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This month’s cover pictures depict the variation in lens power over the surfaces of
SOLA progressive multifocal spectacle lenses. Red is the distance power and blue, the
reading power. The picture in the bottom left shows the levels of astigmatism with red for
very low levels and blue for higher levels. See page 123 for details of the South
Australian branch visit to SOLA Optical.
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PRESIDENT'S COLUMN

The Contributions of Physicists

It was a pleasure to be in Sydney on the 14th of May to help celebrate the 75th Anniversary of RACI. There is clearly a vigorous chemistry community in Australia with strong, direct links to industry. Improving and expanding those links will be a major theme of the Strategic Plan for Chemistry, if the address by RACI President Frank Larkins is any guide.

Also at the dinner were Messrs. Free and McGauran representing both major political parties. Dittar Bartels, the new President of FASTS, was also there, making good use of her place at the same table as these two gentlemen. While I was unable to catch Mr. McGauran I did have a chat with Mr. Free, who was well informed about the preparation of our Strategic Plan. He has agreed to meet me when it is complete. I have no doubt that the opposition will be just as interested.

Although my chat with Dr. Bartels was necessarily brief we will get together again at the UNSW at the end of May. I will be looking for advice on the best ways of achieving the goals expressed in our Strategic Plan - which is taking final shape! The Science Policy Committee considered the latest, near final draft on May 21st and State branches will receive copies for comment in June.

Returning to FASTS for a moment, I know some members have been concerned by Dr. Bartels emphasis on directing funding to specific technologies. Personally, I am convinced that she does not believe that this should be at the expense of basic science, which must provide a solid foundation for the whole, national R & D effort. I am also sure that physics will not suffer from the policies she has proposed provided they are sensibly interpreted.

The Australian Prize this year is a superb example of what I mean. In two pages of the March-April edition of ASCENT describing the winners and their work, the word physics did not appear once, whereas engineering appeared four times. Given the chosen area, "mining or mineral processing", that is what many would have expected. However, both Drs. Howarth and Sowerby are physicists, and physicists...
A ‘Finance’ View of University Research

Most people will be aware that the deliberations on the White Paper on Science and Technology are in their final stages, pending release either with or alongside the Budget papers in August. Minister Free has listed four main areas to be addressed within the White Paper, one of which related to the provision of infrastructure to both the higher education sector and the ‘science’ agencies (Department of Finance jargon for CSIRO, DSTO, etc.). Minister Free has also warned the Higher Education Sector not to expect too much in the way of new funds from the White Paper.

The adequate funding of the infrastructure for science and technology research and development is a major problem, not the least of which is the definition of ‘adequate’. This will, in all probability, be different if one comes from the user sector rather than the provider (of funds) sector. It is worthwhile then to share with members of the research community some snippets I have gleaned from a variety of sources. These relate to the ability of Universities in particular to manage their research activities.

i. The ASTEC report entitled, “Research and Technology: Future Directions”, suggested that a major cause of the present shortfall in infrastructure provision in Universities was due to ‘poor planning and management’.

ii. By inference, the acceptance by research institutions of this situation is short-sighted and imprudent.

iii. Research institutions may have to resolve their infrastructure problem by allocation of resources in line with a policy of incentives which create an atmosphere supportive of high levels of performance.

iv. Research institutions must be accountable and responsible for the decisions they make in accepting and fostering research.

v. While research agencies such as CSIRO, DSTO, etc., have apparently developed management structures which are well suited to accountability, the same might not be true for Universities.

On the basis of this sort of analysis, the Department of Finance is apparently advocating that the current infrastructure problems in Universities should be solved by introduction of a new ‘clawback’ from Universities and redirection of the funds to project specific infrastructure through the Commonwealth (and other) granting bodies.

This analysis fills me with dismay. It displays all the worst caricatured aspects of the ‘bean-counter’. Rather than recognise that in Australia the research community is struggling valiantly against the impossible to maintain the range of quality research for which it is noted, we are told that we should cut that activity to fit a well managed way into the scheme of an accountant. Universities particularly are irresponsible because they encourage (or perhaps force) their researchers to rely on their ingenuity, their skill and their dedication to keep Australia in a reasonably informed position in most areas of research. The cost of doing additional research is by their definition short-sighted, imprudent and actionable.

The fact that the Universities have responded to Government policy, and Government entreaties to maximise their research effort and to increase their training of postgraduate and postdoctoral researchers means nothing. The problem for Universities in particular and science agencies (I have taken an instant dislike to this term!) in general, is that their management has been short sighted in believing that the Government would match the implementation of its policy with the funds to support it.

The intent of the criticism of management is obvious. If the Higher Education Sector is so poorly managed that it imprudently does additional research on its current funds, it obviously has too much funding, so Finance would instigate another clawback. By whatever means possible, the bean-counter will force the Universities to indulge themselves in exactly the amount of research Finance thinks Universities should do i.e. zero.

Hopefully Minister Free and the co-ordinating committee will not bend to the short-sighted, uninformed, unaccountable views of Finance and the White Paper will still provide the support for science and technology which this country so badly needs, even in the context of a $9bn deficit. Sometimes I think that the accountants’ view of Higher Education is that it is a cheap way of keeping approximately 400,000 people, most of them young, off the unemployed list. I sincerely hope I am wrong in this assessment, otherwise there may be no-one in this country in the future with the skills to find the lightswitch, let alone switch off the power.

R. J. MacDonald

---

**New Honorary Editor**

We are pleased to announce that there will be a change in the Honorary Editor of The Australian & New Zealand Physicist from the November, 1992 issue. Jak Kelly has been induced to come out of retirement (!) to take on the task of informing our readers of what is new and good. Perhaps this is the onset of Physics Grey Power? The Editorial Board of The Physicist will shift to Sydney over a period of time following Jak’s taking over the editorship.

Those who know Jak (probably most of us) will be looking forward to an entertaining series of columns and a stewardship of the journal based on insight and a sharp intellect. The future of the journal is assured and I can ask for no more than that.

---

A. W. Thomas

*Australian & New Zealand Physicist* Volume 29, Number 6, June 1992
OF INTEREST

A.J.P. NEW APPOINTMENT

The Australian Journal of Physics recently appointed Associate Professor David Neilson to its Editorial Board. David succeeds Juan Olmaz who had served as the condensed matter representative on the Board since 1985. David was born in 1946 in Sydney where he spent his early years. He attended boarding school in Geelong and was resident at Trinity College at the University of Melbourne where he completed a first class honours degree in Physics in 1968. He then travelled to the United States on a Fulbright Scholarship to work with Ben Lee at the Masters degree in high energy physics at the Institute for Theoretical Physics at the State University of New York at Stony Brook. He chose theoretical condensed matter physics as the research area for his doctorate which he carried out under the supervision of Gerald Brown at Stony Brook and at the NORDITA Niels Bohr Institute in Copenhagen. The thesis topic involved strongly correlated electron liquids, systems for which he has retained a lasting fascination.

Moving to Northwestern University in Chicago he worked on quantum liquids and solids with Chia-wei Woo who later founded the Science and Technology University in Hong Kong - before accepting a position as Assistant Professor at U.S.C. in Los Angeles where he first became acquainted with the potential of compound semiconductors like gallium arsencide to act as passive containers for strongly correlated electrons. He returned to Australia in late 1977 to the University of New South Wales.

David has continued to maintain close links with overseas physicists in North America and Europe. Research centres at which he has worked include Argonne, Brookhaven, Copenhagen, Paris and Stuttgart. From his experience as a research director at the International Centre for Theoretical Physics in Trieste he has become interested in promoting communication with the physics community in S.E. Asia through physics workshops aimed at the advanced postgraduate or postdoctoral level. A workshop held last year in Sydney was one example.

The ideals of a technically literate community capable of making informed decisions are reflected in David's General Studies lectures at the University of New South Wales on Nuclear War and Energy and also in his work for the Environmental Committee of the NSW Law Society. He believes that additional communication links must be established between the scientific, government and industrial communities and to this end he is coordinator of the Threlfall discussion group.

David is the author of about seventy research articles and review chapters, and has edited the book "Strongly Correlated Electron Systems". He believes that condensed matter physics is at a major new threshold thanks to technological advances which are making possible the fabrication of systems with design features so small they are comparable in size to the quantum wavelength of their electrons. Other research interests include the properties of adsorbates on semiconductor surfaces, the behaviour of positrons and electrons at solid surfaces, the coupling of phonons with electrons in the presence of a magnetic field and some unusual analogues of the Aharonov-Bohm interference effect for the case of rotating systems.

He and his collaborators are responsible for the development of a microscopic field theory for strongly interacting electron liquids such as those found at the interfaces of gallium arsenide semiconductor heterostructures. Currently they are investigating novel inhomogeneous ground states for conducting electrons which are in close parallel layers, including charge density waves and a possible pure electron solid.

Peter Robertson

The First Australian - Asian Conference on Radiation Science and Nuclear Medicine

Since 1962, The Australian Institute of Nuclear Science and Engineering (AINSE) has sponsored conferences in Radiation Chemistry and Radiation Biology. Originally, both chemical and biological aspects were combined in a single biennial conference but eventually, as numbers increased and cross interest diverged, two conferences alternating on successive years were organised. From time to time, it has been proposed that the two groups should recombine, particularly in view of the increasing amount of radiation research in Australia which involves both chemistry and biology. The final stimulus to proceed with this idea came from suggestions at the International Congress for Radiation Research in Toronto last year that Australia should bid to hold the 1999 Congress.

In a sense, the proposed conference (15-19 February 1993 at Macquarie University, Sydney) could be viewed as a dry run for the 1999 congress, but more importantly it provides the basis for a forum for radiation research in Australasia. In particular, the proposal recognises that radiation research extends beyond radiation chemistry and radiation biology which have been catered for regularly in past AINSE conferences.

This will be the first time a combined radiation sciences and nuclear medicine conference is held in Australia. As you are no doubt aware, AINSE is the national organisation representing the membership of all Australian researchers in radiation biology, chemistry, medicine and physics to the International Association for Radiation Research (IARR).

There have been several expressions of interest from prominent overseas scientists who wish to attend and present lectures to the conference. These include Dr E M Fielden of the Medical Research Council Radiobiology Unit, Oxford U.K.; Dr A D Trifunac, Group Leader of Radiation Chemistry at Argonne National Laboratory, Chicago USA; Professor J Mittal, Director of the Radiation Science section of the Indian Atomic Energy Research Centre in Bombay; Professor Y Hatanou of the Tokyo Institute of Technology and Executive Councillor on the IARR.

It would be appreciated if you could bring this conference to the attention of any of your colleagues who have an interest in one or more of the research areas. Please fax expressions of interest to reach AINSE as soon as possible so that lecture facilities and accommodation bookings can be confirmed.

Professor Ron Cooper
Convenor, AINSE/IARR Sub-committee
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Reply to ‘CO₂ - A Burning Future?’

Dear Editor,

I am writing to comment on the thought-provoking letter by Vivian Robinson in the April 1992 issue of ANZP. The long letter presents a superficially convincing argument that increasing atmospheric concentrations of CO₂ do not produce an enhanced greenhouse effect. It is unfortunate that superfi cial arguments are continually presented in the media and unrefereed literature to justify extreme versions of the effect of CO₂ on our climate. The distressing point to climate scientists is that these arguments usually do not highlight the real scientific issues. The present situation is analogous to the peripheral debates over the last twenty five years that have masked scientific investigation on the links between smoking and human health.

The following comments relate to each point made by Robinson. There is little doubt about the reality of the greenhouse effect, essentially as described by Robinson. The presence of trace gases (particularly water vapour and CO₂) causes the surface temperature of the earth to be about 30 K above its effective blackbody temperature. On Venus the greenhouse effect from CO₂ is over 500 K. Having accepted the reality of the greenhouse effect itself, we must conclude that Robinson is asserting that the earth’s climate system is fixed so that any enhanced greenhouse effect due to increases in the concentrations of these trace gases is offset by some internal process, clouds in this case.

It is then stated that “measurements of the Antarctic ice cap” are another origin of concern about the CO₂ led greenhouse effect. In fact observations of the water balance in Antarctica are very difficult, and the polar ice caps are believed to be relatively stable on the time scale of decades. Melting of the polar ice sheets is not considered to make a significant contribution to sea-level rise over the next few decades. On the other hand, the longer-term global climate shows a clear relationship between sea-level and temperature. Similarly there is a correlation between temperature and CO₂ concentration, but the cause of that correlation is not so clear.

Robinson then presents a qualitative argument on the role of clouds in the atmosphere. A large international research effort is being conducted to quantify the effects of clouds. Under the World Climate Research Programme, there are observational, analysis and modelling studies to measure, understand and predict the behavior of clouds in the overall climate system. We are not yet at the stage where one particular simple argument on the role of clouds can be confidently chosen as uniformly valid.

Clouds can lead to either positive or negative feedback to a temperature disturbance. Optically thick low clouds, as described by Robinson, tend to cool the surface because they reflect solar radiation and radiate to space at temperatures near the surface temperature. However, optically thin high clouds (circular) tend to warm the surface because they do not reflect much incoming solar radiation yet they radiate strongly to space at very low temperatures. Indeed much of the enhanced greenhouse effect is calculated to be due to the deepening of the troposphere through convection and the generation of more high cloud.

Robinson correctly points out that the atmospheric concentration of CO₂ is much less than that of water vapour. On the other hand, the concentration of CFCs is miniscule compared to that of either of these gases, yet CFCs have a marked effect on the radiative forcing in the atmosphere. The net radiative forcing of a gas depends not only upon the total amount in the atmosphere but also upon its spatial distribution and its molecular properties. The radiative forcing of the atmospheric gases can be calculated with precision, including the effects of overlapping bands of water vapour and CO₂, for example.

The reality of an enhanced greenhouse effect arises principally from model calculations. Indeed such calculations have been carried out for nearly a hundred years. Quantitative models, varying in sophistication from simple one-dimensional specified-atmosphere columns to three-dimensional ocean-atmosphere representations, invariably predict a rise in global temperature associated with an increase in CO₂ concentration. The current scientific questions are on the geographical distribution and temporal evolution of climate change, rather than on its existence.

Robinson turns to the observational record next. The main lesson from the observational record is that climate is highly variable. (This observation would appear to contradict the hypothesis of Robinson that the global climate has a fixed equilibrium point determined by cloud feedback.) The “noise” from the natural variability of climate (together with our inadequate climate observing systems) makes it difficult to detect any greenhouse-induced climate change “signal” from the existing climate record. It is expected to be at least a decade before any unequivocal signal could be detected.

Robinson suggests that any increase in global temperature observed over the last century is due to the “urban heat-island” effect. There is an intense international research effort on the careful examination of the past climate record, and the scientists involved are well aware of the possible causes of both positive (e.g. urban heat-island) and negative (e.g. shading of instruments from growing trees) biases in the temperature record. Their best estimates indicate a global warming of about 0.5 K over the last hundred years, but the cause of the change cannot be determined unambiguously. Warming is found in both land and sea-surface measurements, and the latter are clearly not contaminated by heat-island effects. The uncertainty about the cause of the observed change does not mean that the present record is not consistent with a greenhouse-induced global climate change. There are ancillary observations (such as the recession of continental glaciers) and other factors (such as the possible offsetting effects of cooling by man-made aerosols) which provide support for the reality of the enhanced greenhouse effect.

Robinson final comments on the benefits of increased CO₂ concentrations to the biosphere. As with the effects on the physical climate system, the net impact of enhanced CO₂ on the biosphere cannot be quantified to the extent that we can accurately condense the argument to a simple qualitative statement. The effectiveness of CO₂ fertilization, for example, is known to be sensitive to the type of plant, to temperature and to the availability of water. Primary impacts on flora and fauna are expected from climate change itself. Indeed in a country like Australia, where the natural interannual variability of climate is high, it is important that we learn to understand and manage the impact of natural climate fluctuations in order to prepare for the gradual impacts of greenhouse-induced climate change.

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Visit To SOLA Optical

The second monthly meeting for the SA branch was to SOLA Optical, which had recently started a $12M expansion of production facilities to cope with increased demand for its products.

SA branch President, Graham Sorell, opened the meeting with the announcement that the SA branch initiative of a Gold Bragg medal for the top Ph.D. Australia-wide, would be supported by the AIP national body. This award is in addition to the existing State Silver and Bronze Bragg medals for top students at tertiary and secondary levels respectively.

The SOLA Optical Australia (SOA) Training Manager, Trevor Wall, explained to the over thirty visitors attending that 700 of the 830 working on site belonged to the Australian SOLA lens making operation. SOA produces 70,000 spectacle, safety, and sun lenses per day covering 80 individual product types and 11,000 physically different lens types. The lenses are being exported to 100 different countries. Eighty of the remaining staff were involved in Research and Development for the International group of fourteen lens and mould making subsidiaries spread around the world. The rest are in the Asian Regional Office, and Australian mould making operation (producing specialist, high technology, moulds for casting sites).

A video was shown giving a company profile and explaining lens making methods for the various types of lenses manufactured. Examples of lenses, moulds, and gaskets were passed around.

A brief overview of the SOLA International Holdings Research Centre was given by Dr. Clive Burton, the head of the Physics and Quality group. The Centre is led by Research Director, Dr. Peter Coldrey. Heads of the other two main R & D groups are Dr. Huan Toh for Polymer Chemistry, and Dr. Bob Stothman for Process Technology. There are approximately thirty professionally qualified scientists and engineers in the Centre.

Dr. Burton talked about the Physics and Quality activities in innovative design of progressive multifocal and aspheric lenses, instrumentation, power control of as-cast lenses, new mould technologies, quality standards and product evaluation. Within the Physics group there is heavy usage of computers, particularly for computer aided lens design with large custom written software packages. He also discussed the project and budget management required in handling such a large and diverse range of projects for the various SOLA sites.

Simon Edwards of the Physics group explained some of his work, initially in lens assessment and measurement technology, and more recently in the equally important lens design and manufacturing technology areas. He indicated how his work touched on chemistry, engineering, computing science, and maths & statistics in dealing with the wide range of projects he was involved with. On the more pure physics side he had been busy in optical design, optical system optimisation, interferometry, Moire topography, coating thickness assessment, and spectral radiometry.

He is now more involved in lens design to make thinner and lighter lenses, taking account of lens shape to minimise astigmatism and blur, lens material chemistry, and production aspects.

John Pockett described his work in the Process Technology and Physics sections. He had developed mathematical models for lens power to determine mould curves for accurately casting various lens powers with different refractive indices, polymer shrinkages, and lens and mould geometries. Spreadsheet and statistical software packages were used for multiple linear regression, data analysis and graphing. He is currently involved with production factors affecting lens power.

His work on lens internal quality had involved setting up a clean room, airborne particle monitoring, monomer filtration, and inspection lamp design. This was aimed at determining world's best-practice technology for defect free lenses. Surface analysis of lenses and moulds has been carried out with techniques such as EDS, XPS etc...

As with Simon, his work incorporated mathematics and statistics, computing, chemistry, engineering, and project planning as well as a good understanding of the physics of his projects.

A tour was made of the R & D Centre, including a look at the application of lasers to position sensing, and displays from the computer assisted lens design group.

The visit finished with a tour of lens manufacturing departments in SOLA Optical Australia.
Public Lecture - Prof. Michael Berry FRS

The AIP was fortunate indeed that DEET funded a visit to Australia by Professor Michael Berry of the HH Wills Physics Laboratory University of Bristol, UK, who after attending the National Congress in Melbourne as an invited speaker, spent about 10 days in Perth at UWA.

During his visit Professor Berry presented several seminars and a public lecture on the evening of Thursday 18th February titled 'Beyond Rainbows: Nature's Optical Catastrophes'. Despite a number of competing attractions, a large audience of members, students and the public came to the Ross Theatre to hear a lucid exposition of the manifestation of the mathematical theory of catastrophe in wave optical phenomena. The lecture was plentifully illustrated, not only with slides but with breathtakingly beautiful laser demonstrations.

The link between optics and catastrophe theory was illustrated first with a discussion of the sparkling sea leading to a statement of the concept of codimension in one, two or three dimensions and the formation of simple folds, swallowtails, elliptic and hyperbolic umbilics. The mathematical theory of catastrophe was used then to explain the patterns of light at the bottom of a swimming pool and the dark bands at the inner edge of a rainbow. On a grander scale, the theory was used to predict that during the 1976 occultation of β-Geminorum by Mars a brief double flash should be visible at earth. This was in fact observed in measured light curves of the 1976 occultation and their resolution was high enough to determine the departure of Mars from sphericity.

We thank Michael Berry not only for the wonderful lecture but for all his contributions during his visit.

R Severin Crisp
(With acknowledgement to Cyril Edwards)

NSW

Who ever picked such a dilatory Branch correspondent as me? Funny how I have often complained to my colleagues about lack of Branch News, too! Now after 6 months on the 'job' or rather not on the job, I am putting pen to paper or one finger to the keyboard and promising myself to be a more regular correspondent in the future.

What has been happening in the premier state? Going back to last September, there was a brilliant (at least to me) talk by Karl Kruszelnicki (Radio and TV reporter from JJJ, Quantum and Midday Show) on Popularisation of Science. He rambled lateral thinking over some of my favourite scenes such as the Gibson Desert (and how to keep his two-year old daughter hydrated, stromatolites, Arkaroola, Buzz Aldrin and faces in zero-gravity), earthquakes on Mars (or was it Venus, ask Andrew Prentice), Murphy's Law, the worst height scenario for cash who fall out of New York windows (much more damage from 7 floors up according to statistics) and a final solution Barry Jones for Prime Minister and Karl K for Deputy PM. I stayed awake and enjoyed that evening.

Next month was more serious but also good stuff with Professor Mary Skylas-Cazacou from the Electrochemistry Research Group at University of NSW describing their fine work on the Vanadium Batteries and Efficient Energy Storage, the story of developing a high efficiency and low cost battery with a recyclable electrolyte and usual difficulty of finding a commercial producer in the banana republic.

In November, our multi-medalist Dr Hariharan (Frau Hofer, Henderson, Thomas Young, Boas and Gabor Medals in past two or three years) of CSIRO Division of Applied Physics spoke on Laser Interferometry: Current Trends, Future Prospects in his usual delightful low-key but very lucid style. He surveyed applications of laser interferometry to measuring lengths, surfaces, particle velocities, rotations, pressures, magnetic fields etc.

Unfortunately I missed the NSW Branch Christmas Party at Macquarie University Staff Club overlooking the Fox Valley as I was enjoying the hospitality at the Australia Telescope near Narrabri. I also missed the first monthly talk of 1992 by Professor Bruce Miller of Texas Christian University (Fort Worth) on Positron Annihilation as a Probe of Localised States in Fluids.

April 14 was an important occasion at University of NSW with a talk by the Minister for Science Ross Free on Science Policy and the White Paper, preceded by his Opening of the National Pulsed Magnet Laboratory (NPML). This latter facility established at the University in the Physics School by Professor R. G. (Bob) Clark and his colleagues includes dilution refrigerators for reaching millikelvin temperatures with availability of high magnetic fields (over 70 T) and high pressure via a diamond anvil cell. The prime aim is to study electron-gas energy states in semiconductors, an area in which Bob achieved prominence in his years at the Clarendon Laboratory, Oxford. The dilution refrigerators include one which was assembled and operated at CSIRO Division of Applied Physics for some years. Sadly the pressure on staff at CSIRO to concentrate on short-term 'project physics' had left the refrigerator underused hence the transfer to the University. However we look forward to this new facility as a National centre of a type long needed to encourage Condensed Matter Physics in Australia. The only way to retain or attract the best young people is to provide state-of-the-art facilities such as ultra-low temperatures with high fields as well as neutron beams, lasers and synchrotron radiation sources.  

First Announcement

8th Conference of the
AUSTRALIAN OPTICAL SOCIETY

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1 - 5 February 1993

For copies of a detailed First Announcement and provisional registration forms, contact the Chair of the Organising Committee:

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The Minister gave a short clear summary of his government's initiatives in the science area in the past few years and commented briefly on the Opposition policy or lack thereof as he saw it, including uncertain financial aspects of the GST package for research funding. Most time was devoted to questions which ranged over topics such as 30% cost recovery in CSIRO, encouraging students to take up physics (or science), community attitudes to science as a career, public expenditure on R&D as percentage of GNP (is it reasonable to compare Australia with USA or Sweden noting the great differences in geography or population density) the lack of scientific background among directors of major companies (say 28 out of 450 with a science or engineering degree), financial support for start-up companies (they need equity rather than debt), how successful has GIRD been?, university funding (heavy teaching load and resulting lack of research time, consolidation of capital and recurrent funds). I think that the comparatively large audience appreciated the Minister's responses which did not sound too party-political. Needless to say, he did not make commitments of government to the much-needed major facilities in physics, despite his apparent appreciation of Bob Clark's national facility and it's prime use in exciting ('blue sky') research. He did leave a small ray of hope for some icing on the cake(!) in the next White Paper.

Guy White

**T A S**

**Invited Lecture by Dr Don McEwen**

Dr Don McEwen of the Institute of Space and Atmospheric Studies, at the University of Saskatchewan, Saskatoon gave an invited talk entitled 'Solar Eruption Buffets the Earth' to the Tasmanian Branch on the 3rd of February. In his presentation, Dr McEwen indicated that to many people living at low latitudes, the major solar disturbances of 1989 and 1990 provided unique opportunities for viewing dramatic auroral displays. He provided examples of newspaper reports from Japan, and as close to the equator as Texas, indicating the impact of these displays on the public. The red glows occasionally associated with such intense solar activity may be misinterpreted as the glow of distant fires.

Aside from the popular appeal that the auroral displays associated with these events have, Dr McEwen discussed other more serious effects such as the increased solar disturbances may have on man and his systems. He discussed the 9 hour duration blackout in Quebec, Canada that resulted from the catastrophic failure of power system transformers due to currents induced by the intense March 13-14 magnetic storm. The total cost to the province of Quebec for repair of the power system, and in lost revenue from power exports, of this solar induced breakdown was $26 million. Further points raised included the significant disturbance of the orbits of low altitude satellites and space debris due to the increased drag associated with a heated and expanded upper atmosphere of the Earth, and the degradation of satellite systems by the increased levels of energetic particle impact.

Dr McEwen also talked about the scientific research resulting from observations by his research group of the intense 'red' aurora associated with the March 1989 event, and of new Canadian initiatives in polar aurora and airglow studies associated with the establishment of an observatory at Eureka in northern Canada, near the location of the magnetic pole.

Dr McEwen visited Australia on sabatical from his Canadian research group. He has a long history of involvement in aurora studies and has developed optical instrumentation and particle detectors for rocket and satellite observations. He spent time in Australia working with the Adelaide University group under Dr Vincent and on collaborative research work at the Antarctic Division, Hobart. He took the opportunity to attend the 21st Australian Institute of Physics congress as an invited speaker to the South Pacific Solar Terrestrial Energy Program (STEP) workshop and to visit other Australian research groups with common interests. His talk to the Tasmanian branch was well appreciated by all who attended.

**Public Lecture by Dr. Ian Allison**

Dr Ian Allison presented a public lecture, organised by the Tasmanian Branch of the AIP, entitled 'Antarctic sea-ice: a misunderstood element in global climate' on the 23rd April. Dr Allison is a Principal Research Scientist in the glaciology program of the Australian Antarctic Division, with research interests in both the Antarctic Ice Sheet and surrounding sea-ice. He has been involved in the investigation of air-sea-ice interaction for more than 20 years and is the sea-ice sub-program manager in the new Cooperative Research Centre for the Antarctic and Southern Ocean Environment.

Dr Allison began by demonstrating the importance of Antarctic sea-ice to the 'global climate change' debate by presenting the predictions of three models for the global temperature changes resulting from a doubling of atmospheric CO₂ concentrations. In all cases large temperature variations were predicted for the Antarctic sea-ice region, but the magnitudes of the variations predicted varied widely. Air-sea interaction in polar regions is influenced by the extent, concentration and thickness of the sea-ice cover due to the high albedo of the ice and because it forms a physical barrier between the water and the air. The Antarctic sea-ice region is also important to global climate because it is a region where the cold, saline surface waters sink to form bottom waters. This is an integral part of global ocean circulation.

Dr Allison indicated that consideration of the complexity of the development, dynamics and variability of the Antarctic sea-ice zone is not incorporated in most climate models. More understanding of the processes involved has come with satellite observations of the extent and concentration of Antarctic sea-ice, drifting-buoy observations of sea-ice dynamics, observations of sea-ice development, and measurements of energy and mass transfer for an air-ice-water system.

Interesting points relating to these processes that were explained by Dr Allison included:

- Antarctic sea-ice grows in thickness rapidly, principally by aggregation and rafting, up to the order of 30 to 50 cm, and thereafter develops much more slowly.
- The movement of the sea-ice by wind and ocean currents plays a significant role in extending the coverage of Antarctic sea-ice. Sea-ice generally drifts away from the coast, and eventually into the eastward flow of the Antarctic Circumpolar Current.
- The average albedo of newly formed sea-ice is significantly less than for snow covered, older sea-ice. Because of the dynamics of the sea-ice zone, patches of open water and thin sea-ice exist even in mid-winter, resulting in a significantly decreased average albedo.

The talk was well attended and very much appreciated.

Marc Duldig
PHYSICS EMPLOYMENT IN 1991
Down - but better than most

JOHN PRESCOTT

At a time when many lines of hard evidence show that Australia is in the grip of a pretty grim recession, and
hearsay tells us that many university graduates are not
finding jobs, it is timely to look at the job prospects for
physicists. The present paper does just that. It is the
fourteenth in the series of surveys carried out by the author
for the Australian Institute of Physics. The news is rather
like Mr Punch's curate's egg: good in parts.

The good news is that, while moderate, the demand has been
steady for most of the year and may be picking up. The bad
news is that jobs were down again in 1991; in a perverse
sort of way, physicists can celebrate the fact that we are
much better off than many and that the profession does not
share the extreme fluctuations shown by some other
professions, for example, by architecture.

The good news is that the number of limited term
appointments in universities is at the highest annual number
on record; the bad news is that tenurable appointments in the
universities are down for the third successive year.

The good news is that physicists for the mining industry
(including geophysicists) are in good demand; the bad news
is that other industries are recruiting at about one third of
the peak 1988 rate.

In short, most employers are not offering permanent
employment but there is a surprising number of limited
tenure positions available. The data on which these
conclusions are based are discussed below.

The surveys are based on positions advertised in The
Weekend Australian and in the Higher Education
Supplement of the Australian on Wednesdays. The general
principles of the surveys were set out in considerable detail
in the first report in the series (Prescott 1988) and the data
for the first decade were summarised in 1988 (Prescott
1988). These references can be consulted for the historical
data, for detailed discussion of some of the ground work
which led to the ideas behind the surveys and for an
indication of changes both in the surveys themselves and the
employment patterns that they reveal.

In general the positions are those for which a degree in
physics or applied physics or a diploma in applied physics is
a suitable training, even though this may not be explicitly
stated in the advertisement. In many cases further training
would be expected, e.g.

Most of the advertisements in The Australian call for an
honours degree or post-graduate qualifications. Positions for
which an ordinary degree or diploma in physics would be a
suitable qualification are mostly to be found in the local
press. For example, twenty or so positions were advertised
only in the Adelaide Advertiser in 1991 (the same as in
1990). In the past these "local" advertisements in the main
metropolitan daily have accounted for as many positions
again. However, in the 1983 recession the number of such
places fell disproportionately and, if the evidence of the
Advertiser is anything to go by, the same is true for the
present one.

A number of firms recruit new graduates at interview
sessions on campus and do not advertise, and it is known that
Western Australia is marginally under-represented. The
present survey, therefore, really represents a lower limit to
the opportunities for employment for physics graduates,
although it probably accounts for most of the positions
which would be regarded as for "professional" physicists, in
the sense that the A. I. P. would recognise.

No positions are included that call for membership of the
Institution of Engineers, Australia, even when it is clear that
a physicist would make a suitable appointee. It is not
uncommon for an advertisement to state alternative
qualifications. For example, there were upwards of thirty
positions in 1991 in which the position was described as,"physicist/engineer", or vice versa. Very often qualifications in,"physics, per se are listed in the body of the
advertisement but not in the heading.

The DEET Skilled Vacancy Survey and ANZ Bank
Employment Advertisement Series are widely regarded as
authoritative indicators of the state of the employment
market. Both report total advertisements; in addition the
former subdivides them into categories of skilled workers.
During calendar year 1990 and into the first quarter of 1991
they showed a continuous decrease in employment
opportunities in most categories. In the case of trades the
decrease was severe e.g.

The statistics for 1991 are shown in the table, where they
can be compared with those for the previous four years. The
data for 1983 (the previous recession) are also included. The
total number clearly shows the effects of the current
recession and the lead-up to it. While the economic picture

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revealed by these data is bad, they nevertheless offer some unexpected encouragement to those who hope to follow a career in physics: The figures, backed by long-term data (see e.g. Prescott 1991), show that the demand for physicists has remained remarkably steady whether the economy is growing or falling.

One of the interesting features of the job market for physicists has been the stability over time of its structure as expressed, for instance, by the relative proportions of each class of appointment. This is still true at present and most categories are down in much the same proportions. The outstanding exception is in limited term research positions in universities, which have gone against the trend and stand at the highest level ever, both in proportion and in absolute number. This is discussed further below.

As with most other groups, the demand for physicists in CSIRO is down after a bumper year in 1990. As in 1990, positions were generally permanent though a number of limited appointments were offered towards the end of the year. The fields of appointment covered the whole gamut of CSIRO activities, continuing a strong emphasis on very practical projects.

Advertising for Defence (mostly for the various Laboratories of DSTO) was down proportionately. Many of the advertisements were for senior positions. Sixteen(1) positions for Chief of Division were advertised. Enquiries revealed that it was open for the previous incumbents to apply for these positions and that most of them were reappointed. Accordingly, only one of these positions is included in the formal count.

Other Commonwealth Government recruiting usually covers a great diversity of fields, but in 1991 this section was dominated by ANSTO and the Antarctic Division.

State Government organisations do not advertise much in the national press and this year they were down to only 1.7% of a reduced base: only six posts were advertised in 1991; plus one for an Environmental Scientist in the Shire of Sutherland - a rare bird indeed in this company. It may not be entirely a coincidence that Sutherland is just down the road from Lucas Heights.

Most Hospital and Medical posts are in state hospitals but this year there were three jobs in private practice. The demand has stayed firm despite the recession and several of the positions were readvertised.

In Higher Education, the distinction between Universities and Colleges of Advanced Education has disappeared. The table distinguishes between academic appointments that involve some element of teaching and those that are mostly for research. The former is further subdivided into permanent and limited term appointments.

The “teaching” category should give us all cause for great concern. For the third year in a row, the number of tenurable positions has fallen - and this at a time when entry into Higher Education has never been higher. It was only 22 in 1991 and this included three Professors, two Directors and a Head; there were 45 limited term appointments. There were only eight appointments for theoreticians among the 67. This set of figures must surely represent not even replacement numbers, let alone the new staff that ought to be employed to take account of the additional student places provided by the Dawkins universities. Teachers in institutions of higher education will need no reminding that their teaching loads have gone up.

On the other side of the ledger, research-type appointments in the universities are buoyant, and I use that word advisedly. For the first time the total number comfortably exceeds one hundred. This reflects a considerable number of ARC-supported posts - a big plus for the ARC. Almost all call for a PhD; about 25 were specifically for theoreticians. NOT included in the count are ARC Post Doctoral Fellows (50 in all disciplines), ARC Research Fellows (25 in all disciplines), Queen Elizabeth II Fellows (15 in all disciplines) and ARC Senior Research Fellows (15 in all disciplines). These are responsible for the “*” next to entries in the table and readers can fill in their own best guess. On past experience, somewhere between ten and twenty will be in offered the field of physics.

It is also interesting to see a significant number of postgraduate awards for specific purposes, often with a premium stipend. These, of course, do not count as “jobs” for the present survey although the pay is sometimes comparable.

The category, Technical and other, contains a wide variety of positions, mostly at the first degree level and all “professional officers”, including those appointed to assist with specific research projects. This category is holding its own although still down from the 1989 peak level.

The entry for physics Teaching suggests that the demand has leveled off, albeit at a level about half of the long term average. This covers only the independent schools. State Education Departments have usually advertised for specialists in short supply (which includes physics) but only the Northern Territory Teaching Service did so in 1991. The effect of the recession has made it impossible to judge whether the fall in demand is also partly due to the fact that some of the smaller schools are no longer offering physics at year 12 level and/or that larger schools are teaching fewer classes.

Private Industry/Commerce is down 40% and this is perhaps the real earnest of the state of the economy. It is hard to believe that only Telecom and CRA advertised more than two positions below managerial level and that BHP advertised not at all.

Geophysics is included in the present survey, notwithstanding that it is usually classed with the Earth Sciences in Australia. These positions are not included in the formal count, even though “physics” is often listed as a sufficient qualification (nine posts in 1991). Geophysics has defied the recession and a senior geophysicist from whom I inquired tells me that there is a shortage of qualified personnel. These posts are traditionally filled without advertisement and the fact that such advertisements are appearing is identified as an indicator of the shortage.

Overseas positions are, of course, only those advertised in Australia. They are mostly in New Zealand and our other immediate Pacific neighbours. Since the journal that carries this article is published jointly with the New Zealand Institute of Physics, it may be noted that six out of twenty four overseas positions were in New Zealand. The latter is down from 1990.

Across the board, for some 45% of the positions, a PhD was a stated or preferred requirement - some 210 positions. As
PHYSICS EMPLOYMENT IN 1991

has been the case for the past few years the annual output of Australian Physics PhD’s is about sixty (Jennings and De Laeter 1991). As noted in previous surveys, this represents a rough balance between supply and demand. However in 1991 the demand was heavily weighted towards limited term positions in Universities. For this we clearly have to thank the ARC. At least these have the effect of keeping physicists productive in physics against the time when they will be needed to teach and to contribute to Government and industry.

A list of all positions surveyed, classified by employment sector, and giving the employer, the job classification, a brief job description, whether a PhD is specified, whether the position is indefinite or limited term, and the month of the advertisement will be sent to all Australian Physics departments, to careers officers in tertiary institutions and to government employment agencies. Copies are available from the author.

References

Department of Employment, Education and Training, Skilled Vacancy Survey (1991) Vol.5 No.12

ADVERTISED POSITIONS IN The Australian

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

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A brief survey is given of the nature of nonlinearity and the transition to chaotic behaviour in vibrating systems of interest in acoustics. Chaotic behaviour is illustrated by considering the response of a circular plate or thin axisymmetric shell excited sinusoidally at its centre. Chaos sets in at an unexpectedly small amplitude and leads to large excitation of non-driven modes. Some practical implications are considered.

Introduction

If there is one development in basic understanding that, over the past ten years, has had greater impact than any other on the way we look at physical phenomena, then it is the theory of nonlinear and chaotic phenomena. Along with its associates, catastrophe theory and fractal geometry, it is one of the most exciting areas of research today in a whole range of classical areas of study such as mathematics, mechanics, acoustics and fluid dynamics, and it is beginning to penetrate into the world of quantum phenomena. There was a special section on acoustic chaos at the 13th ICA in 1989, a major conference on more general aspects of chaos was held in Sydney early last year, and we even read about the subject in the weekend newspapers!

It is not possible, in an article as short as this, to give any extensive discussion of either chaos theory or its implications. What we have tried to do, therefore, is to give an outline of the basic background, and to illustrate it with some examples from our own experience of the chaotic behaviour of a vibrating panel. Not only is this potentially simple enough to understand in detail - though we are as yet a good way from such understanding - but it has important applications in the real world of acoustics and vibrations. For those who wish to delve deeper, we recommend the popular non-technical book by Gleick [1] and the extensive set of more technical papers edited by Cvitanovic [2]. There have also been numerous articles on chaos and fractal geometry in the pages of Scientific American.

Nonlinearity

A physical system is linear if its response amplitude is proportional to the stimulus amplitude, all other things being kept constant. A simple linear spring (extension proportional to applied force) is a familiar example, but linearity is assumed in mechanics (force = acceleration) and in electric phenomena (Ohm's law). Predictions of system behaviour based on such linear assumptions generally work well provided we do not depart too far from equilibrium, but for extreme cases a linear theory is inadequate - springs unwind, beams buckle, resistors get hot.

In acoustics and ordinary vibration applications we are generally in a domain where linear theory is adequate, though there are exceptions for such things as the sound production mechanism of musical instruments [3].

Nonlinearity is more noticeable when the pressure amplitude of a sound wave becomes appreciable in comparison with normal atmospheric pressure, say greater than 10 kPa or about 174 dB, as in an explosion or a lightning flash or the passage of an aircraft at supersonic speed. Then the temperature of the air in the pressure crests rises significantly relative to that in the troughs which falls similarly. Because sound travels more quickly at higher temperature, this leads to distortion of the pressure wave to an N-shaped shock wave.
The nonlinearity with which we shall be concerned here however, is of a much less extreme variety, and concerns only the gradual stiffening of various types of springs as their deflection is increased. This is illustrated in Figure 1. This sort of behaviour is found in many ordinary springs, and also in the sideways deflection of plates, in which a tension force builds up to assist the stiffness arising from simple bending. If f is the distorting force and x the spring deflection, then this type of behaviour can be written

\[ f = ax + bx^3 \]  (1)

where a is the normal spring stiffness and bx^3 measures the severity of the nonlinearity. There are, of course, many more complex forms of nonlinearity than that shown in equation (1); the deflection of a slightly dished plate, for example, requires the addition of a term in \( x^2 \).

If we think of the motion of a simple loaded spring with stiffness given by (1), acted on by a sinusoidal force \( f \sin \omega t \), then this motion is described by the equation

\[ m\ddot{x} + r\dot{x} + ax + bx^3 = f \sin \omega t \]  (2)

where \( m \) is the loading mass and \( r \) is the viscous damping. Dots signify differentiation with respect to time, so that \( \dot{x} \) is velocity and \( \ddot{x} \) is acceleration. If we plot the amplitude response of this system as the frequency \( \omega \) is varied, then we get the distorted resonance curve shown in Figure 2, the small-amplitude resonance frequency being \( \omega_0 = (am)^{1/2} \). The amount of distortion is proportional to the nonlinearity \( bx/a \). It is convenient to simplify equation (2) by dividing by \( m \) and changing the unit of time to \( t = \omega_0 t \), so that it can be written

\[ \ddot{x} + k\dot{x} + x + cx^2 + bx^3 = F \sin \Omega t \]  (3)

where \( k = f/m_0 \), \( \beta = bx/a \), \( F = f/\omega_0 \), and \( \Omega = \omega_0 \) is the ratio of the driving frequency to the small amplitude resonance frequency. A quadratic term \( ax^2 \) has been added for generality. The parameter \( k \) is called the damping coefficient and is the reciprocal of the quality factor \( Q \). Equation (3) is closely related to the Duffing equation, which has both the linear and quadratic terms omitted, so that the restoring force is simply \( bx^3 \). The Duffing equation is nonlinear at all amplitudes and has been extensively studied.

We can hear the effects of this nonlinearity quite easily with a rather loose metal string on a musical instrument such as a guitar. If we pluck the string to large amplitude, rather than exciting it with a sinusoidal force, then its oscillation decays along the spine of the curve, shown as a broken line in Figure 2, and the sound dies away with a twang as the pitch falls. Experiments with sinusoidal excitation of such a metal string show that we can have a sudden fall in amplitude from point A to point B if we slowly increase the frequency while keeping the force constant. This is an elementary example of a catastrophe - a large change in some physical result (the amplitude) for a very small change in the excitation (the frequency in this case) near a critical point A. Catastrophe theory deals with more general features of this sort of behaviour.

**Orbits and Attractors**

We are used to looking at oscillatory phenomena in two complementary ways - either we examine the waveform with an oscilloscope, or we look at the frequency spectrum using, for example, an FFT (Fast Fourier Transform) analyser. These two approaches, provided we record the phases of the spectral components, give us exactly the same information, and one representation can be derived from the other mathematically.

For discussions of chaotic behaviour, it turns out that a rather different representation is also useful. The time behaviour of a vibrating system can be described by giving the value of its displacement \( x \) at all times \( t \), but it can also be described if we know the displacement \( x \) and the velocity \( v = \dot{x} \), which is just the slope of the \( x(t) \) waveform, at every point. We can then describe the behaviour by plotting the motion of the point representing the system on a graph in which the axes are \( x \) and \( v \). If the waveform is repetitive, then the curve in \((x,v)\) space, which is called phase space, is a closed orbit which repeats itself in every cycle of the motion. This is illustrated in Figure 3a for a nearly sinusoidal wave, such as would arise from solution of a particular case of equation (3) at rather small amplitude. If the wave were exactly sinusoidal then the curve would be an ellipse. There is actually a value of the time parameter \( t \) or \( s \) associated with every point on the orbit, and we will need to know this later.

A simple repetitive wave represents a steady state but, if we apply a sinusoidal force to a system, it takes an appreciable time to settle down. This approach to a steady state can be represented in phase space, as well as in the \((x,t)\) time domain seen on an oscilloscope. Figure 4a shows what happens for an arbitrary starting condition - the initial orbit can begin anywhere in phase space, but it is "attracted" towards the final stable orbit and eventually coincides with it. The stable orbit is then called an attractor for this particular motion. If the exciting force is zero, then the attractor is simply the point A.
NONLINEARITY AND CHAOS IN ACOUSTICS

Figure 3a Waveform, spectrum and orbit in phase space for a nearly sinusoidal solution of equation (3) corresponding to a slightly dished plate with $k = 0.02$, $\alpha = 0.3$, $\beta = 0.1$, $\Omega = 2$, $F = 12$

Figure 3b Bifurcation and generation of a subharmonic of order 2 for the same system with $F = 20$.

Figure 5a Subharmonic splitting of order 5 for the system of Figure 3(a) with $F = 12$

Figure 5b Chaotic behaviour for the same system with $\Omega = 1$, $F = 23$

$x = 0, v = 0$, as in Figure 4b.
To further simplify the presentation it is useful to employ a device introduced by the French mathematician Poincaré, and hence called a Poincaré section. The easiest way to think of this is to recognise that we are dealing with a system driven by a regular sinusoidal force, according to equation (3). The time scale is thus fixed by this external force, and we can imagine taking a flash photograph of the phase space just once in each cycle, at a fixed phase of the external force, and plotting the position of the point representing the system response. Once we are on the stable orbit, this always shows up as a single point on the section, while the behaviour of the system in approaching the steady state shows up as a sequence of points steadily approaching this limit point.

**Bifurcations and Strange Attractors**

All this is quite straightforward and introduces nothing unexpected. It is possible to calculate the approach of the system to its attractor by simply integrating the equation (3) from its given starting conditions. With a modern desktop microcomputer this takes only a few seconds. However, playing around with such calculations soon turns up some very strange behaviour. Actually it was found first for even simpler equations, but the generalised Duffing equation (3) is most suited to our discussion here. The first thing to be discovered is that, for particular values of the relative frequency $\Omega$ and force amplitude $F$, the orbit doubles, or bifurcates. This shows up as a period doubling on the waveform display, a subharmonic of order 2 on the frequency spectrum, or a double orbit in phase space, as illustrated in Figure 3b. This phenomenon appears on the Poincaré section as two point attractors, which we have not bothered to illustrate.

Even this bifurcation behaviour is easy to accommodate among our usual ideas - it is simply the nonlinear driving of the mode at half the driving frequency, and occurs most easily when the driving frequency is about twice the free mode frequency.

The other components in the spectrum in Figure 3b then simply arise as nonlinear distortion products. Rather surprisingly, however, an increase in the force amplitude or a decrease in the damping sometimes leads to further bifurcations, giving subharmonics of order 4, 8, and so on. Feigenbaum [2] has shown that this behaviour is governed by universal rules. For the particular equation we are studying, however, this does not appear to happen; if the force is increased outside a small range, then the system returns to simple periodic behaviour. However, for other small ranges of frequency and force we find more complex behaviour such as 3rd or 5th order subharmonics. The fifth order case is illustrated in Figure 5a.

Further computer integration of the equations, however, shows up an entirely different and unexpected behaviour. For larger values of the driving force, the orbit simply never
repeats! The orbits scribble over a large region of phase space when they are drawn in full as in Figure 5b, and the spectrum shows a large amount of wideband noise, with superposed peaks at the driving frequency and some of its harmonics or subharmonics. This behaviour is called chaotic - but it is deterministic chaos, in that it results from exact integration of the equation (3), and we get exactly the same result every time.

The beauty and unexpected structure of chaos appears when we examine the behaviour in the Poincaré section plane, plotting one point per orbit at a defined phase of the external force. After the initial transient has died down, the points on the section plane are not simply randomly placed, but all lie upon a complicated swirling figure of the type shown in Figure 6. It is clearly some sort of more complicated attractor for the chaotic motion and, with good reason, it is called a strange attractor. Its form is characteristic of the parameter values in the equation representing the physical system, together with the values of the external force amplitude and frequency. Transition to chaotic behaviour is again a catastrophic change - the system goes from a simple attractor to a chaotic attractor for a very small change in parameter values. In some cases, there is a progression through sudden bifurcations of progressively higher order, as mentioned above.

If we watch the points, one per orbit, building up on the attractor, then we note that their placing is apparently random though it is deterministically random in that the orbits can be calculated exactly. The essence of chaos, however, is that the exact sequence of orbits depends with the utmost sensitivity upon the initial conditions. For an ordinary attractor, two orbits or representative points that start off very close together remain close together, and indeed slowly approach one another. In a chaotic system, however, the points diverge exponentially, at least for a start, so that very soon their subsequent motion is quite uncorrelated. This behaviour in phase space and in its Poincaré section reflects what is occurring in real physical space - detailed behaviour is very sensitively dependent on initial conditions. Examination of the geometry of strange attractors shows that they are much more complex objects even than they appear at first glance. The structure, indeed, remains equally complex if they are examined at higher and higher magnification - they are self-similar or fractal objects. Only a few attractors generated from differential equations have been examined in detail, but there is a wealth of beautiful pictorial information available on fractal objects, such as the Mandelbrot set, generated from simpler nonlinear algebraic equations [1,4,5].

The capacitor can be taken as the physical variable x, and the quantity y = x is then the current through the inductive element. More complex examples with larger numbers of variables abound.

Our experiments have concerned the vibration of a freely suspended metal plate, excited sinusoidally at its centre. The stiffness of the plate provides the linear part of the restoring force in (1), and the tension forces, which vary as the square of the amplitude and have a normal component additionally proportional to amplitude, provide the cubic restoring force term bx³. The plate itself is an extended system and has an infinite number of normal vibration modes, but we can make an approximate separation of the motion so that each mode is described by a nonlinear equation of the form (3), with different value of the mode frequency ωn, and with extra nonlinear terms linking the modes together. The mathematics is thus rather complicated and has not yet been explored in detail.

In the experiments, the plate was cut from steel sheet about 1 mm thick and had a diameter of about 40 cm. It was held vertically by light strings passing through holes near its edge, and was excited with a small B & K shaker attached to its centre. The displacement at any point could be measured with a B & K capacitive transducer - essentially the electrode of a condenser microphone with the plate forming the diaphragm - and the velocity by integrating the signal from a B & K subminiature accelerometer attached to the surface. Actually one could simply integrate this accelerometer signal once more to find the displacement, but a direct method has some advantages.

Exploration of the ordinary linear vibration modes showed that the two of lowest frequency were the (0,0) and (0,1) modes illustrated in Figure 7, the first number in the description giving the number of nodal diameters, and the second the number of nodal circles. The (2,0) mode had a frequency of about 39 Hz and a Q value of 650 (k = 0.001) while the (0,1) mode had frequency 69 Hz and Q = 330 (k = 0.003). The (2,0) mode is actually a degenerate pair with the same frequency, the nodal lines of one being rotated by 45° relative to the other. The linear behaviour of these modes was quite unremarkable. The (0,1) mode was efficiently driven at

Physical Examples

Very many experimental studies of the occurrence of chaotic behaviour have been made for appropriate nonlinear systems. Many of the most convenient use electrical resonant circuits with nonlinear inductive elements, since these are easy to measure and are appropriately one dimensional, in the sense that the charge on

Figure 6 The strange attractor generated by the system of Figure 5b

Figure 7 (0,1) and (2,0) modes of a freely suspended disc
the centre of the plate, but the (2,0) modes were nearly inactive, because their nodal lines cross there.

Interesting behaviour was found when the frequency was set at about 75 Hz, near to that of the (0,1) mode, and the driving force was increased. Quite suddenly, for an (0,1) amplitude of only a few tenths of a millimetre at the disc centre, the (2,0) mode became active at a frequency exactly half the driving frequency and reached an amplitude of about 1 mm at the disc edge. The orbit, as measured some distance from the disc centre, bifurcated, and a subharmonic of order 2 appeared on the FFT analyser. At a rather increased level of drive, giving an (0,1) mode amplitude of about 0.5 mm at the centre, the whole vibration became wildly chaotic in both modes, and the vibration amplitude at the disc edge exceeded 2 mm. Fortunately the low-frequency and the small size of the disc meant that the radiated sound intensity was small! For other combinations of force and frequency near these values, subharmonics of other orders were observed, while if the shaker amplitude was increased much above that necessary for chaotic behaviour, the response again became simple.

One might be tempted to simply take this as a nice illustration of the general behaviour discussed above, except for one feature. This feature is that, while numerical integration of equation (3) leads one to expect a transition to chaos at an amplitude such that the nonlinear terms comfortably exceed the linear term ($\beta x^3 > 1$), the experimentally observed transition occurs for an amplitude nearly 10 times smaller, so that $\beta x^3 \sim 0.001$. The reason for this extreme sensitivity is not clear, but seems likely to be associated with the existence of two or more nonlinear modes, and the particular nature of the nonlinear coupling between them. It does not appear to be accounted for by the smaller damping of the experimental system. We discuss the significance of this behaviour in the final section.

Very similar behaviour was found for the case of an orchestral cymbal, which is essentially a shallow spherically dished shell about 40 cm in diameter, and for a large Turkish gong, again a dished shell 50 cm in diameter and surrounded by a stiff conical flange [6]. The curvature of the shell adds a quadratic term $\omega^2$ to equation (3). The conical flange on the gong reverses the frequency order of the two low-frequency modes of the gong and adds a nodal circle to (2,0), so that these modes are (0,1) at 96 Hz and (2,1) at around 150 Hz. There is also a mode (1,1) at 136 Hz, and many other modes of higher frequency. The cymbal modes were not investigated in detail but, because of the high curvature of the shell, the (0,1) mode frequency was about 600 Hz.

For these both systems the behaviour when excited sinusoidally at the centre at a frequency close to that of the (0,1) mode was very similar to that of the simple plate. Subharmonics of various orders, particularly 2, 3 and 5, were observed, and the onset amplitude for chaotic behaviour was again of order 1 mm. The main difference was that, because of the higher frequencies involved, and the flange effectively baffling the gong, the radiated sound intensity was large, almost painfully so in the case of the cymbal. It was also noticeable that the timbre of the sound in the chaotic regime was very similar to that produced when the gong or cymbal was simply struck a heavy blow, as in normal playing.

**Conclusion**

It would be a mistake to regard nonlinear and chaotic behaviour as simply an interesting curiosity, for it has profound basic significance and important practical consequences. The proliferation of current research literature attests to the former fact, and it is appropriate here to comment only briefly on the latter.

The behaviour of musical instruments such as gongs and cymbals is important to musicians, but is hardly seen as being significant in the larger world. It is often in musical instruments, however, that acoustic phenomena are most clearly exhibited, and for this reason their study can give valuable pointers in more practical fields. In this connection, it is perhaps the observation of chaotic behaviour and nonlinear mode coupling at force amplitudes several orders of magnitude smaller than expected from consideration of a simple Duffing equation that is most significant. Once chaotic behaviour has been initiated, the system then displays large vibration amplitudes in modes that might have been expected to be quiescent.

The most direct application of these ideas is the vibration of panels, not necessarily of circular shape, under the influence of periodic exciting forces, generated for example by reciprocating machinery. If conditions are such that the response becomes chaotic, then panel amplitudes may greatly exceed those normally expected and may be in unexpected modes, leading to unpredictable and perhaps dangerous stresses on the structure. The same thing may apply to the flutter of panels under aerodynamic forces, where the initial vibration is to a large extent self-excited, rather than provided by an external force. Even the case of a plate or shell may be an unduly restricted model, for similar behaviour might well be expected of any extended system with multiple modes and appropriate nonlinearity. Certainly chaotic behaviour is a subject of which we will hear a great deal more in the future.

**References**


**Editorial Acknowledgement**

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First year university physics courses traditionally contain a major laboratory component which simultaneously serves a number of aims. Laboratory sessions provide a means of learning experimental skills, demonstrating physical concepts in practical situations and enhancing the classroom lectures. It is only possible to carry out realistic types of experiments which require complex data recording and analysis if computers are introduced into the laboratory. Computers can be used as data loggers and data processors, the resulting improved analysis techniques enabling underlying concepts to be emphasised.

Computers are ideally suited for classroom experiments in which rapidly changing parameters are being measured. The input signal to the computer needs to be in the form of a voltage and an analogue to digital converter is required to enable the computer to handle the data. A Macintosh computer and in-house built A/D converter with four separate input channels were used in the following experiments but alternatively a compatible A/D converter may be purchased from Apple. The internal clock on the Mac was used to display the data as a function of time. Parameters such as position, current and temperature can all be converted to voltages by simple devices which enable the computer accumulation of data to be achieved for a wide variety of experiments.

**Torsion Pendulum Experiment**

A steel disc is suspended from a heavy gauge steel wire (Figure 1). The wire is suspended from a freely rotating ball bearing which allows the disc to rotate around a vertical axis. The suspension is rotated sinusoidally by an electric motor with a variable speed control. Potentiometers are attached to both the disc and the wire and these move with the rotation of the disc and the suspension. The voltages developed across the potentiometers are directly proportional to the position of the pendulum (disc) and the driver (wire suspension) respectively and may be plotted on the computer screen to produce traces of the form shown in Figure 2.

The movement of a simple harmonic oscillator in the absence of a driver and damping is described by the equation of motion:

\[
d^2A/dt^2 + \omega_0^2 A = 0 \tag{1}
\]

with a solution of the form \( A(t) = a \sin(\omega_0 t + \delta) \), where \( a \) is the maximum amplitude of the oscillation and \( \delta \) is a phase constant. The resonant frequency \( \omega_0 \) is determined by the moment of inertia of the pendulum and the torsion constant of the wire.

For a driven oscillator the right hand side of equation (1) must be replaced by a term describing the periodic motion of the driver

\[
B(t) = b_0 \omega_0^2 \sin \omega_0 t
\]

where \( b_0 \), the maximum amplitude of the driver, is fixed and the driver frequency, \( \omega_0 \), is variable. If friction is present in the system, damping of the oscillations will occur. The friction is generally taken to be proportional to the velocity of the oscillator and so the additional term \( 2\gamma A/dt \) must be introduced where \( \gamma \) is the damping coefficient.

Equation (1) then becomes:

\[
d^2A/dt^2 + 2\gamma A/dt + \omega_0^2 A
\]

\[
= b_0 \omega_0^2 \sin \omega_0 t \tag{2}
\]
COMPUTER EXPERIMENTS

Figure 3 (a) Relative amplitude of torsion pendulum relative to driver near resonance

\[ A(t) = a(\omega_0) \sin(\omega_0 t + \delta(\omega_0)) \]

where \( a(\omega_0) = b_0 (\omega_0^2 - \omega^2)^{1/2} \) and

\[ \tan(\delta(\omega_0) - \pi/2) = (\omega_0^2 - \omega^2) / 2\gamma \omega_0 \]

It may be verified by substitution that the solution of this equation has the form

\[ a(\omega_0) \/ \beta_0 \text{ and phase shift } \delta(\omega_0) \text{ of the driver and pendulum oscillations as a function of driver frequency } \omega_c \text{, resonance curves such as those shown in Figure 3 are obtained.} \]

Heat Experiments

The use of a temperature sensor such as the National Semiconductor Corporation integrated circuit LM35A, enables changing temperatures to be monitored. The sensor produces a linearly varying output of -0.55 V up to +1.5 V over the temperature range -55°C to 130°C with an accuracy of 0.5°C. Applying the output voltage directly to the A/D converter, while using an appropriate calibration factor, temperature variations can be recorded directly on the computer as a function of time. The heat sensor can therefore replace other types of thermometer in heat experiments and is particularly useful where changing temperatures are being monitored. For example, we have used a heat sensor to replace a mercury thermometer in an experiment, where the specific heat of a metal drum is found by measuring its temperature rise as work is done on the drum via a frictional torque.

A more complex application is in the monitoring of temperature changes in a model of a solar house. The effect of different insulating materials such as slate floors, insulation in the roof, walls and windows, on the rate at which different areas of the house heat up or cool down can be monitored effectively by placing four heat sensors in different positions in the house. An infrared lamp is used as the 'sun' and plots such as those shown in Figure 4 can be analysed to determine the effect of insulating materials and illustrate the features of exponential decay.

Figure 4 Temperature variations at different positions in a solar house as a function of heating time. Heater switched off after 30 minutes

Figure 5 Circuit for measuring the discharge of a capacitor, using an electrometer

Capacitor Experiment

Current variations can be monitored by insertion of a suitable resistance into the circuit and measurement of the voltage change across the resistor with the computer. The input impedance of the computer must be high compared with the resistor. In the circuit of Figure 5 a Unilab electrometer is used to measure the voltage on the capacitor at any instant; the output of the electrometer is fed to a microammeter and the voltage developed across a 50 Ω meter may be applied directly to the computer input. The circuit enables the charging and discharging of the capacitor in the RC circuit to be followed as a function of time and hence the time constant of the circuit to be determined.

Simulations

A number of computer programs which run directly on a Mac computer (without an A/D converter) have been developed for illustrating physical principles. These include the modelling of chaos using a mathematical equation and the flow of air around an aircraft wing.

The authors would like to thank David Cooper for the development of the A/D converter and Mark Andrews for writing the computer software used in these experiments.

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Optical scientists have now succeeded in generating light with less noise than complete darkness or the vacuum. This new source of light has been called squeezed light. The term squeezed light refers to manipulating or "squeezing" the quantum fluctuations in a light wave. A light beam consists of an oscillating electromagnetic field. In a classical or wave description of light these oscillations may be pictured as a smooth wave with a perfectly well defined amplitude and phase. In quantum mechanics however, such a well defined wave is not permitted and there must be fluctuations in the amplitude and phase of the wave as dictated by Heisenberg's uncertainty principle. These fluctuations persists even when no light is present and are termed vacuum fluctuations. So in the quantum picture of light the wave is no longer smooth but contains irregularities due to the vacuum fluctuations. These vacuum fluctuations impose a limit on the precision of many optical measurements, for example the fringe visibility in optical interference experiments. While it is not possible to produce light fields which violate the Heisenberg uncertainty principle it is possible to redistribute the fluctuations between different parts of the optical wave. Heisenberg's uncertainty principle dictates that the product of the uncertainties in the two normalized amplitudes of the in and out of phase components (we shall designate these as amplitude and phase) of the field cannot be less than unity. In the vacuum the fluctuations in the amplitude and phase are equal. Without violating Heisenberg's uncertainty principle it is possible to reduce the fluctuations in either amplitude or phase at the price of increased fluctuations in the other variable. Such states with less fluctuations in either amplitude or phase than the vacuum are known as squeezed states. A pictorial representation of an electromagnetic field with squeezed quantum fluctuations is shown in Fig 1.

Squeezed light is one example of nonclassical light, that is light with properties which are not predicted by the classical theory of light. It is a uniquely quantum phenomena. Another nonclassical effect is photon antibunching, a phenomena where the probability for two photon to arrive simultaneously is small. Their arrival times tend to be antibunched rather than the photon bunching effect which occurs for thermal light sources. Another signature of nonclassical light is found in the photon statistics; that is the photon counting distribution of the light field. Whereas a laser exhibits Poissonian photocount statistics, certain nonclassical light fields may exhibit sub Poissonian statistics. Squeezing, photon antibunching and sub Poissonian photon statistics are closely related. For example amplitude squeezed light which has reduced intensity fluctuations exhibits sub Poissonian statistics. However phase squeezed light which has increased intensity fluctuations has super Poissonian statistics.

The unique predictions of the quantum theory of light was brought out by Roy Glauber of Harvard University in his elegant formulation of quantum optics in the 1960's. However it was not until 1975 that I and my student Howard Carmichael then at the University of Waikato, indentified a physically accessible system exhibiting nonclassical behaviour. Our prediction was that the light generated in resonance fluorescence from a two level atom would exhibit photon antibunching. Photon antibunching was observed the next year in this system in an experiment by Leonard Mandel and his students Jeff Kimble and Mario Dagenais at the University of Rochester. This was the first nonclassical effect observed in optics and ushered in a new era in quantum optics. It was to be another nine years before the first experiment generating squeezed light was successful. The properties of squeezed light were described in 1976 in a comprehensive article by Horace Yuen then at the Massachusetts Institute of Technology. In 1979 Yuen and his colleague Jeffrey Shapiro suggested that squeezed light might

Figure 1 Plot of electric field against time showing the uncertainty for
(a) a coherent state
(b) a squeezed state with reduced amplitude fluctuations
(c) a squeezed state with reduced phase fluctuations.
be generated by four wave mixing in nonlinear optics. A number of possible schemes in nonlinear optics were analyzed by myself and my colleagues at the University of Waikato, principally Gerard Milburn, Margaret Reid, Matthew Collett and Crispin Gardiner. In 1985 the first observation of squeezed light was reported. We shall describe in the next section some of the successful experiments which have generated squeezed light.

**Generation of Squeezed Light**

Squeezed states of light do not (as far as we know) occur in nature. Even highly stabilized lasers which may operate at the level of the vacuum for their amplitude fluctuations have fluctuations in their phase far in excess of the vacuum. Squeezed states may be generated by phase dependent nonlinear optical processes. The simplest process involves an interaction in a nonlinear crystal with a second order nonlinear optical susceptibility. An incident laser photon with frequency $2\omega_0$ is split into two photons with frequency $\omega_0$ by the nonlinear crystal. The subharmonic or down converted photons possess quantum correlation such that the fluctuations in the subharmonic field are squeezed. This process is the basis for a degenerate parametric oscillator which consists of nonlinear crystal inside an optical cavity built from two mirrors. The cavity is driven externally by a coherent laser field with frequency $\omega_0$ input at one of the mirrors. The cavity is resonant at $\omega_0$ and also at the subharmonic frequency $\omega_0/2$. The light field output from the cavity at frequencies around subharmonic frequency $\omega_0/2$ is squeezed.

In order to detect the squeezing a phase sensitive detection scheme must be employed. A homodyne detector is used where the squeezed light is mixed with light from a local oscillator. The phase of the local oscillator is varied so that the component of the squeezed field with reduced quantum fluctuations is measured. Squeezed light has been generated using an optical parametric oscillator by Jeff Kimble and his coworkers then at the University of Texas. A schematic sketch of their experimental set up is shown in Fig. 2. A degenerate parametric oscillator is constructed using a lithium niobate crystal inside a resonant cavity. The cavity is driven by light at the harmonic frequency (0.53nm) by frequency doubling a NdYag laser (1.06nm). The down converted light at 1.06nm emerging from the optical parametric oscillator is squeezed. This squeezing is observed by homodyne detection using the original laser emission at 1.06nm as the local oscillator. Kimble has reported that squeezing with a quantum noise reduction nearly ten times below the vacuum level has been achieved in this system. However, squeezing is fragile and sensitive to any loss mechanisms. Thus detector inefficiencies and other losses reduce the amount of squeezing observed to a factor of three. Squeezing by almost a factor of ten has recently been observed in a parametric down conversion experiment using pulsed light by Pram Kumar at Northwestern University. As the fluctuations in one quadrature of the field is reduced so the fluctuations in the other quadrature is increased. In Fig 3 it is shown that the fluctuations in the light generated by the parametric oscillator have the minimum fluctuations allowed by Heisenberg’s uncertainty principle. The experimental points lie along the minimum uncertainty curve.

In the parametric oscillator below threshold the light field has no coherent amplitude so one has what is known as a squeezed state.
vacuum. In second harmonic generation, the time reversed process to parametric down conversion, two photons with frequency \( \omega \) are upconverted to produce a photon with frequency \( 2\omega \) in a nonlinear crystal. The light produced in the upconversion process is amplitude squeezed in the output both at the fundamental and second harmonic frequencies. In a recent experiment Sizman and coworkers at the Max-Planck-Institute for Quantum Optics in Munich have observed amplitude squeezing on the second harmonic mode. The squeezing is generated in a \( \text{MgO} \cdot \text{LiNO}_3 \) monolithic cavity pumped by a Nd:Yag laser. The system exhibits more than 40% reduction in quantum noise power.

Squeezing may also be generated in other nonlinear processes such as four wave mixing in media with a third order optical nonlinearity. In four wave mixing two laser photons with frequencies \( \omega_1 \) and \( \omega_2 \) are coupled via the nonlinear medium to a signal and idler photon with frequencies \( \omega_3 \) and \( \omega_4 \), such that \( 2\omega_1 = \omega_3 + \omega_4 \). In degenerate four wave mixing \( \omega_1 = \omega_3 \) and in non degenerate four wave mixing \( \omega_1 \neq \omega_3 \). The first demonstration of optical squeezing was performed by Dick Slusher, Bernard Yurke and coworkers at Bell Laboratories using four wave mixing in atomic sodium. The experiment was performed in an optical cavity and squeezing was observed in the cavity output by homodyne detection. However noise from spontaneous emission from the atoms and other sources reduced the maximum squeezing observed in this experiment to \( \approx 25\% \). A recent experiment on barium atoms by Deborah Hope, Hans Bachor and coworkers at the Australian National University has produced a squeezed light beam with 18% observed squeezing.

Another four wave mixing experiment was performed using an optical fibre by Marc Levenson, Bob Shelby and coworkers at the IBM Laboratories in San Jose. Though the third order nonlinearity of a glass fibre is small this can be compensated for by the long interaction length (100m) and the high laser power that may be focussed in the fibre. In this experiment broad band squeezing was observed in the non degenerate configuration. However owing to noise arising from Brillouin scattering from acoustic photons in the fibre the squeezing observed was \( \approx 13\% \). Recent experiments on fibres using pulses light which evade the Brillouin scattering and achieve larger squeezing have been reported by Herman Haus and coworkers at the Massachusetts Institute of Technology.

One may also study quantum noise reduction in variables other than the quadrature phases. In a parametric down conversion process the two photons may be distinguished by different polarizations in the degenerate case or by different frequencies in the nondegenerate case. Since these photons are produced in pairs the difference in the photon number \( \Delta N_+ - \Delta N_- \) is a constant. This conservation law leads to a squeezing in the fluctuations in the difference current of the signal and idler modes. This squeezing in the difference current has been observed in continuous wave experiments by Elizabeth Giacobino at the University of Paris using a parametric oscillator. In this case the parametric down conversion occurs inside an optical cavity and the correlation between the two photons is lost for times short compared to the cavity lifetime due to the independent nature of the escape of signal and idler photons. For times longer than the cavity lifetime the conservation of the photon number between the signal and idler beams is restored. Consequently the spectrum of fluctuations in the difference of the intensities in each beam exhibits squeezing over a bandwidth of the order of the cavity bandwidth. In an experiment at Stanford University by Dave Nabor and Bob Shelby a monolithic parametric oscillator has been used where the surface of the nonlinear crystal is mirror coated to form the optical resonator.

The correlation in the intensities of the twin beams may be used for "intensity squeezing" on one beam, via electronic intensity correlation. To accomplish this the intensity of the idler beam is monitored by a photodiode. Knowledge of the idler intensity is used to modify the transmittance of an intensity modulator in order to control the pump intensity (feedback correction). Alternatively knowledge of the idler intensity is used directly to correct the intensity of the signal beam (feed forward correction) by the same technique. Rarity has reported 50% intensity squeezing using the feedback technique and Giacobino has reported 20% intensity squeezing with the feed forward approach.

Efforts have also been made to directly reduce the noise in the output of a laser rather than processing the light through some nonlinear device. While lasers produce coherent light the revival of individual photons is characterized by Poissonian fluctuations. These Poissonian fluctuations of the photon number give rise to the "shot noise" of the laser. This shot noise represents a fundamental noise floor and is limiting in many laser applications. Can one make the output of a laser more regular? That is, is it possible to have a laser which generates light with sub-Poissonian photon statistics? Such light has been termed photon number squeezed light.

Both noise in the pumping mechanism and spontaneous emission noise contribute to the noise in a laser. If these sources of noise can be suppressed a sub-Poissonian output is possible. In a high impedance constant current driven semiconductor lasers it has been shown that the fluctuations in the pumping electrons are reduced below Poissonian. This results in the photon statistics of the emitted photons being sub Poissonian. Consequently the intensity fluctuations of the light from the semiconductor laser are squeezed below the shot noise level. Semiconductor lasers with amplitude noise reduced by 10dB after compensating for various losses have now been operated by Yoshi Yamamoto and coworkers at the NTT Research Laboratories in Tokyo.

Efforts to reduce the phase fluctuations in lasers which contribute to the laser linewidth have also been made using the principle of correlated spontaneous emission between two competing atomic transitions. If a coherence is established between the two exited atomic states the laser radiation has reduced fluctuations in the difference phase between the light emitted on the two atomic transitions as pointed out by Marlan Scully at the University of New Mexico. A laser operating on this principle with reduced phase fluctuations has recently been reported by Jan Hall and coworkers at the University of Colorado.

The above experiments all refer to squeezing at optical frequencies. Recently however squeezing of quantum noise at microwaves frequencies using a Josephson parametric amplifier has been achieved by a group at the AT & T Bell Laboratories and the TRW Space and Technology Group. The amplifier was operated at 19.6 GHz where the vacuum noise floor is 0.5K. This required considerable cryogenic technology in order to observe the squeezing. The amplifier was cooled to 30mK and they observed a 224mK drop in the noise emitted from the amplifier. This corresponds to a squeezing of the order of 50% The generation of squeezed microwaves opens up some interesting new possibilities. For example we can now study
the interaction of Rydberg atoms interacting with squeezed electromagnetic field modes. This will allow the study of single atoms in microwave cavities with squeezed fluctuations. Another application is in the study of nonlinear quantum phenomena where the strong nonlinearities of Josephson junction devices will enhance these effects over the much weaker optical nonlinearities.

Applications of Squeezed Light

Applications of squeezed light occur in quantum noise limited situations such as high sensitivity measurements of optical phase. One potential application occurs in the interferometric detection of gravitational waves. Gravitational waves are predicted to be generated in catastrophic cosmic events such as super nova explosions. The effect of the gravitational wave on detectors on the earth is small and projects to build large optical interferometers with several kilometre arm lengths are in progress. In these interferometers the gravitational wave will induce a differential length change in the arms of the interferometer. This length change manifests itself as a phase change in the interference pattern. It was suggested by Carl Caves now at the University of Southern California that the signal to noise ratio of the phase change may be enhanced if squeezed light is injected into the unused part of the interferometer as shown in Fig 4. This reduces the noise due to vacuum fluctuations entering the unused ports. Increased sensitivity in optical interferometers using squeezed light has been observed in the laboratories of Slusher and Kimble which gives the possibility that the sensitivity of gravitational wave interferometers may be enhanced by squeezed light.

Consideration has been given to utilising squeezed light in optical communications where the low noise properties promise some advantages. The suggestion is to encode the information on the quiet component, say the amplitude of the light wave, and to use detectors which are insensitive to the noisy component, in this case the phase. This would enable one to transmit information with a higher signal to noise ratio than using coherent light as the carrier. Unfortunately, the losses present in current optical fibres restrict the potential use of squeezed light in the transmission of information to local area networks. For example, a loss of 0.2 dB per km will ensure that a factor of 10 squeezing will be lost over a distance of 50 km. However, in the distribution of information to a number of different receivers it is possible that squeezed light may find an application as suggested by Jeff Shapiro of the Massachusetts Institute of Technology. The criterion here is to tap off information with minimum depletion of the carrier signal. Using a normal optical tap the tapped signal must at least be greater than the vacuum fluctuations. If, however, the vacuum fluctuations are squeezed the same signal to noise ratio can be obtained in the tapped signal without significantly depleting the carrier signal. Since this application only requires the squeezed light to be used locally and not to propagate over any distance, dissipation is not a limiting factor. A sketch of an optical tap with a squeezed vacuum is shown in Fig (5).

Figure 5 Sketch of an optical tap depicted as a beamsplitter with an squeezed input.

Closely connected with the optical tap is the concept of quantum nondemolition measurements. The essence of an ideal measurement is that an exact measure is obtained of an observable of the system without in any way changing the value of that observable. In quantum mechanical terms the coupling of the meter to the system variables must be such that the interaction is back action evading. That is, quantum noise from the meter does not affect the system observable to be measured. In certain QND schemes realized in optics the amplitude quadrature of a signal light beam is measured via some nonlinear coupling to a probe light beam (the meter). The coupling is judiciously arranged such that the back action noise from the measurement is shunted into the phase quadrature of the signal. Such couplings have been experimentally realized in four wave mixing in optical fibres and in nonlinear crystals with a e\(2\phi\) nonlinearity.

The interaction of atoms with squeezed light opens a new window on spectroscopy. The decay of an excited atom in the usual vacuum is independent of phase. If, however, the vacuum is squeezed the atomic dipole will experience a phase dependent decay with a shorter lifetime where the fluctuations are greatest and a longer lifetime where the fluctuations are least as predicted by Crispin Gardiner of the University of Waikato. Such phenomena may be observed in the fluorescent spectrum △
although technical difficulties in requiring the atom to interact only with the squeezed vacuum must be overcome. Experiments using microcavities which only support a few modes of the electromagnetic field are one possibility.

The quantum correlation which exist between the air of photons produced in parametric down conversion may be exploited in a number of ways. For example one may make use of the properties of this correlated photon pair in ultrasensitive absorption measurements where by using one beam as a reference any absorption in its twin is readily detected. The twin light beams with identical intensity fluctuations are ideally suited to reduce the noise floor in absorption measurements. The absorbing medium with an absorption coefficient resonant at frequency $\omega$ placed in the idler beam of a parametric oscillator. The frequency of the idler beam is tuned to vary around $\omega$ and the absorption dip is measured on the intensity difference $I_2 - I_1$ as a function of frequency. Since the background noise power on such a signal is reduced with respect to the shot noise, this technique allows for weaker absorptions coefficients to be measured than could be measured by a single laser beam. This method will be useful for example in measurements where increasing the laser intensity is not feasible (biological samples for instance).

In another application a one photon state may be prepared by parametric down conversion using the detection of the twin photon to gate the arrival of the single photon. This technique has been used in demonstrating Berry's phase experiment with single photon states by Ray Chiao and colleagues at Berkeley. A similar technique was used by Alain Aspect and colleagues at the University of Orsay to demonstrate Young's interference experiment with a single photon state. In Aspect's experiment the correlated photon pair was produced by a two photon cascade from a three level atom.

The correlated photon pairs produced in parametric down conversion maintain their initial quantum correlation even after they have spatially separated. They have been used in experiments to demonstrate the nonlocality of quantum mechanics. That is, a measurement of one photon of the pair will affect the measurement of the other photon at a different position. Experiments which show a violation of Bell's inequalities in contradiction to locality assumptions but in agreement with quantum mechanics have been performed using a correlated photon pair. In the first experiments by Alain Aspect and coworkers the correlated photon pair was produced by the cascade transition in atoms. However recent experiments by the groups of Leonard Mandel at the University of Rochester, Carol Alley at the University of Maryland, and Ray Chiao at the University of Rochester, and John Rarity at the Royal Radar and Signals Establishment in Malvern have produced the correlated photon pair by parametric down conversion which has the advantage of directional beams and hence improved signal to noise.

The discovery of new quantum sources of light such as squeezed and sub Poissonian light have opened a new window in optics. Until very recently all optical experiments could be adequately explained by a classical theory of light. The experiments of the kind outlined in this article, however, are outside the domain of classical optics. The effects described are characteristic of the uniquely quantum nature of light. While these studies are of fundamental interest in increasing our understanding of light they may also open the path to new technologies based on quantum phenomena. ✪

An abbreviated form of this article was published in The New Scientist, October 1991, No 1791, page 41.

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### Medical Imaging Scientist

Applications are invited for the position of Medical Imaging Scientist to the Austin Hospital Centre for Positron Emission Tomography. Relevant background should be in either computer image analysis, and/or applied mathematics/physics. A strong interest in applying knowledge to biomedical image analysis including PET, MRI and other imaging modalities is desirable. Experience on UNIX based workstations would be useful. Postgraduate qualifications with Ph.D. preferable, but not essential. Joint hospital/University of Melbourne appointment may be negotiated. Salary dependent upon qualifications and experience ($27,716-$34,871).

Enquiries: Dr. G. A. Donnan (03) 450 5914 or Gary Egan (03) 450 5729

Written applications to the Personnel Officer, Heidelberg 3084, by 26 June 1992.

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Barometric Pressure Products at Vaisala Sensor Systems

The Advantages of Silicon Capacitive Pressure Sensors

The silicon capacitive pressure sensors developed by Vaisala Sensor Systems combine two powerful basic principles for pressure measurement: the excellent elastic properties of single crystal silicon and the capacitive sensor principle. The perfect elastic properties of bulk silicon result in outstanding pressure hysteresis and pressure repeatability characteristics. The silicon capacitive pressure sensors exhibit a much wider dynamic range and far better temperature and long-term stability than e.g. silicon piezoresistive pressure sensors.

The stability of the silicon capacitive pressure sensors results from the symmetrical sensor structure and the optimized and stable combination of materials. An inherent characteristic of the silicon capacitive pressure sensors is the built-in overpressure stop mechanism that protects the sensitive silicon diaphragm at pressure extremes. Optimized packaging is an essential part of the total performance of a pressure sensor and results in very low errors in temperature repeatability and temperature hysteresis. Furthermore, a stable electrical ground potential and rugged mechanical ease for the capacitive pressure sensor element are also achieved.

The PTA 427 analogue barometer

One of the most natural application areas for the silicon capacitive pressure sensors developed by the Sensor Systems Division are barometric pressure measurements in environmental monitoring and industrial control applications. The silicon capacitive absolute pressure sensors excel technically in these applications and offer superior characteristics in comparison to other technologies. These application areas and products match well Sensor Systems' humidity and temperature measurement applications and products. Extending the sensor and product development to these new areas forms a natural and synergic opportunity for Sensor Systems.

The BAROCAP® Silicon Capacitive Absolute Pressure Sensor

Meteorological observations and industrial pressure control applications set a number of critical performance demands on a barometric pressure sensor. Of prime importance are pressure repeatability and pressure hysteresis characteristics and longterm stability. Good sensitivity at sea level pressures and small temperature dependence are also useful characteristics.

The BAROCAP® silicon capacitive absolute pressure sensor exhibits very good characteristics in barometric applications. The combined effect of pressure repeatability and pressure hysteresis errors is typically only a few pascals. Long-term stability is better than ±0.3 hPa/year and with software compensation this highly repeatable offset drift can be brought down to ±0.1 hPa/year. The temperature dependence of the pressure sensor capacitance is typically ±200 ppm/°C, which makes further temperature compensation easy.

With the capacitive measurement techniques refined by Sensor Systems for digital barometers, a pressure resolution of 1 Pa (0.01 hPa) is easily achieved. For analogue barometers a pressure resolution of 10 Pa (0.1 hPa) is a realistic limit because of the noise level of the signal conditioning electronics.

A silicon capacitive absolute pressure sensor can be designed to have optimum sensitivity at low absolute pressures as well. Low absolute pressure sensor prototypes have already been evaluated for use during a mission to the planet Mars. This sensor type opens up new opportunities in altimeter applications as well.

The PTA 427 Analogue Barometer

The PTA 427 was designed as the first member in a family of barometric pressure transmitters from Vaisala Sensor Systems. The PTA 427 uses analogue signal conditioning techniques and achieves at room temperature a linearity of ±0.3 hPa from 800 to 1000 hPa. A wide pressure range version adjustable from 600 to 1000 hPa has also been developed.

The temperature dependence of the PTA 427 is ±0.02 hPa/°C at 1000 hPa. The total accuracy of the PTA 427 is ±0.5 hPa at room temperature range and ±2.0 hPa over the temperature range from -20 to +60°C. The PTA 427 with its excellent linearity and stability is at its best in applications where the temperature range is narrowly defined and near room temperature. When a very accurate measurement over a wide pressure and temperature range is required in AWS applications, additional temperature compensation must be used.

The PTA 427 has already been used in many industrial and medical applications and it has also been taken into use successfully by several AWS manufacturers. Laser interferometers for accurate length measurements typically require atmospheric pressure, relative humidity and air temperature to be measured for the optimization of the laser beam properties. Vaisala Sensor Systems can now supply all the environmental transmitters needed for these applications.

For further information on these barometric products please contact Vaisala Pty Ltd Unit 4, 8-12 Sandilands Street South Melbourne VIC 3205 Telephone (03) 696 5699 Fax (03) 696 5776

HMP 260 EX Intrinsically Safe Humidity Transmitter

HMP 260 EX is an intrinsically safe humidity transmitter meant to be used in potentially explosive atmospheres in e.g. chemical, petrochemical and many other processing industries. The transmitter can be used in areas where explosive atmosphere is present.
The HMP 260 EX Humidity Transmitter

continuously or for long periods of time and its explosion protection is maintained with up to two component or other faults. The HMP 260 EX can be used even in hydrogen, which is one of the most easily ignitable gases.

The HMP 260 EX Humidity Transmitter has been certified as intrinsically safe by laboratories in Finland, the EC and the United States. It conforms to the European standards EN 50014 and EN 50020 according to which its classification is Ex ia IIC T6. In the United States it has received classification IS/II,II,III,A,B,C,D,E,F,G.

For more information please contact Vaisala Pty Ltd. Unit 4, 8-12 Sandilands Street South Melbourne VIC 3205 Telephone (03) 696 5699 Fax (03) 696 5776

Eye Protection from Titanium: Sapphire Radiation

LaserVision now offers safety glasses with clear filters designed for Titanium: Sapphire lasers. They allow good visibility and hence reduce the risk of accident. The clear filters are obtained either by using absorbing glass or laminated glass layers and dielectric coatings. Combined with the modern frames, LaserVision have achieved a maximum field of view with an attractive style. These glasses are lightweight and can be worn comfortably for hours, even over prescription glasses.

For more information please contact Lynn Smith-Alen at Coherent Scientific.

CO₂ Lasers/Optically Pumped Far Infra-red Red Lasers

Coherent Scientific now supplies optically pumped far infrared (FIR) lasers manufactured in the UK by Edinburgh Instruments, a leading technical innovator in the field of infrared lasers for over 15 years. This product line includes three types of FIR lasers and three types of CO₂ pump lasers. All the FIR lasers feature an invar stabilised resonator, integral water cooling system and dichroic output coupler for optimum system performance. Each system provides stable, coherent far infrared radiation with output powers up to 1W in the spectral range 40-1,222 microns when pumped by a strong CO₂ laser.

The CO₂ pump lasers feature an invar stabilised resonator, off axis suppression, and diffraction grating tuning with piezo-ceramic cavity length control. These tuneable CO₂ lasers offer single line powers from 50W to 200W for all four bands in 9 and 11 microns. Not only can they be used to pump FIR lasers, but they, as well as others in the CO₂ series, have many other research applications, e.g. high resolution spectroscopy, infrared photochemistry, material processing, atmospheric sensing, optical fibre characterisation, interferometry and plasma diagnostics.

For more information, please contact Narrelle Murphy at Coherent Scientific.

Thermal Imaging System

The new model 760 thermal imaging system from Infraometrics is one of the most advanced and flexible infrared imaging systems currently available. Applications include industrial condition monitoring, process control, quality assurance and laboratory research. The 760 produces high resolution infrared images on an integral colour LCD screen and is fully compatible with standard video equipment. A variety of measurement modes is provided for real-time display of target temperatures on the system monitor. Images can be stored on the integral 3.5” disk drive or may be recorded on videotape for subsequent analysis. Built-in image averaging allows exceptional temperature sensitivity to be achieved.

The 760’s detector is cooled by an air-conditioned Stirling cycle refrigerator which eliminates the need for liquid nitrogen or bulky gas bottles associated with other systems. The system may be operated as a benchtop unit or may be made fully portable by means of an ergonomically designed vest which allows the operator to carry and operate the system with ease and comfort.

For more information or to arrange a demonstration at your site please contact Paul Wardill at Coherent Scientific Pty Ltd. 138 Greenhill Rd, Unley SA 5061 Phone (08) 271 4755, fax (08) 271 1202

Optical Radiation System

Oriel Corp. has introduced a new radiometry system, the Merlin optical radiation measuring system, which includes a true digital lock-in amplifier, chopper drive and large LCD display. A family of calibrated detector heads allows measurement of low-level radiation over the spectrum, while a powerful digital signal processor accurately calculates the radiation level and presents it in selectable units.

Each Merlin includes an RS-232 interface for uptake of data or custom spectral calibration, as well as function keys and a keypad to provide control over measuring parameters.

For more information contact LASTEK Pty Ltd. 400 King William Street Adelaide SA 5000 Phone (08) 231 2155, fax (08) 231 2169

Safety glasses available from Coherent Scientific
Lexel Laser Inc.'s new 479 Ti:Sapphire laser is a tunable, standing wave laser system capable of being pumped by a small or large frame ion laser system. It offers 800mW with a 5W pump and better than ±0.5% power stability with the optional IR light regulator, and incorporates a birefringent tuning filter (one, two or three plates) and the necessary optics sets to cover the 690 to 975nm tuning range. The 479 uses a Z-shaped folded cavity design consisting of a high reflector, two dichroic folding mirrors, and output coupler and a Ti:Sapphire rod, as well as two input routing mirrors and a waveplate that rotates the vertically polarized pump beam to the horizontal plane.

For more information contact
LASTEK Pty Ltd
Phone (08) 231 2155, fax (08) 231 2169

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Dr. B. H. Briggs of the Department of Physics and Mathematical Physics, the University of Adelaide, is the second recipient of the Harrie Massey Prize awarded by the Institute of Physics and the Australian Institute of Physics. The prize was awarded to Dr Briggs at a Plenary Session of the Tenth AIP Congress, the presentation being made by Prof. Cyril Hilsen, immediate Past President of the Institute of Physics, and Prof. Tony Thomas, President of the Australian Institute of Physics. In response, Dr Briggs delivered a lecture on “Observations of Atmospheric Dynamics Using Radar Techniques”.

Modern atmospheric radars are very sophisticated instruments with many characterised by large antenna systems. Radar developments began during the Second World War, growing out of ionospheric research using pulsed sounders. Dr Briggs worked on radar in the UK during the war, returned to Cambridge where he worked on ionospheric research with Ratcliffe at the Cavendish Laboratory, and then to Adelaide where he developed the large 1 km x 1 km 2 MHz radar for ionospheric and middle atmospheric research. Thus Dr Briggs’ career has spanned the entire development of atmospheric radars, giving him an authoritative perspective on both the history and science of the subject.

In his lecture, Dr Briggs began by discussing the early radio experiments designed to measure ionospheric drifts based on spaced receiving antennas. He clearly explained the basic concepts of the methods used to determine velocities using correlation techniques and the difficulties faced in correctly interpreting these velocities. He then moved on to describe the development of the Buckland Park Array in the mid-1960’s and the novel ‘ultrasonic lens’ technique used at the time to form images of ionospheric structures which could then be photographed. In this way movies of ionospheric structures and their motion were made and one of the highlights of Dr Briggs’ lecture was when he showed some of the movie segments. In more recent years the Buckland Park Array has been used to study the middle atmosphere, and Dr Briggs described how it is used to measure winds, turbulent intensities and the upward flux of horizontal momentum due to gravity waves. Dr Briggs concluded his lecture by outlining how the Array is being modified so that it can be used for transmission as well as reception, thus increasing its experimental capabilities.

Dr Briggs is noted not just for his research, but for his lecturing as well. Not surprisingly then, he presented both simple and complex ideas with clarity, so that his Massey Prize Lecture was an excellent presentation of the development of atmospheric radar techniques for the audience of physicists with diverse backgrounds.

P. L. Dyson

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Australian & New Zealand Physicist Volume 29, Number 6, June 1992
Radioactive Environments and Health

The Proceedings of the 26th Annual Meeting of the US National Council on Radiation Protection and Measurements, held in Washington in April 1990, bears the titles 'Health and Ecological Implications of Radioactively Contaminated Environments'. It looks rather unattractive at first glance. Its pictures of elderly gentlemen at microphones, or presenting awards, turned me off and made me wonder which reviewer had selected it. Not having a grudge against any of our reviewers, I began to browse and got hooked enough to make it my own contribution for the month.

Like all good conference proceedings, this publication brings one up to date on progress in its field. It is clear from the post-paper discussions that controversy still reigns in this disputatious area of science, but I couldn't help gaining the impression that radiation specialists are edging closer to a useful understanding of the subject and a recognition that those issues Alvin Weinberg describes as "trans-science" will never be answerable.

Various contributors lament the lack of public appreciation of the relative significance of natural versus man-made radiation hazards. Blame is directed to ineffective science education and the sensationalist role of the media. It is a subject where a hidden political agenda often dictates attitudes in the printed word, not to mention the TV documentary.

We see this problem in our own country. There is a conspicuous lack of reliable presentations on radioactivity available, especially for teachers. I guess our University Library is little different from most in Australia, but I am appalled that the shelves contain more popularly written anti-nuclear books of the calibre of "We almost lost Detroit", or Helen Caldicott's 'Nuclear Madness', than readily readable factual presentations that are not highly technical. The former are for the most part donations, often by the authors, or the choices of library staff and the academics of non-technical departments.

Anyway, this volume, which has the bland look of a government document, does contain enough up-to-date factual material to make it a desirable addition to any library dealing with scientific matters. It is always interesting to read the views of real experts on the latest findings on radon exposure, Hiroshima victims, leukaemia clusters (Sellafield and Dounreay scares), nuclear wastes disposal and, of course, Chernobyl. So it would be irresponsible of me if I did not recommend the acquisition of this book by our University library.

'The Health and Ecological Implications of Radioactively Contaminated Environments' is a 233-page paperback published for US$25 by the US National Council on Radiation Protection and Measurement, 7910 Woodmont Avenue, Bethesda MD, 20814. They refer to it as Proceedings No. 12.

Colin Key
Book Reviews Editor

Scientific Dating Methods

H.Y. Goksu et al (Eds)
xi + 317pp., US$99 (hardcover)

This forms part of a new series devoted to the publication of courses and educational seminars (EURO COURSES) organized by the Joint Research Centre, Ispra. It is the first of a subseries on "Advanced Scientific Techniques". The target readership is "human scientists using or intending to use dating methods in their field of research, museum curators, and [presumably] students of history, geology and archaeology". Thoughtfully, it would be of interest to physicists.

The Dating Methods that are described fall under three headings:
1. Based on Radioactive decay e.g. C-14
2. Based on energy deposition in solids (commonly called trapped electron methods) e.g. thermoluminescence
3. Natural rhythmical and chemical changes e.g. palaeomagnetism, obsidian hydration.

The articles are informative and easy to read but at the same time patently authoritative. They are all by researchers active in their fields and are thoroughly up to date. In so far as some of them have a very heavy emphasis on the authors' own work, they fall somewhat short of review articles per se but this is not a serious shortcoming. Two of the articles, "Pseudo dating", by I. K. Bailliff and "Authentic Dating", by D. Stoneham are the best available on these topics. The omission of amino acid racemisation and carbon dating makes the volume less complete than it should have been. In view of its provenance it is not surprising that most of the examples are European.

There is an impression of conformity with a consistent editorial directive. All the articles thoroughly address the question of both the advantages and limitations of the methods and several would adequately direct a tyro wishing to enter the field for the first time.

The present volume bears some of the characteristics of a collection of articles by different authors. The text has been reproduced from camera-ready copy and has a wide variety of type styles; some of the proof reading is dreadful, including missing references. There is no comprehensive index.

In short, this is a good text for what it covers. Nevertheless, for the intended readership (and for physicists), I would prefer Martin Aitken's "Science-based dating in archeology", in paperback at one quarter the price.

John R. Prescott
Physics and Mathematical Physics
University of Adelaide

Topics in Lightwave Transmission Systems

Tingye Li (Ed)
x + 308pp., US$69.95 (hardcover)

This is the second volume of a treatise entitled Optical Fibre Communications edited by Tingye Li of AT & T Bell Laboratories. The first volume dealt with fibre fabrication. This volume contains five chapters on fibre communications topics: Optical Transmitter Design; Lightwave Receivers; Frequency and Phase Modulation of Semiconductor Lasers; Coherent Optical Fibre Transmission Systems; Nonlinear Effects in Optical Fibres.

The eight contributors are well known workers in these fields (Chraplyvy, Dixon and Hokanson from AT & T Bell Laboratories, Kimura, Satto and Yamamoto from NTT Basic Research Laboratories Williams, Williams Nynex Corporation, and Kobayashi from Photonic Integration Research, Inc. This, like the 1980 Springer-Verlag volume "Semiconductor Devices for Optical Communication" will serve as both an introduction and an advanced reference to optical communications.

Australian & New Zealand Physicist Volume 29, Number 6, June 1992
BOOK REVIEWS

Laser Light Scattering, Basic Principles and Practice (2nd Ed.)
B. Chu
Academic Press, San Diego, CA 1991 ix + 345pp., US$74.50 (hardcover)

The first edition of this book, published in 1974, became one of the important references in the then emerging field of dynamic light scattering. The second edition is a timely and eagerly-awaited update of the first edition. As Chu points out, the technique of dynamic light scattering has matured in this period, although the basic principles remain the same. Advances in technique and instrumentation have resulted in dynamic light scattering becoming a standard tool in particle size measurement and dynamics of suspended material. The second edition is an attempt to acquaint the reader with the current state of development in the field and concentrates purely on the technical aspects of the technique of light scattering.

The first part of the book introduces time-averaged and time-dependent light scattering and optical mixing and photon correlation techniques in some detail. Workers new to the field would perhaps be confused by the detailed discussion of optical mixing since these are rarely used these days. The discussion of photon correlation would also lose nothing by reducing the description of the various schemes that have been used to implement the correlation operation.

The real strength of the book is in its latter part which discusses experimental procedures and the practical aspects of light scattering. Chu has been a prolific worker in this area in the last twenty or so years and the book draws heavily on the work of him and his colleagues.

A negative feature of the book is its very large number of typographic and printing errors. This often makes the book confusing and would frustrate the

Application of Metrological Laser Methods in Machines and Systems
G. Frankowski, N. Abramson & Z Fuzessy (Eds)
Akademie-Verlag, Berlin, 1991 vii + 381pp., DM36 (softcover)

This book surveys metrological laser methods in machines and systems. In the Preface, the Editors emphasize that it is intended to be a source book of applications and further references to literature behind the described techniques. It is not a comprehensive Handbook which alone will enable the reader to replicate the technologies described (although it goes far along the way).

The book begins with two chapters of overview of laser methods in metrology. The applications discussed range from alignment techniques through speckle metrology to interferometry and holography. Chapter two is an especially useful primer of the basic physics behind the specialized methods involving modern computer-assisted opto-electronic methods which are described more fully in the text.

The areas covered are presented in sufficient detail to enable the reader to assess whether further investigation is justified for a particular application, including the range and resolution capabilities of the method. The approach will assist someone contemplating instrument purchase or design to understand the practical limitations, as well as the capabilities of the technique. Although each field is covered only briefly, there is sufficient detail to enable readers conversant with the expression of wave theory and Fourier analysis to understand the physics behind the newer techniques described.

The approach is practical and includes: Double-Pulse Holography applied to measurement of workshop machine distortions; Whole Vehicle and Automotive Part Metrology; Vibration Analysis using Time-Average Holographic Interferometry, and Image Enhancement Techniques applied to Speckle Computer-Aided Fringe Pattern Analysis; Surface Shape analysis by Heterodyne Fringe Pattern Analysis; Digital Image Processing and Enhancement Techniques applied to Interferograms, Holograms and Speckle Patterns; and finally discussion of Surface Microurface Measurement using Optical Methods.

The International Commission for Optics (ICO) under the creative editorship of Joseph Goodman, has by invitation produced this invaluable book on modern optics, consisting of 34 chapters by 42 distinguished authors. As it is impossible to review all the chapters, some attempt to classify them might be useful.

Firstly, there are the articles on optical hite, which especially relate to advances in optical communications, and to the possibilities of optical computing. These chapters contain introduction to component design and manufacture, systems, signal processing, and pattern recognition.

Then there are groups of articles which relate to classical optics, such as coherence, interferometry, and optical testing. The article on interferometry by Harirahan is especially rewarding.

Several chapters relate to pure and applied quantum optics. On the applied side, we can learn about the increasingly important area of semi-conductor lasers. On the pure side there is an outstanding article by Aspect and Grangier on the theory and their experiment on "one-photon light pulses versus attenuated classical light pulses". (I am pleased to tell you, quantum mechanics won again).

Another set of chapters could be entitled natural optics. It includes, water waves, atmospheric optics, and animal eyes.

Finally, there is a group of chapters which could be entitled the history, philosophy, pedagogy and sociology of optics. This group includes Optics in China, Philosophies of Diffraction, and an especially useful survey article entitled, The Essential Journals of Optics. This last article will be of use to people entering the field of optics and their librarians.

I can think of no better and more enjoyable way to become informed of all the major aspects of optics today, than by
Sensors: Technology, Systems and Applications
K. T. V. Grattan (Ed)
Adam Hilger, Bristol, 1991, xii + 559pp., UK£25 (hardcover)

Adam Hilger specialise in sensor related books having begun its Sensor Series by first publishing a collection of conference papers. This, the fifth book in the series, is also a collection of papers, being the Proceedings of the 'Fifth Conference on Sensors and Their Applications', held in Edinburgh, in September 1991.

Close to 100 papers are arranged in sections on chemical sensors, gas sensors, process tomography and flow measurement, optical sensors, micromachined and resonant sensors, ultrasonic sensors, signal processing and detection, biomedical sensors and sensor applications.

The quality of the papers is consistently good. The publishers and Editor have spared no effort to make this more than just a set of conference papers. Whilst the originals were processed from camera-ready submissions, and thus have variable formats, the illustrations are of uniformly high definition. Primed using quality gloss paper and a firm binding also help makes this a book that one wants to possess. An author index is supplied but, unfortunately there is no subject index - a necessary feature for any technical book and it takes little extra effort to compile it.

So what is the contribution of such a volume? Immediate release after the Conference makes available a wealth of scientific and technological knowledge about a very wide range of sensor research and development aspects as carried out across the world. The many papers paint an accurate and detailed picture of the current state of sensor research and development. They illustrate the sophistication now becoming compulsory within modern sensors. They give information about the plant and processes needed for sensor manufacture and they reveal the practical problems to be overcome in making effective sensors. The need to work in an interdisciplinary manner in this field is reinforced by the impact of electronic and optical techniques in the many designs reported and in the fact that only a few papers were not the result of team activity.

These papers can also be used as an indicator of where sensor research is heading. The disappointing side of the collection, to this reviewer, was the almost complete lack of papers covering important foundational scientific issues that badly need research to assist the sensor research field gain the stature of such areas as its partner, control. At the generic level one paper discusses sensor fusion, but that is all. Sensor performance assessment and optimisation, classification of sensor forms, sensor system specification and design methods again have no following. Whilst the title mentions "systems" there is actually little about sensor systems of any extent. It is clear that sensor research is still strongly device driven and its adherents still find generic issues less attractive to the experimental work aimed at providing solutions by the application of derivative science taken from chemistry, physics and mathematics.

It is, therefore, not a book that will be seen as a milestone in didactic development of sensor science knowledge but certainly is one that will act as a fine source book of ideas and as a listing of who is doing what, and where, in the international sensor research fraternity.

P. H. Sydenham
Sensor Science and Engineering Group
University of South Australia

Readers who cherish their copy of the small first offering in 1985 of this historical summary of laser development will be rushing out to buy this nicely presented, well-illustrated new edition. Much of it has been rewritten and new material has been added, bringing it up to date as of the thirtieth anniversary of Theodore Maiman's first successful laser. Visitors to the Hughes Company's Malibu laboratories in the 1960's were sometimes lucky enough to meet Maiman and inspect the little beauty which revolutionised optics.

But it takes a book like this to set the laser in context, to show how it emerged from earlier maser work and how it has been extended to work at wavelengths all the way to x-rays and in all sorts of media from gases to semi-conductors. "Even a telegraph pole would lase if you hit it hard enough!" Most of the book is in the form of interviews with the pioneers themselves. As a first-hand source, it deserves a place in all technical libraries and on the personal shelves of all who teach laser physics.

New Books

Biomagnetism
R. S. Wadas
Ellis Horwood (Prentice Hall), Chichester 1991 xi + 170pp., AS$68 (hardcover)
E.M.C.: Electromagnetic Theory to Practical Design
P. A. Chatterton and M. A. Houlden
John Wiley & Sons, Inc. Chichester 1992 xiv + 295 pp. UK£39. 95 (hardcover)

Basics of Interferometry
P. Hariharan
Landau Fermi-liquid Theory
G. Baym and C. Pethick

Quantum Noise
C. W. Gardiner
Springer-Verlag, Berlin 1991 xviii + 364 pp. DM 99 (hardcover)
Misadministration of Radioactive Material in Medicine - Scientific Background
N.R.C.P., Bethesda MD 1991 vi + 49 pp., US$15 (paperback)

Graphics and Animation in Surface Science
D.D. Vvedensky & S. Holloway (Eds)
Adam Hilger, Bristol 1992 xi + 117 pp., UK£27.50 (hardcover)

Laser Pioneers (Revised edition)
J. Hocht

Laser Pioneers (Revised edition)
J. Hocht

Discrete Mathematics for New Technology
R. Garnier and J. Taylor
Adam Hilger, Bristol 1992 xvii + 678 pp., UK£19.50 (paperback)
CONFERENCE & MEETINGS

1992

June 29 - July 3
ICSFS-6 6th International Conference on Solid Films and Surfaces
Esiee - Cité Descartes - BP 99, Noisy-Le-Grand, France
Dr. J. Lecante, CEA and LURE, Bâtiment 209D, Université Paris-Sud-91405
ORSAY Cedex. Phone (33) 164 46 80 03, fax (33) 164 46 41 02

July 6 - 10
Fifth International Conference on Thinking - Exploring Human Potential
James Cook University of North Queensland, Townsville, Australia
John Edwards, Conference Convener, Department of Pedagogics
James Cook University, Townsville QLD 4811 Australia
Fax (077) 251 690 (within Australia) or 61 77 251690 (overseas)

July 20 - 21
Recent Advances in Two-Dimensional and Nonstructure Electron Systems
School of Physics, University of New South Wales, Sydney, Australia
Contact: D. Neilson, University of New South Wales, Kensington NSW 2033
Phone (02) 697 4564, Fax (02) 663 3420,
or Internet neilson@newt.phys.unsw.oz.au

August 17 - 20
The 14th Triennial URSI International Symposium on Electromagnetic Theory, Sydney, Australia
Dr. G. L. James, Chairman of the Organising Committee, CSIRO Division of Radiophysics. Phone (02) 868 0222 or (02) 868 0290, Fax (02) 868-0400

August 26 - 28
Fifth New Zealand National Physics Conference, University of Auckland
Dr. G. D. Putt, Department of Physics, University of Auckland. Private Bag 92019 Auckland N.Z. Phone NZ (09) 373 7999/Xin8228, fax NZ (09) 373 7443

Sept 8 - 11
ASPEN Symposium - Introductory Physics Education in University, Japan
c- Prof. Yasuhiko Tsuruoka, Dept. of Physics, Tokai University,
1117 Kitakaname Hiratsuka City, Kanagawa 259-12, Japan
Phone 81-463-58-1211, Fax 81-463-58-812

Sept 14 - 18
APSEM/BECON'92 Physical Sciences in Medicine and Biomedical Engineering Conference
Contact: A/Prof. B. J. Thomas, School of Physics, Queensland University of Technology, GPO Box 2434, Brisbane QLD 4001, Australia
Phone (07) 864 2386 or Fax (07) 864 1521, OR Dr. M. McCarthy, Department of Physical Sciences, Royal Brisbane Hospital, Bowen Bridge Road, Herston, QLD 4029, Australia. Phone (07) 253 8520 or Fax (07) 253 1389

November 12 - 14
16th Scientific Meeting of the Australian Society for Biophysics,
University of NSW, Sydney
Prof. Hans Coster, Department of Biophysics, University of NSW
PO Box 1, Kensington NSW 2033, Phone (02) 6974583, Fax (02) 663340

November 25 - 27
Australian Acoustical Society Annual Conference 1992, Ballarat, Victoria
John Upton (Convener), Phone (03) 370 7666 or (03) 370 7166,
Fax (03) 370 0332, Geoff Barnes. Phone (03) 720 1266, Fax (03) 720 6952

December 1 - 5
ICPE Conference on Physics Education for Development, Philippines
Prof. Geoffrey I. Opat, School of Physics, The University of Melbourne,
Parkville, Victoria, 3052, Australia. Phone (03) 344 5121, Fax (03) 347 4783

1993

Jan 11 - 29
6th Physics Summer School: Modern Perspectives of Many Body Physics,
Canberra, Australia
J. Mahanty, Dept. of Theoretical Physics, R.S. Phys.S.E., ANU,
GPO Box 4. Canberra ACT 2601 Australia
Phone (06) 249 2952, Fax (06) 249 4676

Feb 1 - 5
8th Conference of the Australian Optical Society, University of Sydney,
NSW 2006 Australia
Chair of the Organising Committee: Dr Brian James, School of Physics,
University of Sydney NSW 2006. Phone(02) 692 2599, fax (02) 660 2903,
email: james@physics.sydney.edu.au.
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- Helium-Neon Lasers
- Krypton Ion Lasers
- Lead Salt Lasers
- Mixed-Gas Ion Lasers
- Nitrogen Lasers
- Neodymium:Glass Lasers
- Neodymium:YAG Lasers
- Neodymium:YLF Lasers
- Ruby Lasers
- Titanium:Sapphire Lasers
- Xenon-Helium Lasers

- Ion Laser & Dye Laser from Coherent (top left)
- Nd:YAG Lasers & Dye Laser from Continuum (top right)
- Ultrafast Ti:Sapphire Laser from Coherent (bottom left)
- Excimer Laser from Lambda Physik (bottom right)

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