertising for teachers; N.S.W. has advertised for students to train as physics teachers and the Northern Territory is offering scholarships for students to train to teach in specified disciplines, including physics. This situation is serious and the Institute of Physics, both nationally and through its branches, should be pursuing the matter actively. Perhaps lobbying of Ministers and Directors of Education by local branches would be effective. Certainly no opportunity should be lost to point out to physics graduates with a bent for teaching that they are in a buyers’ market. As a rather depressing footnote, it has to be recorded that in the recent reorganisation of the South Australian teacher-training CAE’s into the monolithic South Australian CAE, science and mathematics somehow got lost. In their new six-faculty structure, there is no mention of either!

As in previous years, if you know what to look for, it is possible to identify small-scale structure in the academic area which would not normally appear statistically significant. The Australian National University continues to dominate this group of positions. Of the eleven tenurable university positions six were for professors or professional fellows. An increase in the number of posts funded by the ARGs is just detectable in the “academic temporary” category. The academic market place, however, continues to be depressed and it is difficult to escape the impression that the worst is yet to come.

The only other area in which a major change is visible is private industry and commerce. Here, indeed, employment opportunities reflect the market place, with a fall that closely parallels the general employment picture. This pattern is also found for the number of advertisements in all employment classifications in the major state newspapers. If the statistics of the 1978-79 survey are assumed to be still valid on a broad scale, this implies a fall of the number of positions for
physicists in commerce and industry from about 500 to
about 250. This is not good news for first-degree pass
bachelor graduates because many of the jobs for such
students have been in this area. Since the number of
pass graduates has been steady for some years, it is
likely that some such students may find it more difficult
to find a job in 1983.

Finally a note about geophysics. This is not included
in the table because geophysics is traditionally grouped
in Australia with earth sciences. Nevertheless, expansion
in mineral exploration which peaked in 1981 and carried
over into the first half of 1982, brought a demand for
exploration geophysics which the traditional sources
could not fill. Graduates with physics degrees helped
provide the shortfall. In 1982 there were 94 positions
advertised for geophysicists. Mostly these were for
mineral exploration although about 20 could be
classified as either academic or laboratory-based.
However, it has to be noted that recruiting in this area
has followed the downward trend shown by private
industry generally and at the end of 1982 was currently
lower than at any time in the past five years.

Summary
In summary, employment for physicists presents a
somewhat confused scene: Opportunities for honours
and higher degree students remain good in spite of rising
unemployment elsewhere. Although the TEC figure for
Ph.D. graduates for 1982 is not yet published, it is
unlikely to exceed last year's figure of 53 which falls
well short of the number of jobs for which a Ph.D. is
required or implied. Opportunities for post-doctoral
fellows have also been widening overseas. It continues
to be true that there is a shortage of Ph.D.
graduates in physics in Australia — at least in some
fields. The situation for pass graduates is less clear. Jobs
in the Commonwealth and State Government services
is less clear. Jobs in the Commonwealth and State
Government services are still available. There is a critical
shortage of trained physics teachers. Commerce and
industry (including geophysics) on the other hand are
recruiting at a low level.

It will be interesting to see how all these trends
develop in 1983.

References
4. ANZ Bank Business Indicators No. 160, Melbourne,
December 1982.
5. ibid, No. 159, November 1982.
Physicist 18, 216.

Author
Professor Prescott is convenor of the AIP sub-
committee, which also comprises Ian Maclean, Oliver
Raymond, John Harries and John MacFarlane.

ADVERTISED POSITIONS IN “THE AUSTRALIAN”

All jobs, advertised in “The Australian”, for which a degree in Physics, Applied Physics or diploma in Applied Physics
provides a suitable starting point. All figures are percentages.

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Geophysics not included above

Total 94

STOCHASTIC PROCESS IN NONEQUILIBRIUM SYSTEMS (Lecture Notes in Physics, Vol. 84), L. Garrido, P. Seglar, and P.J. Shepherd (Eds.), Springer-Verlag, Berlin, 1978 xi + 352 pp., $16.60.

Reviewed by C.A. Croxton, Department of Mathematics, University of Newcastle.

This collection in the Springer-Verlag Lecture Notes in Physics series represents the proceedings of the Sitges International School of Statistical Mechanics, held in Barcelona, Spain in 1978. A specific objective of the meeting was to make material presented accessible to students and scientists in adjacent fields — in particular, chemistry, biology and sociology, extended areas of application posing exciting challenges for the utilization of statistical mechanical techniques which have served so well in more conventional areas of the physical sciences. From the standpoint of the theoretical physicist the book generally succeeds in introducing an ambitious range of interdisciplinary applications. However, other than those of a decidedly theoretical disposition, biologists and social scientists may well feel themselves ill at ease with the essentially mathematical presentations.

The book begins with an introduction to stochastic processes for physicists (N.G. Van Kampen), followed by a number of chapters on various applications of the statistical techniques in simple dynamical systems (Y. Pomeau), kinetics of phase transitions (O. Penrose), aspects of the theory of Brownian motion (R.M. Mazo), stochastic differential equations with non-Markov processes (E. Santalo), path integral methods (R. Graham), computer simulation of transport properties (B.J. Alder) — and a fascinating new field, synergies (H. Haken). The level and quality of presentation is evident from the above listing of the contributors. The lectures themselves are generally highly readable, but are nevertheless presented in sufficient depth as to provide a useful reference text. The book concludes with a number of seminars and short communications contributed by some of the participants attending the school.


Reviewed by J. Mahanty, Research School of Physical Sciences, The Australian National University, Canberra.

This book contains eighteen review articles on the interaction of electromagnetic waves with various types of excitations occurring at solid surfaces. The excitations which couple with electromagnetic waves are those arising out of polarisation fluctuations in the solid, both electric and magnetic, such as plasmons, optical phonons and magnons. The consequence of the coupling of such modes arising at a solid surface with electromagnetic waves is the generation of surface polaritons, which are the combined states of photons with the appropriate excitations. The response properties of the surface are determined by these surface polaritons, the study of which is thus of importance in surface physics.

Most of the articles deal with plasmon-polaritons at surfaces within the framework of continuum models, such as the hydrodynamic model of the electrons in a metal, and the dielectric continuum model for semiconductors and insulators. The editor, who has made notable contributions in the former field, has given an excellent review of the hydrodynamic model. There are articles examining the use of such models in analysis of the interaction of surface plasmons with photons, the surface plasmon modes in different geometries, in layered media and in small metallic particles. In addition, the topics which have been discussed in other articles are, a quantum mechanical treatment of surface plasmons from the microscopic point of view, evaluation of van der Waals interactions from the surface response functions, experimental techniques for observation of surface polariton modes, magnon-polaritons, and the non-linear optics of surface polaritons.

The limitations of continuum models in this field are well known, in so far as they ignore the effects of the microstructure of the solid and its surface. Also, the coupling of the collective modes with single particle excitations leading to life-time effects in the former cannot be included in such models except in a phenomenological way. However, as the articles in this book demonstrate, continuum models are simpler to analyse and solve exactly in a variety of situations, and have enhanced our understanding of a large range of surface phenomena. All the articles are well written, readable and would be enjoyed, particularly by the nonspecialist who wishes to get into this field.


Reviewed by D.J. Miller, School of Physics, University of New South Wales.

This volume of the well known series of Willardson and Beer contains chapters on the effects of crystal defects on optoelectronic devices, crystal growth and properties of Hg$_x$Cd$_{1-x}$Se alloys and magneto-optical nonlinear optical properties of Hg$_x$Cd$_{1-x}$Te alloys. It is probable the latter section of the book on the continuous medium (CMT) that will be of the widest interest. CMT has dominated recent advances in the detection of infrared radiation and a multibillion dollar industry has developed with applications mainly to thermal imaging for military use. Volume 18 of the series will be entirely devoted to CMT.

The chapter on the effects of defects is especially concerned with the degradation of carrier lifetime and minority-carrier diffusion length. The treatment is particularly useful because the author avoids including too many equations and because he expresses a personal view about some of the topics. The second chapter is the first review in the literature on Hg$_x$Cd$_{1-x}$Se which is a material which may be important for infrared detection in the future. The chapter contains a fairly detailed account of the properties of Hg$_x$Cd$_{1-x}$Se with some notes on how the crystals can be grown. In the next chapter, M.H. Weiler summarises the fascinating magneto-optical properties of CMT and uses the quasigeummin model to extract a detailed picture of the electronic energy levels. The final chapter explains the physics, and gives the state of the art, of spin-flip Raman lasers, multiphonon mixing and other nonlinear effects in CMT.

Reviewed by J.C. Macfarlane, CSIRO Division of Applied Physics, Lindfield, NSW.

This book contains 52 papers that were presented at the Fifth International Conference on Noise, held at Bad Nauheim, W. Germany, in 1978. There are seven sections entitled: Noise in Semiconductor Devices; Hot Carrier Noise; f/f Noise; Noise in Magnetic Materials; Noise in Superconductors and Superconducting Devices; Noise Measuring Techniques; and Theory.

A. Van Der Ziel deals theoretically with the fundamental noise mechanisms in p-n diodes and transistors, using a one-dimensional model and transmission-line technique. He derives expressions for recombination noise at low and high injection; thermal noise in JFETs and MOSFETs; and noise due to donors in an n-channel JFET. References are given to experiments which support the theory.

D. Wolf brings together a surprising range of systems, from the rotating Earth to highway traffic to ionic solutions, in which f/f noise has been studied.

BRANCH NEWS

A.C.T. Branch Meeting

At the A.C.T. Branch meeting on 1st March, Dr. Tony Klein from the Physics School of the University of Melbourne gave an interesting and entertaining talk on neutron optics. After discussing the similarity between the optics of neutrons and the optics of light, Dr. Klein described some of the applications of neutron interferometry carried out using neutron beams from the reactor at the Institute Laue-Langevin in Grenoble, France.

A particularly interesting application was the experimental confirmation that rotation of the spin $\frac{1}{2}$ of a neutron through $2\pi$ produces a change in sign of the neutron's wavefunction. Since this change in sign is only a phase factor, it was for a long time described in the textbooks as not observable. But by splitting the beam into two halves and rotating the spin of the two halves in opposite directions, the effect of rotation through an odd number of $2\pi$ was very clearly demonstrated. The neutron flux for this experiment was such that only one neutron was in the apparatus at a time.

Among the other aspects of neutron optics discussed by Dr. Klein were Fresnel diffraction, double slit diffraction, and image formation by a Fresnel zone plate. Dr. Klein is the co-author with S.A. Werner of a review article on neutron optics appearing this year in Reports on Progress in Physics.

L.J.T.

Prizes in Physics

Each year the A.C.T. Branch presents a prize to the best physics student in the second year of study at each of the three A.C.T. tertiary institutions, A.N.U., Duntroon and C.C.A.E. The winners for 1982 were, J.P. Homer, A.N.U.; P.W. Clarke, Duntroon and S. Ngan, C.C.A.E. The prizes of $80 plus a year's student membership of AIP were presented at the branch meeting on 1 March, 1983.
To allow adequate time for each of the 16 scientists to describe some of the work in one field, the visit was divided into two parts and the visitors chose one or the other of 8 fields. Your correspondent chose molecular collisions, temperature, mass, magnetics, acoustics, microwaves, electrical potential and optical measurement of length. The other part comprised engineering metrology, gaseous electronics, impedance and frequency, power frequency, solid state, radiometry, optics and a visit to the optical laboratory. The diversity and ingenuity of the work we were shown may be imagined from the following examples:

— a microwave discharge generating free radicals of gaseous halogen compounds, useful for etching silicon chips; the advantages are the use of relatively harmless initial and final compounds and extremely fine etching through the use of gases; the particular objective of this research is to determine the spectrum of free radicals generated and their behaviour under a range of controlled conditions.

— the development of a miniaturised wireless hearing aid using a ferrite core antenna to amplify low power radio signals in a range of about 8 m using a less cluttered part of the f.m. band; the system discriminates totally in favour of the nearest, pocket-size transmitter; it is expected to benefit the education of the non-sighted in particular and should be ready for large-scale evaluation later this year.

— the 'locating reflectometer', a microwave measuring apparatus for investigating flaws and discontinuities in waveguide components; a frequency swept microwave signal is used in circuitry arranged as a phase detector between the signal applied to the component under test and a reference signal; faults in the test waveguide reflect some of the test signal, resulting in 'spikes' at points of discontinuity such as cracks, splices or end faces, which are related to the distance of the fault from the end of the waveguide.

— a frequency stabilised helium-neon laser apparatus as a standard of length, using one of several very narrow line absorption lines to servo-control a piezo-electric mirror adjustment; wavelength stability is better than 1 in \(10^{-9}\) and reproducibility 1 in \(10^{-10}\); the output wavelength of two lasers can be compared with an accuracy 100 times better than by standard optical methods by using this equipment in combination with frequency counting techniques which are inherently more precise than optical interferometry.

The outstanding impression left from this visit was the stimulating atmosphere of inquiry and invention in the application of basic physical principles over the whole spectrum of physics and physical measurement. Another was the common factor of co-operation both within NML but especially with outside bodies.

**AWA Research Laboratory**

The next afternoon the Canberra members assembled at AWA's North Ryde Division where Dr. Don Nicol, the Research Chief, gave a short introductory talk about the Company and in particular about the work of its research division at North Ryde. It is AWA's policy to seek support and co-operation for longer-term research projects from industry, government and agencies such as the Australian Industrial Research and Development Incentives Board. Its current major research project is the development of optical fibre communications, which has been supported by contracts with Telecom, the Department of Defence, Support and others.

After the talk, the group was shown the complete fibre manufacturing operation, quality control procedures and fibre applications research and techniques. In the AWA process, a glass tube about 40mm in external diameter is internally coated with many thin layers of a closely controlled, evaporated glass mixture under heat, both the mix and the temperature being continuously monitored and computer regulated. The coated tube is then collapsed by internal surface tension to a solid glass bar which is drawn directly to final fibre diameter and resin coated to protect the glass from mechanical or chemical damage. The most efficient fibre has a radially graded refractive index, giving attenuation within 1 dB/km for a 1500 nm wavelength. The simpler, step-index fibre, also made by AWA at North Ryde, has an attenuation of about 2.5 dB/km and is used in less demanding circumstances. Both types have the same dimensions, a core diameter of 0.05 mm, total glass diameter of 0.125 mm and coating diameter of 0.38 mm. AWA are currently developing fibre for single mode transmission, which will achieve significantly increased data capacity.

A comprehensive suite of tests is applied to each 3 km length of fibre at the time of manufacture. Of particular interest is the application of optical time-domain reflectometry to measure fibre attenuation, detect faults and locate their position within a few metres, using a 0.01 mm laser beam to scan the cross-section of the fibre. Some long-term tests have been in progress in the laboratory for several years, also, mainly to investigate what effects there may be from a variety of environmental conditions arising in particular applications such as in a vibrating ship or a submarine cable.

Applications of fibre optics in Australia have aimed naturally at exploiting its communications advantages: immunity from radio and electrical noise, reduction of wiring bulk and complexity and long-distance transmission of digital signals. Telecom has been installing experimental optical links since 1981, the University of Sydney began installation of a computer link network the same year, and the Royal Australian Navy installed an experimental undersea optical fibre cable about 2 km long last year in Sydney Harbour between Rushcutters Bay and Clarke Island. At North Ryde the Canberra visitors were shown the methods of linking fibres, inter-faceting input and output devices and transmission line relays, and repairing broken fibres. An intriguing live demonstration was given of closed circuit television using fibre transmission between a camera and monitor through various couplers and a range of signal sampling rates aimed at optimising the system's signal carrying capacity. An example of cable fault location was described as a result of transmission loss on the Navy's Sydney Harbour cable mentioned above. The fault was located by optical reflectometry not far from Clarke Island and Navy divers then found that the cable had been disconnected, apparently by a ship's anchor. It will be raised and the glass fibre repaired by a relatively simple electric arc 'weld'.

**ACT Branch Committee 1983**

The Committee elected by the annual general meeting of the branch on 24 November, 1982 comprises the following:

- **Chairman:** Dr. A.M. Baxter
- **Vice Chairman:** Dr. D.H. Chaplin
- **Hon. Secretary:** Dr. G.A. Stewart
- **Hon. Treasurer:** Ms. E.M. Wakefield
- **Members:** Prof. J.H. Carver, Dr. P.J. Edwards, Dr. D.F. Hobbard, Dr. A.M.R. Joyce, Dr. P. Lynam, Dr. O.J. Raymond, Dr. J.P. Rayner, Dr. B.A. Robson, Dr. R.J. Sandeman, Mr. P.W. Brown

*The Australian Physicist, Vol. 20, May 1983 — Page 102*
The marine scientist who first discovered that the warm ocean current from the north does a ‘U-turn’ off the N.S.W. coast near Jervis Bay, Mr Bruce Hamon, has been honoured by a special issue of the Australian Journal of Marine and Freshwater Research. Mr Hamon, an Honorary Research Associate in the Marine Studies Centre at the University of Sydney, was presented with the special case bound ‘commemorative issue’ at the Australian Physical Oceanography Conference last month. It contains 16 papers by well-known physical oceanographers.

Mr Hamon became interested in physical oceanography 30 years ago, when, as a member of the CSIRO’s Division of Electrotechnology, he developed the ‘temperature depth salinity’ recorder, a profiling instrument which set a new trend for oceanographic instruments around the world.

He joined the Division of Fisheries and Oceanography and went on to develop another instrument, the ‘inductive salinometer’, which is still being manufactured in Australia for use throughout the world.

His detection of short term fluctuation in tidal heights laid the basis for new discoveries about continental shelf waves, and he pursued an independent line of research which dispelled some currently held fictions about water currents. His research revealed that the current of warm Coral Sea water off the N.S.W. coast was not continuous, but was U-shaped, ‘pinched off’ by an anticyclonic eddy off the coast of Jervis Bay. This picture has been confirmed by satellite-tracked drifting buoys and satellite infrared pictures.

Since his retirement from the CSIRO in 1979 at the age of 62, he has worked as an Honorary Associate in Marine Studies at Sydney University, where, in addition to giving courses in physical oceanography and supervising research students, he continues work on ocean variability now using satellite data.

The Australian Development Assistance Bureau has given Professor A.W. Snyder, Applied Mathematics, R.S. Phys., Australian National University, a grant of $10,000 within the Supplementary Funding Scheme to support technical cooperation with the Wave Sciences Laboratory in the Shanghai University of Science and Technology.

Mr D. R. Christie, Professor K. Lambeek and Dr K. J. Muirhead, of the Research School of Earth Sciences, ANU, have received a grant of $32,000 from the US Air Force Office of Scientific Research in support of research into solitary waves in the lower troposphere at the Tennant Creek infrasonic array.

Monash theoretical physicist Dr Harry Perlman, who is working on the mathematics that forms the foundation of the quantum theory, says the difference between classical and quantum mechanics is illustrated by the often misunderstood Heisenberg Uncertainty Principle.

"The standard deviation (the measure of spread) of the distribution you obtain when you measure the state of a particle has nothing to do with experimental error. It depends upon the state the particle is in."

Quantum mechanics employs two basic kinds of mathematical constructs — observable operators (which are associated with constructs such as energy and momentum), and "state vectors in Hilbert space", a highly sophisticated mathematical concept which specifies the states of particle systems.

It turns out that when you attempt to determine the "time evolution" of a particle system (i.e. the behaviour of the system at some subsequent time) it makes no difference to observational results whether you take "state vectors" to be time-independent and blame all the time dependence on the operators, or whether the operators are regarded as time-independent and the time dependence is blamed on the "state vectors", or whether the time dependence is shared between "state vectors" and operators.

"Which approach we use," Perlman says, "will depend on which is the most convenient for the particular problem at hand."

What Perlman has done is to generalise this technique of arbitrarily sharing the blame for the effects of "time translations" between operators and "state vectors", to the effects of rotations in four-dimensional space-time.

This permits him to share the blame in such a way that operators which are normally vectors (quantities that have both magnitude and direction) behave like scalars (quantities that do not have direction and are independent of the frame of reference).

"This can be of considerable convenience," he says.

Perlman believes his conceptual development could have applications in areas such as elementary particle theory, the relation between quantum theory and general relativity, and perhaps, solid state physics. Work on its application is proceeding.

Modern physics, particularly quantum mechanics, raises profound philosophical questions. Does science, at this level, present to us a picture of reality which becomes clearer as knowledge increases? Or are the physicist’s electrons and the like simply intellectual constructs which help us make sense of the world around us?

There are two extreme approaches to this problem — the realist and the instrumentalist.

To the realist, the scientific view of the world is, in some sense, a picture of reality. Scientific theories, in this view, are either true or false.

The instrumentalist view (which is held by Perlman) is that entities such as particles are convenient fictions and that scientific theories are mnemonics, so to speak, which serve to correlate observations and enable predictions to be made.

In this view, scientific theories are not true or false. They are simply successful or tenable, unsuccessful or untenable.

The instrumentalist does not deny that the realist position is appropriate for some theories, Perlman says. He merely asserts that it need not be appropriate to all.

Later this year Perlman will present an elementary lecture on quantum theory to HSC students as part of an "enrichment" series of lectures which have been prepared for the students by the Monash physics department.

Professor C. A. Hurst of the University of Adelaide is at present a Visiting Fellow in The Department of Mathematics, Research School of Physical Sciences, ANU (until June).

Dr Eric Butcher, Reader in Theoretical and Space Physics at La Trobe University, spent part of September and October last year as the guest of Bombay’s Indian Institute of Geomagnetism (IIG). This was a result of

* * * * *

science and particularly physics is very relevant," he said, "I want to take the mysticism out of science....
"There is an old Chinese proverb which says 'When I hear I forget. When I see I remember. When do I understand.' Julius Sumner-Miller did all the things while you watched. At Questacon you get to do it.....

Questacon was a tourist attraction, and school parties visited from as far as Queensland and South Australia. Already there were more than 70 exhibits for a national science museum. But, although there was interest from academic groups, government departments and private enterprise, financial support was needed.

"I am delighted with the award because it will give publicity to Questacon and help us on our way," he said.

Dr Gore was chosen Canberra of the Year by a panel of judges from The Canberra Times, the Canberra Festival Committee and the House of Assembly.

A Sydney University scientist who has devoted most of his research career to analysing the behaviour of liquids like 'Silly Putty', which children (and many adults) like to play with, has won one of the most prestigious awards of the Royal Society of N.S.W.

Dr Nhan Phan-Thien, 30, was presented with the Edgeworth David Medal by the Society at a ceremony last Wednesday, 6 April, in recognition of his outstanding contributions to research in fluid and solid mechanics.

In its citation, the Royal Society said Dr Phan-Thien was clearly the leading young scientist in his field in Australia, and had been 'astonishingly productive', having produced 64 research papers since 1977, "about ten times the norm'.

Dr Paul J. Edwards, formerly Associate Professor of Physics at the University of Otago, has taken up the position of College Fellow in the School of Applied Science at the Canberra College of Advanced Education where he now heads the Electronics, Engineering and Applied Physics group. Dr Edwards is a Visiting Fellow in the Research School of Physical Sciences, Australian National University.

The U.S.S.R. Academy of Sciences has invited Professor Dan Haneman of The School of Physics, The University of New South Wales, to visit the Soviet Union and a number of research laboratories as their guest. He will give a number of lectures on semiconductor surfaces and interfaces at Universities and Institutes in Moscow, Leningrad and Kie, in July-August.

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**Bilateral Science and Technology Agreements**

The 1984 program has a revised closing date for applications by Australian scientists and technologists for activities between 1 July and 31 December 1984 under the Science and Technology Cooperation Agreement with Mexico.

The revised closing date is 1 September 1983, a month earlier than previously advised.

Correspondence should be sent to: The Director, International Activities, Department of Science and Technology, PO Box 65, Belconnenact 2616.
PHYSICS ROUNDBOOUT

Halley's Comet

In mid-April, 1910 after officials at the Melbourne Observatory caught their first glimpse of Halley's Comet, The Weekly Times reported with apparent relief: "Now that Halley's Comet has made itself visible to observers in Melbourne without so far the disastrous results forecasted by some astronomers, people are beginning to regard the visitor with a not unfriendly gaze."

But the newspaper added a note of caution: "According to the astronomers the 'danger period' is the latter end of May, when, if some of the seers are right, Halley's Comet will whisk its tail and the earth will disappear."

Happily, as it turned out, Earth did not disappear. Preparations are now in train for the return of Halley's Comet, which will be brightest during the first three weeks of February, 1986.

In early 1985, Halley's Comet will cross the orbit of Jupiter and by the end of the same year the accelerating comet will have passed the asteroid belt, the orbit of Mars, and arrived again for its once-in-a-lifetime visit to the neighborhood of Earth.

Scientists hope that a detailed study of the comet will yield clues to the origin of the solar system and, perhaps, life itself.

Comets and planets probably formed from the same reservoir of gas and dust. However, the birth records of planets and their satellites are obscured by thousands of millions of years of evolution during which external and internal processes have reshaped their interiors and surfaces.

By contrast, comets are among the most primitive objects remaining in our solar system, and may have been a major source of organic materials in the atmosphere of the planets. A study of their composition could provide clues to the nature of the prebiological environment of Earth.

Since, the composition of comets appears to be similar to that of interstellar clouds, detailed study of a comet such as Halley's may also help solve problems concerning molecular formation and the nature of interstellar dust, clouds, and the dark nebulae.

The scientific program will be co-ordinated by the International Halley Watch, which was officially established at last year's triennial meeting of the International Astronomical Union.

The most important elements in the International Halley Watch are the professional observers and the discipline specialist teams. The latter will co-ordinate observations of the comet.

![A schematic drawing of Halley's orbit 1910-1986.](image)

Experts have been selected for seven discipline specialist teams which will co-ordinate observations in seven areas of astronomical research — astrometry, infrared spectroscopy and radiometry, large scale phenomena studies, near-nucleus studies, photometry and polarimetry radio science, spectroscopy and spectrophotometry.

Monash professor of chemistry, Professor Ron Brown and Dr Peter Godfrey, senior lecturer in chemistry, are members of a discipline specialist team which will coordinate radio science observations in the southern hemisphere. Brown and Godfrey are the only Australian scientists on any of the committees.

Brown says Halley's Comet spends most of its time deep frozen far from the sun. Only as it approaches the sun — once in every 76 years — will the gases and solids of the comet's nucleus start to burn, releasing dust and gases to form the tail and coma (the gaseous "halo" around the nucleus).

Observations by powerful radio telescopes of radio frequency spectral lines from molecules in the coma may provide important information about the composition of the comet's nucleus, he says.

Detailed analysis of the sublimation processes as the nucleus starts to burn could provide important information also on the conditions under which comets are formed, the nature of interstellar grains and gas, and (more speculatively) the early stages of chemical evolution and the origin of life.

**Satellite probes**

Some of the most interesting results in the International Halley Watch should come from the satellite probes.

The European Space Agency (ESA) plans to send its Giotto spacecraft past Halley's Comet on March 13, 1986. The Soviet Union and Japan plan to send spacecraft past the comet about the same time.
The ESA spacecraft should go within 500km of the
comet's nucleus and should penetrate its coma and tail.
It will carry instruments to measure the chemical
composition of the coma and a camera to photograph
the nucleus itself.

Unlike its last appearance in 1910 when it blazed
across the sky, the return visit of Halley's Comet will
be something of an anticlimax for the casual observer
because of the comet's alignment with the Earth and
the sun.

It will be brightest during the first three weeks of
February, 1986, when it is nearest the sun (closest
approach occurs February 9). Unfortunately, it cannot
be observed from the ground then because the Earth
will be on the other side of the sun.

However, if you have binoculars and you can find
a spot away from city lighting, the comet should be a
rewarding sight in November and December of 1985
and at its best in March and early April of 1986.

Second dish antenna
opened at Moree

A new 511m satellite earthstation antenna has been
opened at Moree in northern NSW.
The dish antenna, the second at OTC's Moree satellite
earthstation, provides telecommunications services via
a Pacific Ocean satellite to North America, New
Zealand, South east Asia, Japan and other destinations.

Called Moree 2, it was built to cope with the increased
demand for telecommunications which, in
Australia, is growing at about 25 percent a year. This
means OTC must double the traffic-carrying capacity
of its facilities every three years.

Moree 2 transmits and receives all types of
telecommunications traffic, including telephone, telex,
satellite television, facsimile and data transfer. It is
designed to accommodate dual polarisation.

Communications received by the new antenna are
carried by coaxial cable and microwave links to OTC's
international terminals at Paddington and Broadway in
Sydney, from where they are distributed throughout
Australia.

Construction of the new dish, which is 35.2m high,
took just over a year to complete. Moree 2 is a slightly
larger antenna than Moree 1 — 32m diameter as against
27.2m — and weighs about 240 tonnes.

One of the features of Moree 2 is a "beam wave guide"
— a periscope-type apparatus enabling the incoming
signal to be reflected by appropriately angled metal
surfaces into the equipment room below the antenna.
The received signal has to be amplified more than a
million times to compensate for the loss of strength
during its 36,000km journey through space.

A 35-seat visitors centre plus a display and viewing
area has been incorporated in the expansion of the
station.

Water Treatment

With water being a crucial issue to landholders it was
no suprise that the Department of Science and
Technology's public-interest project, the SIROFLOC
water-treatment system, excited much interest at a
National Field Day display in Orange.
The SIROFLOC process decolourises and clarifies
turbid water and is being demonstrated at Mirrabooka,
outside Perth. It produces 35 megalitres of water a day.

Other related processes being tested are
SIROTHERM which desalinates brackish water to
potable levels, and the Magnetic Dealkalisation process
which removes alkalinity and hardness.

Besides having enormous potential for inland and arid
areas, the water-treatment systems will allow
augmentation of existing and hard pressed metropolitan
and shire supplies.

Nuclear War Symposium

New Agal Laboratory
Opened in Pymble

A new $8.6 million Australian Government Analytical
Laboratory at Pymble in Sydney was officially
opened in November.

The new laboratory is a triumph of cooperative
planning and good design. It is a highly complex, very
modern example of a chemistry and microbiology
laboratory which will probably be in use well into the
next century.

The Pymble laboratory is extensively automated and
the latest technology has been incorporated into the
many services. It will be capable of far greater output
than its predecessor with minimal increase in staff. For
example, the increased efficiency of the new laboratory
is evidenced by a 75% increase in the samples analysed
in 1981/82 over those in 1980/81.

Solar World Congress
Announces Keynote
Speakers

The Solar World Congress and International Solar
Energy Exhibition will attract over 1,000 of the world's
foremost authorities on renewable energy and will be
the largest solar energy gathering ever held in Australia.
The Congress is sponsored by the 8,000-member

It will take place from August 14-19 in Perth.
Technical sessions will cover such major subject areas
as thermal applications for building and industry,
electricity and mechanical work, materials/chemical/
biological systems, resources/wind energy systems,
solar energy in developing countries and non-technical
issues such as economic, environmental and legal aspects
of solar energy.

Eight keynote speakers will address the Congress. The
only Australian among them will be Mr. J.B. Kirkwood,
Commissioner of the State Energy Commission of
Western Australia, who will speak on the socio-
-economic issues of solar energy.

Other speakers include: Prof. J. Cook (Arizona State
University), Dr. F.J. Friedrich (K.F.A. Juleich), Prof. G.
Lehner (University of Stuttgart), Prof. F. Reale
(University of Naples), Prof. A.L. Titchener (University
of Auckland), Prof. J.K. Page (University of Sheffield),
Dr. P. Musgrove (University of Reading) and Mr. D.J.
Fogarty (Southern California Edison).

The Congress will be opened by the Governor-
General of Australia, Sir Ninian Stephen. Special
technical tours will visit such solar installations as the
100kW solar-diesel hybrid station at Meekatharra,
Australia's largest wind generators on Rottnest Island, a solar pond at Alice Springs and numerous solar industrial applications in and around Perth.

The Congress will be complemented by an International Solar Energy Exhibition which will comprise solar energy systems, equipment and related hardware and will represent researchers, designers, manufacturers and private individuals from around the world.

Western Australia has an active solar research, development and demonstration programme and has good potential for the domestic and commercial uses of solar energy. The Solar Energy Research Institute of W.A. is currently supporting more than 40 projects in the fields of solar, wind and biomass energy.

**Warren Centre of Advanced Engineering**

The Warren Centre of Advanced Engineering at the University of Sydney, a new two-million dollar centre financed entirely from donations, will sponsor outstandingly gifted engineers from Australia and overseas to visit the University to share their expertise with study teams of Australian engineers in projects of up to six months' duration.

The first project will begin immediately after the official opening of the Warren Centre by the Governor of N.S.W., Sir James Rowland (himself an engineering graduate of the University) on 17 May.

The project will be a major 're-think' of Australia's marine facilities and structures which provide for its export of bulk materials.

**Snakes see (infra) red**

Darkness is no barrier to a hungry python or viper — it can hunt by 'looking' for the body heat of its prey. We can all feel heat when it's close enough to us, but these snakes have refined the art by developing special pit organs, a pair of deep cavities in the head that open on one side of the head below and in front of the eyes. Not satisfied with just one pair, pythons can have as many as thirteen pairs.

This curious 'heat vision' fascinated scientists so they set out to find out just how well the snakes can 'see'.

They first blindfolded the snakes and presented them with the heated tip of a soldering iron. The video cameras rolled, ready to record the expected strike, but the snake just lay there. It wasn't fooled a bit.

Clearly, that was no mouse!

In order to persuade the snakes to action, they were given a mild electric shock just before being 'shown' the soldering iron. This time they struck with deadly accuracy. They hit within 5 degrees of the target no matter whether it was dead ahead or up to 60 degrees to the side.

The pit organs operate rather like a pin hole camera — they have a small opening through which the heat passes and is projected onto a larger 'screen'.

Pulling out their trigonometric tables and knowing the snake can strike within 5 degrees of a warm spot, scientists calculated that the snake must have its heat sensitive receptors scattered no more than 175μm apart in its pits. In fact they have a mosaic of receptors, each one about 60μm across and so can have quite reasonable images of any warm dinners in the neighbourhood.

Finally came the question of how sensitive to heat are the pits. By flooding the pits with water at a specific temperature and monitoring any changes of the nerve impulses in the axons leading away from the pit organ towards the brain, the scientists could tell whether the snake 'saw' any changes in the water temperature. Some of the most sensitive nerve fibres fired off when the water temperature changed by as little as 0.003 degrees C.

Belive it or not, the skin on your forehead has about the same threshold sensitivity to temperature, in theory at least.

The trick is that your nerves are buried deep in your skin and even though they may be able to detect minute heat changes, it takes a lot of heat to warm up all the skin and tissue that covers them.

The snake's pit organs are specialized receptors — the problem of heat absorption is cut down to a minimum as the thermosensitive ends of the nerve fibres come very close to the surface, within 15.30μm. In your forehead they're buried 300μm down.

*Biology In Action AAS*

**Fibre optics at ANU**

Scientists in the Department of Applied Mathematics, RSpHyS, are carrying out intensive research in the field of fibre optics.

Dr Colin Pask, a Senior Fellow in the Department, recently undertook an eight-week outside study program to visit university and industrial laboratories in Britain, where the telephone network is rapidly being converted to fibre optics.

In Australia, ANU researchers are working in collaboration with Telecom with the aim of eventually substituting present communications systems, which usually operate by means of electrical signals on copper wires, radio- or micro-waves, with fibre optics, which use light.

These have many advantages being lighter than copper wires, more flexible and able to carry more information.

Modern optical fibres have a tiny 'core' region which has a refractive index larger than that of the cladding. The light is then trapped in the core by the mechanism of total internal reflection and very little light is lost as it bounces along the inside of the fibre.

Long distance communications require glass to be transparent over many kilometres. In the last 14 years technologists have achieved glass transparency 10,000 times greater than when optical fibres were first considered for communication purposes.

Pure silica is the basic material used in the manufacture of fibre optics. Additives include germanium, phosphorus or boron.

Along the best of these fibres, pulses of light can be reflected for about 100 kilometres without the need for intervening repeaters to act as boosters. In contrast most electrical-metallic systems need repeaters every three or four kilometres.

Optical fibres are virtually noise free and are not affected by stray electromagnetic fields.

The sources of light are tiny light emitting diodes or semi-conductor lasers which can be flashed on and off at high speeds in order to code speech or TV signals into a series of light pulses. At the receiving end a photodiode

reconverts the light into an electrical signal which then drives the telephone or television receiver.

Even some of the coding and modulating procedures now done electronically may soon be done optically as integrated optics progress and scientists learn to manipulate light waves in the same way that they discovered in the past how to use electrons.

All sorts of refinements and basic or ultimate restrictions on light guiding systems need to be understood.

Questions which seemed esoteric and highly academic a few years ago are now being posed by down-to-earth communications engineers.

Professor Allan Snyder, Head of the Department of Applied Mathematics and active in the Optics/Vision Research Group, is presently helping to organise an International Symposium on Optical Waveguide Theory to be held in Kweilin in China next year.

A visiting fellow in the Department, Dr Adrian Ankiewicz, has just returned from Japan where he was a member of a small delegation investigating collaborative work on optical fibres under the Japan-Australia Science and Technology Agreement.

While no applied research is being carried out at the ANU, mainly because of the lack of funding, the theoretical investigations underway are making a significant contribution to the study of fibre optics.

Scholarship in Laser physics

Council of Macquarie University endorsed the Vice-Chancellor's actions in establishing a joint research program between the University, the Division of Applied Physics at the Commonwealth Scientific and Industrial Research Organization and the Queensland company Radiation Research Pty Ltd.

Under the program the company will provide the University with funds to support a Master of Science candidate under the joint supervision of the University and the CSIRO.

The scholarship will enable the student to work on the development of a high power carbon dioxide laser for industrial application.

Ozone monitoring program

The Bureau of Meteorology has taken over responsibility for the management of the ozone-monitoring program in Australia.

The program was established 25 years ago by the CSIRO, and is part of a world-wide network of stations contributing to the World Meteorological Organisation's Global Ozone Research and Monitoring Project.

Australia's contribution is especially important because there are few other measuring stations in the Southern Hemisphere.

The program, consisting of ozone observations by spectrophotometer at five Bureau stations (Macquarie Island, Hobart, Brisbane, Cairns and Perth), will continue unchanged.

A more intensive program of observations, involving measurements by balloon-borne electronic instruments to heights of 30 km, as well as spectrophotometer measurements, is being undertaken in Melbourne.

The information received is used for research in Australia, and is also sent to the World Ozone Data Centre in Canada.

Ozone is found in the lower stratosphere at heights between 15 and 25 km. It is essential to human life, animals and crops by its absorption of lethal ultraviolet radiation from the sun.

Research has shown that human activity could deplete the ozone layer. For example, the use of aerosols, the operation of aircraft in the lower stratosphere, changing agricultural practices, and the expected increase in carbon dioxide due to the burning of fossil fuels all present dangers.

14th International shock tube symposium

The Fourteenth International Symposium on Shock Tubes and Waves is to be held at Sydney University from 15th to 18th August this year. Research in this field began towards the end of the 19th century, with the first laboratory experiments on the effects of explosions in coal mines, but it is only over the last three or four decades that it has begun to find wider application. Thus, shock tubes have been used for purposes as diverse as aerodynamic re-entry measurements and the making of diamonds. Papers presented at the symposium will include these interests as well as chemical kinetics, condensation phenomena, explosions and blast waves. The Mount St. Helen's volcanic explosion will be discussed in an invited paper.

The purpose of the symposium is not only to provide a forum for scientific exchange between established workers, but also to educate the continual flow of new workers in the area in the techniques and potential of this work. Interested participants should contact J. Mackie, Chemistry Department, University of Sydney.

LETTER

Dear Sir,

Having just returned from a 6 week trip to Antarctica and visiting all the continental Australian stations, I was surprised to read that Mawson "enjoyed comparatively little wind" when compared with Casey during June.

Reading back through the climatic summaries in the ANARE News volumes I found that although Casey did have the highest wind gust for the month and a few extra days of gale wind, the number of days of strong wind was somewhat less than Mawson. Similarly the Casey average wind speed was lower, though not by much.

Mawson is generally regarded as the windiest of the Australian continental stations due to the presence of a catabatic wind not found at the other two bases.

By the way Davis minimum temperature should read 38.1°C not 83.1°C, that would be really getting cold. The minimum ever recorded on earth was, −89°C at Vostok, a Russian base on the Antarctic continent and over 300m above sea level.

M. L. Duldig, Antarctic Division, Cosmic Ray Section
'Solitary' waves

ANU researchers believe they may have discovered the cause of some aircraft accidents at take off and landing. They attribute these accidents to previously unrecognised phenomena called solitary waves which buffet and divert aircraft from their planned flight path. They believe the risk to aircraft is world-wide.

The researchers Mr Doug Christie and Dr Ken Muirhead, led by Professor Kurt Lambeck, of the Research School of Earth Sciences, have been studying atmospheric solitary waves for six years.

Solitary waves were first noted in 1834 on the surface of a canal in Scotland. For the next 130 years they were regarded as a curiosity of no real importance to the physical and mathematical sciences.

The first definitive observations of solitary waves in the atmosphere were made in 1976 by the ANU Earth Sciences staff. These observations were recorded on a sensitive microbarograph array located near Tennant Creek in the Northern Territory. An extensive investigation followed and it was realised that solitary waves are a common feature of the atmosphere.

Spectacular visible examples of solitary waves can be seen near Burketown in the south-east corner of the Gulf of Carpentaria. this solitary wave, known as the Morning Glory is an impressive roll-cloud formation.

'Pilots in northern Queensland will not attempt a landing or takeoff when the Morning Glory is in the vicinity,' Professor Lambeck said. 'What the pilots may not recognise is that this same phenomenon also occurs without the dramatic roll-cloud.

'Of 17 large solitary waves recorded in a two-week period in September, 1980, only one was visible. Invisible waves, equally intense, come from directions other than the direction favoured by the Morning Glory.'

The waves travel over long distances and are not restricted to the Gulf region. In the six-year observational period, over one thousand significant solitary waves disturbances have been recorded. Some disturbances have been tracked over hundreds of kilometres.

Diagram shows how the flight path of a plane is affected by a solitary wave. The aircraft is first forced upwards and then thrust downwards.

Conferences and Meetings

1983
May 30-31 The Consequences of Nuclear War for Australia and Region, Canberra.
Symposium Officer, Centre for Continuing Education, ANU, P.O. Box 4, Canberra 2600.
Aug 19-21 Antarctic Scientific Research.
Antarctic Research Policy Advisory Committee, ANU, Australian Academy of Science, Canberra 2600.
Aug 30- EMAG '83 (Electron Microscopy and Analysis Group), Guildford, UK.
Sep 2 Meetings Officer, I.P., 47 Belgrave Square, London, SW1X 8QX
Sept 12-16 Asian Regional Conference on Laboratory Physics Education, Beijing (Peking).
Dr. M. Mazzolini, School of Physics, Melbourne University, Parkville 3052.
Sept 13-16 ESSDERC '83 (European Solid State Device Research Conf.), Canterbury, UK.
Meetings Officer, I.P., 47 Belgrave Square, London, SW1X 8QX
Oct '83- Classical and Quantum Gravity (Diploma Course), Kings College.
June '84 Head, Maths Department, Kings College, Strand, London, WC2R 2LS.

1984
Apr 1-4 Vacuum '84, York
Meetings Officer, I.P., 47 Belgrave Square, London, SW1X 8QX
Apr 9-14 Satellite Aided Beach and Rescue, Toulouse.
Centre National d'Etudes Spatiales, Department des Affaires Universitaires, 18, ave Edouard-Belin, 31055, Toulouse, Cedex, France.
Sept 17-21 9th European Conference on Thermophysical Properties, Manchester.
Meetings Officer, I.P., 47 Belgrave Square, London, SW1X 8QX
Low Cost Picosecond Pulses

Small Ion Laser Based Synch-Pump System From Spectra-Physics

If you’re looking for a start in the picosecond dye laser field, now you can get reliable picosecond pulses from a small-frame ion laser as well as your large-frame ion laser with the new Model 346-03 cavity extension package from Spectra-Physics. This versatile new option utilizes a temperature-compensated quartz tube and a high-precision ruggedized mirror mount to stretch the cavity of your Model 164 or 165 Ion Laser, to match the length required for operation with Spectra-Physics’ Model 342A Ultra-Stable Mode Locker. Together with the extended-cavity dye laser for synchronous pumping, these components combine to deliver extremely reliable operation and many of the key features previously available only in a large-frame ion laser system.

- Picosecond Pulse Generation
- Convenient Interpulse Separation
- Mode Locked or Mode Locked, Cavity Damped Operation
- High Peak Power
- Broadband tunability—540-690 nm using R66, R110 and DCM Dyes

This unique capability is made possible by the excellent stability of the 164 and 165 series ion lasers, the ultra stable operation of Spectra-Physics’ Model 342A Mode Locker and the efficient design of the Model 376 Standing Wave Dye Laser, which minimizes the number of reflective surfaces within the cavity and greatly lowers the amount of ion laser pump power required to reach threshold.

The system is inexpensive to run and easy to maintain. Everything you need for ion

PRELIMINARY SPECIFICATIONS

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<th>Performance Category</th>
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<td>4 MHz to Single Shot</td>
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Figure 1. Typical Tuning Curves for Operation with — 07 Model Ion Laser and up

Figure 2. Typical System Configuration for Mode Locked Cavity Damped Dye Laser Operation

Total Versatility

The extended cavity option is only one of several distinct modules that make the small-frame ion laser from Spectra-Physics the most versatile laser system available today. Up to twelve unique system configurations are possible with capabilities ranging from ultra-short pulse generation to production of tunable single frequency UV. All systems offer the proven reliability and flexible format you need for today’s rapidly expanding research applications. Let us know your requirements today.

Figure 3. 1.2 kW Pulse From Extended Cavity Ion Laser Synch-Pump System Operating with R66

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